Stalagmite-inferred hydroclimate changes in northern Italy during Allerød/Younger Dryas transition

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Abstract

The Younger Dryas (YD), a 1200-year-long cooling event interrupting the warm Bølling-Allerød period, started from 12,870 ± 30 yr BP (2σ, before 1950 C.E.). Here we present decadal-resolved stalagmite BA18-2 multi-proxy records from Bàsura cave, northern Italy. The StalAge age-depth model with 8 U-Th dates with 2-sigma errors of ± 26-193 yrs shows that BA18-2 encompasses Allerød/YD transition, from 14,038 ± 92 to 12,090 ± 54 yr BP. Oxygen isotope data fluctuate between -7.16‰ and -3.68‰, with a clear 2.4‰ increase during the YD onset at 12,870 ± 30 yr BP. Stalagmite BA18-2 Sr/Ca and Ba/Ca linger from 0.060-0.085 mmol/mol and 6.4-9.1 μmol/mol, respectively, from 14,038 ± 92 to 12,681 ± 55 yr BP, ~ 2 centuries after the beginning of YD. A clear 160-year-long two-step increase in both Sr/Ca and Ba/Ca records started from 12,681 ± 55 yr BP, which is a 200-yr lag relative to the timing of BA18-2 oxygen isotope increasing trend. We argue that the oxygen isotope could be governed by moisture source; while, the carbon isotopes, Sr/Ca and Ba/Ca ratios predominantly reflect precipitation change. Our results suggest asynchronous thermal and hydrological changes in northern Italy during the Allerød/YD transition.

1. Cave locations

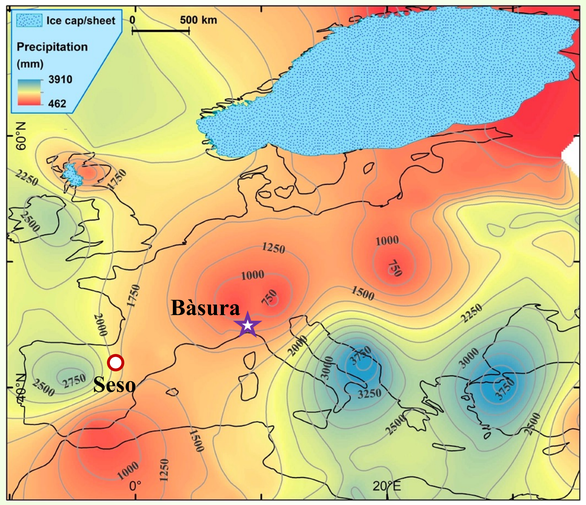

Figure 1. Map of cave sites of Bàsura cave (northern Italy, this study) and Seso cave (Spain) (5). This map was modified from Figure 2 in Rea et al. (2020) (1). Contours and colored shading denotes the reconstructed precipitation amount during Younger Dryas.

2. Stalagmite U-Th dates and age model

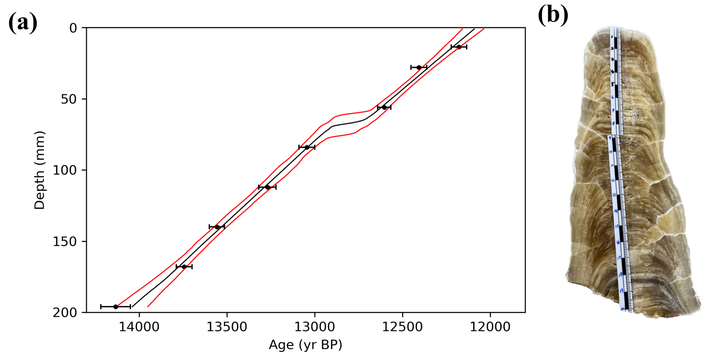

Figure 2. (**a**) An age-depth model of BA18-2 built with U-Th dates with StalAge methods (2). (b) Stalagmite BA18-2.

3. Stalagmite $\delta^{18}O$, $\delta^{13}C$, Sr/Ca and Ba/Ca records

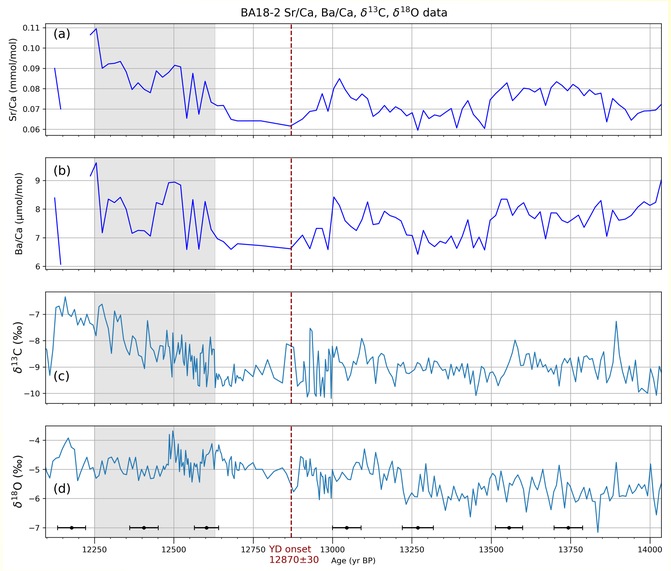

Figure 3. Stalagmite BA18-2 records of (a) Sr/Ca, (b) Ba/Ca, (c) $\delta^{13}C$, and (d) $\delta^{18}O$. U-Th ages and 2-sigma errors are given below. The dark red dashed line denotes the onset of the YD based on "BREAKFIT" analysis of NGRIP $\delta^{18}O$ record (6).

