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„GLIMEE" DEEP-SEATED LANDSLIDES FROM TRANSYLVANIA
-
A GEOMORPHOLOGICAL STUDY

PHD THESIS

~ summery ~

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Key words: glimee, deep-seated landslides, Transylvania, evolutions o “glimee” deep-seated landslides, mounds, scarp, erosion, recent landslides, slope modeling, new detachments, slope dynamic, landslides reactivaton, Tăureni, Cheia, Dâmburile, Corunca, Aiton, Şoimeni.

1. INTRODUCTIVE ASPECTS. CONCEPTS AND METHODOLOGY

1.1. The term "glimee"

At the beginning of our analysis concerning the characteristics of "glimee" deep-seated landslides, we considered the way in which they were looked upon in time, by the locals, historians or officials. A brief analysis of topographical maps, from a toponymical point of view, leads to the conclusion that there are a lot of names which includes terms as "movile", "glimei", "risipituri" etc. The frequency of those toponyms occurs from the large number of villages which exists on these specific areas called: "Movile"-"Mounds", "Dâmburile"-"Knoll" (Transylvanian Depression) or "Suta de Movile" – "A hundred Mounds" (Republic of Moldova).

Concerning the genesis of these mounds, there are a couple of assumptions; some historians believe that there are tumuli of ancient tribes (as scythes) or some local noblemen. Yet, the geographers and geologists consider these phenomena as a result of massive and deep landslides. In his work, **Năstase** (1937) relates about a travel journal of a polish writer and traveler, Kreszewsky, in which these "mounds" were described as a "*vast necropolis of Scythian Kings*", and on a list published on the webpage of the Romanian Ministry of Culture some "glimee" deep-seated landslides sites are considered tumuli.

In popular terms, deep-seated landslide names find their correspondence in terms which define either their *shape* – "glimee, țiglăi, copârșaie, gruieți" or their *genesis mechanism* – "fugitură, ruptură" (**Surdeanu**, 1998). The landslide term is often accompanied by numerous synonyms as: furrows, slide lens, steps, waves, mounds, "glimee"- which defines their morphological and physical characteristics, at a given time, of the affected deposits.

"Glimee" deep-seated landslides are specific to Transylvanian Planes, Târnave Plateau, Someș Plateau, but they are also present in the Moldavian Plateau, Getic Plateau and some regions of Sub Carpathian. These are partially stabilized, having their sliding surface at 10-30 meters deep (**Grecu**, 1985), or even deeper (**Urdea et. all**. 2008).

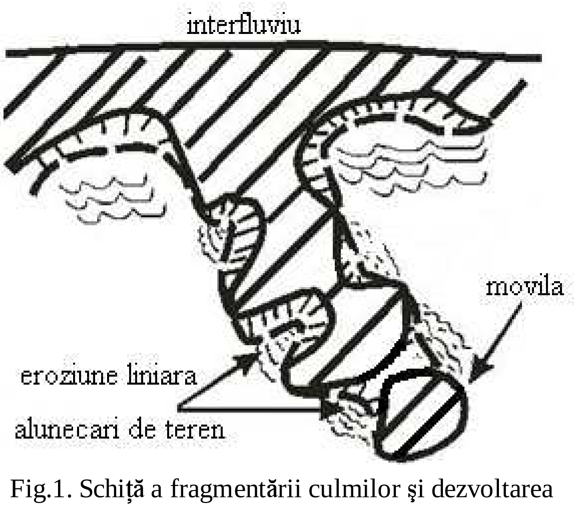


Fig.1. Schiță a fragmentării culmilor și dezvoltarea movilelor (Surdeanu, 2011-nepublicat).

Since the morphology of "glimee" deep-seated landsides is what gave them this name, we must give special attention to these areas that have mounds (i.e. a morphology similar of landslides mentioned above), but which are not the result of sliding but the mound fragmentation. Fragmentation of these heights is due to geomorphological processes (erosion, mass movement), acting on the side slopes of ridges, reaching interfluves. In figure 1 we present an outline of how that action leads to geomorphological processes shaping the mounds. In the field, these mounds are “lined” on one line, positioned from the top of the slope to the base.

1.2. „Glimeele” in the specialty literature

In scientific literature, “glimee” deep-seated landslide term was first used by **Bucur** in 1954, taking over the term from folklore, in *“The Complex of Glimee from Hills Region of Moldova”*.

Morariu was the one who has established , to this type of landslide, “Glimee” name, trying even to international recognition, so that at the XXI International Congress of Geography, India (1968) he used this term to define “*...massive mass movements on slopes, affecting both regolith and geological substrate, at large depths (most times of tens of meters)”*.

“Glimee” deep-seated landslide areas in Transylvania falls under attention of numerous researchers that have scientific concerns about the condition of sliding release, the genesis mechanisms, age, morphology and their evolution. Morphological appearance was one of the factors that drew attention to these landslides, so that in the scientific literature they are present in numerous studies, with detailed description of areas of “glimee” deep-seated landslides.

