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SOME GEOMORPHOLOGICAL RISK FACTORS IN THE CURVATURE CARPATHIANS AND SUBCARPATHIANS (Rumania)

ABSTRACT: DINU M & CIOACĂ A., *Some geomorphological risk factors in the Curvature Carpathians and SubCarpathians (Rumania).* (IT ISSN 0391-9838, 1996).

The Curvature Carpathians and SubCarpathians are a high seismic risk area (Vrancea Seismogenic Region) underlain by a complicated flysch structure developed on brittle formations. Torrential precipitations raging here are connected with dorsal cyclones, as a consequence, very active and dangereous geomorphological processes occur.

A map of geomorphological risk was elaborated for this region, through the analysis of ten test areas. Nine geomorphological risk types were distingished and they were grouped into three main risk classes for slope dynamics, depending on basic rock and surface deposits.

A detailed description is made of one of the study cases, the Poiana Braşov area; it is shown how the categories of geomorphological risk were outlined in terms of mass movement, dynamics on slope, frequency and intensity of present-day geomorphological processes and level of anthropic activity.

The method employed proved to be quite efficient and the necessity to multiply such studies is outlined.

KEY-WORDS: Geomorphological hazards, Geomorphological processes, Curvature Carpathians and SubCarpathians, Vrancea Seismogenic Region, Rumania.

RIASSUNTO: DINU M & CIOACĂ A., *Alcuni fattori di rischio geomorfologico nel settore della Curvatura dei Carpazi e dei SubCarpazi (Romania).* (IT ISSN 0391-9838, 1996).

La Curvatura dei Carpazi e quella dei SubCarpazi sono aree ad elevato rischio sismico (Regione sismogenetica di Vrancea) costituite da rocce flyschoidi deformate in una complessa struttura sviluppata su formazioni fragili. Le precipitazioni torrenziali qui diffuse sono connesse con i cicloni dorsali, di conseguenza sono attivi processi greomorfologici molto dannosi.

Per questa regione è stata elaborata una carta del rischio geomorfologico, attraverso l'analisi di dieci aree campione. Sono stati distinti nove tipi di rischio geomorfologico, raggruppati in tre principali classi di rischio per quel che riguarda la dinamica dei versanti, a seconda del tipo di roccia madre e di deposito superficiale presenti.

Uno dei casi di studio, la zona di Poiana Braşov è stato descritto in dettaglio; viene illustrato come sono state distinte le classi di rischio geomorfologico in termini di dinamica dei movimenti di massa sul versante, frequenza ed intensità dei processi geomorfologici attuali e livello dell'attività antropica.

Il metodo impiegato si è dimostrato efficace e si rileva la necessità di una sua applicazione più puntuale.

TERMINI CHIAVE: Rischio geomorfologico, Processi geomorfologici, Curvatura dei Carpazi e dei SubCarpazi, Regione sismogenetica di Vrancea, Romania.

INTRODUCTION

Climate changes at both global and regional scale influence the geographical and biological systems which strive to adjust to them. Therefore a priority target of geographical research today is to find out the direction in which the surrounding environment is likely to evolve. Hence, a historical approach to natural climate variability long before meteorology-based studies came to the forefront. Similarly, of great interest is the interpretation of correlative geomorphological processes on slopes and in deposits and disaster processes. Generalizing the data obtained through such studies would help establishing the evolution of the environment over wider areas than it has been done so far.

PROBLEMS OF GEOMORPHOLOGICAL RISK IN RUMANIA

Rumania is situated in the South-East of Europe. It covers a surface of 238,100 km^2 and presents a great natural diversity: mountains, hills and plains, quite proportionally and concentrically distributed.

Lying in the central part of Rumania, in a radial display around the Transylvanian Depression, with a vast opening to the North-West, the Carpathian Mountains cause some

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rifts in the general circulation of air from the West and of Mediterranean cyclons. Thus, the Western circulation, dominant along the 45-48 N parallels, is deviated by the Curvature Carpathians to the NW or SW with the consequent time-persistance of some cold fronts sheltered by the Curvature Carpathians (BORDEI, 1988). Similarly, the regressive influences and trajectories of the Mediterranean cyclones are associated with heavy rainfalls in the Curvature Carpathian area (BORDEI, 1983). It becomes obvious, therefore, that the dynanic effect on the movement of the masses of air over Europe is felt at the lower tropospheric level, and the extreme atmospheric events connected with them play a major role in triggering geomorphological processes within this Carpathian area.