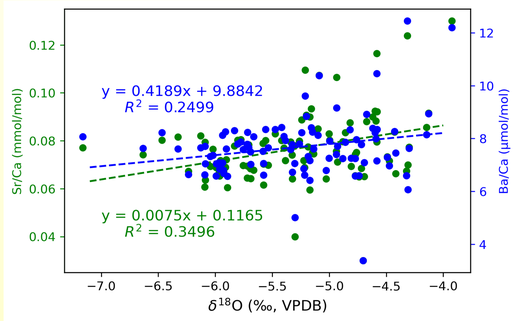

Figure 4. A plot of Bàsura Sr/Ca and Ba/Ca vs. $\delta^{18}O$ data. The green (Sr/Ca) and blue (Ba/Ca) dashed lines represent the lines of best fit. The regresssions show low correlations between $\delta^{18}O$ and Sr/Ca and Ba/Ca.

4. Comparison of European stalagmite and Greenland ice core $\delta^{18}O$ records

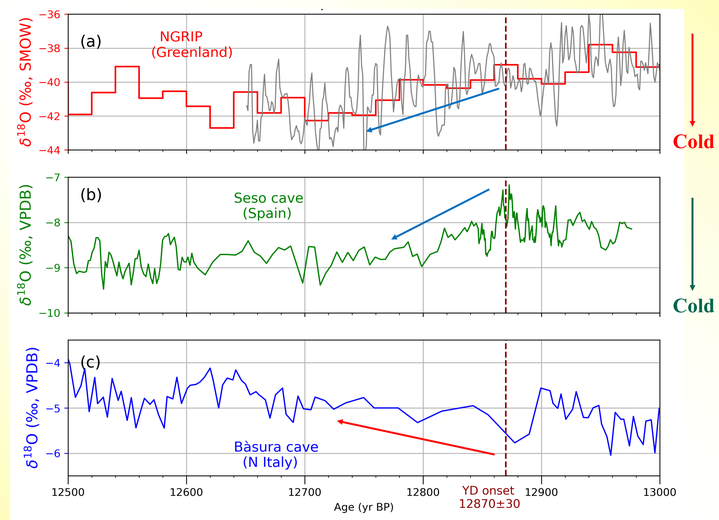

Figure 5. (a) NGRIP $\delta^{18}O$ ice-core record in Greenland on the GICC05 chronology in 20-year resolution (red) (3) and annual resolution (gray) (4). (b) SE09-6 $\delta^{18}O$ stalagmite record in Seso cave (6). (c) BA18-2 $\delta^{18}O$ stalagmite record in Bàsura cave. The dark red dashed line represent the onset of the YD (6).

5. Hydroclimate change in northern Italy and southern Europe

- **$\delta^{13}C$: precipitation change (more postive $\delta^{13}C$ → drier condition)**
- **Sr/Ca: aridity (higher Sr/Ca → drier condition)**

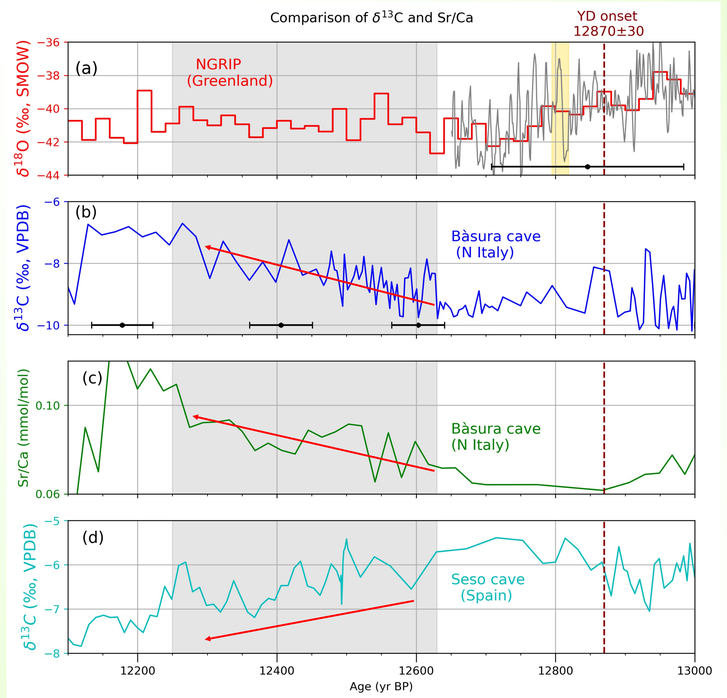

Figure 6. (a) NGRIP $\delta^{18}O$ ice-core record in Greenland on the GICC05 chronology in 20-year resolution (red) (3) and annual resolution (gray) (4). The error bar at the bottom shows the beginning of GS-1 cooling at 12,846 (±138 years) BP (4). Yellow shading denotes YD onset at 12,807 ± 12 yr BP estimated by Laacher See Eruption (7). (b) BA18-2 $\delta^{13}C$ stalagmite record in Bàsura cave. (c) BA18-2 Sr/Ca ratio in Bàsura cave. (d) SE09-6 $\delta^{13}C$ stalagmite record in Seso cave (5). The dark red dashed line in (a)-(d) is the onset of the YD (4).

7. Conclusions

Stalagmite multiproxy records from Bàsura cave, northern Italy, reveal the climate variability over northern Mediterranean during Allerød/YD transition. The $\delta^{18}O$ expresses a negative correlation with Greenland temperature series, reflecting a change in moisture sources associated with Atlantic climate variability. The $\delta^{13}C$, Sr/Ca, and Ba/Ca, however, suggest an appreciable rainfall amount change delaying Atlantic wide-basin YD onset in approximate 200 years. The asynchronous hydrological changes in northern Mediterranean realm from high-latitude North Atlantic may arise from the large-scale reorganization of oceanic and atmospheric circulation during the Allerød/YD transition.

8. References

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