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Chronology of the penultimate deglaciation in the Alps: areappraisal

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Speleothems from Spannagel Cave in the Central Alps of Austria provide the only currently available precisely dated chronology on the timing and structure of Termination II in the Alps. Despite a large U/Th-TIMS data set there are no samples from this site of MIS 6 age, implying that conditions during full glacials were not conducive of calcite deposition (confirmed by a second gap at the LGM) and the cave was probably covered by a (partially) cold-based glacier.

Calcite deposition re-commenced early during Termination II, indicating a warming of the subsurface. Our updated U/Th dates suggest a time range between 136 and 133 kyr for this event (based on two flowstone and one stalagmite sample). Previously regarded as evidence of ice-free conditions early during the penultimate deglaciation, speleothem deposition at 136 kyr is now seen as an indication of a major change of the glacier's thermal state most likely as a result of the collapse of ice stream network at the end of the penultimate glacial maximum. Our records revealed a marked difference in the O and C isotopic compositions between this early calcite and the subsequent MIS 5.5 calcite: low δ^{18}O values coupled with high δ^{13}C values indicate that temperatures – albeit increasing – were still significantly lower than during MIS 5.5. In analogy to the Holocene position of the local equilibrium line altitude we now regard it as very likely that ice still covered the area during this early deglaciation phase. We speculate that the MIS 6 dendritic glacier network had collapsed and given way to smaller, warm-based valley glaciers by $\sim$136 kyr, which is reflected by slow calcite deposition on flowstones and stalagmites.

This early growth phase was terminated by a hiatus in all samples from Spannagel Cave during which conditions for speleothem growth apparently deteriorated to the point where calcite precipitation again came to a standstill. Fully interglacial conditions including soil development and vegetation cover were only established by 130-129 kyr, consistent with speleothem data from Israel and China. The early growth phase between 136 and 133 kyr is thus interpreted as a major interstadial rather than the early part of the Last Interglacial. Deglaciation in the Alps was probably underway by 136 kyr, but was interrupted shortly after by a Younger Dryas-type cold spell.