Romania's territory features by a high seismic activity which, from time to time, shows up in violent earthquakes which, by their effects, rank among natural disasters. There are several source regions located in Vrancea, Făgăraş, Banat, Maramureş and named after them. The Vrancea Seismogenic Region is assumed to be the most active subcrustal earthquake province of Europe (MÂRZA & PANTEA, 1991) being the major focal area responsible for the seismic regime of Romania. It is characterized by the existence of three seismic peaks in every century and by a predominantly North-East - South-West direction of the preferential propagation of the seismic waves. (CONSTANTINESCU & ENESCU, 1985).

Recent investigations of Vrancea Seismogenic Region (MÂRZA & PANTEA, 1991), which covers the greatest part of the Curvature Carpathians with extensions toward the Curvature SubCarpathians, have shown that the earthquakes produced here do not follow the ordinary pattern (Benioff plane localized focus of the subduction scheme), but have an origin and evolution of their own, namely crustal and subcrustal, occurring very deep down. It is a unique combination in Europe and worldwide, which the literature mentions by the name of Vrancea earthquakes. Their effects have been showing up in the dynamics of geomorphological processes and consequently in recent and present-day modelling.

THE CURVATURE CARPATHIANS AND SUBCARPATHIANS

The Curvature Carpathians stretch out between the Oituz and the Prahova valleys (GEOGRAFIA ROMANIEI, III, 1987). They cover an area 110 km long and 100 km wide, bridging the Southern to the Eastern Carpathians, comprising lower massifs (Perşani, Baraolt, Bodoc and the large Depression of Braşov on the outside) and the Curvature massifs proper formed of Cretaceous and Paleogene flysch. Apart from huge morphological differences compared to neighbouring landforms, the area features by present-day slope dynamics, due in particular to homogeneity of rock, style and intensity of fragmentation and current denudational processes. These processes are conditioning one another against a very unstable tectonic background favouring the rapid evolution of landforms. So, the Curvature Carpathians and SubCarpathians are marked by the most intense dynamics and severest geomorphological processes in Romania which, together with a lasting and adverse anthropic activity, have generated significant imbalances. In view of it, undertaking an in-depth study of the effects of geomorphological processes on lands, settlements, waters, means of communication, appeared to be of overriding importance in order to get a better insight into the region's environment, impaired by a dense population.

Achieving a correct representation in point of equilibrium, degree of anthropisation, and moreover landuse in an area prone to destructive or catastrophic geomorphological processes, several representative parameters were chosen as case-studies for the elaboration of a map of geomorphological risk in the Curvature Carpathians and SubCarpathians (fig.1). The vast study area - 11,950 km^2 (mountains: 5,250 km^2; SubCarpathian hills: 6,700 km^2) represents little more than 5% of the country's surface area. The major sample selection criterion was appurtenance to the two relief steps. In the mountain unit, with low or medium altitudes, the main orographic and tectonic lines run discordantly.

The Romanian Carpathians, a medium-high range, are fragmented by tectonic depressions and transversal valleys. They are built up by discountinous crystalline and granitic massifs, sedimentary Mesozoic rocks, Paleogene and Cretaceous flysch deposits and Neogene eruptive rocks (SĂNDULESCU, 1984).

The flysch sheets between the Trotuş and the Prahova valleys have individualized some massifs with altitudes decreasing from the centre to the periphery over an area that extends towards the exterior rather than to the Braşov Depression, fact that creates an asymmetry with summits stretching out to the South and East. The orographic axis against which this asymmetry emerges is formed of the following massifs: Goru, 1,785 m; Penteleu, 1772 m; Siriu, 1,662 m; Ciucaş, 1,954 m; Grohotiş, 1,767 m and Baiu Mare, 1,885 m. The location of the samples observed their position against the orographic axis: 1, Poiana Braşov; 2, Ciucaş; 7, Lepşa Peak; 8, Zăbala Covasnei lie in the sector oriented towards Braşov Depression or on the very axis itself. However, the location of all samples took into account especially the geomorphological processes specific to the Cretaceous flysch (Poiana Braşov and Ciucaş dominated by rock-and-soil falls and sinkings rather than sheet slides) and Paleogene flysch (Ruptura, Varlaam, Lacul Negru, Tişiţa Gorges, Lepşa Peaks and Zăbala Covasnei) marked by a significant incidence of deep slides, gullies and mudflows.

