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Decay-induced biomineralization of the saguaro cactus (*Carnegiea gigantea*)

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ABSTRACT

The saguaro, *Carnegiea gigantea* (Englemann), is a columnar cactus that grows to 15 m tall and weighs up to several tons, of which 85 to 90% of the mass is water. Roughly 18% of the dry mass consists of the biomineral weddellite ($CaC_2O_4 \cdot 2H_2O$). The C in the weddellite derives from atmospheric CO_2 via photosynthesis. A mature saguaro can contain on the order of 1×10^5 g of weddellite. The weddellite crystals occur as aggregates up to 1 mm wide. After the death of the saguaro, a series of minerals crystallize in the rotting flesh. These minerals form from elements released from the decay of the cactus by microorganisms and thus is a type of biologically induced mineralization. During the initial stages of decay, authigenic Mg- and Ca-bearing minerals crystallize from elements released by the putrefying flesh and include lansfordite ($MgCO_3 \cdot 5H_2O$), nesquehonite ($MgCO_3 \cdot 3H_2O$), several polymorphs of $MgC_2O_4 \cdot 2H_2O$ including glushinskite, monohydrocalcite ($CaCO_3 \cdot H_2O$), calcite, vaterite, and several unidentified Mg-bearing phases. As the saguaro decays, the soft, water-rich pith shrinks, but the ribs and skin remain intact, producing warm, moist pockets within the dead saguaro. Abundant, glassy lansfordite crystals to 1 mm in diameter grow in these pockets during the cooler winter months. Further decay leaves a dried hollow shell covered by the saguaro skin, inside of which nesquehonite and monohydrocalcite crystallize. Lansfordite and nesquehonite are unstable in the desert and rapidly amorphize after exposure to the atmosphere. Magnesium oxalates are locally abundant in the decayed flesh and occur as crystals up to 1.5 mm in length. The common occurrence of fungal hyphae on the glushinskite suggests that it forms as a result of the reaction between oxalic acid released by fungi and the Mg-rich solutions of the rotting saguaro. During the final stages of decay, the pith consists of a pale-brown to tan-colored sand of weddellite and its transformation product monohydrocalcite. This sand lithifies to porous sponge-like masses during the final stages of saguaro decay. This monohydrocalcite further alters to calcite. The $\delta^{13}C_{VPDB}$ of the monohydrocalcite and calcite after weddellite range from –1.65 to + 0.76‰. The calcite is subsequently solubilized and remobilized, precipitating as caliche in the desert soil, or redistributed by wind. In arid environments, the desert fauna metabolize the atmospheric C bound in the organic matter to CO_2. In contrast, decay of the saguaro adds atmospheric C to the soil as inorganic C via the transformation of the biomineral weddellite to calcite. In areas with high saguaro density, it is estimated that up to 2.4 g/m^2/yr of calcite can be added to the desert from the decayed cacti. This inorganic C has geologically long soil residence times, thus effectively sequestering the atmospheric C.