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Lithoautotrophy primes basalt grains for chemical dissolution in enhanced weathering field trials

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Enhanced weathering (EW) is a proposed scalable negative emission technology in which crushed silicate rock (e.g., basalt) is applied to agricultural soils to drive carbon dioxide removal (CDR) via abiotic and biotic weathering processes. However, it is unclear how belowground microbes weather the applied silicate rock grains, which lack a source of organic carbon (C) required to fuel their metabolism. Here, we use multi-omics combined with chemical characterization of basalt grain weathering in soils from the longest running EW field trial in the US Corn Belt to show that rock grains host vastly distinct communities dominated by highly active CO_2-fixing lithoautotrophs. Isolated genomes and transcriptomic signatures of the dominant lithoautotrophs revealed energy metabolism fuelled by the oxidation of basaltic sulfur and hydrogen. High microbial biomass of colonised basalt was associated with organic C transfer from lithoautotrophs to heterotrophs. As a result of their different diet when compared to their soil counterparts, heterotrophs living on basalt show characteristic expressional shifts in genes involved in the transport, digestion, and metabolism of C substrates provided by their lithoautotrophic producers. Our analyses indicate that despite their 6-fold lower microbial biomass relative to soil, basalt grain microbiomes represent a trophically complex ecosystem powered in part by reduced basalt inorganic substrates and in part by soil organic C sources. Similar to microbe-fuelled ecosystems on seafloor basalt in the dark ocean, the lithoautotrophic colonization of basalt grains in topsoil supplies additional energy required to establish stable microbial communities that promote EW rates and ultimately CDR.