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Stalagmite carbon isotopes suggest deglacial increase in soil respiration in western Europe driven by temperature change

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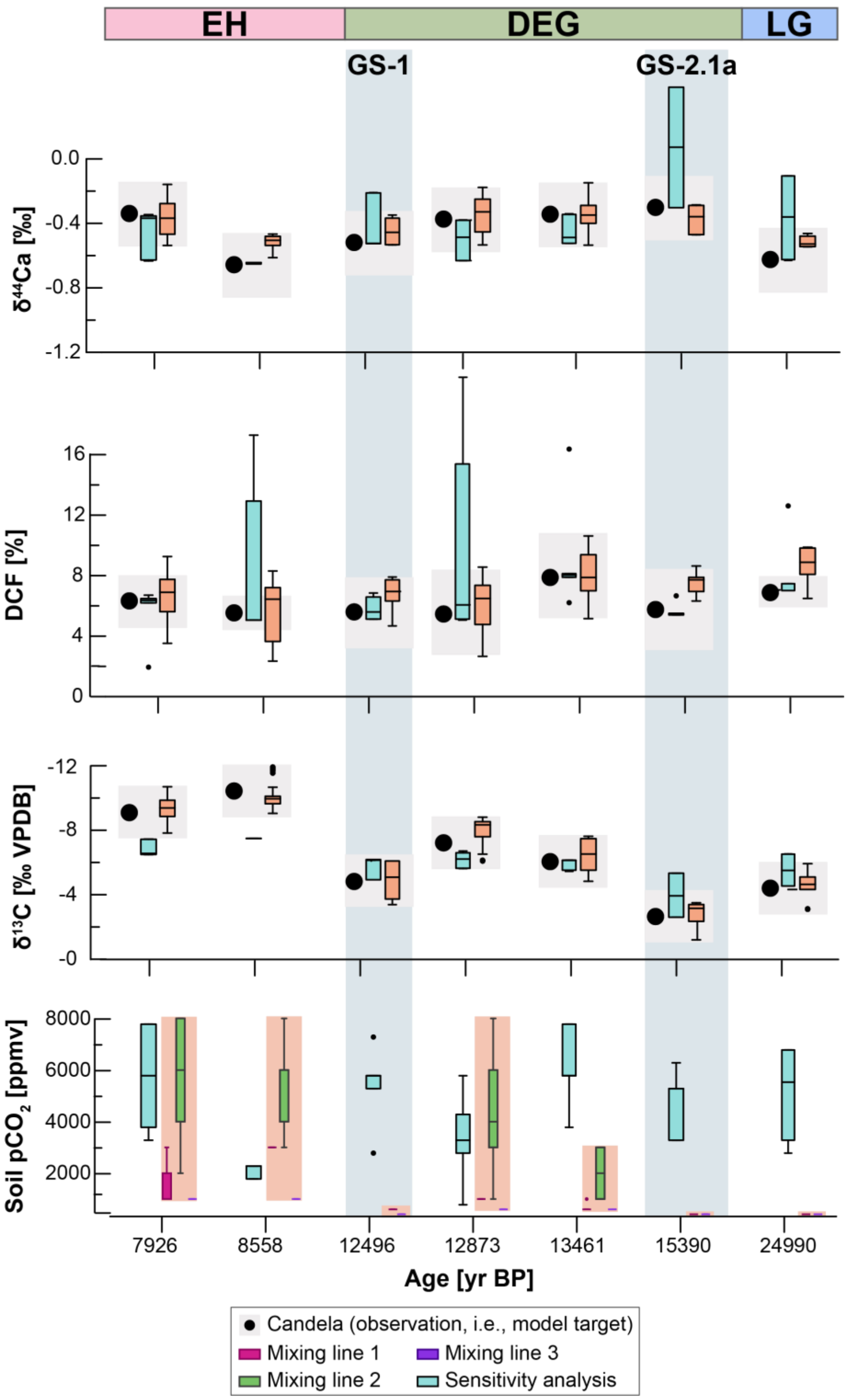
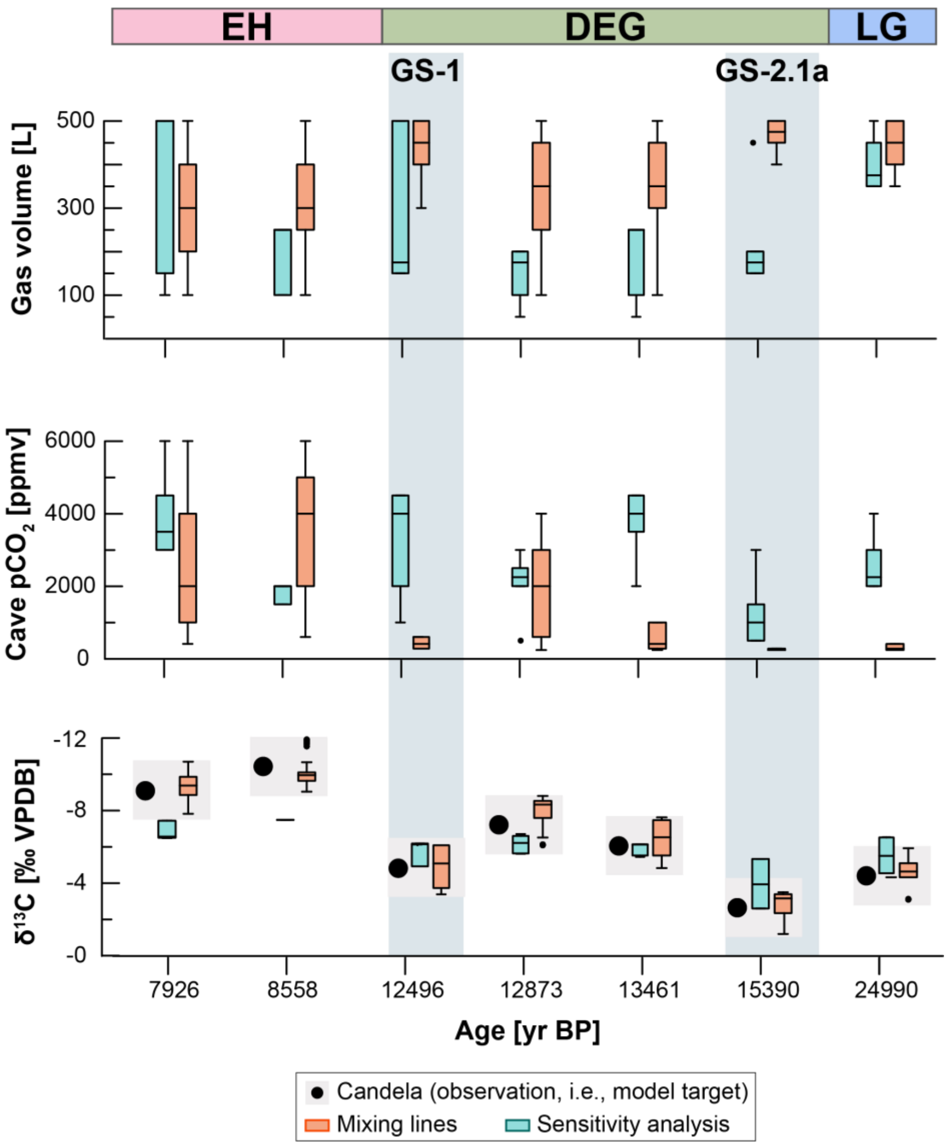


