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Crystallization pathways in speleothems of hydroclimate significance

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Abiotic mechanisms of calcium carbonate crystallization imply that there is no direct participation of living organisms. If the first stages of crystallization are influenced or preserved through by-products of degradation of dead organisms, then the process should still be considered purely inorganic and abiotic. Speleothem formation has been considered, to date, an abiotic process although stalagmites host bacterial colonies that may contribute to speleothem formation.

Here we performed fast (30 min) and 24 hour-long experiments of calcium carbonate precipitation from drip-waters collected in caves at Atiu, Cook Islands, to interrogate how fabrics respond to infiltration changes. Calcite nanocrystals commenced to form only in the 24 hour-experiments, and some nanocrystals assembled into larger meso and single crystals with coherent lattice bridged by amorphous species. Similarly, farmed calcite grown for 3 years consisted of micrometre-sized calcite crystals with coherent lattices, which document the stage of crystal fusion. The 3 years precipitates observed at FESEM and TEM reveal that both typical classical growth mechanisms and particle attachment were operating in the formation of columnar calcite fabric. Crystal tips, exposed to thin film of fluid, show evidence of the screw dislocation growth mechanism, whereas nano-crystals appear to attach to macro-kink sites on lateral faces. The implication is that preferential incorporation of trace elements of climatic importance may vary according to the crystallization pathway mechanism.

The process of calcium carbonate growth of Atiu stalagmites in our experiments seems to be completely abiotic. What is striking is the similarity to growth processes observed in caves where the “influence of organic substances” has been documented. Thus, abiotic and bio-induced processes in caves converge in producing similar fabrics.