The Curvature SubCarpathians, which lie between the Trotuş and the Dâmboviţa valleys (175 km), constitute the most complex structural sector (CIOACĂ, 1985), because of the Paleogene flysch spurs penetrating the highly tectoni-

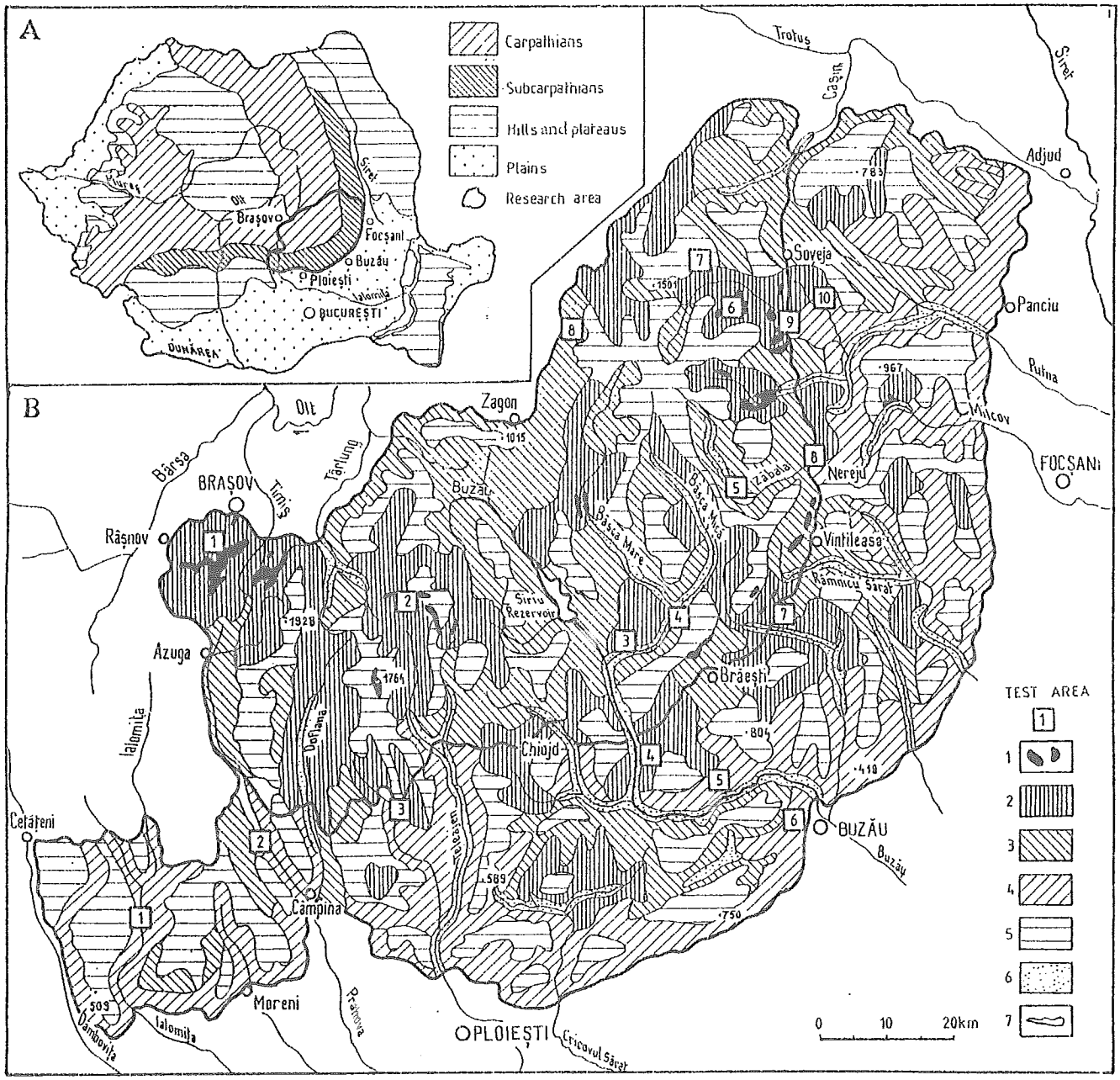

FIG. 1 - Map of geomorphological risk in the Curvature Carpathians and SubCarpathians. A. Location of studied region in Romania's territory; B. Map of geomorphological risk: 1) ridges, gorges, defiles, steep slopes with outcropping rock, no surface deposits, high and moderate risk for sinking and rock-and-soil falls; 2) very steep slopes covered with oak forests, high risk for gullying and strong gully erosion; 3) slopes with great or moderate declivity, deforested, used as hayfields, or covered with beach and oak forests, high risk for deep sliding and moderate risk for gully erosion to extend; 4) wild slopes, moderate declivity covered with pastures, orchards, moderate risk for linear erosion and sheet slides and solifluxion to extend; 5) rounded and flat summits, levelling surfaces, covered with forests, hayfields and pastures, affected by sheet erosion, low risk for sheet wash and gullying; 6) alluvial areas, high risk for flooding and formation of temporary storage lakes behind the dump of slope-yelded materials; 7) reservoir.

zed mass of molasse. Here, one can see areas with recent or Quaternary sedimentary fillings, corresponding to depressions and enlarged valleys. Given that the anthropic impact is particularly severe in the valleys and depressions, samples are located on slopes covered with forests, hayfields and moreover orchards and some crops in the vicinity of human settlements, communication routes or industrial units (in the Ialomița Valley close to the railroad and highway on the fringes of Pucioasa locality (n° 1); in the Prahova Valley, around Breaza locality (n° 2); at the con-

tact between Vărbilău Hills and Bertea Depression (n° 3, Lutul Roşu); in the Buzău Valley close to the mountain (n° 4, Pănătău); on the fringe of Cislău Depression (n° 5, Bădila); in the Nişcov Depression edging Istriţa Hill (n° 6, Nişcov); in the Slănic de Buzău Valley on orchard - covered slopes (n° 7, Jghiab Valley); in the Zăbala Valley, in the sector crossing a diapir axis (n° 8, Poienile Sării); in the Putna Valley at the contact between the Carpathians and the SubCarpathians in the Vrancea Depression (n° 9, Coza) or its tributary, Caciu (n° 10, Bârseşti) affecting Topeşti settlement. There are areas here where the highly degraded grounds have a particularly damaging effect on the SubCarpathian environment.

MAP OF GEOMORPHOLOGICAL RISK

In elaborating the map of geomorphological risk we took into account the types of geomorphological processes that depend on slope and surface deposits, as well as their distribution. The six geomorphological risk types (fig 1) have been grouped in three main risk classes (high, moderate, low) for slope dynamics, depending on basic rock and surface deposits. The scale of the map imposed a high degree of generalization of risk types, yet easily interpretable due to the hachuring technique which highlights risk factor typology. Another aspect followed was the dominant effect of some geomorphological processes originating in the upper section of the slopes and affecting a vast area down to their foot, areas usually occupied by settlements, routes of communications and especially forest or cropland (BĂLTEANU & *alii*, 1989).

A good illustration of the working method in elaborating the map of geomorphological risk in the Curvature Carpathians and SubCarpathians is Poiana Braşov sample (n° 1, in the Curvature Carpathians). This area lies on the Northern flank of the Postăvaru Massif, more precisely in its central part, between the hotels of Poiana Braşov resort and the Postăvaru crest, the site of slalom and downhill tracks and cable transport installations.

The studied area, nearly 36 km^2, is rectangular in shape, stretching out along a N-S direction. The northern third segment, slightly weavy, shelters Poiana Braşov health resort; the Southern section contains both the main summits (the Postăvaru crest, included) and the secondary summits.

Morphographic and morphometric features. The Postăvaru Massif lies in the Westernmost extremity of the Curvature Carpathians, part of the Bârsa Mountain group. The Postăvaru, a secondary orographic knob, reaches the highest absolute altitude of this group (1,800 m in the central part, down to 1,000 m Northward toward Poiana Braşov).

