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Nano-scale evidence of organic matter mineralization in recent tufa deposits.

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Recent tufa deposits forming in fluvial barrage systems in Northern Calabria (Italy) and in the Derwent Valley (Northern England) reveal the remarkable influence of microbial biofilms in the formation of neo-precipitate carbonate minerals. In both systems, tufa is forming in moderate-flow streams generating a series of dams and pools where three types of microfacies are produced: vacuolar tufa, pustular tufa and stromatolitic tufa, all forming in association with biofilm.
Identical petrographic components are recognizable in all facies: micrite, microspar and spar, occurring in more-or-less well-defined alternate layers which can vary in thickness and internal fabric. Micrite and microsparite are often associated forming several types of fabric: peloidal to aphanitc, laminar and dendrolitic. Sparite can occur in layers composed of isolated to coalescent fan-shaped crystals forming respectively botryoids or continuous crusts.
A widespread biofilm colonizes the external surfaces of tufa deposits, composed of heterogeneous communities comprising filamentous cyanobacteria, green algae, heterotrophic bacteria, diatoms, mosses and arthropod larvae. Microbial communities always develop on an irregular surface, constituted by micro-columns of neomorphic calcite separated by interstitial channels. Neo-formed calcite forms in the upper part of the micro columns and pinnacles, and in the interspaces between them, directly on the free fluid/solid interface and within cavities, exhibiting several crystal morphologies and sizes. Submicron-sized crystals about 10-20 nm in diameter, with a subspherical shape, are the smallest mineral units observed. Nano-crystal sub-spherical units agglutinate to form larger crystal aggregates bar and/or spheres up to 100-200 nm in size. These aggregates grow with a geometrical order forming minute triads of calcite fibres, departing from a common cusp forming an angle of $\sim 100^{\circ}$ between them. Fibres forming the triads of calcite vary in size from 0,4 to 1 μm and during their growth develop elongate, needle-like crystals or are connected in a pyramidal-shaped solid. Successively triads can be found closely stacked along their C axis, laterally spaced, to form polyhedrons of calcite (mainly tetrahedrons) that create a mineral framework within the biofilm. Single polyhedrons cannot often be distinguished from the external walls of the columns and pinnacles.
Neomorphic micro-scale precipitates are extensively observed in close association with either organic living matter or non-living components within the biofilm. The nano-scale mineral units begin their formation mainly by replacing the degrading organic matter substrates.