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THE GEOMORPHOLOGICAL RISK IN TRANSFĂGĂRŞAN HIGHWAY AREA

Abstract. This paper looks at a very topical problem in the geomorphological literature. The building of Transfăgărăşan highway has involved a modification of the components of the landscape in the central zone of the Făgăraş Mountains (Southern Carpathians or Transylvanian Alps). The geomorphological component has suffered important modifications, including changes to the dynamics of some present-day geomorphological processes and this has major implications on the development of activity along this road. The preparation of a geomorphological risk map therefore represents a proper response to this problem. The preparation of this map has become even more important because tourist activity has intensified.

The Transfăgărăşan highway is 90.167 km long and crosses the main ridge of Făgăraş Mountains reaching an altitude of 2,042 m in the Bâlea Lac zone between Paltina Peak (2,399 m) and Capra Peak (2,417 m). About 30% of the route lies in the alpine belt. These mountains are the highest in Romania rising to 2,544 m a.s.l.

The drawing of the geomorphological risk map was preceded by a geomorphological analysis of the area. This consisted firstly of making morphometrical maps of the depth and density of the fragmentation of the relief and of the slope and secondly of making a geomorphological map. Of course within the geomorphological analysis a special attention was paid to the analysis of the morphodynamic potential of the zone in conditions in which the stability of the slopes had been reduced by the modification of their profile and by the vibration induced by traffic.

Key words: geomorphological hazard, Făgăraş Mountains, Carpathians

INTRODUCTION

"Hazards" are the results of sudden changes in long-term behaviour caused by minute changes in the initial conditions (Scheidegger 1994). Geomorphic hazard is defined by S. A. Schumm (1988) as any landform change, natural or otherwise, that adversely affects the geomorphic stability of a place. Geomorphic hazards must be regarded as the suite of threats to human resources arising from the instability of surface features of the earth. The threat arises from landform response to surface processes, even though the initiating processes may originate at great distances from the surface (Gares et al. 1994).

Geomorphological studies have shown their importance in practical applications in the study of geomorphological hazards. These therefore represent some of the problems that have received continued interest from geomorphologists (Slaymaker 1996). Geomorphologists have considerable expertise in process studies and the mapping of the precursor and antecedent conditions for surface phenomena. They also have a significant understanding of magnitude and frequency concepts applied to the earth sciences (Rosenfeld 1994).

The building of the Transfăgărăşan highway has also represented a modification of the components of the landscape in the central zone of the Făgăraş Mountains (Southern Carpathians or Transylvanian Alps). The building of this unique highway in the Carpathian Mountains required solutions to some special geotechnical problems, problems that came directly from the specifically alpine relief, from the lithology and from the geological structure. The geomorphological component has suffered important modifications, including changes to the dynamics of some present-day geomorphological processes and this has major implications on the development of activity along this road. A proper response to this problem will therefore look at the geomorphological hazards in this area. The aim of our study was to identify the actual and potential geomorphological risk caused by the construction of the Transfăgărăşan highway and subsequent geotechnical work. We took into consideration the following material: the morphometrical study, the morphological and morphodynamical study, and the draft geomorphological risk map.

Our studies have been directed at the recognition and analysis of the natural, potential and active risk as a result of human intervention (participation) in the landscape. This intervention is seen in material form in the building and equipping of this highway with an associated set of necessary and obligatory geotechnical arrangements to maintain its function and also to ensure the safety of traffic. Part of this equipment is the berms, the embankments, the excavation, the ramps.