The South-Eastern part of this area is governed by the main summit of the massif and corresponds to a limestone cuesta edge, with its scarps in the direction of the Timiş Valley. A structural step-like surface sloping down to Poiana Braşov is separated by the following summits: Groapa Lupului, Cristian and Poiana Doamnei, with Northward extensions in the form of short, valley-divided secondary summits. All these valleys run toward the Cheia Valley. The altitude of secondary summits: 1,600 - 1400 m down to the 1,100-1,000 m in the levelling surface of Poiana Braşov. This surface, bordered by the Postăvaru crest in the East and by several limestone hillocks in the West, has developed through the widening of two drainage basins - the Cerna Valley and the Sticlăria Valley. Landforms in Poiana Braşov area, formed during the Upper Pliocene and the Lower Quaternary, are dominated by the structure-controlled Postăvaru crest.

Declivity variations are rock-structure dependent: 300-600 on the limestone slopes of the Postăvaru, 5°-15° on the levelling surface of Poiana Braşov, and 10°-30° on the summits of secondary slopes. The density of relief fragmentation varies from 6-8 km/km^2 on the limestone ridge of the Postăvaru to 4-6 km/km^2 in the rest of the area. Depth of fragmentation: 300-500 m/km^2 in the Postăvaru and the Cristianu Mare-Poiana Doamnei Mts.; 150-200 m/km^2 in the levelling surface of Poiana Braşov.

The region's drainage network is dominated by the Bârsa Valley, channelled by the Cheia Valley (the Săsoiaca and the Valea Sticlăriei). Most valleys in this limestone zone are short, with troughs and torrents; their floor is covered with gravels in which the few water veins are lost. The Săsoaica and the Valea Sticlăriei, which fragment the Poiana Braşov level, are short with a steep thalweg slope and many springs. The man-made lake in the centre of Poiana Braşov resort, stands in the Cheia Valley (Poiana Valley). After collecting the waters from the North-Eastern corner, the Cheia flows toward Râşnov settlement.

Structural and petrographic features. The area belongs to the Curvature Carpathians. Lithological diversity is rooted in the Mesozoic formations represented by 200 m - thick Upper Jurassic limestones (blackish and greenish radiolarians and limestone slabs), and 500 m - thick white grayish reefogenic Tithonian limestones belonging to the Braşov Series. The main cone-shaped peak is part of a pointed limestone crest extended to the North-East. Limestone also occurs in the South-West (Muchia Cheii and in Vanga Mare summits), being associated with Vraconian-Caenomanian deposits consisting of conglomerates, sandstones, calcarenites, and marls with conglomerate intercalations (Postăvaru conglomerates).

In point of structure (SANDULESCU, 1984), the Postăvaru Massif belongs to the Mesozoic limestone cover of the Getic Crystalline unit, forming together the Leaota-Postăvaru anticline. The Aptian-Albian conglomerates of the Bucegi-Piatra Mare syncline occur in the lower part, on the Jurassic limestones of the Leaota-Postăvaru anticline; in the outer part they lie on the Cretaceous flysch of the Ceahlău sheet. Vraconian -Caenomanian deposits form the Timiş syncline.

Present-day geomorphological processes. Lithological diversity and appurtenance to the Timiş Basin contribute to the permanent reactivation of erosion at the basic level of the Braşov Depression (500 m) which lies at a short distance away (fig. 2).

Landforms in the Bucegi and the Piatra Craiului massifs are similar though less varied. The Postăvaru ridge is a structure-controlled interfluve, a tectonic and erosion-governed cuesta continued by a series of lithological steps down to Poiana Braşov. The karst and the pseudo-karst relief is due to the presence of the limestones and limestone-cement conglomerates of the Postăvaru (1,799 m) - Muchia Cheii (1,500 m) summits subject to strong gelifraction-induced degradation. This would also explain the formation of masses of scree and stones on the Eastern slope.

