Direct U-Pb age constraints on Arctic speleothem formation and their implications for climate change in deep time

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Carbonate deposits formed in caves (speleothems) are important proxies of past climate, as regional hydrology and temperature control their formation. In particular, Arctic speleothems found in permafrost regions record past episodes of permafrost thaw because they require liquid water to grow. Understanding the precise timing of speleothem growth relative to other well-established climate proxies is crucial to a quantitative evaluation of permafrost's sensitivity to warming.

Previous age determinations of speleothems by the U-Th (disequilibrium) technique have greatly enhanced the utility of this chronometer in Quaternary climate research. However, the relatively short half-lives of the U-series intermediate isotopes place a limit of ca. 600 ka on calcite specimens that can be dated. In this study, we apply the U-Pb ID-TIMS method to several Canadian Arctic and sub-Arctic speleothems exceeding the U-Th limit in order to extend the record of speleothem growth to the early Pleistocene and beyond. The samples were selected from a range of latitudes to represent a variety of permafrost conditions and range in U-Pb dates from 416 ± 12 ka to 7.74 ± 0.18 Ma. These dates are corrected for initial ^{234}U and ^{230}Th disequilibria by direct measurements of their activities, although the magnitude of these correction becomes less significant with increasing sample age. Our successful analysis of young (<600 ka) speleothems by the U-Pb ID-TIMS method provides the opportunity for intercalibration of the U-Th and U-Pb geochronologic schemes. Interestingly, our highest latitude speleothems from the continuous permafrost zone in the northern Yukon have so far produced consistent dates at ca. 7.7 Ma, older than those from the majority of previous terrestrial Arctic proxy records.