Research, in which descriptions of “glimee” deep-seated landslides appear, can be divided into three categories, namely: 1. Geomorphological studies of specific areas, regions or basins; 2. Projects focused on the processes of mass movements or slope modeling. 3. Geomorphological studies focused on detailed research of specific areas with “glimee” deep-seated landslides.

1.3. The “place” of “glimee” deep-seated landslides in the classification of mass movement processes

In literature there are several classifications of mass movements, due to:

- the genesis mechanism and the effects of the processes;
- the position and the morphology of the slips surfaces;
- the physical characteristics of the deposits that are affected;
- the dynamic behavior of the landslides.

Regarding only the landslides there are also several classifications based on different criteria, starting with “the speed (with which materials slip on the slope) and the character of it” (Terzaghi, 1950, quote by **Surdeanu**, 1998), leading to the complex types.

“Glimee” type landslides were considered as special phenomena, due to their morphology, which is why most times they were included in the category of “steps landslides”. A more complex classification is that of **Tufescu** (1966), in which the basic criterion is the micro morphology as a result of the slip. He identified on the field: landslides in the furrows, lenticular ones, sliding with mounds, landslides with pseudo steps and of transition (from mud flow to collapses). A more detailed classification is made by **Surdeanu** (1998), which identified five types of landslides, according to their morphology: lenticular sliding, sliding in steps and furrows, sliding with mounds and sliding waves, sliding valleys and sliding with a complex morphology.

In our study we analyzed the deep slips, with mounds and waves, known in popular language as “glimee”. Those landslides are remarkable not only because of the resulted morphology (the mounds), but also due to the affected layer thickness (often over 35 meters). Although this type of slip requires special conditions of the genesis, compared with other landslides type, their frequency is high in the Transylvania Depression, and because of the areas that are affected with such landslides, those are considered “*catastrophic moments in the evolution of slopes*” (**Jakab**, 1981).

1.4. The study methodology

The methodology that we used for this study is based on the classic one specific or the landslides, but for which we made some modifications, due to the fact that we could not use all the methods and techniques in our research. This is due to either time constrains or the financial ones.

Because we considered that is it absolutely necessary to start from “what it is known” about this landslide type, we have started our research with the literature. The methods and techniques used were selected according to the main line of the approach to the subject of the thesis, namely: locating and identifying the “glimee” sliding type, analyzing their morphology and study their dynamics.

In order to achieve these objectives we followed the classic structure of a dynamic geomorphology study, by staging our work: office stage, field phase, laboratory stage and the stage of synthesis.

The office stage

Studying the literature we have identified the main ideas behind our previous studies on the subject and the theories that have been developed and used to address the issue of the mass movements and, in particular, the “glimee” type landslides. In this stage we consulted cartographic documents - topographical maps with scale at 1:25000 and 1:5000, from different time series, and aerial photographs (series 2002-2005), geological maps, thematic maps. Also in this stage we have made: a map o the identified “glimee” type landslides, using as base the topographic maps and the field, in which we were focused on delimitation of the existing surface of the “glimee” landslides; several geomorphological sketches, which we then faced with the reality on the ground; as well as retrieving information about the evolutionary stages o these landslides.

Field stage

In the first stage we gathered information mainly through field observations, which were supplemented by qualitative side by the observations on the field. We can now make a proper tracking of the resulted forms of the sliding process and the conduct of its areas and perhaps a hierarchy of the sliding waves of the same area with “glimee”.

The field research was focused on: determination of the stage evolution; forms of interaction between the modeling agencies and the morphology of the “glimee” type landslides; and also the factors that contribute to the degradation of “glimee” type slides.

Also on the research field we can determine the possible directions o evolution and their influence on land (particularly where households are located on the landslides area). We have established the spatial area of the landslides and the modeling processes that are developed on the surface of the mounds and of the scarp.

Regarding the mapping of “glimee” type landslides’ areas that are subject to various studies, the researchers did not yet get to a consensus on the degree of “details” for specific elements, so or each researcher the implementation of a map can be “personalized”, being directed connected to the purpose of the study. Of the case study that we have in our paper, comparing the data from the cartographic materials with the field was an important stage for establishment of the evolutionary stage of the landslides and also for their dynamics. For the areas where we had the possibility we have done topographic profiles, which we used than for establish the evolutionary directions. For this we compared those profiles with the ones extracted from the cartographic maps, at a scale 1:5000.

Laboratory stage

The analyses that we have done were focused on determining the physic-mechanical and mineralogical deposits. Measurements were made according to the classic methodology.

Physical and mechanical analysis on deluvial deposits aimed at delimiting the types of deposits from the slope, according to the lithological substrate, the physical degradation and chemical one and of their implication in the dynamic process (**Surdeanu**, 1998). Important for our study are the following analysis: natural humidity of the substrate and of the deluvial materials (total humidity of the materials – Wo, humidity of the dry materials – Ws), the limits of plasticity (Atterberg limits), grains size and porosity of the materials. Through calculation we estimated the following parameters: plasticity index and the colloidal activity index.

