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Optimized U-Th Chronometry for Carbonates Using MC-ICP-MS: Advancements in Precision and Applications

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U-Th geochronology is a key tool in Quaternary geology, widely applied to carbonate matrices with significant advancements achieved through MC-ICP-MS technology. However, ²³⁰Th dating remains challenging for samples with low-uranium concentrations and high-detrital thorium content which often reflecting open-system behavior. These factors increase uncertainties in age calculations. This study introduces an optimized U-Th dating methodology that integrates refined wet chemistry protocols and 10¹³-ohm amplifiers, significantly reducing expanded uncertainties.

The study employs a four-step validation process: i) testing 10¹³-ohm amplifiers using the NBL U-reference material (CRM 112A), and Th-reference material (IRMM035) of IRMM, ii) application to low-U (10–15 ppb) speleothem samples from the *Cueva Fantasma* (Atapuerca paleontological-archeological site, Burgos, Spain), iii) analysis of open-system shell samples from Turkey, iv) analysis of the internal speleothem standard (BSS2) of CENIEH.

Initial results using CRM 112A and IRMM035 reveal a tenfold improvement in signal-to-noise ratios with the 10¹³-ohm amplifiers. This configuration enables the use of Faraday cups instead of SEM detectors for U and Th-standard analyses, even at very low intensities (0.002–0.007V), a critical improvement for minimizing uncertainty budgets during bracketing sequences in U-Th dating. Comparative analyses of real samples from Atapuerca, Turkey, and the CENIEH speleothem standard (BSS2) show that the refined methodology reduces U-Th age uncertainties from 2–3% to 0.5–1%.

Beyond improved precision for younger, low-U samples, the method reduces the required sample size from ~100–150 mg to 40–50 mg, substantially lowering the influence of detrital Th contamination. The broader significance of this optimized approach lies in its application to environmental reconstruction during the Quaternary, offering robust tools for deciphering climate archives, paleoenvironments, and archaeological contexts.