Suppl. Fig. 1: Modelling results compared to measured proxies in stalagmite Candela. Stalagmite measurements ($\delta^{13}C_{spel}$, DCF, $\delta^{44/40}Ca$; black dots) are compared to best fitting model solutions (colour-coded by simulation type). The results from the three mixing lines are shown separately. Simulation results are shown as box plots, with the median and upper and lower quartiles displayed. Outliers are shown as dots. Grey shading indicates intervals of the measured proxy values used to filter the simulations. The soil pCO_2 derived from the different model solutions is shown. The time periods (LG, DEG, EH) at the top of the figure indicate the intervals used for the modelling to define temperature and atmospheric pCO_2.

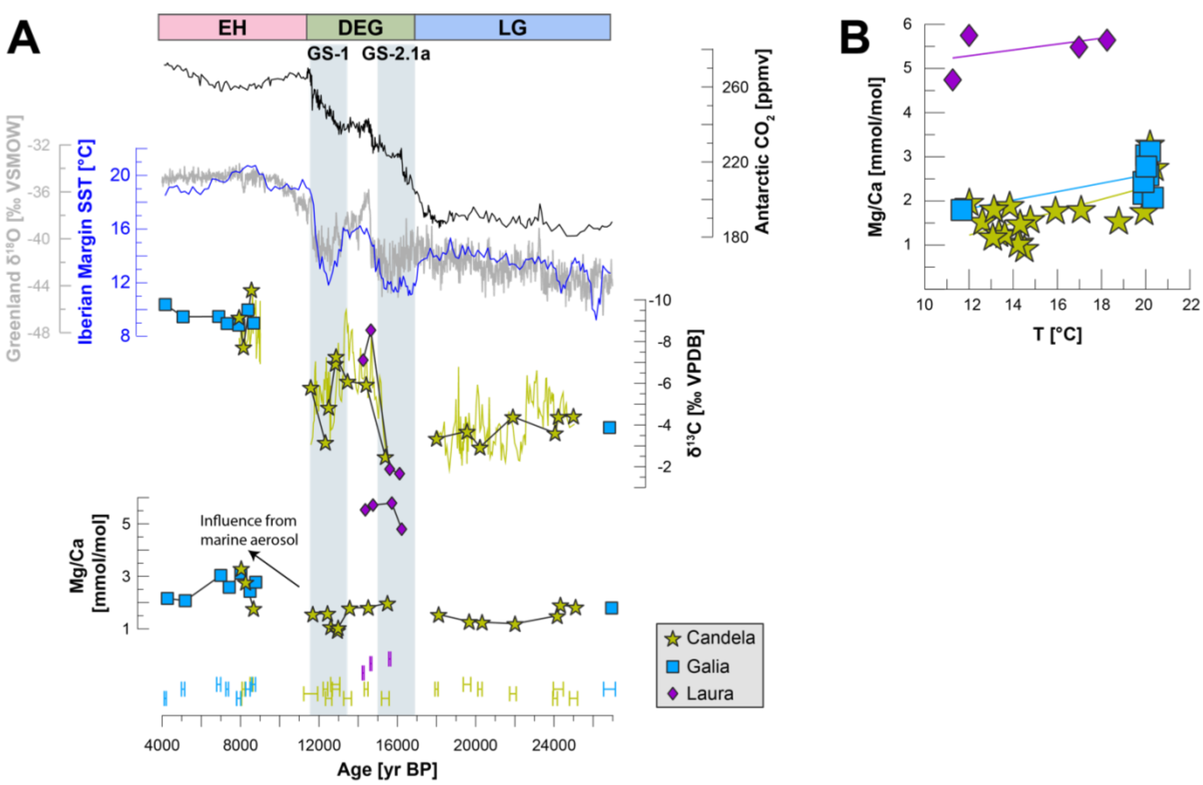


Suppl. Fig. 2: Modelling results for cave pCO_2 and gas volume, compared to measured and modelled $\delta^{13}C_{spel}$ in stalagmite Candela. Stalagmite measurements ($\delta^{13}C_{spel}$, DCF, $\delta^{44}Ca$; black dots) are compared to best fitting model solutions (colour-coded by simulation type). Simulation results are shown as box plots, with the median and upper and lower quartiles displayed. Outliers are shown as coloured dots. Grey shading indicates intervals of the measured proxy values used to filter the simulations. The time periods (LG, DEG, EH) at the top of the figure indicate the intervals used for the modelling to define temperature and atmospheric pCO_2.

