August 31, 2020

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Review Report on PhD Thesis

Charles University

Faculty of Science

Study programme: Physical Geography and Geoecology

student: RNDr. Tomáš Uxa

Supervisor: RNDr. Marek Křížek, Ph.D.

The subject of the evaluation is the work consisting of the study: "Past and Present Permafrost and Active-Layer Phenomena as Indicators of Late Quaternary Environmental Changes" with accompanying publications, prepared by Tomáš Uxa at the Faculty of Science, Charles University, Praha, Czech Republic, 2020.

Attached publications:

1. Křížek, M., Krause, D., Uxa, T., Engel, Z., Treml, T., Traczyk, A. (2019). Patterned ground above the alpine timberline in the High Sudetes, Central Europe. Journal of Maps, 15(2), 563–569. https://doi.org/10.1080/17445647.2019.1636890
   JCR 2018: IF=1.836.
   T. Uxa's contribution: 10%
2. Křížek, M., Uxa, T. (2013). Morphology, Sorting and Microclimates of Relict Sorted Polygons, Krkonoše Mountains, Czech Republic. Permafrost and Periglacial Processes, 24(4), 313–321. https://doi.org/10.1002/ppp.1789
   JCR 2012: IF=3.049.
   T. Uxa's contribution: 50%
3. Uxa, T., Křížek, M., Krause, D., Hartvich, F., Tábořík, P., Kasprzak, M. (2019). Comment on 'Geophysical approach to the study of a periglacial blockfield in a mountain area (Ztracené kameny, Eastern Sudetes, Czech Republic)' by Stan et al. (2017). Geomorphology, 328(1 March 2019), 231–237. https://doi.org/10.1016/j.geomorph.2018.10.010
   JCR 2018: IF=3.681.

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T. Uxa's contribution: 30%

4. Uxa, T., Mida, P. (2017). Rock Glaciers in theWestern and High Tatra Mountains,Western Carpathians. Journal of Maps,13(2), 844–857. https://doi.org/10.1080/17445647.2017.1378136
   JCR 2016: IF= 2.174.
   T. Uxa's contribution: 80%
5. Uxa, T., Mida, P., Křížek, M. (2017). Effect of Climate on Morphology and Development of Sorted Circles and Polygons.Permafrost and Periglacial Processes, 28(4), 663–674. https://doi.org/10.1002/ppp.1949
   JCR 2016: IF= 2.815,
   T. Uxa's contribution: 70%
6. Uxa, T. (2017). Discussion on 'Active Layer Thickness Prediction on the Western Antarctic Peninsula' by Wilhelm et al. (2015). Permafrost and Periglacial Processes, 28(2), 493–498. https://doi.org/10.1002/ppp.1888
   JCR 2016: IF= 2.815.
   T. Uxa's contribution: 100%
7. Hrbǎcek, F., Uxa, T. (2020). The evolution of a near-surface ground thermal regime and modeled active-layer thickness on James Ross Island, Eastern Antarctic Peninsula, in 2006–2016. Permafrost and Periglacial Processes, 31(1), 141– 155. https://doi.org/10.1002/ppp.2018
   JCR 2018: Impact factor 3.000.
   T. Uxa's contribution: 50%

   Declared-authorship confirmed also by RNDr Marek Křižek, Ph.D., supervisor.

At this point, I want to emphasize right away that this is the first time I meet a case where the dissertation includes not only the so-called *positive achievements* of the author. but also critical works - polemics, commentaries on the published works of other authors. I accepted it with great interest and with the conviction that such a scientific statement can be at least equal to a work based on empirical scientific research. Therefore, it may fall within the scope of a doctoral dissertation as a valuable scientific work. Writing a polemic requires a particularly careful and precise expression and certainty of knowledge. Besides, such a critical text is subjected to very harsh judgment of the authors who are commented on. It also takes some courage.

Such a work, however, has also a certain formal deficiency, which I am also seeing for the first time, and which most likely is not included in the doctoral procedure (as I suppose). It consists in the fact that in order to evaluate each comment it is necessary to read two more works. The one that is commented on and the reply to the comment. In the case of dr. T. Uxa, therefore, to the seven papers submitted as a *doctoral dissertation*, four additional works should be attached. Without reading them, the assessment would be incomplete.

