Glacial processes in the relief of mid-height mountains of the Bukovynian Carpathians (Northern Bukovyna, Ukraine)

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The Chornyi Dil Range situated in the upper reaches of the White Cheremosh River and is bounded on two sides by its sources, the Perkalab and Sarata rivers. It is the highest and most remote part of the Bukovynian Carpathians within Ukraine. At the same time, it is the least studied in terms of geomorphology. The ridge extends submeridionally. Its highest mark is 1483 m. Geologically, it is the eastern edge of the Marmarosh crystalline massif, which extends from Transcarpathia and Romania, and here we meet only its extreme north-eastern part (Fig. 1).

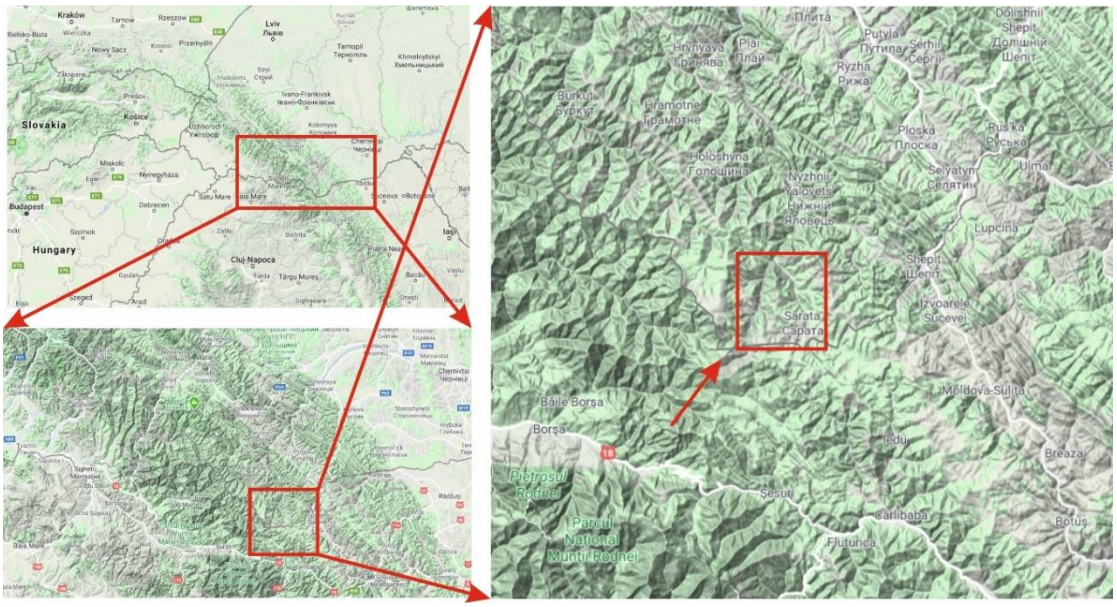

Figure 1 Map of the location of the Chornyi Dil Range.

In the modern relief formation, the fluvial factor dominates among exogenous agents, with the subordinate participation of nival-cryogenic factor. But our observations on the studied territory indicate the possible existence of glacial processes in the past.
Tectonically, the Chornyi Dil Range area is a series of the nappes, displaced to the northeast: the lower one is Bilopototskyi Nappe, almost horizontally overlaid by the upper Dilovetskyi Nappe, and a narrow zone of the Rakhiv Nappe (Tectonic map of Ukraine, 2007). Later, on the crystalline basement of these two nappes, the "post-tectonic", relatively thin Soymulska Suite (K1-2sm) of the Cretaceous was formed. It is believed that this suite completes the thrusts on the massif. After that, it took part in Alpine tectogenesis (Matskiv et al., 2009). Thus, almost

throughout all its extension, the north-eastern slope of the Chornyi Dil Range in the upper part is represented by rocks of the Bilopototsky Nappe, and in the lower part by rocks of the Rakhiv Nappe, which are composed mainly of Cretaceous flysch.

We paid attention to the well-rounded boulders of the quartz conglomerate, more than 1 m in diameter, in the channel of the Sarata River, already at its confluence with the Perkalab River. The source of these rocks is the basal stratum of the conglomerate-breccia, up to 30-50 m thick, which consists of rounded and sharp fragments of milky white and pink quartz and belongs to the terrigenous batch of the Krasnoplesynska sequence (Pkp)of the Permian stratum. The latter belongs to the Bilopototskyi Nappe.

The conglomerates found in the channel of the Sarata River exposed on the top of the Chornyi Dil Range, a few kilometres upstream, where small stone runs (kurumniki) formed in the apical part (Fig. 2). Downslope, they can be observed as individual boulders, protruding from the slope sediments (moraine?).