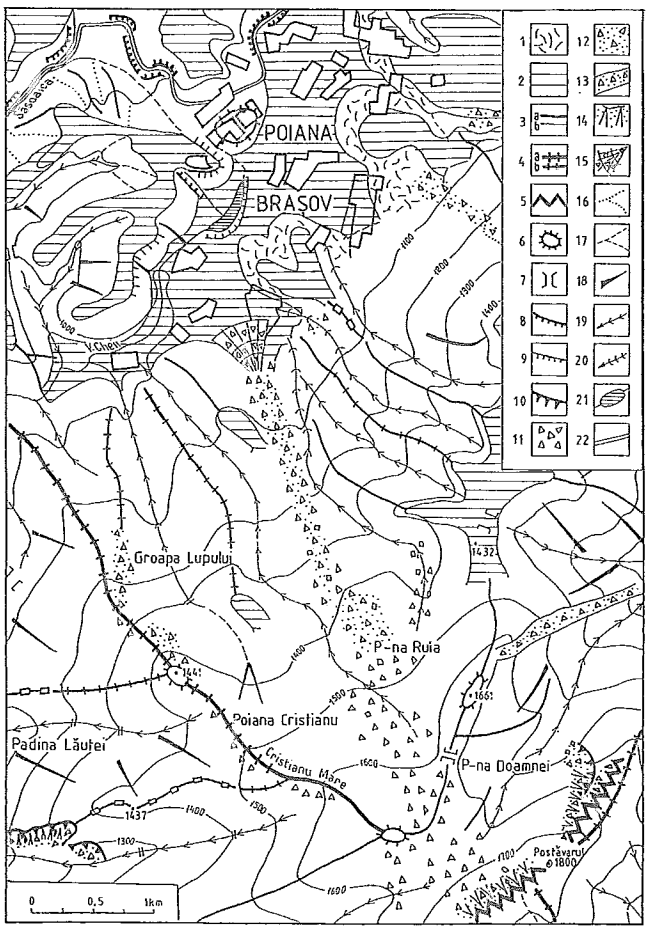

FIG. 2 - Poiana Braşov area. Geomorphological map: 1) Accumulation glacis; 2) levelling surface; 3) rounded summits: a, principal; b, secondary; 4) step-like summits: a, principal; b, secondary; 5) ridges; 6) erosion outlier; 7) saddles; 8) delevellings: 2-10 m; 9) delevellings: 10-25 m; 10) delevellings: 100-200 m; 11) moving debris; 12) fixed debris; 13) sinkings; 14) rock-and-soil falls; 15) alluvial fan; 16) cove; 17) small-fixed valley; 18) gully; 19) V-shaped valley profile; 20) U-shaped valley profile; 21) man-made lake; 22) road.

The Postăvaru crest shows residual outliers, saddles and rock streams; declivity is over 25°.

The valley floor and some step-like slopes are covered with variously-sized scree material formed by gelifraction. This material spreads from under the Postăvaru crest to the deforested slopes below the cable-chair line, also covering the winding tracks. Most of this scree material is fixed on slopes; some of the scree-covered areas are occupied by forests; other surfaces are invaded by rock falling into the scree layer, which in the lower slope section is over 1 m thick. Sheet wash and rill wash are characteristic of deforested slopes. The scree layer is sometimes so deeply affected by rill wash that the marmites forming at the foot of the slope imbalance it . On vast portions the imbalanced scree layer has unrooted the trees (coniferous species, in particular). Talus cones use to accumulate at the slope foot becoming partially rooted there.

GEOMORPHOLOGICAL RISKS

Categories of geomorphological risk (fig. 3) in the Poiana Braşov area have been outlined in terms of mass movement dynamics on slope, the frequency and intensity of the present-day geomorphological processes, and the level of anthropic activity. On the basis of field quality surveys a number of nine risk categories could by identified and grouped under the name of risk classes commonly referred to: low, moderate and high.

Low geomorphological risk: the slightly weavy levelling surface of Poiana Braşov, with mild slopes, fairly well-afforested; the rounded, afforested summits of the Postăvaru down to Poiana Braşov; glacis and alluvial fans occurriring at their junction level. This area shelters Poiana Braşov resort.

Moderate geomorphological risk: the afforested slopes with moderate declivity forming all secondary summits; linear erosion (small-fixed valleys, marmites flows) tends to extend; afforested slopes invaded by talus falls; deforested slopes turned into ski tracks, with cable transport lines (chair, ski). There is a risk for deep erosion and the temporary fixed talus to become reactivated.

High geomorphological risk: the crests and steep rocky slopes of the Postăvaru and the Cristianu Mare; the very steep deforested slopes covered with moving debris. This risk area is small - 10-12 %. The gelifraction processes, dominant throughout Poiana Braşov area, began in the Pleistocene, and continue to be active to this day.

Present-day slope modelling processes in the area are not dangerous for human activity.

Except for some uprooted forests due to deep erosion, or degraded by scree, no damaged areas were signaled out. The only settlement with low risk for disaster processes to develop now is Poiana Braşov (+/– 1,000 m alt.)

