

## **Chemically oscillating reactions in the formation of botryoidal malachite**

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### **ABSTRACT**

The origin of banding patterns in malachite [Cu<sub>2</sub>CO<sub>3</sub>(OH)<sub>2</sub>] is an enduring problem in geology. While the bright green, vivid colors of this mineral have been attributed to the presence of Cu, no specific process has been proposed that can explain the perfect circularly concentric banding and geometrical shapes in botryoidal malachite. These patterns of concentric equidistant laminations are comparable to those arising from chemically oscillating experiments using the classical reactants of the Belousov-Zhabotinsky (B-Z) reaction. Through optical microscopy and micro-Raman imaging, this contribution documents that the geometric centers of the self-similar geometric patterns are often composed of organic matter. Carbon isotopes and trace elements further suggest that non-biological decarboxylation reactions of biological organic matter took place during diagenesis. Hence, the morphological and chemical characteristics of chemically oscillating reactions offer a plausible explanation for the formation of botryoidal malachite and abiotic environmental decarboxylation reactions.

**Keywords:** Malachite, botryoids, Belousov-Zhabotinsky reaction, organic matter, Raman, decarboxylation; Earth in Five Reactions: A Deep Carbon Perspective