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IDENTIFYING LANDSLIDE HAZARD IN THE CHECHIȘ CATCHMENT, BAIA MARE DEPRESSION

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ABSTRACT. – Identifying Landslide Hazard in the Chechiș Catchment, Baia Mare Depression. One of the starting points when assessing landslide risk is hazard identification, represented by the description of the landslide process and the extent to which it has an impact on the human community. Different areas affected by sliding processes have been identified and mapped on the field in the 100 km² of the Chechiș catchment, a territory situated to the south of Baia Mare municipality. Several other areas are considered to be susceptible to sliding processes, based on the factors which have influenced the occurrence of the ones already identified. Past and present effects of the existing landslides are illustrated and discussed together with the costs associated to the measures needed for their mitigation. In the view of these results, a landslide risk assessment is considered necessary in the area.

Keywords: *landslide hazard, Baia Mare, Chechiș catchment.*

1. INTRODUCTION

The stage of investigation is of great importance in hazard and risk assessment, carrying one of the main responsibilities for the quality of the results. A landslide investigation and identification process has been carried out in the area of Baia Mare Depression, with a specific focus on the Chechiș catchment. This process has included the study of local newspapers and administrative sources, the analysis of topographic and geological maps, orthophotographs and direct observations in the field, which were transferred in cartographic form using a GPS and the software ArcGis 9.3.

In order to determine the suitable methods for the landslide risk assessment, the geomorphic process must be identified and described both qualitatively and, as far as possible, quantitatively, at the spatial and temporal scale. If the spatial distribution of landslides can be determined directly, their temporal occurrence can only be inferred from the recurrence interval of causing factors, such as rainfall, if specific dates of landslide occurrence are recorded. Because the present investigation has encountered only a limited number of such events, this aspect will not be dealt with at this point.

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In the Chechiș catchment several areas were identified as having been affected by landslide movements and are currently characterised by different degrees of stability. As the complete inventory of landslides is still being built up, our study presents only the preliminary results of the landslide investigation process and the main characteristics of the landslides, which will eventually be used in a susceptibility analysis.

2. LANDSLIDE AREAS IN THE CHECHIȘ CATCHMENT

The study area is located in the north-eastern part of Baia Mare Depression, between Mogoșa Mountain in the north-east and the confluence with the Lăpuș River, to the south of Baia Mare municipality. The Chechiș catchment has an area of approximately 100 km^2 and includes the southern slopes of the former piedmont unit from the foot of the volcanic mountains Gutâi (P. Coteț, 1973). The river Chechiș springs from the volcanic mountain Mogoșa and receives two main streams and several other permanent and temporary ones before flowing into Lăpuș River (fig. 1).

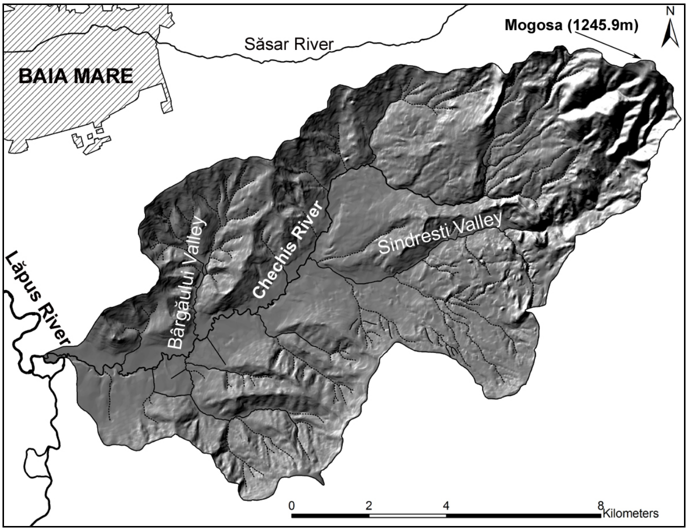

Fig. 1. The Chechiș catchment

The main lithologic units include Andesite rocks (Neogene) in the north-east and sedimentary rocks represented by Pannonian and Sarmatian deposits (Miocene - Pliocene) in the rest of the area (fig.2), covered by 4 to 6 m of Quaternary deposits consisting mainly of contractive clays, with a high water - retentive capacity and silty clays. The climate is characterized by an average temperature of 9.7 °C and 901.8 mm/ year rainfall, due to the orographic convection of the western air masses (S. Filip, 2008). The land is mainly used for agriculture, with orchards on the main slopes, arable land in the Chechiș flood plain and small patches of forests, more extended on Mogoșa Mountain.

