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Controls on the rate of ureolysis and the size distribution and morphology of carbonate precipitate by S. pasteurii biofilms

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The biogeochemistry of carbonate precipitation via ureolysis using bacteria suspended in solution is relatively well characterised. However, despite its potential contribution to a range of environmental technologies (e.g. soil strengthening, permeability reduction, solid state capture of radionuclides, carbon sequestration), relatively little is known about the controls on the rate of ureolysis and the size distribution and morphology of carbonate precipitate by attached bacterial colonies and biofilms. We present the results of experiments using Sporosarcina pasteurii biofilms, of varying density, grown on perspex and granite surfaces then immersed in media containing varying concentrations of calcium chloride and urea.

The results show that S. pasteurii can form biofilms under high and low nutrient concentrations on both substrates. In media with higher nutrient concentrations, denser biofilms were formed resulting in higher rates of urea hydrolysis (as measured by ammonium production) in turn leading to faster nucleation of calcium carbonate and smaller crystal sizes. The morphology of the carbonate precipitate formed was found to be highly variable ranging from simple rhombohedral calcite crystals to more complex shapes at higher precipitation rates. In some cases the resulting carbonate layer was non-porous, and the bridging of pores exposed at the granite surface was also observed.

A key finding is that urea hydrolysis (and therefore calcite production) is eventually limited by the carbonate precipitate restricting the supply of urea to the biofilm. This may limit the extent to which wider pores or fractures can be infilled using microbially induced carbonate precipitation (MCP) with attached bacterial communities (for example for engineering applications where permeability reduction is desirable) unless repeated inoculation is carried out. Although further research is needed to test these concepts within flowing fracture systems, the results have important implications for the design of possible engineering technologies involving MCP.