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TYPES OF PERIGLACIAL FORMS AND PROCESSES IN THE HUNGARIAN MOUNTAINS IN RELATION TO ROCK DIFFERENCES

The 380 km long and 400 to 1000 m high Hungarian Mountains consist of two mountain types basically different in composition and structure. As a consequence of their different histories their sculptural forms are highly dissimilar. The older block mountains (Transdanubian Mountains), are built up mainly of Triassic dolomite and limestone and also of Jurassic, Cretaceous and Eocene limestone, marl and sandstone, and in the south, of Permian sandstone, while the younger Miocene volcanic mountains (the major part of the North Hungarian Mountains) are dominantly formed of andesite and its pyroclasts, with rhyolite and rhyolite tuffs, basalt cones and coverlet remnants. The generally wide hilly zones, however, surrounding the mountains proper (the pediments) consist of Tertiary and Quaternary looser sediments, chiefly of clay, sand, looser sandstone and clay-marl as well as of conglomerate and gravel or tuffs.

The most substantial differences in lithology appear between the three main constituents of the mountains proper; the Miocene andesites, the Triassic dolomites and the Triassic-Eocene limestones on the one hand and the less consolidated Tertiary deposits of the mountain foreland on the other. From the viewpoint of cryofracture, the physical properties of rock masses, their structure, vertical (thickness of beds), and horizontal (solidification columns) differentiation, mineral composition, the ratio of finest clay minerals are of decisive importance. In respect of susceptibility to frost action and of related periglacial features, the rocks of the Hungarian Mountains can be referred to four major groups. In the various rock groups the effects of frost action differ in degree and form, highly influencing the efficiency of periglacial denudation and the resulting forms. The bulk, size and shape, the whole nature of felsenmeers, taluses, mingled covers[1] and stone-flows vary accordingly.

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[1] A mixture of ungraded, sharp or slightly rounded debris, moved chiefly by gelisolifluction, mingled with soil, loam or yellow clay, whereas under the influence of gravity the material of the talus mantle accumulated pure.

1. Owing to its textural characteristics, it is dolomite that is comminuted most rapidly. On flat tops and plateaux, as residual eluvium it disintegrates relatively quickly to small-grain debris, 1 to 4 cm in diameter and even smaller. During transportation even on gentle slopes, some hundred metres away from its place of origin it disintegrates into fine debris and after a further hundred metres distance a considerable part of it becomes sand, silt or even the finest loess fraction.

Unlike the bulk of dolomite, the hard crystalline dolomite bands rich in hornstone are comminuted very slowly, and are left over in huge blocks of 1.5 to 3 m in size on slopes where further creep is controlled by gravity.

The produce of dolomite comminution dominantly comprises two fractions of the most opposite nature: (a) the mass is fine debris, (b) the large blocks are only a minor feature, but, owing to their size, characteristic features. While the former is spread widely, the latter can be connected to certain stretches of slopes or rock zones.

A major part of dolomite in Hungarian mountains has a hornstone content. Hornstones with a diameter of 5 to 15 cm were usually sculptured out at fragmentation and, due to their resistance, they did not disintegrate any more but were conveyed on in fist-size, slightly rounded pieces in the rapidly comminuting detritus of dolomite which was getting finer and finer. Thus they have become abundant at the bottom of slopes where their fist-size pieces dominate the fine--grain dolomite.

The small grain size due to intensive fragmentation, the largely increased debris transport and the joint effect of the two factors led to a quicker denudation of dolomite terrains and a remarkable re-sculpturing of their forms in the periglacial periods. The steep bare dolomite slopes underwent strong weathering and retreat by cryofracture; valleys broadened, so cryoplanation was effective. As a consequence of the relatively rapid shattering and transport, in the Hungarian dolomite mountains less weathering product was left over than elsewhere. A good part of these finer periglacial correlative sediments was accumulated in the foreland of mountains and therefore well developed thick alluvial and debris fans (Fig. 1) are characteristic of the mountain foot zone.

Thus the wide-spread and typical felsenmeers of our mountains are substituted on dolomite terrains by only some centimetres, or perhaps decimetres, thick eluvial detritus of fine sharp rock fragments. Similarly, because of the relatively rapid transportation, the mingled cover on slopes is very thin, on steep, more than 15 °, slopes it is generally merely some cm and thickens rather abruptly, at the base, to several metres. At bottom of steep slopes talus slopes are typical but these, in contrast to taluses of other rocks, preponderantly consist of fine debris in which dolomite blocks are embedded. Because of intensive disintegration only the areal variant of stone-flows, the debris cover could develop and only on gentle slopes. In stripes of durable rocks frost action sculptured out 3 to 5 m high bizarre pinnacles and short free faces parallel to the slope (Sas-szikla — Eagle Cliff in Zajnát Mountains).

