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Key Points:
- Silicate versus carbonate weathering has an influence on speleothem trace elements
- Yttrium, phosphorus, and aluminum reflect detrital content of the speleothems
- $\delta^{18}O$ values of the stalagmites are a proxy for mean annual temperature

Supporting Information:
- Supporting Information S1

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High-Resolution Proxy Records From Two Simultaneously Grown Stalagmites From Zoolithencave (Southeastern Germany) and their Potential for Palaeoclimate Reconstruction

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Abstract Two small annually laminated stalagmites from Zoolithencave (southeastern Germany) grew between CE 1821 and 1970 (Zoo-rez-1) and CE 1835 and 1970 (Zoo-rez-2), respectively. Trace element concentrations were determined by Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). Samples for $\delta^{13}C$ and $\delta^{18}O$ analyses were micromilled on annual and subannual resolution. Soil and host rock samples were analyzed by X-Ray Diffraction (XRD) and their elemental concentrations determined via inductively coupled plasma optical emission spectrometer (ICP-OES). Trace element concentrations in the stalagmites show two groups in the principal component analyses: one with Mg, Ba, and Sr and another with Y, P, and Al, respectively. The second group reflects the content of detrital material. Increased weathering of soil minerals seems to have a strong influence on the silicate/carbonate weathering ratio controlling the variability of Mg, Ba, and Sr. Meteorological and Global Network of Isotopes in Precipitation (GNIP) station data were used to calculate the $\delta^{18}O$ values of the drip water (infiltration-weighted, mean annual, and the mean of the winter precipitation $\delta^{18}O$ values) as well as the corresponding speleothem calcite. The $\delta^{18}O$ values calculated by the infiltration-weighted model show similar patterns and amplitudes as the measured $\delta^{18}O$ values of the two stalagmites. This suggests that the $\delta^{18}O$ values of speleothem calcite reflect the $\delta^{18}O$ values of infiltration-weighted annual precipitation, which zis related to mean annual temperature, resulting in a significant correlation between mean annual temperature and the measured $\delta^{18}O$ values of stalagmite Zoo-rez-2. This relationship could potentially be used for quantitative climate reconstruction in the future by extending the time series back in time with further stalagmites from Zoolithencave.

1. Introduction

Quantifying past temperature and precipitation changes is an important but challenging task to set the recent climate change in relation to variations in the past. To achieve this aim, annually to subannually resolved proxy records from climate archives are needed. The most prominent climate archive providing temperature or precipitation reconstructions with annual resolution are tree rings (e.g., Büntgen et al., 2011; Esper et al., 2014; Wilson et al., 2005). Due to the overlap of the tree-ring chronologies with instrumental data, a calibration of the proxy records with meteorological data is possible, and the quantitative reconstruction of climate parameters back in time using the calibration is a standard technique in dendrochronology (Fritts, 1976; Schweingruber, 1983). Speleothems can provide similar high-resolution proxy records, especially if they show annual laminae. A big advantage of speleothems is that they can be precisely dated by the $^{230}Th/U$ method (e.g., Cheng et al., 2013; Richards & Dorale, 2003; Scholz & Hoffmann, 2008), and the derived age-depth models can be further improved by lamina counting, which anchors internal age-models for annual to subannual proxy records (Baker et al., 1993, 2015; Scholz et al., 2012; Smith et al., 2009; Tan et al., 2003; Warken et al., 2018). Speleothem $\delta^{13}C$ and $\delta^{18}O$ values can be measured with annual to subannual resolution and have provided information on past temperature and/or precipitation variability (Boch et al., 2011; Mattey et al., 2008; Myers et al., 2015; Orland et al., 2012; Ridley et al., 2015;