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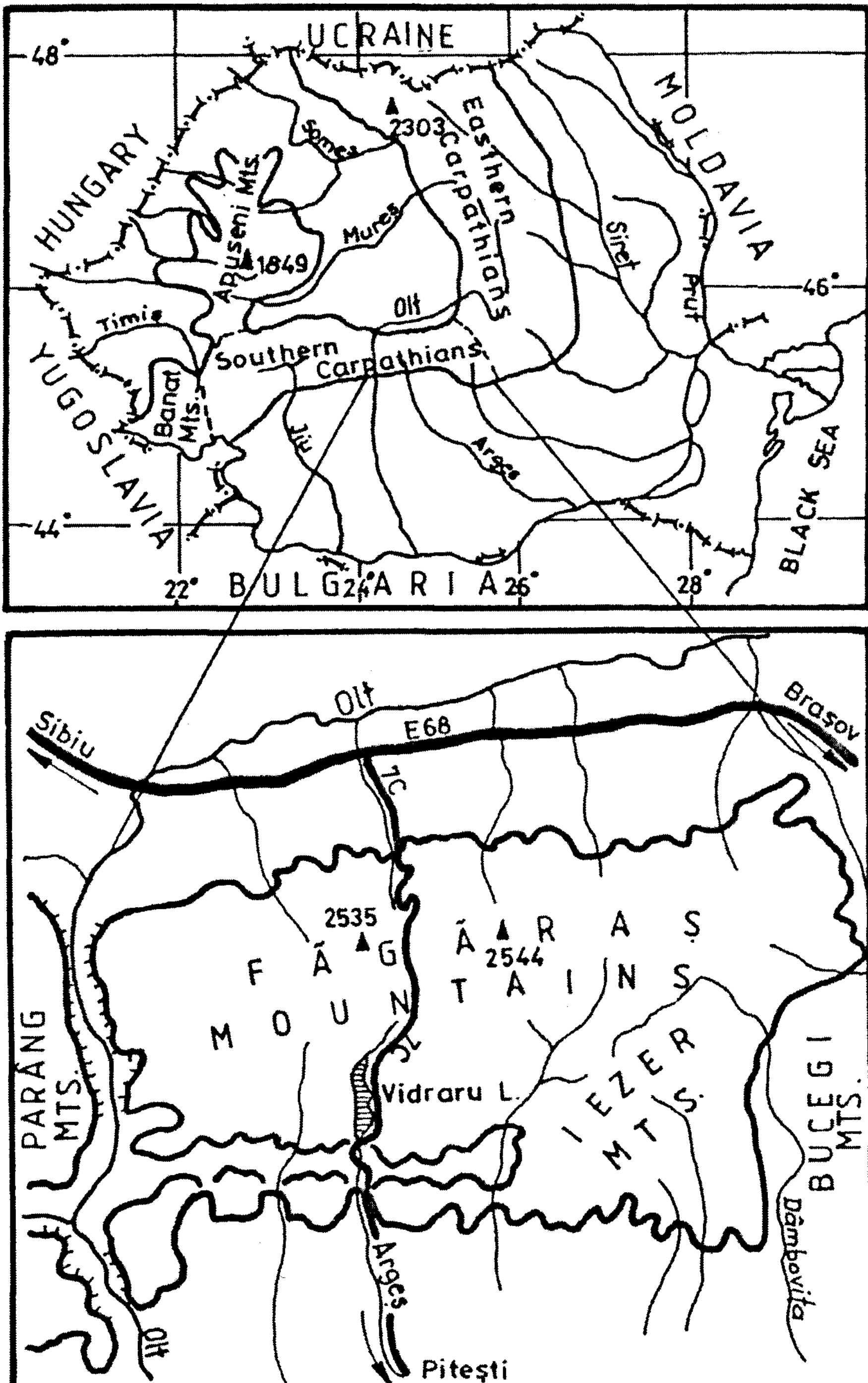

Fig. 1. Location of the study area

THE SPECIFIC GEOLOGICAL, MORPHOMETRIC AND MORPHOGRAPHIC DATA

Geologically speaking, the area studied lies in the lithostratigraphic domain of the Făgăraş Subgroup, which is represented here by the Suru Formation. The Suru Formation includes retromorphic paragneisses and micaschists and quartz-sericitous schist, whose alternations often include amphibolitic limestones and crystalline dolomite bands (Gridan et al. 1986). All these rocks are very sensitive to frost-thaw — with a gelivity index between 18 and 32. This explains the efficiency of frost shattering, especially in the escarpment areas.

These rocks form an anticline structure whose axial zone is the crest area. On the northern flank of the anticline the strata dip northwards at about 52–82°, and on the southern flank the dip is 40–60° towards the South. There are a few faults parallel with the anticline axis on the southern flank and these cross the Capra valley.

The estimation of geomorphological risk is closely linked to the judging of the morphodynamic potential. One cannot tackle this without some morphometrical and morphographical data.