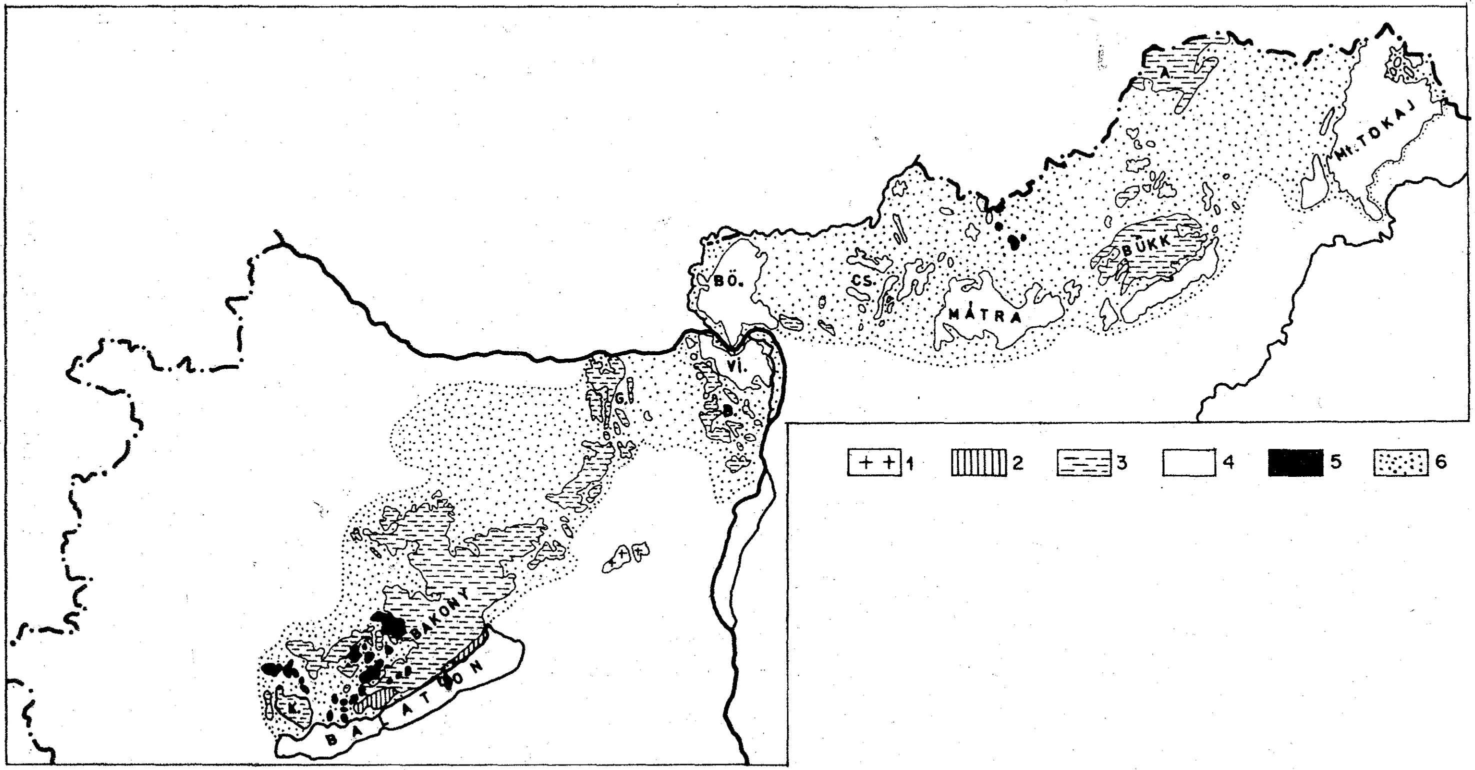

Fig. 1. Structural-morphological sketch of the Hungarian Mountains 1. Hercynian granite mountains; 2. Permian sandstone mountains; 3. Mesozoic block mountains mainly of dolomite, limestone and marl; 4. Miocene volcanic mountains mainly andesite and its pyroclastics, with rhyolite and rhyolite tuff; 5. Late Pleistocene basalt coverlet and cone remnants; 6. hills of Tertiary sediments in major part covered by Quaternary deposits

Abbreviations: A — Aggtelek Mountains; B — Buda Mountains; Bö — Börzsöny Mountains; Cs — Cserhàt Mountains; G — Gerecse Mountains; K — Keszthely Mountains; V — Vértes Mountains; Vi — Visegárd Mountains