2.1. Main characteristics of the landslide process

This study is concerned with the movement of material along a shear surface under the influence of gravity, described by the term "slide" or the more generic "landslide" (J. Buma and T. van Asch, 1996, V. Surdeanu, 1998) and with the landforms resulted from this process. Starting from the morphological features described by D.J. Varnes (1978), most of the landslides which were identified in the Chechiș catchment present the main characteristics of rotational slides with several scarps and the main body with an upward – curving, easy to recognise in the morphology of the slope, especially when slope revearsal occurs. A disrupted drainage pattern (M.J. Crozier, 1984) is also noticeable through specific vegetation and the presence of springs and swampy areas between the slide blocks (D.J. Varnes, 1978). Cracks from 2 to 10 cm in width were found in the crown areas of most of the landslides, as well as tension cracks on some landslide toes, indicating the dynamic activity of these areas (V. Surdeanu, 1998). In the identification of the landslides, tilted trees represented to a great extent by fruit trees indicated not only the patterns of landslide movement, but also the relative age of past activity, according to their growing pattern.

Conditioning factors are represented in this area by the Quaternary deposits consisting mainly of contractive clays with a high water-retentive capacity, making them susceptible to develop wide cracks in the dry season, which allow surface water to reach underlying impermeable deposits represented by Pannonian marly clays. Recorded landslides occur on slopes with angle values between 5 and 25 degrees and mainly on slopes facing south and west, but there are also exceptions. High water tables follow periods of rainfall and snowmelt and they represent the main triggering factors in the area. Therefore, in Baia Mare area, the periods with the highest landslide activity are autumn and spring, with more recent situations during winter, when warm air masses cause sudden snow melt. Human activities leading to explosions or sudden increase of overburden seldom represent triggering factors in the area, but excavations and construction activities may often influence the stability of the slope (fig. 12) creating an additional causal situation, together with undercutting by streams (D.J. Varnes, 1978).

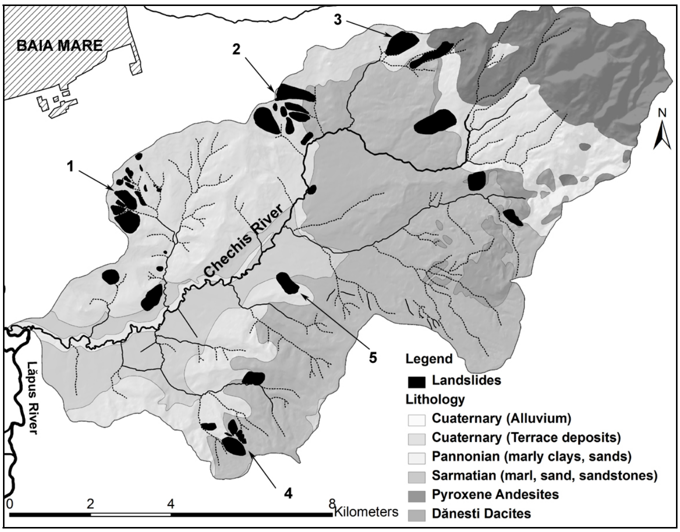

Fig. 2. Lithology of the Chechiș catchment and the main areas with landslide activity: 1-Groși, 2-Unguraș, 3-Baia Sprie - Șișești, 4-Cărbunari, 5-Dumbrăvița. Arrows show the relative position of profiles.