The highest altitude of the area studied is Vânătoarea lui Buteanu peak, 2,507 m a.s.l. The largest part of the interfluves consist of typical sharp ridges and pyramidal peaks, peaks and ridges that are found even on the highest area over 2,200 m a.s.l. Only in the Paltinu-Picioru Paltinului area and on Fântâna Mountain are the interfluves smoother and more rounded. These latter areas belong to the Borăscu levelled surface complex. These interfluves are separated by glacial cirques and valleys which have the specific U-shape. Most of their walls are very steep, while their floors contain numerous glacial rock-bars.

The depth and density of the fragmentation of the relief (Fig. 2) — calculated by the Partsch–Krebs method — are respectively about 400–880 m and between 3 and 8.5 km $\cdot$ km^{-2}. Taking account of the declivities it can be noted that most of the area studied has slopes of over 20°, the declivities under 5° being found on extremely small areas on the floor of glacial cirques and valleys and on the levelled surfaces (Fig. 3). These morphometrical elements sustain, and at the same time, explain the high morphodynamic potential of the mountain zone crossed by the Transfăgărăşan highway.

It is necessary to link the morphometric and morphographic analyses with the analysis of climatic conditions in order to emphasise the dynamics of the geomorphological risk phenomena. These are noticed in the mean annual temperatures which go down to –2.5°C in the area of the ridges (Vf. Omu at 2,505 m a.s.l., in Bucegi Mountains) –0.2°C at Bâlea Lac (2,038 m a.s.l.). These are also noticed in the precipitation figures which rise to more than 1,200–1,246.2 mm $\cdot$ year^{-1} at Bâlea Lac (2,038 m a.s.l.), in the snow layer which at Bâlea Lac is on average about 136.5 cm thick, with a maximum of 308 cm, and in the period of over 200 days with frost.

