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Record of the Late Glacial-Holocene palaeoenvironmental changes in landslide forms and deposits: from gravity induced caves to landslide peat bogs; Polish Outer Carpathians case study

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Extension cracks (gravity induced caves, if they are accessible for people) which separate fragments of rock massifs, represent the first stage of slope gravitational deformation preparing massifs to extensive and rapid mass movements. Intensification of external factors stimulated final movement of the landslides, which had been initiated a long time ago (Margielewski, Urban, 2003). Therefore, the estimation of time-frame of the evolution of gravity-induced caves is crucial for the recognition of stages of landslide formation.

Radiocarbon datings (over than 30) of the carbonate speleothems (regarding the carbon reservoir effect) as well as organic speleothems found in the caves, supplemented by pollen analyses of both types of speleothems, indicate the beginning of development and transformation (reflected e.g. by de-concentric growth of speleothems) of the caves. Such events occurred at the end of the Plenivistulian (Weichselian Pleniglacial), Late Glacial, as well as in the Holocene climatic humidity growths: in the Preboreal, at the turn of the Boreal/Atlantic, during the climatic optimum at the decline of the Atlantic and the beginning of the Subboreal, at the Subboreal/Subatlantic transition and during the Little Ice Epoch (Margielewski, Urban, 2017). The correlation presented above allows us to interpret the occurrence of phases of mass movement intensification as connected with climatic changes in the Holocene. During these humid periods, the increase in the intensity of mass movements is observed in the Polish Outer Carpathians (Alexandrowicz, 1987; Starkel et al., 2013) as the landslide formation (over 80 14C dated landslides), as well as the deposition of mineral horizons in landslide peat bogs (over 100 14C datings), which are sensitive indicators of the changes in the mountainous environment, regarding also human activity (Margielewski, 2006; 2018). The long-term existence of cracks/caves enables us to formulate the hypothesis about the continuous evolution of slopes in the Carpathians since the Late Glacial. The gravitational failures of these slopes, started in the period of the permafrost melting, were affected by subsequent mass movements related to the fluctuations of the temperate climate during the Holocene. However, these modifications often did not significantly change the slope structure; therefore, the system of cracks (caves) have existed for thousands of years.

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