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ABSTRACTS VOLUME

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A Late Pleistocene ice field in the Godeanu Mountains, Southern Carpathians

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The possible existence of plateau type glaciations – ice caps, ice fields or plateau glaciers - in the Godeanu Mountains, Southern Carpathians during the Late Pleistocene is the main topic of this investigation. The Godeanu Mountains is one of the westernmost mountain range of the Southern Carpathians. It is located north of the River Cerna and south of the Ţarcu and Retezat Mountains. The question about the existence of former plateau type glaciers in the Godeanu Mountains emerged due to the widespread presence of the Borăscu surface in the region. The Borăscu surface, which was described for the first time in the early 20th century by Martonne (1907), is an uplifted peneplain, which could be found in many mountain ranges in the Southern Carpathians. It's main features are a quite small relief and a high elevation range of 1800- 2200 m a.s.l.. The most typical appearance of it is located in the Godeanu Mountains, where shallow glacial valleys surround the central plateaus.

Equilibrium-line altitude (ELA) reconstructions from the neighbouring Retezat Mountains show that 1725 m, 1770 m and 2030 m a.s.l. were the typical ELAs in the region during the Late Pleistocene, MIS 4 and MIS 2, and the Younger Dryas glacial stages respectively (Reuther et. al. 2007). Therefore, a quite big and even surface was located higher than the regional ELA during the last glaciations in the Godeanu Mountains due to the presence of the Borăscu surface. These Borăscu plateaus could have served as ice accumulation sites and could have fed valley glaciers as previously suggested for other mountains in the Southern Carpathians with similar conditions (Urdea et al. 2011). Although the topographical situation could be suitable for this type of former glaciation, there is no direct evidence or exact reconstruction about the existence of these plateau glaciers, neither in the Godeanu Mountains nor in any other mountain range in the Carpathians. This is mainly caused by the fact that geomorphological evidences left on the plateaus by these supposed plateau glaciers and ice fields are limited or absent (Urdea et al. 2011). However, glacial landforms, especially terminal and lateral moraines, are highly concentrated in the valley sections. Though, indirect, intuitive implications for the potential presence of glacial ice on these plateaus based only on the presence of glacial landforms in the valleys are uncertain at best. Therefore, an exact reconstruction method based on the glacial landforms in the valleys is needed in order to provide well-founded evidence on the former presence of glaciers on the plateaus.

In order to solve this problem, I chose an approach based on the mechanics of glacier flow and geoinformatics. The first step was the collection and integration of the necessary data. This meant collecting and processing 1:25.000 topographical maps, orthophotos with a resolution of 0.5 m, and of course relevant literature. Based on the topographical maps, I created a digital elevation model (DEM) with the resolution of 20 m. In order to limit the resources needed for the creation of the DEM, I restricted the study area to the central region of the Godeanu Mountains. Thus the investigation covered the Scărişoara plateau and the surrounding glacial valleys, an area of 70 km^2. This location was ideal for the study due to the dominant presence of the Borăscu surface in the region.

Unfortunately, relevant literature on the Godeanu Mountains is rather scarce, mainly because it is quite hard to access. The only available source is a geomorphological survey by Niculescu (1965), which provides a good geomorphological map. The georeferenced geomorphological map, together with the information obtained from orthophotos served as an effective tool in identifying marginal glacial landforms. In the summer of 2013, I conducted a field excursion to the Godeanu in order to validate the geomorphological map and the orthophotos on the field. Thus the reliability of the identified former glacier margins improved substantially.

In order to reconstruct the glaciers in the study area and to determine whether these glaciers originated from the plateaus theoretical ice surface profiles were calculated. These calculations were based on a model, which assumes perfectly plastic ice rheology. Key assumption of the model is that ice deforms thus flows only when the downslope driving stress exceeds a specified yield stress (Nye, 1952; Cuffey & Paterson, 2000). Until it happens no movement could occur and the ice will thicken and/or steepen. Benn and Hulton (2010) produced a novel approach based on the steady-state form of the aformentioned model with which it is possible to calculate the two-dimensional longitudinal surface profile of a glacier lying on an irregular bed. They implemented their approach into an Excel spreadsheet to provide a user friendly application for the calculation of ice profiles.

