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Enhanced Weathering of Stone by Salts: a Chemical Process

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Salt weathering is recognized as an important mechanism contributing to the shaping of the earth's surface, in a range of environments spanning from the Sahara desert to Antarctica. It also contributes to the degradation and loss of cultural heritage, particularly carved stone and historic buildings. These stone monuments, in the presence of salt and water, suffer from two main mechanisms of decay associated with salts, namely physical and chemical weathering. An effective remediation strategy should inhibit both weathering processes [1], but in order to develop this type of conservation treatment, a full understanding of salt-enhanced physical and chemical weathering must first be achieved.

Physical weathering occurs when relative humidity, temperature or salt concentrations fluctuate so that soluble salts such as sulfates, nitrates, chlorides and carbonates of alkali and alkali earth metals can crystallize within the porous system of rocks and building stones, exerting sufficient pressure against the pore walls to fracture the substrate. This physical damage results in increased porosity, thus providing a higher surface area for salt-enhanced chemical weathering. The degree of damage caused by physical weathering is related to the pressure exerted within the stone by the salts crystallizing, which in turn is dependent on the solution supersaturation with respect to the first crystallizing phase.

Physical weathering processes have been fairly well studied, although there is much more work to be done. On the contrary, research in chemical salt-enhanced weathering is scant and merits further detailed investigation. Chemical weathering involves the dissolution of minerals in porous substrates at a much higher rate due to the presence of soluble salts [2], resulting in increased porosity and surface pitting.

Our experiments related to chemical salt-enhanced weathering seek to quantify the deleterious effect of different soluble salts on carbonate-based substrates. Flow-through experiments are performed in a stirred flow-through cell that is fully immersed in a thermostatic water-bath that maintains a constant temperature of 25 ± 1 °C [3]. Concentrated salt solution or MilliQ water is injected into the cell using a peristaltic pump at a flow rate of 46 mL/day, yielding a residence time of 1 day. The bottom chamber of the cell contains a magnetic stir bar where the input solution is homogenized. The upper chamber is separate by membrane filters from the remainder of the cell and holds solid calcite grains. Output solutions are collected regularly and analyzed for pH and calcium concentration. After completion of the dissolution experiment, the remaining calcite grains are collected and examined. Parallel flow-through experiments are performed in AFM (atomic force microscopy) allowing in-situ, high magnification observation of the dissolution of calcite by highly concentrated salt solution.

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[3] Rozalen, M. L., et al. (2008) Geochim. Cosmochim. Acta, 72, 4224-4253.