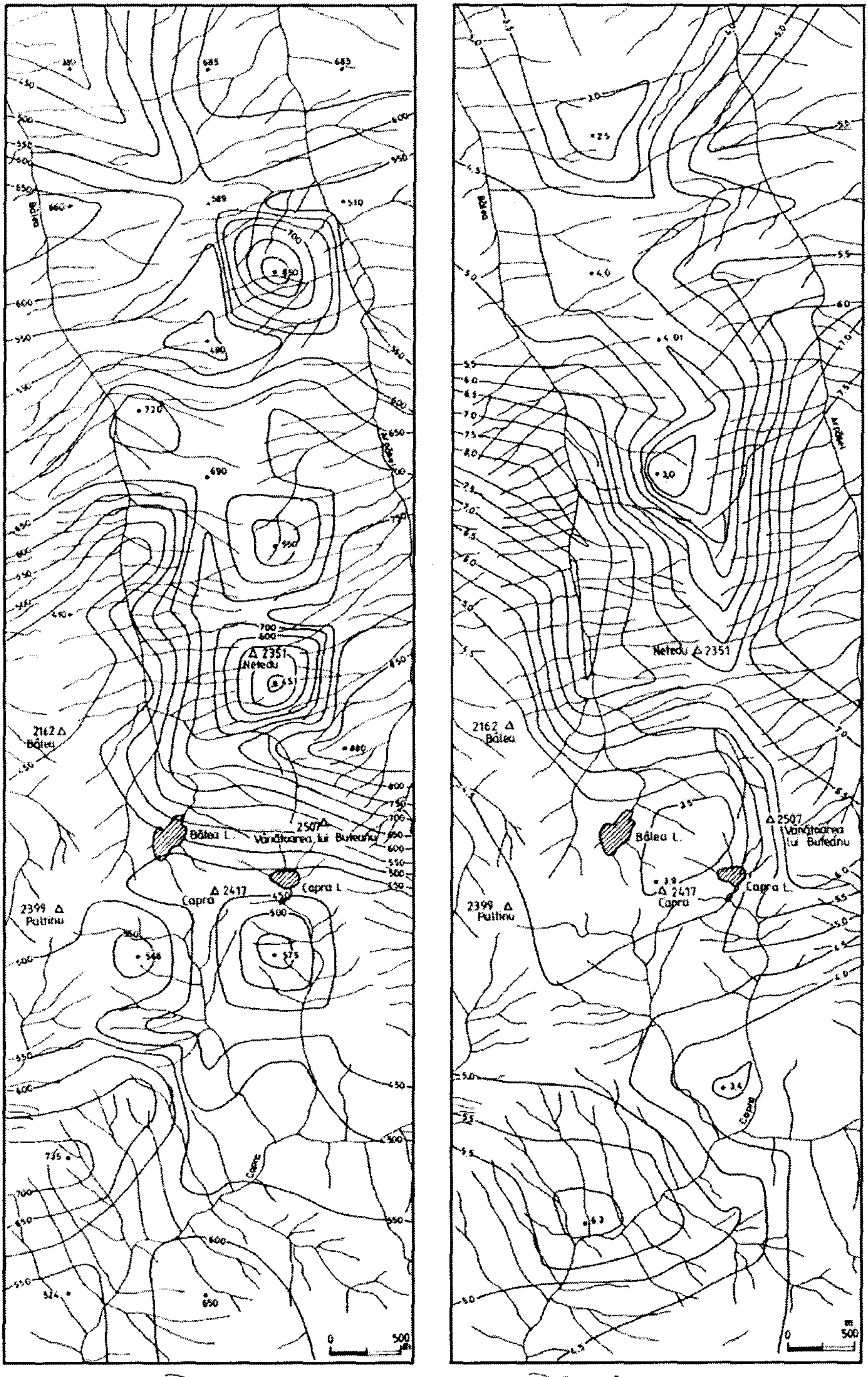

Fig. 2. The maps of the depth (in meters) and density (in km · km^{-2}) of the relief fragmentation

DATA AND FIELD OBSERVATIONS, DISCUSSION

The Transfăgărăşan highway was built between 10 March 1970 and 20 September 1979. Over 3.8 millions m^3 was excavated, 212,000 m^3 being in hard rock and 150,000 m^3 in terrace (unconsolidated) material. If we consider the fact that this work changed the profile of the slopes, that new slopes a few metres high appeared and that the woodland on both sides of the route was cleared, then we can understand why the morphodynamic potential of the zone has increased. From a morphological point of view, geomorphological risk phenomena even appeared while the works were being carried out because of the conditions induced by the vibrations resulting from the removal of rock and because of the heavy machinery used. It should be noted that landslides occurred on 14th June 1972 when 7,000 m^3 moved, on 28th April 1972 when 100,000 m^3 moved, on 15th April 1973 when 8,000 m^3 moved. A landslip occurred on 30th June 1974 when 8,000 m^3 moved, and an avalanche on 13th March 1973 which was 1.5 km long, 150 m broad, 10 m high and involved the destruction of 5 ha of woodland.

Some bridges and support walls became unstable because they were undermined by regressive and vertical erosion. This was affected by the clearing of 325 ha of woodland in our study area and the destruction of vegetation as a result of the construction and modification of the profile of slopes to produce very steep gradients which favoured the intensification of gullying processes.

Piles of debris accumulate at the margins of the cuttings on the mountain highway due to traffic vibration and natural processes such as frost action, falling and rolling. This disturbs the traffic. As a result of our observations and measurements, we have discovered that between 0.5–3.5 m^3 of debris appears per linear metre of newly created artificial slope, compared to 0.1–0.7 m^3 in natural conditions. Protective structures had to be installed on the areas exposed by these processes and on landslides for example in Bâlea Cascadă, Poarta Geniştilor–Poarta Întâlnirii, Cota 2000, Stâna Capra. The fact that the bedrock had become more fissured due to the excavation process must not be overlooked since this had effects on its internal stability.

The steepest versants (slopes) such as the glacial cirques and valley walls are traversed by numerous, simple or branching avalanche corridors, with talus cones at their base (Fig. 4). There are situations in which slopes or versants of frost-shattered blocks are formed, for example in Văiuga cirque, under Vânătoarea lui Buteanu, and in the Căldarea Pietroasă a Doamnei cirque. These masses of debris are in an unstable balance being easily dislodged by avalanches and also by the debris-flow phenomenon. This is favoured by the abundance of small frost-shattered blocks, a specific characteristic of micashists and quartz-sericitous schists, and by the frequency of torrential rain during the summer (U r d e a 1995). When these torrential rains fall in May, a month when there is still snow, they can produce sudden thaws which intensify this phenomenon.