RNDr. Tomáš Uxa (1986) is a PhD student at the Department of Geothermics since 2016, and his main research interests are in periglacial geomorphology and temperature conditions inside the Earth. He focuses on periglacial landforms and past and present of active layer and permafrost in different locations. He obtained his master's and advanced master's (2016) degree in Physical Geography and

Geoecology at the Faculty of Science, Charles University, where he has been continuing his PhD studies since 2011.

T. Uxa is the co-author and author of several works, most of which are published in high-class international scientific journals, and the co-author of a book on the analysis of geomorphological sculpture. Currently, he is associated with the Institute of Geophysics of the Czech Academy of Sciences, Department of Geothermics.

In order to limit the size of the following long-enough comment, I will not refer to the individual author's sentences that I am discussing. I think that both the author and any other reader will easily find them in the dissertation.

The author begins his dissertation by providing a definition of permafrost and a precise description of this phenomenon in the introduction. This is a very good practice also used in the attached articles. It allows to precisely define the subject of research. He also gives a very approximate global range of permafrost, emphasizing the importance of research on this phenomenon for contemporary science. However, this range is still a difficult issue and not fully understood and explained, and the discrepancies in determining its range reach millions of square kilometers, and still arouse justified controversy, in particular regarding the role of ice in this environment (e.g. Dobiński 2020a, Obu et al 2019). The boundaries of permaphrost occurrence are often very difficult to determine, as is its detection in some places, especially of extrazonal occurrence. The author is aware of this and understands it well, which results in later published works. The second definition that the author gives is the definition of the active layer of permaphrost, which he describes as a layer in which the temperature rises above 0 ° C seasonally. This is the correct definition according to the definition of permafrost, although in permafrost glossary (Everdingen 1998) the definition is slightly different: this is the soil layerwhich seasonally thaws. It is also very good to emphasize the asynchronicity in the development of permaphrost and glaciations. For its development, permafrost requires a frosty and dry climate with rather little precipitation, while the development of glaciation does not have to be accompanied by very low air temperatures, but rather a large amount of solid precipitation.

Thus, it can be seen at the beginning of the dissertation that the author's choice of research in the periglacial field for his studies is very accurate and useful because he finds here a chance to achieve significant scientific progress on an international scale.

In the next part of the work, which should constitute a separate chapter, the author first pays attention to the processes responsible for the formation of forms collectively known as *permafrost landforms*. then he goes to description of the selected geomorphological forms. He rightly calls them thermally and gravitationally induced, but he emphasizes also, that the decisive process of their development is recurrent freezing and thawing. Perhaps it is worth remind here that although the term "permafrost features" has been used for a long time, it should be treated rather as a specific simplification. If permafrost is not of material nature and is defined as a thermal state, then the only process that can be attributed to it is aggradation / degradation and its form is the layer bounded at the top and bottom by a surface of 0^{o}C (top of permafrost and permafrost base). The relief forms of the Earth's surface classified as permafrost are rather related to the thawing / freezing process, which in fact can only occur in the presence of water. However, the water is not a prerequisite for the permafrost presence, as indicated above.

The author limits the characteristics of the geomorphological forms to *patterned ground* and *rock glaciers,* which is sufficient, because these forms are also the subject of the articles included in the presented work.

The author sees the motivation of his research in what is currently and commonly dominating big part of earth sciences, that is with climate change, climate warming and possible threats that may be directly or indirectly related to it. I understand this motivation and to some extent share the author's opinion. It often happens, however, that this right motivation causes scientists to go beyond the scope of activity associated with science. It happens when the emotions enter into science, which, as a rule, science should be deprived of. Therefore, any changes occurring in the natural environment, whether natural or artificial, can only be classified into four categories: they can be large or small, fast or slow. However, they cannot be dramatic. From a scientific point of view, it is an immeasurable category, which makes it impossible to take an objective position in a scientific discussion. Similarly, I assess the more and more frequently appearing contemporary works that raise issues related to the future, related to forecasting and prediction. I understand the need that causes them to arise. Here, however, great caution and restraint are needed, because science, which after all relies on evidence and empirical observation, does not have any scientific tools allowing it to express anythink about the future. Sometimes scientists seem to forget this. I am very glad that the author does not focus too much on these issues.

I am very positive about the fact that the author also uses the less accessible publications written in Czech or Polish. These are often very valuable works that I have also used personally. Here it is worth mentioning the *Biuletyn Peryglacjalny* the first journal in the world devoted to periglacial research. It played an important role in the early development of the discipline. Unfortunately, it is a hard-to-reach and no longer published journal.