J. Buma and T. van Asch (1996) also describe the movement and morphology features of multiple landslides which develop two ore more sliding units with sliding surfaces intersecting a common basal sliding surface. They usually have complicated movement forms, but small velocities due to their slow rotation and steady heave. Such features can be also recognized in the Chechiș catchment through the presence of multiple scarps in a stepped form, created by the enlargement of an original slide. Similar morphology, slow movement, but smaller depths are features which describe successive slides (J.N. Hutchinson, 1988), failures affecting a slope one above the other, with the possibility to intersect or influence each other. However, in our area of study the lack of information regarding the position of the sliding surfaces makes the identification of the exact slide typology very difficult, especially because most of them are old and degraded, their original morphology being difficult to reconstruct. In addition to this, a clear division between successive slides or slides which intersected each other through lateral enlargement is difficult to make for old and weathered slides where the only existing sign is represented by the remaining hummocky ground (J. Buma and T. van Asch, 1996).

2. 2. Landslide areas

Past records of landslides occurring in the area of study and direct field observations have indicated several areas with visible landslide features and recurrent landslide activity, either in the shape of slow movement or occasionally as sudden displacement.

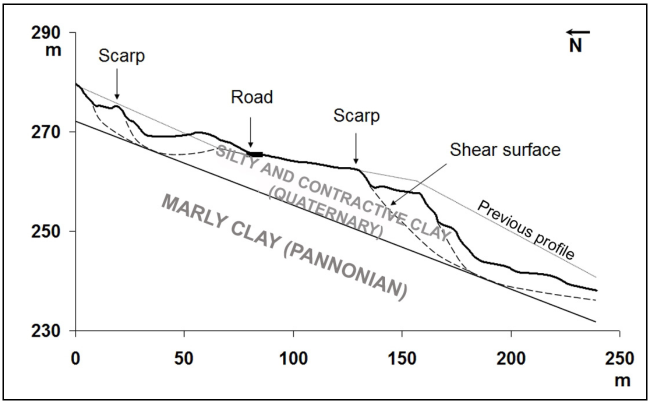

Fig. 3. Geomorphologic profile in Groși area.

Fig. 2 illustrates the general lithology of the Chechiș catchment and the main areas affected by landslide movement identified through field mapping. It must be stated that at this point the coverage of the study area in the mapping process is of approximately 60% and inter-mediate areas with similar geomorphologic and lithologic characteristics are considered as susceptible and require further investigation.

However, we consider the landslide areas presented further on as representative for the territory under investigation and their analysis can result in the identification of the main causing factors and landslide morphological features.

Fig. 4. Overturned fountain in Groși area. Water table at 1 m from ground surface (2012).

Groși area (fig. 2) has been previously studied (F.L. Măguț et al., 2012) using large areas affected by landslide movements as the basis for mapping landslide susceptibility using logistic regression and the heuristic methodology from the Romanian legislation. At this point the landslide contours have been improved with further field observations and GPS mapping and profiling (fig. 3), as far as the weathering processes and the anthropic activities which transformed the landslides have allowed. Recent visible activity (fig. 4 and 5) confirms the 30-year recurrence interval (V. Surdeanu, 1998) through records of damages caused by several landslides at the beginning of the 70s, although many of them were reactivations of older ones dating from the 40-50s. Therefore, there are frequent situations of adjacent landslides or successive and multiple landslides which intersect and overlap former bodies, making it very difficult to identify distinct, individual landslide bodies. However, it is of great interest to compare the results of a new landslide susceptibility analysis using the more accurate cartographic information with the results of the previous study.

Fig. 5. Scarps marked in Fig.3. Left- northern scarp on the profile with fresh cracks, right – southern scarp with tilted vegetation (2012).

As illustrated in fig. 2, the lithology is represented mainly by Pannonian marly clay (Miocene-Pliocene) covered with Quaternary deposits of contractive clays. The latter ones are usually affected by slope failures determined by increases in water level due to rainfall and snowmelt and human construction activities.

Similar conditions exist on the entire southern slope of the former piedmont unit bordering the Chechiș catchment in the north, including ***Unguraș area*** (fig. 2). The village with the same name is crossed by the local road linking Baia Mare and Baia Sprie with the inner parts of the catchment. Rotational landslides can be found on the whole length of the slope (fig. 6, left), the road crossing them transversally (fig. 6, right and fig.7) with only few stable segments.

Fig. 6. Rotational landslide toe (left) illustrated in fig. 7, and damage to the road crossing landslide area on the southern Unguraș slope (right) (2012).