In order to estimate the surface profile of a glacier with this tool the topography of the bed has to be known. This was extracted from the DEM along the longitudinal profiles, up to the topographical divides, of each glacial valley. These longitudinal elevation profiles correspond to the maximal extents of each former glacier which was determined by the geomorphological map by Niculescu (1965). The calculations used the yield stress of 100 kPa for the whole profiles of all reconstructions. Since lateral glacial landforms are mainly absent, empirical fine tuning of the yield stress to match the theoretical profiles with these landforms was impossible. Therefore the standard yield stress value of 100 kPa was employed (Nye, 1952; Rea & Evans, 2007). In order to enhance the reliability of the reconstructed ice surface profiles, a yield stress value of 50 kPa was used for calculations. This produced the low threshold of the possible ice surfaces (Hughes et al., 2011, László et al., 2013). As lateral landforms are absent, the glacierized perimeters of the valley cross sections were unknown also. Thus it was not feasible to consider the influence of the shape factor, which incorporates into the model the effects of side-drag (Nye, 1952; Benn & Hulton, 2010), directly on the calculated surface profiles. This simplification produces an underestimation of the ice surface. However, if the reconstruction still produced an ice field on the plateau, the result would be quite reliable, since the real former ice surface could be even higher than the reconstructed.

For estimation of the area and the ELA of the former glaciers it is necessary to reconstruct a three-dimensional ice surface. It also could serve as a powerful tool to visualise the extent of the former glaciers. The three-dimensional ice surface was produced by extrapolating the ice surface profiles with minimal curvature extrapolation method using standard parameters in Surfer software environment. After several straightforward data processing steps outlines, extent and the digital surface model (DSM) of the former glaciers could be derived from the extrapolated surface. Former ELAs were estimated by accumulation-area ratio (AAR) method, using an AAR_0 of 0.75 so the results could be correlatable with the paleo ELAs of the neighbouring Retezat established by Reuther et al. (2007).

Results based on calculations with the 50 kPa and 100 kPa yield stress values both show that during the maximal glaciation an extensive ice field / plateau glacier, with up to 40-65 m thick ice, occupied the central plateau of the study area and valley glaciers the surrounding valleys (Fig. 1.).

The central ice field fed predominantly the northern valley glaciers. The pattern of the ice coverage is quite the similar in both reconstructions, though their area differs significantly: 7.94 and 11.01 km^2 respectively. Reconstructed glacier outlines show good correspondence with the glacial landforms mapped by Niculescu (1965) in the valleys. However, glacial landforms are absent on the plateau thus on this section only the reconstructed DSM provide evidence on the ice coverage (Fig. 1.). As the standard yield stress value is 100 kPa and the reconstruction based on this value produced somewhat more realistic glaciers, all further presented results will be based on this reconstruction (Fig. 1.).