Objectives

The autor declares, that: „*The main objective of the thesis is thus to obtain new primary data on some of the poorly investigated permafrost and active-layer phenomena in mostly past permafrost landscapes of selected Central European mountain ranges situated north of the Alps as well as in present-day permafrost environments of the Svalbard archipelago and the Antarctic Peninsula*".

Some research which are focused on past "permafrost landscapes" is mainly oriented on the comprehensive mapping and analysis of the distribution and morphology of the permafrost features mostly patterned ground and rock glaciers, and their interpretation in terms of past and potential present-day permafrost occurrences (First four papers). Research of present day permafrost regions is focused on the analysis of the distribution and morphology of patterned ground, their developmental rates, chronology, and relation to present-day environmental conditions, reconstructions of past permafrost environments, and long-term monitoring and modelling of the thermal regime and thickness of the active layer. Research was conducted in both hemispheres: High Sudetes Mts, Western and High Tatra Mts, northern Billefjorden, Svalbard, James Ross Island and Amsler Island on Antarctic Peninsula. The characteristics of the natural environment of each research area have been well presented, taking into account the purpose of the article.

In my review, I also do not want to focus on the methodology chosen and used by the author. Overall, I can say that it was correctly selected for the purposes of the work in question. It can be noticed that in the future the author may also use geophysical methods i.e. electroresistivity imaging or seismic methods, which are becoming more and more popular and can significantly enrich the image of the studied forms and their interpretation.

Overview of publications.

As mentioned at the beginning, due to the originality of the author's approach to the presentation of the doctoral dissertation, the subject of the analysis were 7 papers declared by him as a doctoral thesis, and four others, not authored by him.

First publication presents comprehensive map of mostly relict patterned ground in the sub-alpine belt of the Krkonoše Mts., Králický Sněžník Mts., and the Hrubý Jeseník Mts. The map depicts sorted polygons, sorted nets, sorted circles, sorted stripes, earth hummocks, peat hummocks, and non-sorted stripes. It is a very interesting study, but I cannot devote more attention to it in the review for formal reasons. The declared participation of T. Uxa here is only 10% (data collection, manuscript and maps editing) and it could be omitted without prejudice to the entire dissertation.

In the second paper, T. Uxa's share is 50% and it is a serious contribution and an interesting scientific achievement. The detected statistical regularities and studies of the literature on the subject allow the authors to draw important scientific conclusions: 1) Larger sorted polygons are formed by larger clasts and tend to occur in poorly drained sites at lower altitudes, 2) Smaller polygons and polygons with greater relative height are better sorted. 3) More up-domed and better sorted polygons are located at the summit area, Most interesting are, however: 4) The up-doming of fine centres of sorted polygons and the displacement of clasts towards the borders of sorted polygons are a result of positive feedback between polygon morphology and frost susceptibility, driven by microclimate, and 5) Differences in the morphology and distribution of clasts in sorted polygons, preserved since the Last Glacial period, indicate the high palaeoenvironmental potential of the relict large-scale sorted polygons located on flat or convex parts of the terrain.

Authors indicated also that: "*sorting increases frost susceptibility in polygon centres, which in turn leads to more intensive ice segregation and cryogenic processes and therefore to further sorting a self-sustaining or self perpetuating process*", "*The better sorting of polygons with greater relative height is associated with the steeply inclined surfaces of these polygons, where more intensive slope processes, such as frost creep and needle-ice creep", "the larger sizes of these sorted polygons could be attributed either to the higher moisture content or higher groundwater table*".

However, it would be interesting to know in more detail what the authors mean when writing about the so-called „palaeoenvironmental potential."

In the third publication, T. Uxa is the first of six authors and his share is 30%. Although formally this study has the form of a commentary, in fact it is an extensive scientific article in which the authors discuss the results of geophysical research published in "*Geomorphology*" by Stan et al 2017. It is worth noting that Uxa et al in their commentary first emphasize the value of the idea of the commented authors. The extrazonal occurrence of permafrost is an important issue for periglacology, but one of the most difficult task I have encountered. The discovery of permafrost in the Tatra Mountains has met with great criticism at the beginning, although the mean annual air temperature (MAAT) reaches almost -4^{o}C there. It was even more difficult to accept in scientific society the presence of permafrost when MAAT is positive, as high as + 7^{o}C. In some locations, its occurrence is due to the low temperatures of the winter season combined with a special micro-scale air circulation, which can be observed in the most spectacular way in ice caves. It is known that a similar circulation, although on a smaller scale, may occur in large enough block fields located in a convenient topography.

