Geophysical Research Abstracts, Vol. 8, 07521, 2006
SRef-ID: 1607-7962/gra/EGU06-A-07521

High-resolution U-Th chronologies for speleothems

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Speleothems are of increasing importance in producing long absolute-dated paleoenvironmental proxy records, and in some instances are being used to provide alternative chronologies for ice core and other isotopic records on the basis of apparent similarities in their measured geochemical proxies. Here we will discuss the importance of dating at the highest practicable resolution for such records, and demonstrate the use of Monte Carlo techniques to provide continuous interpolated estimates of uncertainty in age and growth rate vs age.

Uranium-thorium dating of speleothem calcite is arguably the most robust absolute Quaternary geochronometer there is, but has often been constrained by its considerable expense in terms of laboratory and instrument time leading to a tendency to under-date speleothem records. Because growth rate can vary by three orders of magnitude within a single speleothem it is never safe to assume linear growth between two age determinations, and it is easy to demonstrate that the quantity of age determinations produced is more important than achieving the best possible analytical precision for each of them.

Multi-collector inductively-coupled plasma mass spectrometry delivers the ability to run large numbers of high-precision U-Th age determinations, giving sample throughputs several times greater than can be achieved using thermal ionisation. MC-ICP-MS requires between one and two orders of magnitude less uranium per age determination meaning considerably smaller samples can be used, reducing spatial uncertainty in slow-growing speleothem age models. This is carried to an extreme by the use of in-situ laser-ablation analysis, in which some age precision is sacrificed to obtain spatial resolution of ca. 100 microns or better.

Monte Carlo simulation can be used to objectively interpolate age uncertainty versus time or distance for any speleothem given a suite of U-Th analyses and an assumed magnitude of growth rate variability for that sample, and clearly shows where further dating will provide the strongest gains in terms of constraint of the resulting age-distance model. This will be demonstrated using data from New Zealand and Italian speleothems that grew over the last several glacial-interglacial cycles, and from slow-growing Australian and Italian speleothems using mixed conventional and laser-ablation U-Th analyses. New age-depth envelopes have also been developed in this way for some recently published speleothem U-Th data sets and will be contrasted with their existing models.