

## Author's response to reviews

Our separate responses to comments of both reviewers were uploaded to the interactive discussion:

- Referee 1
- Referee 2

We now summarize our replies to the reviews below. Also attached is a **revised manuscript** and a version with **marked changes**. In the marked version, old text is typed in red with a stroke through, new text is typed in blue, and comments are marked in green.

Below, we list the comments from the reviews, along with our replies and changes:

### 1. Suffosion sinkholes

*I disagree with what stated. Suffosion sinkholes do not belong to the category of collapse sinkholes but are formed by different processes. Authors are kindly invited to have a look at the classification proposed by Gutierrez et al. (2014), recently revised by Parise (2019, 2022).*

We agree with the referee that suffosion sinkholes do not fall into the collapse-sinkhole category. We have corrected this mistake and added the three citations to more recent publications concerning the classification of sinkholes.

We have clarified, that the Münsterdorf sinkholes are somewhere between the end members cover-collapse and caprock-collapse sinkholes.

### 2. Photos of site(s)

*It is reported that “In the mines, numerous karst features can be observed, such as dissolutionally-enlarged fissures and bedding planes and small collapse sinkholes. One figure, with two or more pictures, to show these features and their size could be useful to readers.*

*Still as regards figures, no photo of the sinkholes is provided. I would appreciate adding one figure with some pictures to show the main characters of the phenomena.*

The referee asks for photos of the site and the karst features in the nearby open-pit mines. We have added a photo of a sinkhole just next to the sports field for clarification (see revised manuscript). However, as we have no access to the private open-pit mine, we can only refer to photos in other (unpublished) publications concerning the karst features in the mine.

### 3. Water table

*About the depth of the water table, it would be interesting to know at what depth it is, and if water fluctuations in response to rainfall occur. Some more information should be provided at this regard.*

We have extended the section of the water table, adding both absolute numbers from the past and present time, and about the fluctuations induced by rainfall.

#### 4. Suffosion sinkhole

*(3.2. Hypotheses): both presented hypothesis start from the presence of an underground void. What if the void was not present, and the sinkholes are not of collapse origin? Is there the possibility of suffusion sinkholes? The lack of photographs of the sinkholes make difficult to understand if this third hypothesis could be true. In any case, why do you suppose the presence of voids for the sinkhole formation?*

*This is the main problem I see in this article, since it is assumed that a void is present, and the possibility of a different typology of sinkholes is not taken into consideration at all. Authors should clarify the reasons why they consider only the presence of voids (either in the peri-glacial sand or in the chalk), excluding the other possibility.*

The referee asks for the reason why we start proposing an initial void as cause for the sinkholes. Basically we have three lines of evidence, pointing us to a collapse sinkhole:

- The occurrence and the initial shape of the sinkholes, both sudden and near-vertical, points to a sudden collapse, and not slow suffosion.
- Also the size of the sinkholes, 3 meter diameter and 4-5 meter deep, thus a volume of around 30-35 cubic meter, needs a larger volume in the sub-surface.
- There are several collapse sinkholes in the area, which are much older than the sinkhole cluster of the sports field.

We have clarified this in the text.

#### 5. Previous geophysical measurements

*Various assumptions about the geological structure of the subsurface come from earlier geophysical investigations, which unfortunately only briefly described. A table with the measurements carried out so far with reference to literature should be added.*

We have added a table summarizing all previous geophysical measurements.

#### 6. Forward Modeling

*From the reviewer's point of view, two overly simplified model calculations for the detectability of cavities by means of gravimetry and geoelectrics are presented. In addition, the rock physical parameters used must be checked for consistency in the paper. For example, some of the resistivities used for modeling do not match the values given in Table 1. Furthermore, the effect of the described glacial till layers was not taken into account, although these influence the density distribution and resistivity distribution in the subsurface.*

*This section should be supplemented by geophysical measurement examples for gravimetry and geoelectrics from the investigation area. If this is not possible, the section can also be omitted.*

We have cross-checked all material parameter values, and corrected wrong values in table 1.

We did not consider the glacial till layer in the forward model for two reasons:

- The glacial till layer tapers out in the sinkhole zone.
- The electrical resistivity values of the till and the wet chalk are similar.

We have mentioned these two points in the revised version.

### **7. Drop of the groundwater level as an initial event**

*The drop of the groundwater surface causes the formation of earth falls. The hypothesis is explained in detail and comprehensibly. However, there is a lack of information on the past and present location of the groundwater surface as well as on the course of the groundwater surface between the study area and the opencast mine. In Figure 11, information on the location and topographical height of the stör river and the opencast mine as well as the distance between the objects must be supplemented to scale. Is a lowering of the groundwater level by several meters away from the opencast mine really realistic and what role does the mentioned fault zone on which the sinkholes are located play?*

The drop of groundwater level due to pumping in the open-pit mine is modelled with a large-scale model with simple setup. The modelled drop in groundwater level by several meters, forecasted by the model, has been observed in boreholes on and around the sports field. We have made this a bit more clear in the section on groundwater levels.

### **8. Typos**

We have also changed all typos spotted by the referees, and these changes are also marked in the annotated manuscript.

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Although we are aware that some concerns of the reviewers may remain, we hope that the changes and our reasoning fulfill their expectations.

Georg Kaufmann, Douchko Romanov, Ulrike Werban, Thomas Vienken