

The development of gravitational caves versus periods of mass movement intensification during the humid phases of the Late Glacial and the Holocene: study of dated speleothems and slope deposits (Polish Outer Carpathians)

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Mass movements have been one of the most efficient processes controlling the morphogenesis of the Outer (Flysch) Carpathians. Dated by ¹⁴C method 180 landslides and related processes in the Polish Carpathians enabling to reconstruct mass movement chronology, confirm the thesis formulated by Starkel (1966), that the periods of acceleration of gravitational processes during the Late Glacial and the Holocene were connected with the stages of climatic humidity growths (Alexandrowicz, 1996; Margielewski, 2006; Starkel et al., 2013). Gravitational slope failures have often generated formation of non-karst caves. In the Polish part of the Outer Carpathians ca. 1400 caves, mainly of gravitational origin, have been explored up till now (Klassek, Mleczek, 2015). Part of these caves formed in the initial stage of landslide development, some ones formed during subsequent stages of landslide evolution (Margielewski, Urban, 2003; Lenart et al., 2013). Radiocarbon datings of speleothems allow us to reconstruct the stages of cave development and related mass movements. Pollen analysis of speleothems confirms these datings (Urban et al., 2015).

The oldest dated speleothems were formed in the Late Pleniglacial (Jaskinia Słowiańska-Drwali cave, Beskid Niski Mts.). The composition of carbon stable isotopes in these speleothems indicates their formation due to repeated water freezing or evaporation. The first stage of common speleothem formation (recorded in two caves of the Beskid Śląski Mts. and two caves of the Beskid Niski Mts.) fell on the short climate warmings of the Bølling and Allerød as well as at the beginning of the Holocene. The intensive water circulation in those periods was related to the permafrost deterioration. The stages of cave opening are correlated with the intensification of mass movements (Starkel et al., 2013), during the periods of an increase in precipitation in the close of the Boreal Phase and at the beginning of the Atlantic Phase as well as during the Middle Atlantic Phase - climatic optimum of the Holocene (ca 7.5-7.2 ka cal BP). Climate coolings and increases in humidity at the turn of the Atlantic-Subboreal Phases, as well as at the turn of the Subboreal-Subatlantic Phases are recorded by the beginning of speleothem formation or change from concentric to deconcentric growth of speleothem rings. All periods of speleothem formation (or their deconcentric growth) are correlated with phases of the intensification of slope failures (landslides), as well as with palaeoenvironmental changes recorded in peat bogs situated close to the caves (Margielewski, 2006; Urban et al., 2015).

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