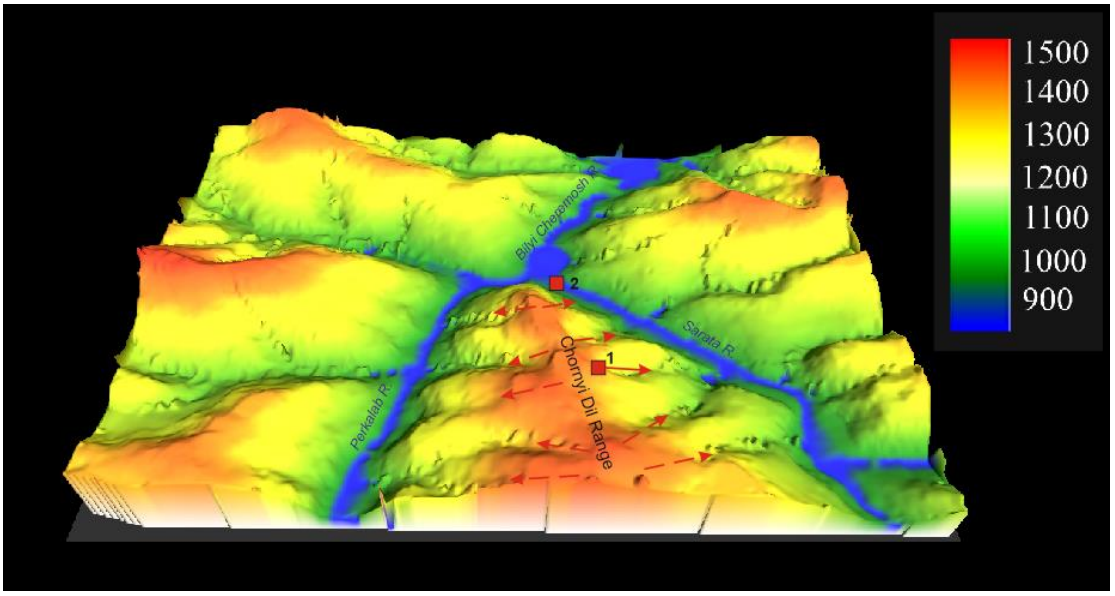

Figure 2 3D model of the relief of the Chornyi Dil range: 1 - exposure of conglomerates; 2 - boulder of conglomerates in the Sarata riverbed; red arrows show the assumed directions of the glaciers sliding.

The prevailing opinion is that glaciers existed in the Ukrainian Carpathians only in the massifs of Chornohora, Svydovets and Chyvchyn, where distinct erosional forms of glacial excavation (glacial cars, circuses, troughs, etc.) and moraines have been preserved. However, the transporting of large boulders for several kilometres suggests the probable action of the glaciers on the Chornyi Dil Range. The presence of stone runs is evidence of the periglacial conditions here in the Pleistocene. Most researchers accept the altitude of the snow line for the Ukrainian Carpathians at 1400-1500 m, and sometimes 1200 m (Lushchyk, 2017). Thus, theoretically, in some epochs of the Pleistocene, the apical part of the Chornyi Dil Range, with altitudes of 1300-1450 m, could well accumulate snow masses with their subsequent transformation into glaciers. And if we consider the north-eastern exposure of the macroslope, the snow accumulation zone could move even to lower altitudes. For example, a snow line altitude of 1300 m was recorded for the north-eastern macroslope of the mountains at Corsica Island and in Dinaric Alps during the last glacial maximum (LGM) (Kuhlemann et al., 2013).

Of course, the transportation of conglomerate blocks from the top of the ridge to its foot can be explained by the usual gravitational transport. But how did these blocks become rounded

and end up in the riverbed 4 km downstream? Here we should assume that the glacier's tongue not only descended to the bottom of the Sarata Valley (about 1000 m a.s.l.) but also moved along this channel, or at least here there were glacial surges that moved large boulders. The latter is also not unbelievable because, in the literature, we can find data on the advance of glacial tongues in the LGM to 1100 m (Apennines) and even almost 500 m (Corsica) (Kuhlemann et al., 2009). Moraine ridges at altitudes down to 900-1000 m were also indicated for the Sudeten Mts. (Nývlt et al., 2011).

Partly the long-distance displacement of the rock material and deep carving of the gorges in hard metamorphic rocks of the range could be provided by the avalanche transportation. The composition of the Chornyi Dil Range by hard rocks causes the preservation of the steepness of the slopes at the range. Due to the steep slopes, snow accumulation caused by avalanches could occur on the top of the range and in the valleys of Sarata and Perkalab. Because even in present days, avalanches occur even in low mountains if the slopes are steep enough and deforested (Ridush et al., 2020).

On the other hand, there are still no expressive erosional glacial forms within the range and no expressive accumulative forms - moraine ridges etc. But we assume that the maximal glaciation here was not during the last glaciation (Valdai, Weichselian), but during the Dnieper (Saalian) or even earlier glaciations, then for this long time, fluvial processes could model initial glacial forms beyond recognition, and the modern afforestation prevents recognizing of such records. Incidentally, we note that on the Chyvchyn Range, located only 8-10 km to the west, and which peaks exceed 1700 m, the expressed glacial forms also are not observed.

Thus, the question of glaciation in the mid-mountains of the Ukrainian Carpathians, with altitudes less than 1500 m, in the Pleistocene remains open and needs further study. Because, on the one hand, the theoretical possibility of such glaciation, according to analogues in other mountain systems in Europe, exists. On the other hand, the evidence obtained may be perceived by sceptics as insufficient. Therefore, the study of this issue should be continued both within the Chornyi Dil Range and on other mountain ranges. The observation of modern snow accumulations caused by avalanches can be used in modelling the same processes in the Pleistocene.

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