Due to the nature of this review I cannot discuss this issue in detail, but it should be emphasized that in cases of extrazonal permafrost occurrence, geophysical research (ERT, seismic) should be preceded by monitoring of the microclimate of the studied site. The paleoclimatic analysis presented in the

comment by Uxa et al is also important. This analysis convince me to take a position closer to the opinion of T. Uxa et al than Stan et al., But only from a methodological point of view. I am afraid, however, that the issue of permafrost in Ztracené kameny, Eastern Sudetes, is not yet definitely closed and this is a field for further research in this area. Finally, it should be added that even if the presence of permafrost in this area were possible, Pleistocene paleopermafrost would have to be located at a much greater depth in my opinion.

Summing up, I can say that this work is a valuable methodological and scientific contribution to the issue of recognizing the occurrence of permafrost in difficult for research extrazonal location.

Article four is in many ways the most interesting work of this list and I would personally place it at the top of the list and the entire doctoral dissertation. T. Uxa's share in its study is 80%. As in other works, the authors begin with a clear definition of the research subject. The problem is developed on the basis of the previous research and after presenting the classification of rock glaciers.

The result of the analysis is the finding of a total of 383 rock glaciers occupying the area of 13.84 km^2, which are supplied by rock material from 51.81 km^2 of contributing areas. The total rock-glacier-affected area in research area encompass 65.65 km^2, (i.e.16% of the area above lower limit of its occurrence - 1375 m asl). Most rock glaciers are considered as relict. Only seven landforms in the Western Tatra were classified as intact (ca.4%). In the High Tatra forty nine (c. 25%), representing ca. 15% of the total number, covering 1.34 km^2 of the total area. It is clear that they are the most interesting periglacial landforms, because they *de facto* mark the lower limit of permafrost in these mountains. I noticed with satisfaction that it coincides with my findings from over 20 years ago. However, I am glad that the authors do not approach these findings uncritically, especially updating the issues of climate evolution. The article also contains a number of important geostatistical information regarding the occurrence of inactive and fossil rock glaciers, which need not be mentioned here.

For particular attention deserves is the excellent cartographic presentation, which is the map closing the article: "Rock glaciers in the Western and High Tatra Mountains, Western Carpathians", which was also awarded by the prestigious Journal of Maps" (Taylor & Francis). and was ranked among the top 10 maps published in Journal of Maps in 2017. It must be admitted that the graphic side: illustrations and maps constitute a very strong and valuable part of the doctoral dissertation.

Presented work is a good contribution towards more thorough analyses of rock-glacier distribution, morphology and modeling of discontinuous permafrost distribution, which substantially improve the understanding of present and past environmental conditions in the Western and High Tatra Mts. In order to fully develop the issue of the presence of permafrost in the Tatra Mountains and to understand its evolution, it would be advisable to present a broader palaeoclimatic analysis, similarly to other presented studies. Here the publication by T. Czudek 1986 deserves special attention.

The fifth publication on the impact of climate on morphology and development of sorted circles and polygons concerns a completely different area, which is the northern Billefjorden, central Svalbard. T. Uxa's share is 70%. The work begins with a good description of the research area and the methodology used. The authors briefly describe the deglaciation of this area during the last 12.3 ky, which is important in the discussion of the obtained results. They consistently choose well-known various geostatistical methods to collect the data they need. The first part of the work, however, lacks a broader presentation of the issues discussed in the chapter, which could be entitled "previous studies". This narrows a bit the meaning and evolution of selected landforms. I suggest looking especially at the older work of scientists such as Roger J.E. Brown and Robert F. Black. PDF versions of their work are

relatively easy to find. I am glad that the authors know the works of such authors as. A. L. Washburn or A. Jahn.

The results of the authors' research are interesting scientific discoveries: patterned ground shows a fixed pattern diameter-to-sorting depth ratio, pattern size is controlled by the thickness of the active layer in permafrost areas or by the freezing depth in seasonally frozen ground areas , thinner active layer can explain the smaller diameters of patterns at higher elevations, morphology of sorted patterns can indicate climate conditions, while the altitudinal trends can indicate ground thermal state i.e. permafrost or seasonally frozen ground conditions.