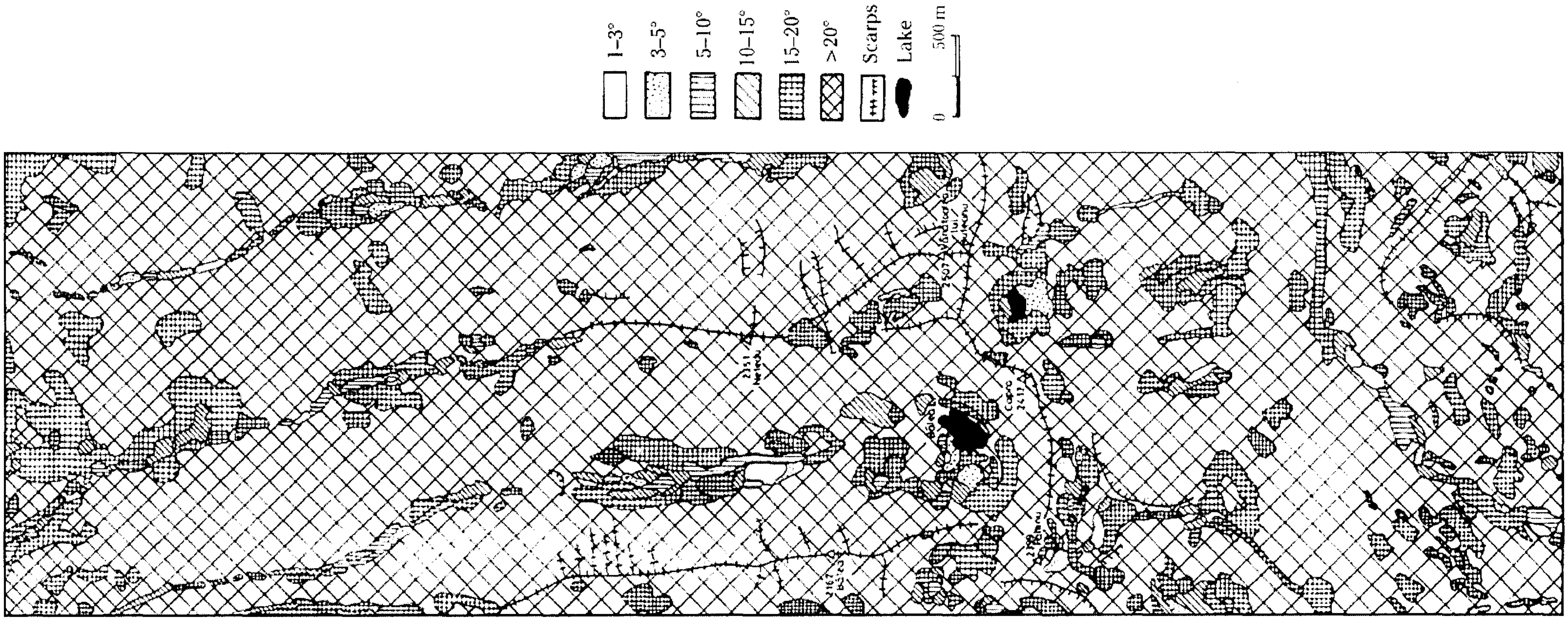

Fig. 3. Surface inclination map of the study area

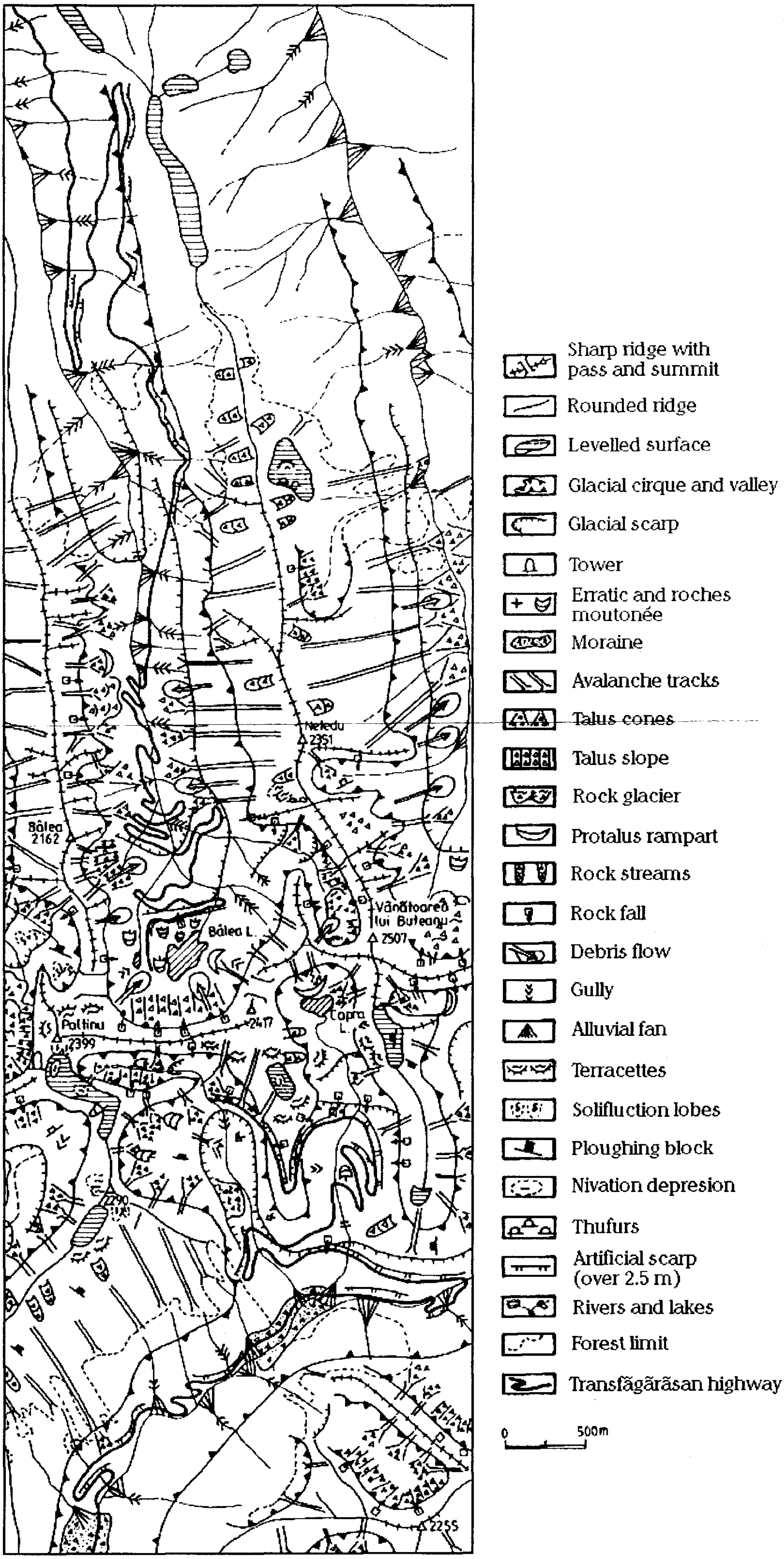

Fig. 4. Geomorphological map of the study area

The growth of tourist activity in the Bâlea–Capra area together with people straying off the tourist paths has caused the vegetation to disappear in these areas which has further intensified the gullying and torrential erosion processes.

Although they are more limited in space and less intense than other natural phenomena, the susceptibility to geomorphological hazards implies that the landscape and geosystems are disrupted, which added to the risk of the loss of human life, gives them the status of a catastrophe of geomorphological origin (Chardon 1990).

THE GEOMORPHOLOGICAL RISK MAP

In our study area, as well as in the Carpathians (Bălteanu 1997), avalanches, rockfalls, landslides, debris flows, gullying, ravine formation and torrential erosion are major risks.

Since the geomorphological risk maps offer a picture of the state of the relief, integrating all the geomorphological factors involved, their preparation has an analytical and in particular a "synthetical" nature (Bălteanu et al. 1989). These maps are made to predict the appearance and the progress of those processes that determine changes in the relief while not making significant changes to this dynamic balanced state. They should also predict those extreme processes which affect the relief, modifying its dynamic balanced state.

