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# High-precision and high-resolution speleothem Th-230 dating by MC-ICP-MS with SEM protocols

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To facilitate the measurement of femtogram-quantity U-Th isotopic compositions suitable for high-precision and high-resolution speleothem Th-230 dating, secondary electron multiplier (SEM) protocol techniques for multi-collector inductively coupled plasma mass spectrometry (MC-ICP-MS) have been developed. The instrumental sensitivities are 1-2%, with a 2-sigma precision of 1-2 permil for abundance determinations of 50-200-fg U-234 (1-4-ng U-238) or Th-230. Measurement consistency of this MC-ICP-MS combined with previous mass spectrometric results on U-Th standards and a variety of carbonates demonstrates the validity of the SEM-protocol method. About 20-200-mg speleothem samples with sub-ppm-to-ppm U are required to earn a 5 permil precision on ages from 5-100 kyrs. Requirement of small sample size, 10s-100s mg carbonate, can permit high temporal resolution to date speleothems with slow growth rates, such as 1-10 mm/kyr. Single-lamina Th-230 dating techniques with precision of $\pm 1$ yr for annual stalagmite layers with an age of 300 years are achievable. This high-precision Th-230 chronology is critical to accurately establish age models, date events and splice geochemical proxy time series records from multiple samples in the fields of paleoclimatology.