The authors do not stop at the geomorphological characteristics of selected landforms, but take up the issue of their genesis and evolution, which also corresponds to the problems of the doctoral dissertation in general. They claim that may take up to hundreds years for large-scale patterns to emerge in a poorly developed form and hundreds more years to achieve higher developmental stage, consistent with our observations and that dating of marine shells and sediments showed that marine terraces above 20 m asl, where all the investigated lower-elevated sorted circles and polygons occur, formed before ca. 8.7 cal kyr BP, the terrace sequence up to 40–45 m asl dates from ca. 10 cal kyr BP, hence, the upper age limit of sorted patterns at most sites is probably the Pleistocene – Holocene transition. Actually, however, at least at lower elevations, sorted circles and polygons are not in equilibrium with present-day climate conditions.

These are important and interesting scientific achievements.

The sixth article is of particular importance as it is an independent work of T. Ux. In fact, only independent work fully shows the knowledge, talent and scientific potential of the author, and therefore I'm glad that I found it. In addition, this work also indicates a critical attitude towards the published research results and courage in criticizing them. This is a very valuable and not very common feature of modern scientists. This article was also helpful for me in defining the author's achievements in works where he was not an independent author.

Without going too deep into the details of the presented discussion, it can be generalized to the question of the amount of water contained in the soil, which is the subject of theoretical calculations, and the role of the latent heat of the phase change. T. Uxa demonstrates that the values of active layer thickness (ALT) are significantly overestimated by the predictive equations because the commented authors incorrectly assumed that little or no latent heat of phase change is absorbed during thawing. In result Uxa's estimates suggest that the ALT should be 1.0 to 8.9m in unconsolidated materials and 10.1 to 16.5m in bedrock, in some contrasts with Wilhelm and Bockheim (2017) predictions of 4.7–8.7m in unconsolidated materials and 11.9 to 18.6m in bedrock.

It must be admitted that the author accurately conducted his criticism, which in principle was largely recognized by the criticized authors. However, they also pointed to the author's slight mistakes, such as the impossibility of assuming a value of 0 for the amount of water present in the ground.

What seems particularly interesting in this discussion, however, is the size of the active layer in general. It is commonly believed that it ranges from a few decimeters to several meters. Sizes reaching several meters are extremely rare, and those where they reach almost 20 meters are almost unknown. (Dobiński 2020). Against this background, the differences that the author showed do not appear to be a great error, and the value of the comment also lies in the fact that it confirms the possibility of this extremely thick active layer.

In the seventh article, the share of two authors is equal and amounts to 50%. it concerns evolution of a near-surface ground thermal regime and modeled active-layer thickness on James Ross Island, Eastern Antarctic Peninsula, in 2006–2016. To begin with, the authors correctly define the permafrost active layer: it is the top layer of the ground underlain by permafrost, which thaws in summer and freezes again in autumn. This means that the active layer is not defined on the basis of the 0 ° C temperature criterion, i.e. as permafrost is defined. Further, based on two very recent papers, the extent of permafrost in Antarctica is presented. Although this information is of little importance for the rest of the work, the permafrost extent in Antarctica is not as obvious as the authors say. The discrepancy here is enormous and the highest value (100%, ca 14 Mkm^2) is given by H French (1996), it is worth remembering because such a huge discrepancy proves that the subject of research (i.e. permafrost extent in Antarctica) is not clearly defined in this scientific discipline. Further, the authors aptly note that the active layer is often defined as the depth of the 0^oC isotherm in the ground, which is extrapolated based on the measurement data. The authors further present the regional setting of the James Ross Island, highlighting several important issues i) that the Antarctic Peninsula region was, in the climatic sense, the fastest-warming part of Antarctica and the world until recently, ii) it is currently a region where the climate is colder, (iii) although it is an island close to the northern part of the Antarctic Peninsula, it has a semi-arid polar-continental climate with mean annual air temperature around -7^oC. Deglaciation of the study area began around 12.9 ka. Ice-free areas are fully covered by continuous permaphrost.

The authors base their modeling of the thickness of the active layer on the measurement of the soil thermology in the studied area, and on the use of Stefan and Kudriavtsev's equations, providing detailed references.

