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Continental carbonates growth pathways, fabrics and diagenesis

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Continental carbonates are a repository of exceptional climate and environmental changes at scales from sub-annual to decadal to millennial. Their fabrics and chemistry encapsulate information about temperature and rainfall variability, volcanic eruptions, earthquakes, vegetation changes, as well as microbial interaction. Yet, fabric and chemical properties are influenced by the crystallization pathways and, crucially, growth mechanisms and diagenesis of the carbonate crystals. Here we present examples from diverse continental settings and discuss why fabrics are extremely important to determine the accuracy of preservation of a “primary” signal.

Most continental carbonate formation is driven by degassing. This is the case of cave carbonate deposits (speleothems), which allowed tremendous breakthrough in palaeoclimate science. Speleothems form in the dark, from drip waters poor in nutrients and organic compounds. Their most common fabric consist of columnar crystals. Nanoscale investigation shows that speleothem crystals have diverse growth pathways, including particle attachment (Frisia et al., 2018). The distribution of climate-sensitive trace elements, thus, rather than following crystallographic sector zoning, follows “parallel growth layers” reflecting environmental changes. The critical parameter in growth process is the drip rate. By contrast, subglacial and cryogenic carbonates, which also grow in the dark and consist of columnar crystals, form in micro-phreatic environment where supersaturation is not attained by degassing, but by concentration of elements by slow freezing. In this situation trace elements are incorporated following crystallographic faces and provide exceptional information of subglacial processes including volcanic eruptions (Frisia et al., 2017).

Lacustrine, spring and fluvial carbonates grow at Earth’s surface, being exposed to Sun’s light. These carbonates’ precipitation, similarly to speleothems, is promoted by degassing, but also by the presence of photosynthetic organisms and high substances organic interaction. Their fabrics are commonly characterized by micrite, which is rare in caves and in subglacial samples.

Evaporitic lake (Great Salt Lake, GSL) and spring deposits described in Della Porta (2015) were observed by TEM. One typical microfabric is peloidal micrite. The GSL peloidal micrite consists of calcite nanocrystals, and the peloids are associated with aragonite and filaments. Spring deposits peloidal micrite also consists of nanocrystal aggregates surrounded by filaments.

Most speleothems and spring/lake carbonates document a phase of growth that involves nanocrystal aggregation, which we did not observe in the phreatic subglacial samples.

Implications for palaeoenvironmental research: In speleothems, Ostwald ripening likely transforms nanoparticle aggregates into larger crystals. Critically, in speleothems, Ostwald ripening processes result in removal of some tracers, such as Si, associated to first growth phases, and preservation of those that we use to reconstruct palaeo hydrology. In lake and spring deposits it would seem that micrite preserves the original environmental data, because micrite means that the crystals were protected from ripening by the organic part of the deposit. In subglacial carbonates, growth appears to follow a classical ion attachment at growth sites, thus, their fabrics preserve pristine primary signals.

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