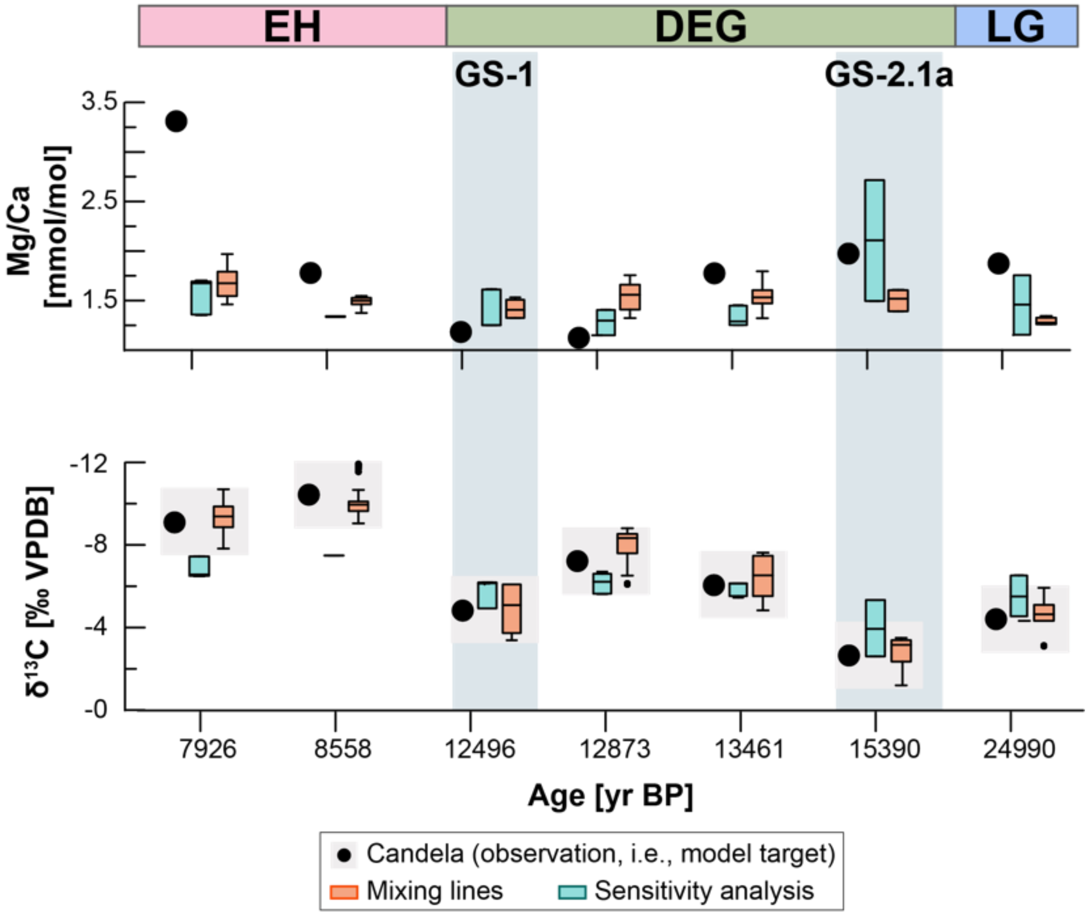
Mg/Ca measurements and modelling:

Mg/Ca ratios are also often used as qualitative proxy for prior calcite precipitation (PCP; Fairchild and McMillan, 2007). At the Pindal Cave site, where the cave currently extends to the sea cliff, Mg/Ca of dripwaters is additionally increased in the Holocene by increasing surf zone marine aerosol generation as rising sea level brings the coastline from >1 km away to within 50 m of the cave entrance. Mg/Ca was still measured on stalagmites Candela, Galia, and Laura using splits of the isotope samples, either at the University of Oviedo following previously described methods (Thermo ICAP DUO 6300, Moreno et al., 2010), or with similar standardization approaches at ETH Zürich (Agilent QQQ 8800); all ratios are reported in mmol/mol standardised to calcium.

