Cellular dissolution at hypha- and spore-mineral interface

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Fungus-mineral interactions play unparalleled roles in shaping the planet Earth but are under-appreciated relative to the bacterial influences. Unique to fungus but largely unknown are the interfacial processes associated with the long thread-like hyphae that can extend hundreds of km cumulatively in soils/kg, and the extensiveness of hypha- vs. spore-mineral interactions in light of the associated turgor pressure differences. Here we examine lizardite [$Mg_3Si_2O_5(OH)_4$] dissolution by a native fungal strain in bulk and at interface through determining the total metal release in culture, the pH local to surface-bound cells, and the material composition and structure beneath cell-colonized surfaces. Our goal is to explore the mechanism, driving force, and magnitude of the interfacial reactions. Results from confocal laser scanning microscopy, atomic force microscopy, transmission electron microscopy–energy dispersive X-ray spectroscopy, and microplater examination showed (1) significant pH reduction around cells once becoming surface-bound, (2) exclusive Fe loss from the mineral at the cell-mineral interfaces, (3) destruction of the mineral crystal structure below the area colonized by hyphae but not that by spores, and (4) substantially enhanced production of total proteins, siderophores, and oxalic acid by the microbe in the presence of mineral. Compared to the results from bulk experiments and at the mineral-water interface, these observations attest to the strong occurrence of cellular dissolution on mineral surfaces, and futher indicate that (1) cellular dissolution proceeds by a mechanism fundamentally different from that at the mineral-water interface, (2) only attached cells release siderophores, and (3) biomechanical forces of hyphal growth are indispensable for fungal weathering and strong enough to breach the mineral lattice. Estimated mineral volume loss at the interface suggests cellular dissolution can ultimately account for ~40%–50% of the overall bio-weathering, significantly larger than the previous estimate of ~1% contribution. Our results thus strongly suggest that fungal cell-promoted interfacial dissolution may have been significantly underestimated and needs to be reassessed in terms of its role in the biogeochemical cycling of nutrients and carbon.