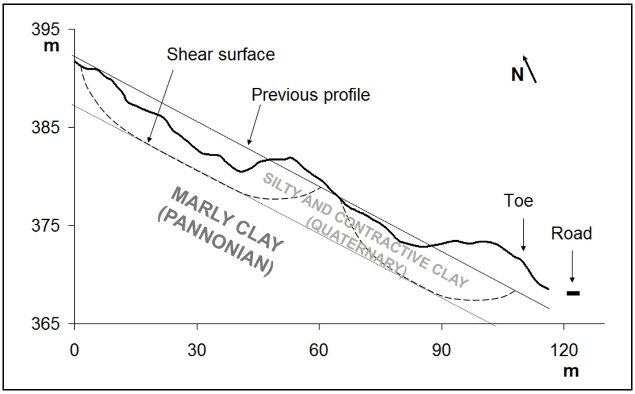

Fig. 7. Geomorphologic profile in Unguraș area.

In addition to frequent undermining of the road, the landslide activity in the area has dangerous potential of causing significant damage to buildings being built in the vicinity of the road, without any geotechnical investigations. New constructions used as holiday houses or permanent homes appeared in the last years on the upper half of the slope with the highest slope angle values (15-25 degrees), although several deep, rotational landslides discharge their load above or near the constructions.

In ***Baia Sprie - Șișești area*** the Pannonian deposits influence the occurrence of landslides on the glacis of Mogoșa volcanic mountain (1245.9 m) with western and south-western slope aspect. As in the rest of the catchment, the 70s were marked by intense landslide activity leading to geotechnical measures necessary for the stabilisation of the DJ 184 road connecting Baia Sprie with Cavnic (fig. 8).

These measures were efficient to a certain extent, preventing new major failures, but constant maintainance measures have been necessary ever since in order to keep the road functional. In addition to this, signs of more recent activity can be seen in the area represented in fig. 9 by a shallow failure in the Quaternary deposits, as no precise data indicating the shear surface has reached the marly clay deposits. However, the situation should be monitored and investigated in more detail.

Fig. 8. Active failure near house indicated by cracks and tilted young trees (left) and the DJ 184 road in Baia Sprie - Șișești area (2012).

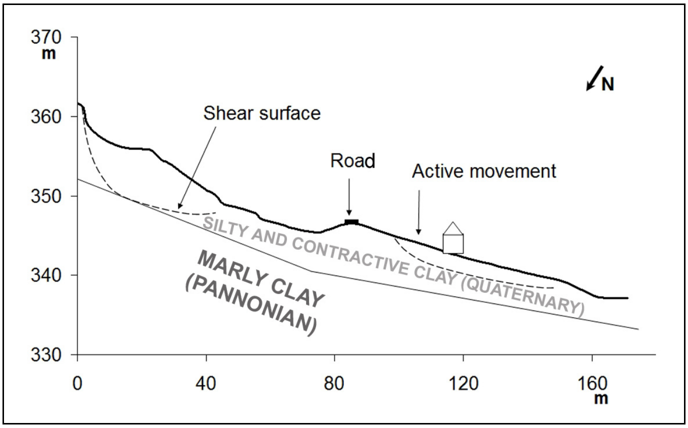

Fig. 9. Geomorphological profile in Baia Sprie - Șișești area. See marked house in Fig.8.

Fig. 10. The road DN 18B from Baia Mare to Tg. Lăpuș (left) and recent landslide movement indicated by tilted young trees in Cărbunari area (2012).

Constant damage to the road is what characterises ***Cărbunari area*** as well, where the DN 18B road was moved in the 50s due to a large landslide and was repeatedly affected in another sector afterwards. At present, cracks and deformations of the road indicate insufficient stabilisation measures in a landslide dynamic area, as just below the sector represented in fig. 10 the wall meant for its stability presents cracks in its turn. Situated at the lithological border between the Sarmatian and Pannonian deposits (fig. 2) the area is characterised by intense landslide activity determined by similar conditions as in the rest of the Chechiș catchment.

