Evolution of microbial biosignatures with increasing metamorphic grade

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Our understanding of the emergence and evolution of microbial life relies in part on a geologic record that has experienced diagenetic and metamorphic alteration. Little is known about the survivability and geochemical evolution of microbial biosignatures within rock substrates when subject to the high pressures (P) and temperatures (T), yet our picture of the Precambrian biosphere is based upon the preserved organic and geochemical remnants of such microorganisms. Using a piston cylinder press we exposed a natural microbial biofilm community hosted within a thermal spring carbonate matrix to 6 different HPHT conditions spanning 500 - 800 MPa and 200 - 550 °C to investigate the persistence of microbial organic material and petrographic association with increasing metamorphic grade spanning zeolite, greenschist, blueschist, and amphibolite facies. Experimental products were analysed with Raman mapping spectroscopy and FEG-SEM mapping to investigate the spatial and geochemical evolution between organic and inorganic phases. Microbial biofilms comprising filamentous sulfur oxidising bacteria (SOB), cyanobacteria, and freshwater diatoms were associated with biogenic and opaline silica, which mineralised biomat EPS and increasingly evolved organic carbon. At the highest PT conditions (800 MPa, 550 °C), organic material becomes excluded from recrystallised calcite. Discrete clusters of sulfur globules associated with the SOB persisted across all metamorphic facies, recrystalising at temperatures > 425 °C. Throughout all PT conditions, organic carbon and sulfur globules co-occurred within a silicified matrix, eventually preserved within a crystalline quartz phase. This study is the first time the HPHT evolution of microbial biosignatures has been investigated within a natural, heterogeneous sample, and builds on recent experimental work focused on microbial biomarkers (e.g. Picard et al., 2015; Alleon et al., 2016). These results demonstrate the value of experimental work on natural samples within this field, providing insights into the micron scale partitioning of organic and inorganic phases within heterogenous materials relevant to early Earth environments.