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Exploring the hydrogeological functioning and microbial habitats of the deep hillslope aeration zone in limestone-mudrock alternations

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The aeration zone beneath topographic groundwater recharge areas, comprising variably water-saturated soil, regolith and bedrock is a typically large but hardly explored compartment of the Critical Zone. Fluid and matter exchange within the deep hillslope aeration zone, the dynamics of its diverse microbial dwellers and their contribution for subsurface matter cycling and groundwater quality are widely unknown. In the Hainich Critical Zone Exploratory (Collaborative Research Center AquaDiva, Küsel et al., 2016), we accessed the aeration zone and groundwater resources in fractured limestone-mudstone alternations by exploratory drillings and hillslope monitoring wells. Multi-year groundwater sampling, environmental monitoring, drill core and petrological analyses revealed a multi-storey architecture of the aeration zone, covering perched water bodies and multi-directional flow phenomena (Lehmann and Totsche 2020). In a ~50 m deep well that underwent pronounced seasonal head fluctuation up to 25 m of oligotrophic groundwater, we incubated bedrock fragments that mimicked large fracture habitats and monitored the dynamic environmental conditions in the fractured mixed carbonate-/siliciclastic alternations as well. During groundwater-saturated colonization, successional exposure to seasonal de-saturation and re-saturation, we analyzed the bacterial and archaeal 16S rRNA diversity and found a diverse bacterial, and less diverse archaeal community, both including persistent genera that withstood the harsh environmental changes. In accordance with mature fracture-surfaces (drill cores), the colonized rock fragments were dominated by Gammaproteobacteria. General compositional differences to communities within the phreatic zone (i.e. groundwater and rock matrices), and shallow sources in soil, suggest a distinct subsurface microbiome that is hardly represented by ecological surveys that utilize groundwater or rock samples.

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