The cryofracture of less frequent laminar limestone and basalt is quite similar, in many respects, to that of dolomite. The laminae, too, disintegrate relatively quickly to small particles though their comminution rate is slower and grain size is larger (3 to 10 cm) than in the case of dolomite. Debris is always flat and the two opposing fractions are absent and there is no considerable gravel, sand or dust formation. All these influence the nature and velocity of transportation which is slower. Thus mingled and debris covers are thicker: otherwise periglacial forms are the same. But, having small extension, these are only a minor feature of the Hungarian Mountains compared with dolomite and indicate a transition between the comminution rate, products and forms of dolomite and thin-bedded rocks.

2. The thin-bedded limestones, andesites and basalts, though their comminution rate is much behind that of dolomite, disintegrate the more easily, the thinner their beds and the more frequent the vertical joints. Cryofracture is especially quick in the case of Eocene nummulite limestone with crevices, andesite necks and coverlets and, most of all, basalts with columnar jointing though the cryofracture of highly jointed basalt columns was often hindered by lack of moisture. But these, in contrast with dolomite, fall apart into medium--size fragments of 10 to 30 cm diameter, the two contrasting fractions of dolomite being very rare. Their surface is covered by well developed felsenmeers of medium-size angular flat blocks to a thickness of several metres. These are the best evolved felsenmeers, especially in our volcanic mountains. Owing to frost susceptibility, cryoplanation steps are also frequent in the margins, mainly at the ends of spurs. The debris of thin-bedded rocks comminutes more slowly than dolomite debris and in a short distance no significant diminution of grain size can be observed, but their edges are worn even after several metres of transportation. This way in several metres, thick debris sheets are formed on slopes, with fragments of 10 to 25 cm dominant at the foot of steep slopes, in the splendid talus mantles, thinner flat blocks of some dcm in diameter are preponderant, but there is smaller grain detritus between them. The narrow lateral spurs are often hidden under a 2 to 3 m thick debris sheet and fresh rock is revealed only on the crest.

The 5 to 25 m wide classic stone-flows are usually fed by steep cliff heads or lateral spurs. Where symmetrical dry valleys cut into a thin-bedded rock, bulky stone-flows crept downwards from their vertical sides filling in the valley to several metres depth. The high roundness of stone-flow debris can be observed after some hundred metres of transportation. In front of the valley mouth they form an elongated alluvial fan of coarsely worn but still large blocks. So their attrition is more rapid than their further fragmentation. Meanwhile valley slopes retreat; according to the bulk of the stone-flow, the valley is broadening and elongating upwards.

Special formations of thin-bedded andesite form the rock bars of 3 to 4 m height and 8 to 10 m width, crossing low ridges and lateral spurs; their length varies with the width of the ridges, it is generally 70 to 150 m. They characterize the ridges of Mátra Mountains falling to the south where their regular forms suggest artificial dams though this is contradicted by circumstances. Blocks are of local origin, hollows between them are almost empty only infilled by little debris instead of finer decomposed material. They are usually connected to durable thin-bedded rock zones rich in vertical joints and fissures. Probably, these are remnants of more durable rock zones worn by frost action and piled up by frost pressure. Regelation of water infiltrated into the joints — a process promoted by the presence of a dense network of fissures — has practically fragmented and piled up the rock slabs and beds. This genesis of the rock bars is supported by an annually recurring, well-investigated phenomenon on the ice of Lake Balaton. The ice-slabs broken into pieces by frost pressure caused by freeze—thaw activity accumulate into pilings (in Hungarian „turolás"), similar to rock bars.

3. Thick-bedded durable rocks, limestone, mainly its more crystalline varieties (primarily Dachstein limestone), siliceous andesites, hydroquartzites, rhyolites, the holocrystalline andesites of subvolcanoes (laccoliths) and the durable, especially the siliceous, sandstones break down only very slowly. Therefore in their surfaces, felsenmeers and debris sheets are less developed or absent in places; they are characterized by fewer but large, mainly cubical, blocks. On the other hand, talus mantles at the base of steep slopes are well-developed and consist predominantly of huge blocks and boulders. As a rule these rocks reacted more slowly to the periglacial processes, than the former rock groups, for this reason also their surfaces had been less modified under a periglacial climate.