We prepared the geomorphological risk map (Fig. 5) starting from the evaluation of the morphodynamic potential of this area, an evaluation made with the help of geomorphological, morphometrical, morphographical and morphological analyses.

The geomorphological risk evaluation and distribution led to the identification of four areas with different levels of risk. The factor used to determine these is the morphodynamic potential — of course, in specific geographical conditions — estimated from the intensity, duration and frequency of specific processes.

The zone without risk — or zero risk — is restricted to the smooth interfluve areas in Paltinu-Picioru Paltinului, the central part of the Capra cirque and the broadly rounded and well forested interfluve areas.

The area with a low level of risk can be found on areas affected by diffuse evidence of present-day geomorphological processes. This can have two causes: either a low morphodynamic potential, as in the case of some smooth and gently sloping areas in cirques and glacial valleys or on the alpine zone interfluves, or a good woodland cover, not affected by mans activities. Human management of woodland can create a higher potential risk during critical meteo-climatic situations, for example very heavy rainfall and snowfall.

The zone with a medium risk is characteristic of the lateral part of axial areas of the valleys and glacial cirques, an area affected by strong vertical fluvial erosion, by rockfalls, landslides and even avalanches on the glacial

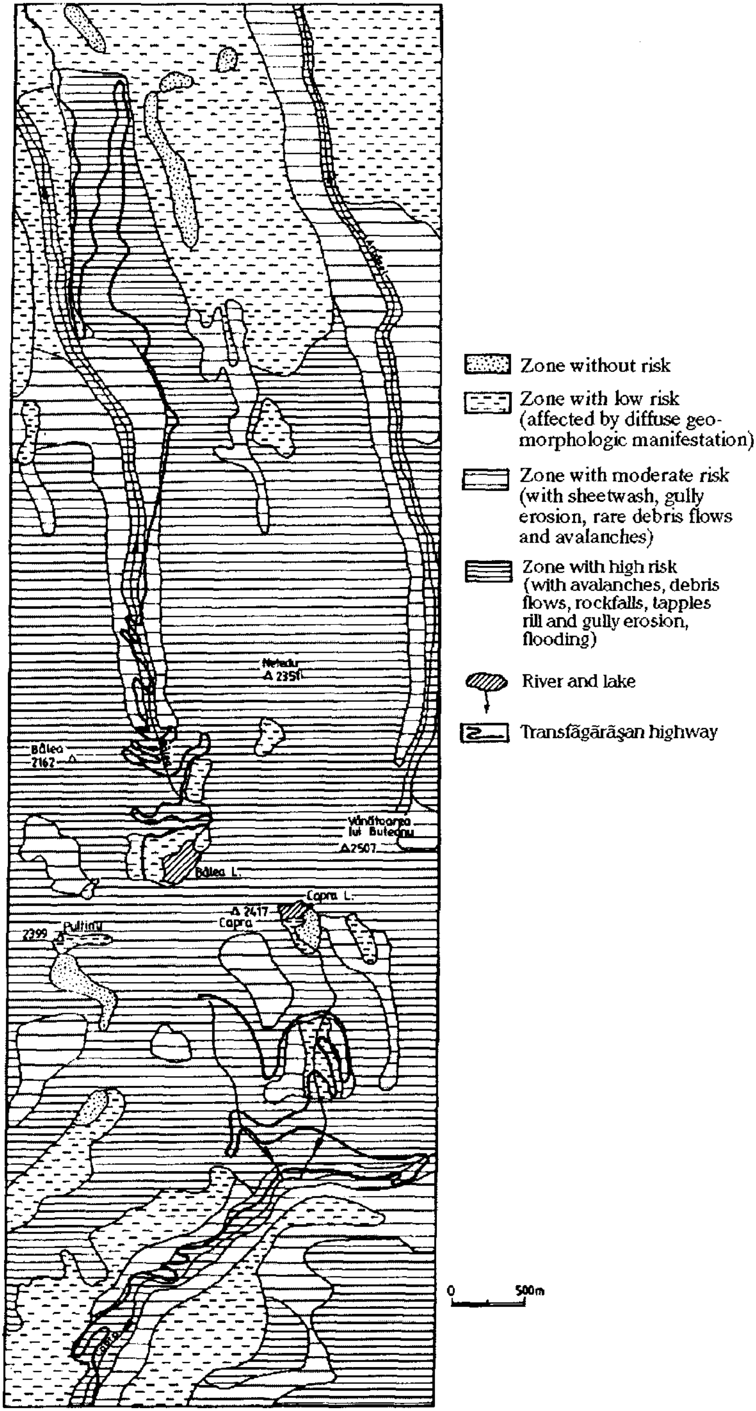

Fig. 5. Geomorphological risk map of the study area

rock-bar. The mobilisation of masses of debris close to the bases of slopes through the debris flow phenomenon or ravine forming processes are the most important elements that disturb the geomorphological balance.

The zone with a high level of geomorphological risk includes the greater part of Transfăgărăşan highway area and is characterised by a high morphodynamic potential. The sharp interfluves, with a pronounced ridge bordered by very steep slopes, together with cirques and glacial valley walls, are the main areas where avalanches, rockfalls, debris flows and vertical erosion are strong.

CONCLUSION

The Transfăgărăşan highway lies in an area with a high morphodynamic potential and because of this, a high level of geomorphic risk characterises the greater part of this area. Building the Transfăgărăşan highway together with other resulting action such as, for example, the clearing of woods on adjoining slopes has made the morphodynamic tendencies of the area even stronger. This could lead to quick and difficult to control changes.