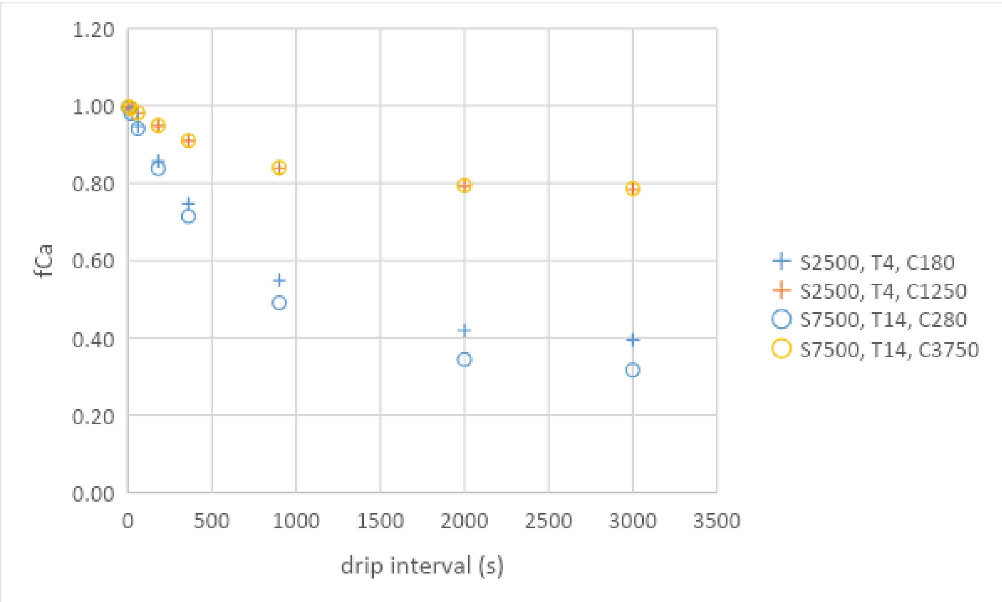
Mg/Ca ratios are similarly low during the LG in Candela and Galia, followed by a 2- 3-fold increase at the transition to the EH (Fig. 3). In Candela, the Mg/Ca dips to its absolute minimum values at the beginning of GS-1, coinciding with an increase in δ^{13}C. Absolute Mg/Ca values are much higher in Laura (around 5mmol/mol, Fig. 3) and display a slight increase from the beginning of GS-2.1a towards GI-1.



Suppl. Fig. 3: A – Mg/Ca record from the three stalagmites, compared to $\delta^{13}C_{spel}$, as well as regional temperature (Darfeuil et al., 2016), the Greenland $\delta^{18}O$ record (Wolff et al., 2010), and global atmospheric CO_2 (Bereiter et al., 2015) reconstructions. Increasing Mg/Ca with the onset of the Holocene are likely related to increasing contribution from marine aerosols at the site, a consequence of rising sea levels. The time periods (LG, DEG, EH) at the top of the figure indicate the intervals used for the modelling to define temperature and atmospheric pCO_2. B – Stalagmite Mg/Ca vs. temperature, colour-coded by stalagmite. The corresponding palaeo-temperatures are linearly interpolated from the Iberian Margin SST record by Darfeuil et al. (2016).



Suppl. Fig. 4: Modelling results for Mg/Ca, compared to measured and modelled $\delta^{13}C_{spel}$ in stalagmite Candela. Stalagmite measurements (black dots) are compared to best fitting model solutions (colour-coded by simulation type). Simulation results are shown as box plots, with the median and upper and lower quartiles displayed. Outliers are shown as coloured dots. Grey shading indicates intervals of the measured proxy values used to filter the simulations. The time periods (LG, DEG, EH) at the top of the figure indicate the intervals used for the modelling to define temperature and atmospheric pCO_2.



Suppl. Fig. 5: Influence of soil pCO_2 and cave temperature and pCO_2 on f_ca (as a measure for PCP) vs drip interval, using ISTAL (Stoll et al., 2012). We compare how drip interval influences PCP under glacial (temperature: 4°C, soil pCO_2: 2500 ppmv, cave pCO_2: 180 ppmv in winter, 1250ppmv in summer) and Holocene (temperature: 14°C, soil pCO_2: 7500 ppmv, cave pCO_2: 280 ppmv in winter, 3750ppmv in summer) conditions. The model assumes fully open dissolution conditions, a reasonable estimate at our study sites.

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