UNIVERSITÄT BAYREUTH

LEHRSTUHL GEOMORPHOLOGIE

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PhD thesis by Mgr. Jakub Mareš:

Vaporization plane and moisture-related characteristics of shallow subsurface zone of porous materials

Assessment by Prof. Dr. Oliver Sass

General assessment

The thesis of Mgr. Jakub Mareš presents results on the formation of cavernous weathering features (tafoni and honeycombs) from three case studies in different climatic settings. The case studies in Italy, Israel and Czechia are interlinked by the use of a similar range of methods. The author has obtained (rock-)hydrological data e.g. on the depth of the capillary fringe, rock moisture, permeability and rock mechanical parameters and performed a wide range of lab measurements. Most methods are technically demanding because it is much less common and mechanically difficult to measure in rock (compared to soil).

The thesis contributes a lot to our understanding of small-scale rock hydrology and of the formation of enigmatic weathering features. The results show similarities and differences of capillary depth, moisture budget and salt precipitation between the three sites. The three papers making up the cumulative dissertation are all first-author papers of Mgr. Mareš and were published in high-ranking international journals. The entire publication record (there are contributions to more than the three core papers) is very good for an early career scientist at this stage.

Even though there are some critical points mentioned in the specific comments which might be improved, I recommend the thesis for the defence.

Specific comments and questions

The Introduction is well-written; however, the overarching aim of the thesis doesn't become entirely clear. Aims are briefly summarized, but kind of generic: "*(Aim) … is to combine these techniques to better describe moisture distribution and fluxes in rock subsurface*." Concrete research questions would be helpful. Hypotheses are currently missing.

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Furthermore, the wider perspective could be worked out better. Salt weathering causes considerable damage to buildings and monuments, however, the terms "cultural heritage" or "historical monuments" do not occur in the Introduction.

Possible questions (to answer in the thesis and/or in the defense):

→ Why is moisture measurement important? (Understanding landform evolution, protecting cultural heritage, quantifying this understudied component of the water cycle?)

→ How is the evaporation rate affected by the presence of deliquescent salts? (This is mentioned in the Introduction but it isn't properly explained.)

The Methods chapter presents an impressive range of field and lab methods which are well suited for the investigations. The important core method is measuring the depth of the evaporation front using uranine probes, a unique selling point of Mareš' working group.

Measuring the tensile strength in the field is very interesting and novel. However, it sounds as if the method was quite destructive. Maybe one sentence could be added on this point. A question on the interpretation (paper Tuscany): "The average values are not significantly different (354 kPa in the pits and 284 kPa in the lips), so case hardening is not present":

→ Case hardening might be present and even lead to a reduced tensile strength, if there was a weak horizon under the hardened crust and the entire crust is torn out of the stone. Can you rule that out?

The moisture content was measured "using a precise SONO-ES T3" (later in the paper summary described "ultra-precise"). Please be a bit more specific what "precise" means and how the device measures down to a depth of 90 cm. "Calibration on an arcosic sandstone block" – was this block from the study area? Differences between different varieties of sandstone (even if they seem to be similar) can be huge.

The lab work, particularly the honeycomb block experiment, is interesting and unique. Question:

→ Does the experimental setting (wet "diaper" around the back side of the sample) match the natural conditions? Is there a moisture reservoir inside the rock, and if so, where does it come from?

The part "Results and Discussion" compares the outcome of the three case studies in Czechia, Italy and Israel. To me it seems there is a bit too much compilation of numbers while a proper discussion (also using literature) is missing. How can the results be interpreted in comparison to earlier studies? Are the measured values high, medium or low in a global context? I strongly suggest to summarize all values in a table, maybe augmented with some literature values from other tafoni sites. Questions:

→ How do the own results relate to earlier studies?

→ What are the conclusions for geomorphological landscape evolution, what can be learned for heritage site conservation?

The work in Czechia provides an interesting and rare example of tafoni in humid climate. The results on salt concentration are surprising: A maximum of 9 wt.% is reached which is very uncommon considering the humidity of the area.

→ Is there a geogenic reason for heightened salt content at the site in Czechia?

→ As climate in Czechia is probably at the limit of what is possible for tafoni formation. I wonder where the exact humidity thresholds are? Are there certain, particularly favourable rock parameters (e.g. the porosity of 22%) that make tafoni formation possible at this site? Could, as a speculation, drier paleo-climate be taken into account?

Evaporation experiment: "The small apparent increase in moisture content is most likely caused by the precipitation of salts, which increased the weight of the block and affected the measurement." This is highly questionable. In order to increase the weight, the salts would have to enter the rock block from outside of the system. Precipitating salts usually come from the inside of the rock and precipitate at the surface. This process cannot cause weight increase. (Condensating air humidity at precipitated salts might be an option.) In Fig. 11, both axes in both panels should be identical in terms of formatting and value range.

The Summary is more or less repetition of what has already been said before, augmented with few sentences where additional information is given (e.g. p. 39: "The dominant salt in Italy and Israel is halite and in Czechia is gypsum" – it is unclear why this information is not found in the results section.)

I strongly suggest to restructure the summary more like a Sythesis, in which the presented results are put together to a consistent synthesis that goes beyond the local results of case studies. (This happens partly in Figs 13+14.)

Overarching questions

These suggested questions go beyond the immediate content of the thesis and are more on the "bigger picture":

- → Where are tafoni developed? Which thresholds of temperature and precipitation apply? Which physical rock parameters are conducive to the development of tafoni?
- → How does salt weathering work, what are the most important mechanisms?
- → Which other weathering processes might contribute to tafoni formation?
- → What is the difference of moisture fluxes and storage between a rock outcrop and a building wall (or a ruined wall)?

My best wishes to the candidate and to the examiners.

Bayreuth, 14th October 2024,

Prof. Dr. Oliver Sass