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Climate of the Past Discussions

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# *Interactive comment on* "Speleothem oxygen record – thermal or moisture changes proxy? A case study of multiproxy record from MIS 5/MIS 6 age speleothems from Demänová Cave System" *by* Jacek Pawlak

**Jacek Pawlak**

dzeq@twarda.pan.pl

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Anonymous Referee 1

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Jacek Pawlak presents a new speleothem record from Slovakia that covers Termination 2 and the last Interglacial. The record is composed of multiple geochemical proxies (stable O and C isotopes, trace elements, and carbonate microfabrics) and supported by a U-Th chronology.

The record is new and of good quality, but I think the discussion of the results and placement in the regional and temporal context needs substantial more work before being accepted in CP.

I found it quite difficult to follow the discussion in several instances. Part of this might be related to wording and language. I made some suggestions for improvement but more could be done to clarify the text. In addition, I think the figures 4 and 6 can be improved as they are quite hard to read, at the moment. I made some suggestions in the specific comments:

I would suggest reorganizing the discussion along three main sub-headings:

1) Drivers of $\delta$18O in Slovakia and comparison with other European $\delta$18O records. 2) Interpretation of the other proxies. 3) The temporal evolution of the proxies in JS9.

I agree that such rearranging of the discussion may improve clearness of the manuscript.

1) Drivers of $\delta$18O in Slovakia and comparison with other European $\delta$18O records.

Here, I found it difficult to understand what is meant by "thermal" control, as $\delta$18O can be influenced by temperature in different ways, which the author describes, but then does not further elaborate on. More clarity in the language (what is meant by "thermal" or "temperature" effect in $\delta$18O at the different locations described?)

and a more in-depth discussion of the likely controls on $\delta$18O at the DCS cave is needed. For example, is there monitoring data from the cave that can back up some of the interpretation of $\delta$18O? Nearby GNIP stations that can be used to test the modern relationship between temperature, moisture source, and $\delta$18O in precipitation? So far, this part of the discussion is tenuous and seems based mostly on speculation.

I agree that this dependence is complicated. I believe that it is more the local thermal signal (changes in mean annual temperature) which influences the $\delta$18O of precipitation and has impact on isotopic fractionation during calcite crystallization in the cave.





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However, in longer time scale the isotopic composition of ocean source which depend on mean global temperature and global volume of glaciers becomes important (source effect). Additionally the circulation changes which causes the changes in proportion of vapors from different sources plays important role here.

There are several stations in Slovakia, where the $\delta$18O of precipitation was measured continuously (Holko et al 2012). The detailed study in the region shows, that there is a strong dependence between the $\delta$18O and temperature. This dependence is observed in the long time monitoring for single sites (Holko et al 2012). Exemplary, for the closest station next to the research area in Liptovski Mikulas the R2 of correlation between the $\delta$18O of atmospheric precipitation and temperature is 0.639 (Holko et al 2012). Additionally, there is a stronger dependence between mean annual temperature of the site, and mean $\delta$18O value in Slovakia with R2= 0.728 (Holko et al 2012). The dependence between mean annual precipitation and mean $\delta$18O value is less visible (R2=0.483) (Holko et al 2012).

There is other methodological work which includes data from many cave sites located on several continents the conclusion of this work is that sites with mean annual temperature lower than 15C and the aridity index higher that 0.65 has a potential for growing speleothems which reflects the mixed signal of past temperature and past precipitation ( Baker et al 2018).

All this information will be included in revised version of discussion.

2) Interpretation of the other proxies. Again, I would welcome some more detailed reasoning on why the proxies are interpreted in the way they are. For $\delta$13C, it would be useful to know more about the soil cover and vegetation assemblage above the cave. Are there palynological/palaeoecological studies from the region that could shed light on expected changes in biosphere responses over glacial-interglacial timescales? The discussion of the trace elements similarly lacks depth. It is not clear to me whether the author is implying a control of prior calcite precipitation (PCP) control on Mg, Sr, and

Ba, or whether the dominant control is thought to be the dolomite dissolution. In any case, this should be elaborated: what is the basis for the claim that dolomite dissolution is dominant? Are there measurements of the host rock composition? Overall, I think there is currently some overinterpretation of small wiggles in the trace element records (Mg, Sr, Ba), in particular. I don't see much variability in the older part of the Mg record. I would also caution against interpreting the trace element record at the base of the stalagmite, as this is often a region where effects that have nothing to do with climate play a role.

Presently the vegetation cover over the Demianovska Cave System is dominated by the mixed forest of mountain type and grasslands connected with mountain slopes activity. Therefore, presently there are two types of soils, over the cave, associated with forest and the other type associated with slopes activity (Hercman et al 2020).