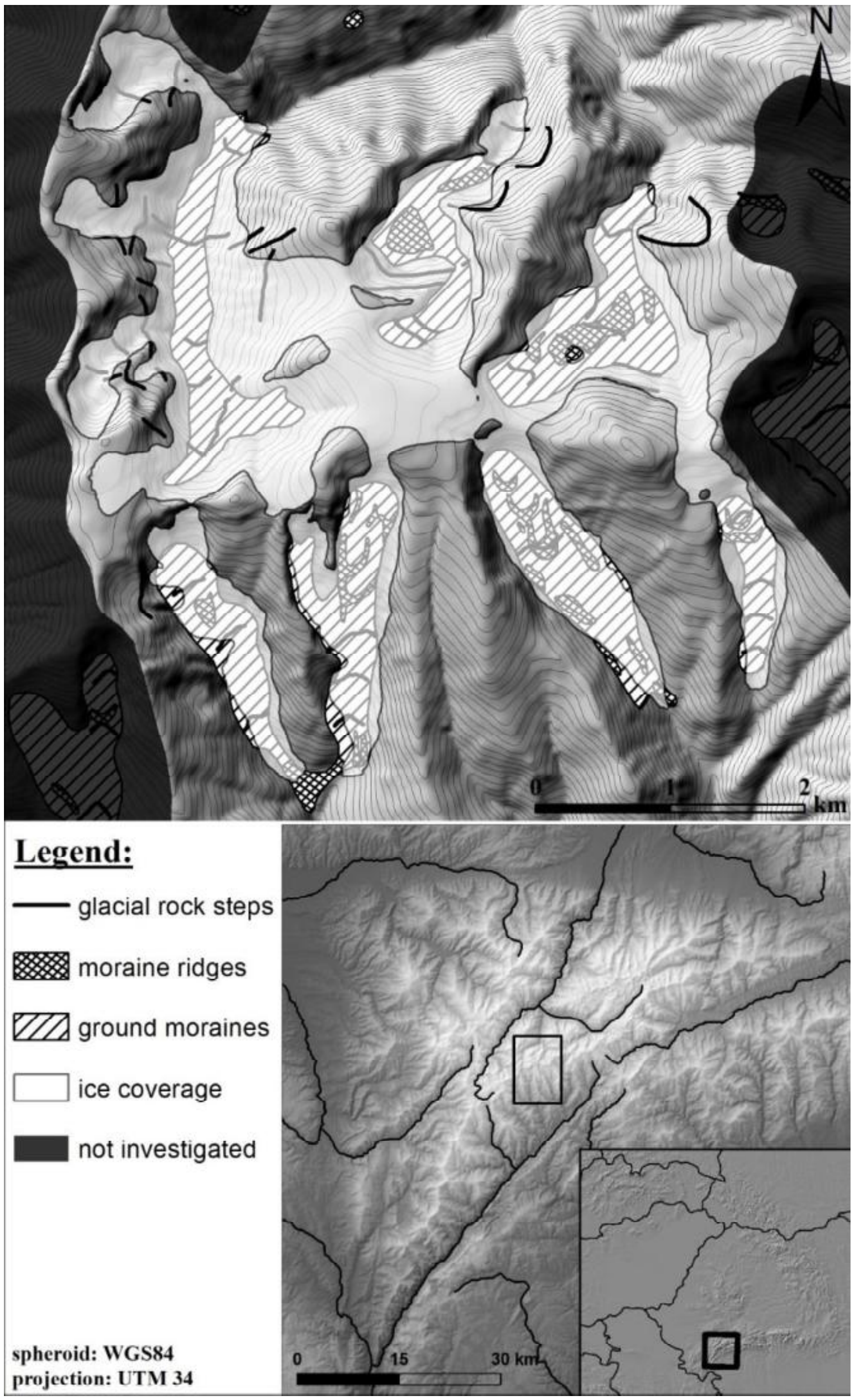

Fig. 1 Situation of the investigated area, outline of the ice coverage based on calculations with 100 kPa yield stress and glacial landforms digitized from Niculescu's (1965) survey.

There are significant differences between the northern and the southern glaciers. The northern glaciers are somewhat longer, 2.4-3.6 km, have higher areas, 1.56-4.13 km^{2}, and maximal ice thicknesses, 90-110 m, than the southern glaciers: 1.7-3.1 km, 0.61-1.28 km^{2}, 50-70 m respectively. This is partially could be the effect of the extra ice inflow from the plateaus.

The ELA reconstructions yielded an average ELA of 1789 m a.s.l. for the whole study area. However, between the average ELAs of the northern, 1903 m a.s.l., and the southern glaciers, 1703.5 m a.s.l., there is a substantial and controversial difference. The pattern should be exactly the opposite, because in a normal case average ELA on the southern side is higher than on the north side, due to the more intensive irradiation.

This serious anomaly could be best explained by the assumptions that the reconstructed glaciers on the two sides are not from the same glaciation period and/or the former northern glaciers extended lower in the valleys than it was reconstructed. The later assumption is supported by the fact that in the northern valleys well recognisable terminal moraines are not present. Instead, there are mainly ground moraines (Fig. 1.). However, the southern glacial valleys are closed by well preserved terminal moraines (Niculescu, 1965) (Fig. 1.). Therefore, it is highly possible that the former northern glaciers extended much further down-valley and their traces at lower heights were destroyed by the erosion since then.

Thus the average ELA for the whole study area is misleading and should not be used for correlation with other mountain ranges. The average ELA of the southern glaciers could be more suitable for this purpose even though that it is not based on a balanced sample in respect of aspect. However, the average ELA of 1703.5 m a.s.l. of the southern glaciers corresponds well with the average ELA of 1725 m a.s.l. of the Retezat's maximal glaciation, which age was assumed as early Würmian, MIS 4 (Reuther et al., 2007). Therefore, the maximal glacial extent could be contemporaneous in the two mountain ranges.

My research showed that during the Late Pleistocene an ice field existed in the central Godeanu Mountains which fed several valley glaciers. The Borăscu surface served as a quite effective ice accumulation site, and profoundly influenced the pattern and type of the Pleistocene glaciation. This could have important implications for the whole Southern Carpathians, as the Borăscu surface is widely spread throughout the mountain chain. It was also assumed that the northern glaciers extended much further into the valleys of the Godeanu Mountains than the former surveys reported. Further and more detailed investigations in the Godeanu Mountains would be desirable which could cover the whole mountain range and reveal the different periods of glaciations.

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