Among the various significant findings, it should be emphasized that although the MAAT trend on James Ross Island was positive, mean annual ground temperature decreased slightly, and the mean modeled active layer thickness thinned by 1.6 cm y^{-1} during the study period. The thinning can be mainly related to the decreasing winter temperatures and shortening of the thawing seasons, which occurred across the whole Antarctic Peninsula and caused similar active layer thinning in other locations (Deception Island, South Shetlands)

It is also very important that the MAAT increased on average by 0.10 ° C y^{-1}, but a negative trend of −0.05 ° C y^{-1} was detected for mean annual ground temperature. The modeled active layer thickness thinned on average by 1.6 cm y^{-1}, which mainly related to a decrease in summer temperatures and to shortening of the thawing seasons.

The above findings provide important scientific information regarding the characteristics of the permafrost active layer and its accompanying climate. They show that in particular climatic conditions, the opposite relationship occurs. Despite the increase in MAAT, the ground temperature may drop. This is a very important finding affecting the overall perception and understanding of permafrost and active layer evolution, as the relationship may be radically different from what is commonly believed. They are also of significant methodological importance. Probably the remote estimation of the size of the active layer and the extent of permafrost, based on satellite measurements, may be burdened with a greater error than previously estimated. This may also include estimating the extent of permafrost degradation in large areas of Antarctica and other regions of the world.

Summarizing the work submitted for evaluation, consisting of seven annotated articles published in high-class scientific journals, it can be concluded that the author presented interesting and previously unknown findings on morphology, sorting and microclimates of relict sorted polygons in Krkonoše Mountains, characteristics of the rock glaciers in the Western and High Tatra Mountains, effect of

climate on morphology and development of sorted circles and polygons, evolution of a near surface ground thermal regime and modeled active-layer thickness on James Ross Island, Antarctica.

He also presented an interesting and valuable polemic about the potential occurrence of extrazonal permaphrost in the Eastern Sudetes and on active-layer prediction on the Western Antarctic peninsula.

I will cover several points with my critical assessment. They are not erroneous in essence, they rather require clarification, or they rely on excessive trust in the opinions published in the mainstream of permafrost studies today. In some cases, these are rather suggestions for the direction of further research.

1) While there is a *periglacial geomorphology*, there is no *permafrost geomorphology*, which results from permafrost definition as an invisible phenomenon defined not on the basis of matter but its thermal state. Therefore, in my opinion, one cannot speak of "*permaphrost forms*" in the geomorphological sense.

2) In terms of the dynamics or evolution of geomorphological expressions, landforms, processes, landscapes, etc., we can talk about variability, changeability, which can have a twofold character: be fast or slow (time), and large or small (quantity). These quantities are measurable. The specific separation of science from other forms of human activity also lies in the fact that it is objective, certain, intersubjectively verifiable, and devoid of emotions. For this reason, both changes and science as such should be devoid of *dramatism*.

3) prediction (predict = předpovědět) is in principle not the goal of scientific research. The aim of science goes rather in different direction, it is about explaining and understanding the reality that exists. Science is based on proof and certainty. These criteria cannot be used in prediction, and therefore their value will always be questionable.

4) Scientific discovery should always be the goal of scientific activity. It does not always have to be large and spectacular. Such discoveries are also presented by the author of the dissertation. Nevertheless, he declares that the main objective of the thesis is to obtain new primary data. I think this is just a simplification.

5) The author uses the term "*permafrost landscapes*". If permafrost is an *invisible phenomenon*, it is also difficult for me to see the permafrost landscape as such.

6) In some applications the word "potential" requires greater precision, such as: "preservation potential", "palaeo-environmental potential", "potential for reconstructions" etc.

7) The issue of permafrost evolution or the terrain relief that may accompany it is one of the most interesting and unresolved issues in periglacial / permafrost research. The existence of paleopermafrost was allowed by Czudek 1986 (Tatra Mts) and Gorbunov 2003 (Sudetes), but at a depth much greater than a few meters. Rock glaciers may be an exception here.

8) Finally, I would like to point out that although the author has and presents a thorough and extensive knowledge of permafrost and periglacial forms and processes, there is not enough reference to older works, especially authors who published in the previous century. A wider presentation of previous studies in articles would certainly have a positive impact on their full shape.

At the end of this study, it can be certainly stated that the author presented an outstanding scientific work and achieved the intended purpose of the dissertation, which was to present past and present permafrost and active-layer phenomena as indicators of late Quaternary environmental changes. In my opinion, this is an achievement that deserves a distinction and an award. In my opinion, the

reviewed thesis fulfills all requirements posed on theses aimed for obtaining PhD degree. This thesis is ready to be defended orally, in front of respective committee / audience.

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