There are few palynological sites nearby. The important one is located in a closed proximity is Safarka (Jankovska, 2002). The pollen record from Safarka covers ca. last 60ka and recording changes of plants cover during the last glacial. The record show a predominance of needle-leaved and cold temperate tree vegetation during warmer episodes of MIS 3. The Last Glacial Maximum part of these pollen record suggests that some woody cover was maintained in the region during the maximum northern hemisphere ice extent (between 26.5 and 19 ka cal BP). The beginning of Holocene is marked by introduction of temperate forest (Feurdean et al 2014). The changes in vegetation at the end of last glacial and the begging of Holocene are well expressed in $\delta$13C records from Demianova Cave System (Hercman et al 2020).

The Demianova Cave is developed mostly in Gutenstein limestones (Early Anisian) and Ramsau dolomite (Ladinian) therefore both the dissolution of limestones and dolomites can happened. During periods of longer water residence time the contribution of Magnesium from Dolomite source is increased. This effect results in higher Mg/Ca values and lover Sr/Ca values (Tremaine and Froelich 2013). The PCP also can occur during dry episodes of longer water residence times. However, the PCP results in increase of





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all X/Ca rations (Tremaine and Froelich 2013) which is rather not observed in a studied record.

3) The temporal evolution of the proxies in JS9. In my opinion, the records are overinterpreted at this point. Many of the smaller wiggles are probably not resolvable given the chronological uncertainty in the record. I would suggest the author focus and expand the discussion on the larger and interesting features in the record, e.g., the large peak in $\delta$13C, P, Fe, and Mn around 100 ka BP, as well as why TII is only weakly expressed in the record. It is possible that with some restructuring of the text this is already possible, but as mentioned above I found it quite difficult to follow at the moment. I think it would be better to use a more recent ice core record (NGRIP for example) to compare the speleothem records to.

I agree with your commend about overinterpretation of some part of that record in revised version of the Manuscript the discussion will be oriented more on the most important fact like the large event around 100 ka visible in this record and the expression of TII.

In previous version I decided to use GRIP due to the fact, that it covers whole studied period. However, after I got several commends and suggestions about that I agree that the NGRIP is better solution even if it covers only part of the studied record.

Specific comments: - line 27 and rest of text: use “precipitation” instead of “rain precipitation”

It will be corrected in revised manuscript.

- line 44 and following: I would not include Middle Eastern records in the discussion about European records. Rather discuss the European records and then add a sentence. showing the similarities with the Middle East and linking that to the prevailing circulation patterns?

It has been changed.

In contrast to the most of European records, the records from Middle-East seems to be influenced by more factors, like the amount of precipitation, temperature, and also changes in the main source of vapor for rain precipitation (source effect; Bar-Matthews et al., 2003). It can be linked to changes in the prevailing circulation patterns, the impact of evaporation on Mediterranean Sea surface $\delta$18O and also lower amplitude of long time mean annual temperature changes during Last Interglacial at lower latitudes (Rybak et al. 2018).

- line 52: I don't understand this sentence.

It has been changed to

Presently, Slovakia is influenced by two main types of climates (Kottek et. al. 2006), the boreal fully humid with warm summers climate (Dfb) on the East and warm temperate fully humid climate (Cfb) on the West.

- line 55: Since it's a single author paper, change the "we" to first person.

It will be corrected in revised manuscript.

- line 67: I think it should be "genesis of DCS" instead of "genese"

It will be corrected in revised manuscript.

- line 78 and in other parts of the text: "peak" instead of "pick"

It will be corrected in revised manuscript.

- line 95: Why were samples for dating drilled to be as thick as possible? This seems counterintuitive, as one would typically try and minimize the amount of sample to avoid integrating too much time within a single sample.

It is a mistake it should be thin here.

- line 117: "To minimalize the difference in resolution between the lower and upper part of the studied record caused by the sedimentation rate, which is slower for the lower part. The lower part of a stalagmite from 0 to 40 mm was additionally sampled with a resolution of one sample/0.3 mm." I think these two sentences should be joined, as the first one does not make sense on its own.

The lower part of a stalagmite ( 0 to 40 mm) was additionally sampled with a resolution of one sample/0.3 mm, to minimalize the difference in resolution between the lower and upper part of the studied record caused by, slower for the lower part sedimentation rate.

- line 118: Use "growth rate" instead of "sedimentation rate" for speleothems

It will be corrected in revised manuscript.

- line 212 and following: instead of "short time signal" it would be clearer to refer to "short term variability".

