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Hydrogeological controls on microbial activity in continental crust

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Earth's deep continental subsurface is a prime setting to study the limits of life's relationship with environmental conditions and habitability. In Precambrian crystalline rocks worldwide, deep ancient groundwaters in fracture networks are typically oligotrophic, highly saline and locally inhabited by low biomass communities in which chemolithotrophic microorganisms may dominate. While fracture water may have residence times ranging from thousands to up to a billion years, these ecosystems do not exist in full isolation. Periodic opening of new fractures can lead to penetration of surface water and migration of fracture fluids, both of which may trigger changes in subsurface microbial composition and activity. These hydrogeological processes and their impacts on subsurface communities may play a significant role in global cycles of key elements in the crust. However, to date, considerable uncertainty remains on how subsurface microbial communities may react to different hydrogeological conditions. To address this uncertainty, we collected naturally occurring fracture waters at ~1 km below land surface from Thompson Mine (Manitoba, Canada). Compositional and isotopic analyses of these fluids revealed different extents of mixing between subsurface brine and (paleo)meteoric waters. To investigate the effects this mixing may have had on microbial communities we applied Most Probable Number (MPN) technique to test community response for a total of 13 different metabolisms. Results showed that all fracture waters were dominated by viable heterotrophic microorganisms which can utilize organic materials associated with aerobic/facultative processes, sulfate reduction, or fermentation. In the most saline sample (brine), the communities had the lowest cell densities and lowest viable functional potential, compared to less saline water samples. This study demonstrates the connection between hydrogeologic heterogeneity and the heterogeneity of subsurface ecosystems in the crystalline rocks, and suggests that hydrogeological activity may be a significant factor influencing scope and scale of subsurface microbial communities on Earth and potentially beyond.