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Geometric bacteria: New patterns of oriented bacterial growth and adhesion to hematite surface with evidence of dissolution at bacteria-metal contact

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Bacteria showing "Geometric patterns" of growth and adhesion, highly enriched in iron, were found mineralized on hematite (α-Fe_2O_3) surfaces with point dissolution at bacteria-metal contacts. The patterns were found on sub-millimeter tabular metallic hematite flakes prepared for experimental work on fungi-mineral interactions. The FE-SEM imaging of the plane surfaces of hematite crystals displayed a 3-D network of bacteria composed of colonies of coccoidal chains ($\sim$1x20 μm long) organized in a range of geometrical patterns: dichotomous and budding, perfectly parallel, intersecting at 60˚ and 90º angles, triangular and sinusoidal. Solitary coccoidal cells ($\sim$1μm diameter), some even showing cell division are also abundant. The distance between parallel chains remains constant and ranges between 1.5 and 2.5 μm. Often, two to three of the straight and parallel chains of bacteria are fused together to form a pack of chains $\sim$2.5 μm wide. The bacterial origin of these chains and cells is essentially suggested by morphological criteria such as their frequent dichotomy and budding, coccoidal cells chambers, sheath fragments, growth continuity and attachment extensions to hematite surface. Frequently the coccoidal chains clearly show attachment material, most probably representing extracellular polysaccharide substance (EPS), which appears as fine threads extending from the base of the coccoidal chains along the mineral surface. At some bacterial adhesion sites, hematite surface shows circular dissolution holes of about 100 nm in diameter. EDX microanalysis of the bacterial chains showed marked Fe-enrichment and frequently total iron mineralization. The chains are made up of a thread-like fabric of spongy appearance and abundant sub-micron sized crystals are embedded into their surfaces. Such bacteria with geometric shapes have so far not been reported for bacterial species known to interact with iron as oxidizers or as

reducers. Several PCR trials for genetic identification produced negative results which suggested ancient bacterial forms strongly associated with iron. It is also suggested here that the geometric growth and adhesion of these bacteria to hematite surfaces is possibly structurally controlled by the internal structure of hematite, and that the bacteria had the capability of preferentially tracking the hematite Fe-O structure.