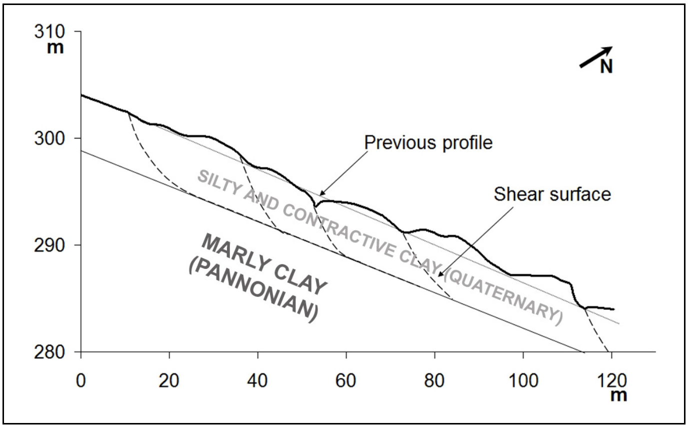

Fig. 11. Geomorphological profile in Cărbunari area.

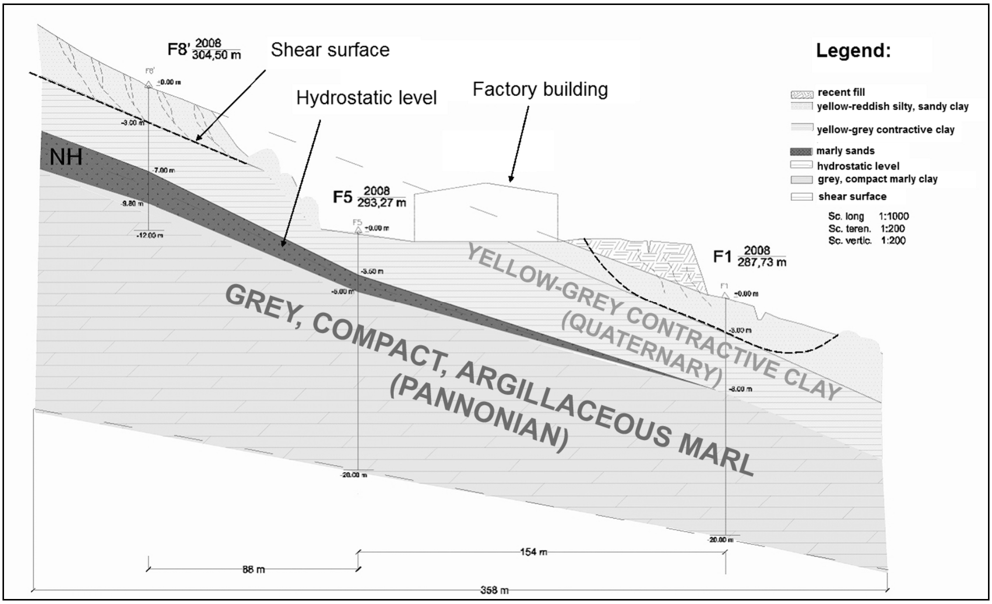

Fig. 12. Geotechnical profile at the aircraft components factory (GEOPROIECT, Baia Mare, 2008)

Dumbrăvița area includes a special example of anthropogenically triggered landslide which was thoroughly investigated and effective mitigation measures were planned and put into practice. The landslide activated in 2008 on an apparently undisturbed slope, on the left side of Chechiș River. Its activation was triggered by the construction activities of a factory building aircraft components. The original slope profile was cut to make room for the factory building and the material was deposited lower on the slope (fig. 12). As a consequence, several failures of the anthropogenic scarp above the building (fig. 13) moved large quantities of material towards and even inside the building under construction. In addition, a landslide toe was advancing daily at approximately 250 m from the building down the slope (fig.12, 13).