4. In the course of weathering and cryofracture both lava bombs and sheets became disclosed from the andesite agglomerates and pseudoagglomerates (SZÁDECZKY, 1959). Thus the resultant felsenmeers, debris sheets and talus mantles show great differences in the size and shape of their particles being dependent primarily on the lava blocks embedded in the agglomerate matrix. However, each individual agglomerate zone or district is characterized usually by one block size. Since their matrices may vary in resistance to weathering, scarps and pinnacles of bizarre configuration have developed, as well as stone niches on the margins (e. g. in the Visegrád Mountains).

The andesites and pseudoagglomerates of onion-skin weathering are special rock types. Both their frost comminution and chemical decomposition produces characteristic greater and smaller stone globes. On their surfaces felsenmeers of spherical shape or frost-fragmented hemispheres or quarters of spheres have resulted, and these predominate in the debris sheets, the mingled cover and the well-developed talus mantles. But the most typical special formations are stone--flows in valley heads and cols and, even more so, at the bottom of some short dry valleys with a wide floor, the strange stone-rivers. In their genesis chemical weathering was also effective. Intermittent brooks carried away the finer material leaving a thick sheet of spherical stones over on the valley floor.

From the viewpoint of periglacial weathering, the various Tertiary deposits surrounding the mountain cores can be arranged into three major groups:

(1) pelitic rocks liable to wearing away by gelisolifluction: clays, marls, sandy clays and clay-marls. Their destruction by gelisolifluction is the strongest. The upper several cm layer was being stripped by gelisolifluction year by year, ridges were lowering, valleys were broadening and filling and slopes were planating. The diverse and typical cryoturbation produced drop, festoon and bundle patterned soils. Layer deformation often makes the sub-surface stratum successions undulate. On the margins of mountains and in basins marl layers to depth of 5 to 7 m are virtually folded by frost deformation;

(2) comparatively durable rocks weathered mainly by cryofracture: e. g. Upper Oligocene and Upper Miocene sandstones and Miocene tuffs. Their frost disintegration was the quickest as the freeze-thaw activity of water percolating into their pores practically broke the rock up. Consequently they have a 1 to 2 m thick cover of fragmented rocks the greater lower part of which remained in place, and only the upper layer some dcm thick moved obviously downhill. Thus these surfaces were lowered in the periglacials by the slow but permanent removal of the layer uppermost at the time;

(3) rocks sensitive to downwash and frost action: various sands, gravelly sands, and terrace gravels. As water-bearing and very pervious rocks, these are the host material of the greatest number of ice wedges, ice veinlets and ice sacks and cryoturbation forms. So periglacial denudation and planation was strong on all loose rocks varying only in process and efficiency.

Since the ever thickening slope deposits of the foothill areas around mountains originate in the major part, in the slopes above them, their composition and nature is highly dependent on the rocks of the mountain slopes.

At dolomite slopes the loessy material with fine sand interbedded with small grain dolomite debris. In their transportation, downwash by showers (pluviation) and snow-melt (niveo-fluviation) was most effective but gelisolifluction also played an important role. Forms of laminar solifluction can be recognized in some places. The fine loessy layers are niveoeolian sediments as fine material derived from dolomite detritus and Neogene sediments was moved on by snow--melt and showers. They are, therefore, stratified and sporadically contain small detritus. They are removed from the bedrock only in 1 or 2 km distance and the way they are getting finer and finer on leaving their place of origin can be traced in exposures. The evidence of their origin is their $CaCO_3$ content, even higher than in typical loesses, the numerous lime-concretions and their pale yellow colour. On the basis of these features, not characteristic of slope deposits, it often appears to be typical loess.

In the transportation of clearly stratified debris bedded parallel to slope at the base of thin-bedded limestone, andesite and basalt slopes downwash might not have been so efficient, therefore (laminar and pipkrake) gelisolifluction and gravitation were dominant. Its matrix and the layers between debris stripes are fine clayey-loamy formations (clayey and loamy slope-loess) with debris particles. At the bottom of tuff-slopes the constituent of the corresponding tuff (e. g. pumice, biotite, etc.) can be recognized. Amongst these the most typical *grèzes litées* have accumulated. On and at the bottom of slopes of sedimentary rocks in mountain forelands, slope deposits vary according to the rock of ridges above them, they are alternatingly sandy or clayey.

Detrital layers of slope deposits accumulated in the humid periods of periglacials, at the beginning or end of periglacials, in the ana- or kata-glacials. Evidence for this is the forest soil remnants occurring in these layers, the material of which was winnowed by wind as well, and deposited in the dry periods (midglacials) judging by their high $CaCO_3$ content and many lime-concretions.

In this study I have tried to show the important role of various rock types in the periglacial sculpturing of relief. Their influence is, of course, combined with the other factors (relief, elevation and exposition).