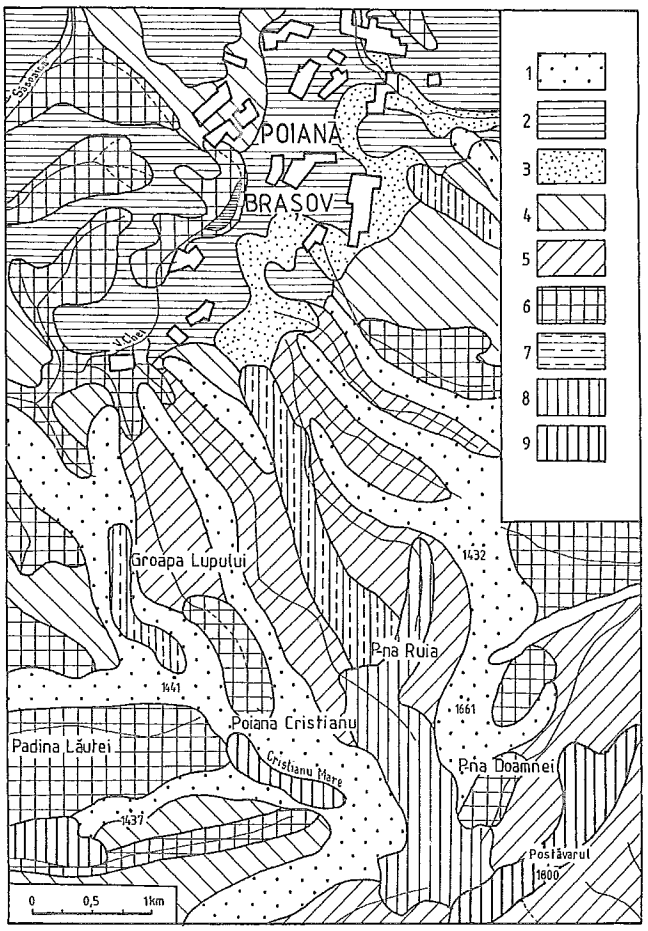

FIG. 3 - Poiana Braşov area. Map of geomorphological risk. 1) rounded or flat summits covered with coniferous forests oak-and beech forests, generally stable: low risk for lateral erosion from gully sources or small fixed valley covered in part with debris fallen from the Postăvaru crest; 2) levelled surfaces (Poiana Braşov erosion level +/- 1,000 m) fragmented by several Cerna Valley tributaries and affected by solifluxtion or suffusion processes: low risk for degradation; 3) wild, deforested, slopes, corresponding to glacis and alluvial fans: low risk for gullying; 4) slopes with average declivity, covered with forests and glades: low and moderete risk for the extension of gullies, ravines, or sheet slides; 5) moderately dipping slopes covered with coniferous forest in the lower part and with secondary meadows in the upper sectors where oak forests had stood: moderate risk for linear erosion and solifluxtion in the upper section to extend; 6) slopes with a moderate dip covered with oak forests, below where there is moderate and high risk for small fixed valleys and gullies to extend; 7) slopes with average and high declivity, developed on fixed scree initially covered with oak forests, deforested today and turned into ski tracks: moderate and high risk for gullying and reactivation of blocks from the mass of fixed scree; 8) very steep, barren, slopes with moving debris: high risk for debris movement; 9) steep rocky slopes, corresponding to gorges walls or intersection edges of the main summit: high risk for the sinking of disagreggation products and the temporary accumulation of wrenched rock blocks.

CONCLUSIONS

This geomorphological study of the Curvature Carpathians and SubCarpathians makes a geomorphological assessment of risk degree in terms of slope declivity, surface deposits and landuse. The cyclical recurrence of these factors in time depends on the occurrence incidence of big earthquakes and the particularities of the local climate under the impact of global climate changes.

The geophysical surveys of Vrancea Seismogenic Region reveal an incidence of three earthquakes of over 7.0 magnitude within a century. As a consequence, cyclic paroxistic movements on slope occur every thirty-three years, on the average. The area is also subject to heavy rainfalls, thick snow layers and high freeze-thaw phenomena all of which are significantly involved in triggering haphazard geomorphological processes. In our opinion, the number of samples studied so far is totally insufficient to afford a precise delimitation between various geomorphological risk areas. Besides, in order to better assess the degree of their vulnerability in areas with great density of settlements and routes of communication such studies should be multiplied.

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