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Non-equilibrium fabrics in speleothems: implications for palaeoenvironmental reconstructions

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The interpretation of climate proxies in speleothems is complicated by the large variations in cave water composition and flow conditions, and by kinetically driven departures from equilibrium during calcite deposition. Growth of speleothems in equilibrium with their parent solution cannot be a priori assumed for fossil specimens as, strictly speaking, a calibration with the hydrological and hydrochemical drip water regime is only possible for actively forming samples. Speleothem calcite that precipitated in morphologic and thermodynamic equilibrium may show kinetic effects on isotopic incorporation. By contrast, speleothem calcite fabrics that developed in morphologic and thermodynamic disequilibrium may show a large range of deviation from equilibrium with respect to isotopic incorporation, including quasi-equilibrium incorporation. Dendritic fabric develops under morphologic and thermodynamic disequilibrium conditions. It is composed of branching polycrystals (0.1 to 1 mm long) and it has been observed to incorporate preferentially ^{13}C, and to a lesser extent also ^{18}O (Frisia et al., 2000). This suggests that speleothems showing dendritic fabric are not suitable for palaeoclimate reconstructions. The presence of dendritic fabric, however, is a reliable qualitative indicator of a hydrological system controlled by alternating wet and dry conditions.

Speleothems composed of dendritic fabric are common in shallow caves in regions characterized by negative hydrological balance during the warm season, which is a common feature of Mediterranean-type climate. In speleothems from Italian cave sites the incorporation of stable isotope in dendritic fabric changed throughout the Holocene recording large hydrological changes. The C-isotope values of dendritic fabrics in stalagmite CR1 from Grotta di Carburangeli (Sicily, S Italy) show large a variability during the early Holocene (-10.5‰ to 0‰ VPDB) and a more restricted

range (-11.3‰ to -7.0‰) in the middle and late Holocene. Covariance of $\delta^{13}C$ and $\delta^{18}O$ values characterizes only the late Holocene part of the stalagmite. In the early Holocene, kinetic effects played only a minor role in controlling the C-isotope composition, which primarily reflects pluvial periods alternated with 30 to 60 yr-long droughts. Similarly, the Early Holocene portion of Grotta di Ernesto stalagmite ER76 (Trentino, NE Italy), is characterized by dendritic fabric and a large range of C isotope values.

In the Mid-Late Holocene stalagmite GZ1 (Cogola di Giazzera, Trentino), scaffold-like dendrites make transition to open columnar plus dendritic in the portion that formed in the last 1000 year. The Mid-Holocene dendritic fabric is systematically enriched in C and O isotopes with respect to the columnar fabric, but the range of C-isotope variability is not as large as that of the Early Holocene portion of CR1. This suggests less extreme hydrological contrast (seasonality) in the Mid-and Late-Holocene than in the Early Holocene in both North and South Italy. By taking into account “fabric effects” on stable isotope incorporation, therefore, non-equilibrium fabric can be used to extract useful information on climate changes.

Frisia, S., Borsato A., Fairchild I.J. & McDermott F., (2000) *Journ. Sed. Res.* 70 (5): 1183-1196.