Thank you, a lot, for all grammar commends they will be corrected. Additionally, the text will be sent for final language and grammar corrections. After all substantive changes and corrections.

- line 233: I think it's interesting that the TII is only visible as such a muted response in d18O, compared to the overall variability in the record. I would be interested in knowing more about why that is.

I agree. Additional question is why the final negative response of $\delta$18O at TII is opposite to response observed in other Central European sites exemplary in northern part of Tatra Montains (Magurska Cave) and in Alpine records (Holloch and Schneckenloch). The response in those Central European sites is clearly connected, with two processes first with increase of mean annual temperature and second with change from winter dominated precipitation to summer dominated precipitation (Moseley et al. 2015; Meyer et al., 2008; Holzkamper et al., 2004). In case of studied site, the observed final negative response must be caused by local or regional effect which was stronger that thermal effect at that time. The possible effect which my cause the lower value of $\delta$18O is circulation effect and change from sources of precipitation like Adriatic Sea or Black Sea to Atlantic Source and vapor recycled over the European continent. The instant change to more negative values may be caused by source and continental effect, which overcame the temperature effect at that time. Therefore, the muted response is a result of both the effect of increase the mean annual temperature and source/circulation effect which overcomes each other.

- line 255: The growth rate appears to be much lower in the interval 127-122, which stands at odds with the interpretation of the isotopes (wetter climate and well-developed soil). Any thoughts on why that might be? Also, I don't agree with the following sentence on Mg, as I don't think there is a significant trend there.

The interval of low growth rate is much longer it starts at ca. 133 ka and ends at ca. 112. In my opinion it may be caused by local effects. Our research of five Holocene stalagmites from Demianova Cave System shows that changes in growth rate are different for all studied stalagmites and they are not connected directly with climate changes (Hercman et al., 2020). Therefore, they must be caused by local effect in the cave.

I agree with your opinion that trace elements like Mg must be treated with caution. It is true that the Mg record is dominated rather by pseudo cyclic changes without the significant main trend. However, there are two short intervals where the Mg content is significantly lower at ca. 100 and 88 ka, which is interesting. Additionally, in my opinion there are several intervals of lower Mg values which repeats $\delta$13C signal at 88, 100, 110, 113 and 124 ka. In my opinion, it is an argument that those intervals may relate to increased amount of precipitation.

- Figure 1: the map of Slovakia could be improved by showing the (Tatra Mountains, Low Tatra moununtains, location of Magurska Cave and the boundaries of climate zones or dominant air masses.

The boundaries of climate zones, locations of Tatra Mts and Low Tatra Mts and the caves in the nearest proximity (Magurska and Baradla ) have been added to fig 1A.







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- Figures 4 and 6: I find these two figures very hard to read, as there is a lot of information. Given that they are so crucial to the discussion, I have a few suggestions to improve them: 1. I would add a second age scale at the top of the figures, to make it easier to read 2. Clearly label the TII, maybe as a bar that covers the figure 3. I wonder if it is necessary to show all the records in figure 6, I think focusing on some key records from each group (maybe the longest ones?) would make it easier to read. But this might be my personal preference.

According to your suggestion I added the additional age scale on the top of both figures and solid line for TII and dotted lines between MIS 5e/5d/5c/5b boundaries.

I like the color scheme linking back to figure 5, please add the explanation of the different groups to the caption.

Thank you. The explanation of the color scheme has been added to the caption bellow fig 6.

Fig. 6. The comparison of JS9 $\delta$18O record with other records of MIS-5/MIS-6 age from Europe and Middle East. GRIP (Chappellaz et al.,1997); Magurska (Pawlak et al., 2020 – submitted); Baradla (Demény et al., 2017); Orlova Tchuka (Pawlak et al., 2019); Schneckenloch (Mosley et al., 2015); Holloch (Moseley et al., 2015); Entrische Kirche (Meyer et al., 2008); Bourgeois-Delaunay (Couchoud et al. 2009); Cobre (Rossi et al. 2014); Han-sur-Lesse (Vansteenberge et al., 2016); Antro del Corchia (Drysdale et al., 2005); Soreq (Bar-Matthews et al., 2003); Peqiin (Bar-Matthews et al., 2003); Kanaan (Nehme et al., 2015); black and gray colors charts - speleothems with temperature as a dominant factor influencing on $\delta$18O value; Green colors charts – speleothems, where the changes of the isotopic composition of rainwater and amount of precipitation are dominant factors influencing on $\delta$18O value; Red color charts - studied site.

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Please also note the supplement to this comment:
https://cp.copernicus.org/preprints/cp-2020-125/cp-2020-125-AC1-supplement.pdf

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2020-125, 2020.