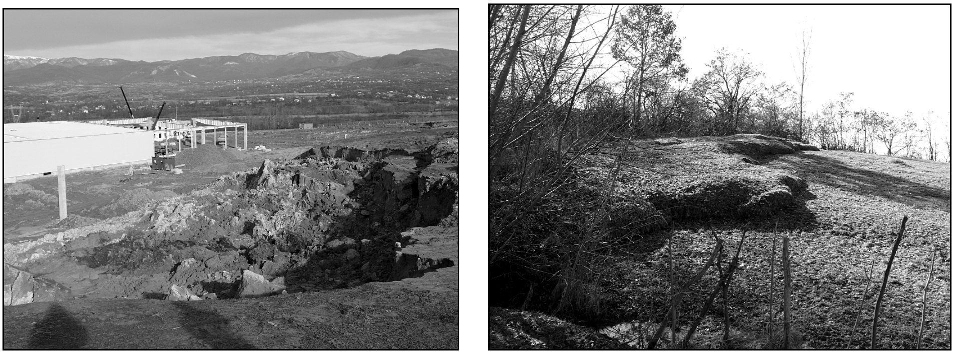

Fig. 13. Scarp of the anthropically triggered landslide at the airplane components factory (left) and the landslide toe (right) in the Dumbrăvița area (2008).

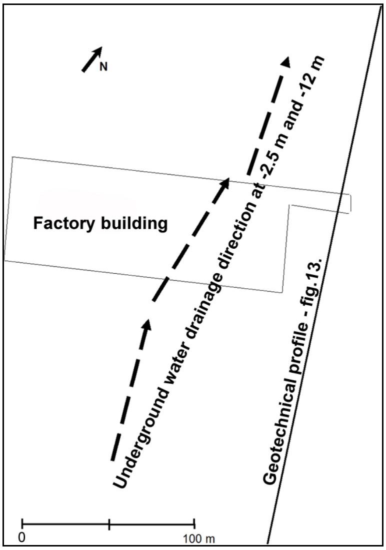

Fig. 14. Position of the geotechnical profile illustrated in fig. 13 and of the undergound drainage direction relative to the factory building.

Eventually, a shear surface was identified underneath the building foundation at the interface between the undelying argillaceous marl and the Quaternary covering deposits at a depth of 4 meters, therefore the foundation pillars were fixed in the underlying layer.

Due to the existence of a paleo drainage system at 12 m discovered through geoelectrical investigations (fig. 14), the danger of a deeper failure at -12 m was acknowledged and additional measures were taken in order to avoid its occurence. These measures included: retaining walls, columns, drainage ditches, reduction of slope angle and stabilisation with geogrids and grass (fig. 15).

3. COSTS

Only the slope stabilisation at the aircraft factory in Dumbrăvița totalised 600,000 €. This situation has had the advantage of foreign investment and further investigation and monitoring are in process at the present for a future expansion of the factory in a second building. However, this is a fortunate exception in the Chechiș catchment, while the rest of the elements exposed to landslide risk, being represented by houses and their secondary constructions, electrical poles and roads, cannot always be protected in order to avoid damage and are mainly repaired or replaced afterwards.

A broad estimation of the costs associated to these elements would include an average of 200 €/m^2 for regular houses and 220-450 €/electrical pole. The costs for road construction and repairment depend on the extend of the damage, the type and width of the road and the additional measures needed for consolidation. Around 100,000 €/km are needed for local roads and the prices rise for more important road sectors. Nevertheless, these costs are estimations for the replacement of destroyed elements without taking into consideration maintainance and stabilisation costs, which could reach even higher values.

4. CONCLUSIONS

Fig. 15. Countermeasures above the factory building, Dumbrăvița (2012).

The Chechiș catchment presents favourable conditions for the occurrence of landslides due to the covering contractile clays allowing water from snowmelt and rainfall to reach the impermeable underlying layer of Pannonian marly clays. Multiple and successive rotational landslides of different ages and intensities have affected the slopes of the catchment, the ones from the last cycle of activity dating from the 70s having the most visible effects in the slope morphology and damage to houses, poles and roads. Smaller reactivations keep the area dynamic and require constant maintenance of the elements affected.

On an apparently undisturbed slope, anthropogenic intervention through the construction of an aircraft components factory caused serious sliding in 2008 involving large costs for mitigation measures. This example highlights the need for geotechnical investigations prior to the building process and the need for a landslide risk map indicating the areas with landslide susceptibility, where these investigations should be compulsory. In addition to this, the estimation of possible costs and damage associated to future landslide occurence would allow the authorities to plan more effectively their intervention in order to prevent at lower costs, rather than be forced to mitigate more costly effects.

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