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Molecular analysis of organic matter in stalagmites: advantages and limitations

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Organic matter preserved in stalagmites has considerable potential to record changes in the surrounding environment, particularly in the overlying vegetation. Stalagmites generally provide chemically closed systems after deposition, and can be dated with high precision using U-Th series techniques. Meanwhile organic matter derived from the cave and from the overlying environment can provide a detailed signal relating to specific parts of the surrounding ecosystem such as the dominant vegetation regime and bacterial activity in the soil and karst system. By combining these signals with established stalagmite proxies such as isotopic and trace element analysis, there is the potential to produce an integrated signal capable of tracking past climatic changes and the associated effects on terrestrial ecosystems.

Here we discuss the major forms of molecular organic analysis that are available to stalagmite workers, and present recent data to demonstrate their potential in environmental research, and the limitations that currently constrain their use. To date, the most widely used method of organic analysis in stalagmite research has been organic matter luminescence, which provides a non-destructive and rapid method for assessing dissolved organic matter quantity and quality, and can give an indication of climatic conditions. However, more invasive organic extraction techniques stand to give

a much more wide ranging signal. Studies of amino acid content, which were initially favoured due to the success of the approach in other carbonate contexts, appear problematic due to the complexity of the origin of the organic matter. More successful is lipid biomarker analysis which has been used to show connectivity between changes in the soil ecosystem and global climate in China, and anthropogenic vegetation change in Ethiopia. The approach can be expanded to include compound-specific isotope analysis, which will allow direct comparisons to be made between the isotopic signal from the stalagmite calcite, and that derived directly from the overlying vegetation. A new sequential extraction technique, recovering both the lipid signal and that of larger organic molecules such as lignin monomers, is also substantially increasing the amount of information that can be recovered.

However, questions remain over the degree of mixing and time-lag that exists in the stalagmite organic matter signal, with early results suggesting that there may be significant differences in transport time for different molecular types. It is therefore crucial that forthcoming studies of stalagmite organic matter pay sufficient attention to identifying the origin (both spatial and temporal) of the different signals, and to modern calibrations to demonstrate that the results are robust. Molecular analysis of organic matter preserved in stalagmites will then be able to take its place as an extremely useful tool in our attempts to understand past environments.