Integrated zircon U/Pb, (U-Th)/He, and oxygen stable isotope study of a normal fault zone (western Alps, Switzerland)

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Small, euhedral zircons (up to 60 μm) were found in late hematite- and quartz-rich veins in the Arolla area (western Alps, Switzerland) crosscutting two different types of Alpine units: the Dent Blanche klippe and the Tsaté nappe. The Dent Blanche klippe is a remnant of the Austroalpine domain, that migrated north-westward during and after the collision between African and European plates starting from ~45 Ma ago. The Tsaté nappe is considered as the remnant of the Jurassic Liguro-Piemontais ocean, subducted before the collision between Africa and Europe palaeocontinents. These zircons are investigated with an integrated approach involving U/Pb, (U-Th)/He, and oxygen stable isotopes to determine the thermal history of this portion of the Alps via the cooling path of these minerals.

U/Pb analysis shows that the zircons have U/Pb ages clustering around 270- 280 Ma, which is the accepted age for intrusive rocks from the Austroalpine Dent Blanche units but which is in apparent contrast with the interpretation of the Tsaté nappe as an ophiolitic remnant of the Jurassic Liguro-Piemontais Ocean. The same samples were investigated with the (U-Th)/He method: first results give a cooling age of 22.3 ± 1.8 Ma for the inherited zircon in late veins of the Austroalpine units. Further measurements on zircon from the Tsaté nappe will provide the cooling age for this unit. Oxygen stable isotope fractionations between quartz and hematite in the same late veins correspond to temperatures of about 170°C. The proximity of the calculated emplacement temperature for late veins and the lower accepted closure temperature for zircon in the (U-Th)/He system (~180°C, [1]) imply that the age of 22.3 ± 1.8 Ma can be interpreted as the formation age of these late brittle fractures. This approach will contribute to the understanding of the exhumation path for this portion of the Alps, which is so far poorly understood.

[1] Reiners *et al*., 2004. *Geochim. Cosmochim. Acta* **68**, 1857-1887.

Opposite export of North Atlantic deep and intermediate waters during the last glacial inception

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We present new sedimentary (^{231}Pa/^{230}Th) data to reconstruct the evolution of the AMOC export during the Last Glacial Inception (LGI: 130 to 60 ka). The records come from three cores located in the North Atlantic: SU90-11 (44°04′N, 40°01′W, 3647m water depth), MD01-2446 (39°03′N, 12°37′W, 3547m water depth) and MD95-2037 (37°05′N, 32°01′W, 2159m water depth). The (^{231}Pa/^{230}Th) changes do not correlate with the variations of opal concentration nor any other sedimentary components. We therefore use these (^{231}Pa/^{230}Th) records as a kinematic proxy depicting changes in AMOC export over the LGI.

Our results show that the vertical structure of the AMOC changed drastically during the LGI and particularly after Marine Isotope Stage (MIS) 5.5. During MIS 5.5, the deep cores show minimum (^{231}Pa/^{230}Th) while the intermediate core shows high (^{231}Pa/^{230}Th), thus indicating that a maximum of export occurs below 3000m and that the intermediate waters export is sluggish. This AMOC pattern is consistent with an efficient convection occurring in the high latitudes during the period of minimum ice sheet extension and climate optimum. This AMOC pattern is consistent with the one occurring during the late Holocene [1]. Within MIS 5.4, the deep water export slows abruptly while the intermediate water export accelerates abruptly as a result of the first massive iceberg discharge of the LGI and the associated freshwater input that limits the deep water formation. The opposition in the strength of the export between intermediate and deep waters is recorded during the entire LGI and its fluctuations respond to the orbitally forced climate changes. During MIS 4, the AMOC pattern is consistent with the long term settling of GNAIW with sluggish export of the deep water and higher export of the intermediate water.

[1] Gherardi *et al.* (in press) *Paleoceanography*.