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REFERENCES

Bălteanu D., 1997. *Romania*, [in:] *Geomorphological hazards of Europe*, eds C. Embleton, C. Embleton-Hamann, Elsevier, Amsterdam–Lausanne–New York–Oxford–Tokyo, 409–427.

Bălteanu D., Dinu M., Cioacă A., 1989. *Hărţile de risc geomorfologic, Exemplificări din Subcarpaţii şi Podişul Getic*. Studii şi cercetări de geologie, geofizică, geografie, Geografie 36, 9–13.

Chardon M., 1990. *Quelques réflexions sur les catastrophes naturelles en montagnes*. Revue de géographie alpine 68, 1-2-3, 193–213.

Gares P. A., Sherman D. J., Nordstrom K. F., 1994. *Geomorphology and natural hazards.* Geomorphology 10, 18 pp.

Gridan T., Balintoni I., Hann P. H., Dumitraşcu G., Conovici N., Şerbănescu A., Conovici M., 1986. *Petrochemical considerations on the Capra Valley metamorphics, The Făgăraş Mts,* Dări de Seamă ale Institutulni de Geologie şi Geofizica 70–71/1, 345–361.

Rosenfeld C. L., 1994. *The geomorphological dimensions of natural disasters*. Geomorphology 10, 27–36.

Scheidegger A. E., 1994. *Hazards: singularities in geomorphic systems*. Geomorphology 10, 19–25.

Schumm S. A. 1988. *Geomorphic hazards, problems of prediction.* Zeitschrift für Geomorfologie, Suppl. Bd. 67, 17–24.

Slaymaker O., 1996. *Introduction*, [in:] *Geomorphic hazards*, ed. O. Slaymaker, J. Wiley and Sons, Chichester–New York–Brisbane–Toronto–Singapore, 7 pp.

Urdea P., 1995. *Quelques considérations concernant des formations de pente dans les Carpates Méridionales*. Permafrost and Periglacial Processes 6, 195–206.

STRESZCZENIE

P. Urdea

ZAGROŻENIE GEOMORFOLOGICZNE ZWIĄZANE Z AUTOSTRADĄ W GÓRACH FOGARASZ

Budowanie autostrady przecinającej górskie pasmo Fogaraszu w Karpatach Południowych spowodowało przekształcenia rzeźby i uruchomienie procesów morfogenetycznych w jej najbliższym otoczeniu. Zaburzenia spowodowane w środowisku przyrodniczym Fogaraszu są znacznie większe niż wszystkie inne wywołane ingerencją człowieka. Autostrada o długości 90.167 km przecina główny grzbiet Fogaraszu i w około 30% położona jest w piętrze alpejskim. Autor przedstawia mapę zagrożeń geomorfologicznych w czterech klasach intesywności wzdłuż tego szlaku komunikacyjnego, zwracając szczególną uwagę na warunki stabilności zboczy.