Synthesis phrase

Data previously collected - in the documentary, field and laboratory stages – were reorganized and processed (ArcMap, ArcInfo and Microsoft Excel) in order to achieve the correlations between possible causal factors of the genesis and development of “glimee” type landslides and of the post sliding modeling. In this step the thematic maps and statistical charts were done, and summaries regarding the processes that are shaping the morphology o this type of landslides, with a special regard upon the effects that those process have on the landslides elements (scarp, mound, depressions).

2. THE INFLUENCE OF THE NATURAL AND HUMAN FACTORS UPON THE DEVELOPMENT OF “GLIMEE” DEEP-SEATED LANDSLIDES

For the analysis of the influence of the natural and anthropogenic factors upon the “glimee” deep-seated landslides, we started from what Surdeanu (1998) said: “*the present relief morphology is the result of several modeling processes, that aren’t a simple repetition, but that are developing, in several stages, under the influence of the natural conditions…*”. This frame defines the role that the “environment” (seen as all the factors considered as existing at a given moment in a given place) had upon the relief morphology.

The morphology and the morphodynamic of the “glimee” deep-seated landslides from Transylvania Depression are influenced by a complex o factors, among which mainly the geomorphological, geological, hydro-climatic and anthropogenic ones.

In the scientific literature there are several opinions about the importance of one or another factor listed above, but what is universal accepted is that the geological and climatic factors have a primordial role. Until the early 1970s was considered almost impossible the development of new “glimee” sliding type, because it was considered that for this type it is needed special conditions, such as the climatic ones from the interglacial periods. What changed this view, for some researchers, were the effects of rainfall from 1970 (May) and 1975 (June), that affected the morphology and dynamic of slopes. Reactivation of some landslides such as “glimee” type due to catastrophic amounts of rainfall from the 70’ has highlighted the importance of geological and climatic factors, “proving” at the same time the possibility or the “glimee” type landslides to develop in the current period.

Correlating the data regarding the spatial distribution of “glimee” type landslides in the Transylvania Depression with the lithological data, it is shown that there is a direct relation between the areas with “glimee” type landslides and the lithological formations with marls and clays, sands, gravel, conglomerates and tuffs. From a structural, tectonically and petrografically point of view, the factors that contribute to the genesis of this type of landslides are: permeable formations alternating with impermeable layers, appreciable thickness of sandbanks, sandstones, conglomerates, tuffs, marls and clays, the inclined position of the layers (for some structure such as domes and folds anticline) and the activity of neotectonics. Stratification of the units facilitated meteoric waters circulation and the phreatic ones towards the impermeable strata, which ones have passed into a plastic state, they migrate to the slope base. This migration determines the movements of the strata that are above those layers, there for the result are the mounds.

The influence of lithology on landslide triggering for “glimee” type is evident in the morphology of those areas with “glimee”. For this reason during the field campaigns we collected samples from different sites and for two of those samples we made physical and mineralogical analysis at the laboratory of the University of Modena and Reggio Emilia (Italy). Our goal was to observe the differences from the lithological point (and mineralogical) that are from site to site. The first site is located nearby Turda City, at Cheia village, Cluj County, being developed in Sarmatian formations and Pleistocen ones, and the second site is in nearby Vultureni village, at Şoimeni, in the Someş Plateau, formed in Helvetian strata.

The samples were taken from the body of the landslides, towards the toe (more precisely from the first depression counted from the toe to the scarp). The depth from which we toke the sample was 2.7 – 3 meters for the Cheia site, and 3 – 3.3 meters for the Şoimeni site. According to the values that we had or the plasticity index (I_p), the sample from Cheia has a mediam plasticity, being composed mosly from clayly and sandy clays, and the sample from Şoimeni has a high plasticity, given by the clays predominance. According to the values of the contraction index (I_c) and that of the classification of the rocks, both samples gave values that are between $0.25<I_p<0.50$, which means that they have a soft plastic consistency. We consider those results as insufficient for the research of “glimee” type landslides, but those analysis can be a start point in determining the way in which lithology influences their genesis and development.

The genesis of “glimee” type landslides has a closely relationship with the climatic conditions, been considered that those landslides are under the “*command of the climatic factor*” (**Pendea**, 2005). In terms o climatic influence, the conditions from the Pleistocene, with rainfall more abundant than today and with large temperature variations (**Morariu, Gârbacea**, 1968; **Pendea**, 2005 etc.), had had a substantial contribution to the genesis o those landslides, being in conjunction with the lithological, morphological, hydrological and bio-pedological factors.

Lack of precipitations, and correlated with positive temperatures, leads to the development of fissures, which during the rainfall periods contribute to the water circulation towards the impermeable strata. Rainfall has a major role regarding the genesis of landslides, by keeping the strata moisture during their migration towards the base of the slope. The water that gets in the deposits changes the properties of those rocks, especially the physical and chemical ones, but also the weight of them. Or the Transylvania Depression, the average annual values are varies between 500 – 700 mm/year (fig. 2) (**Croitoru**, 2006).

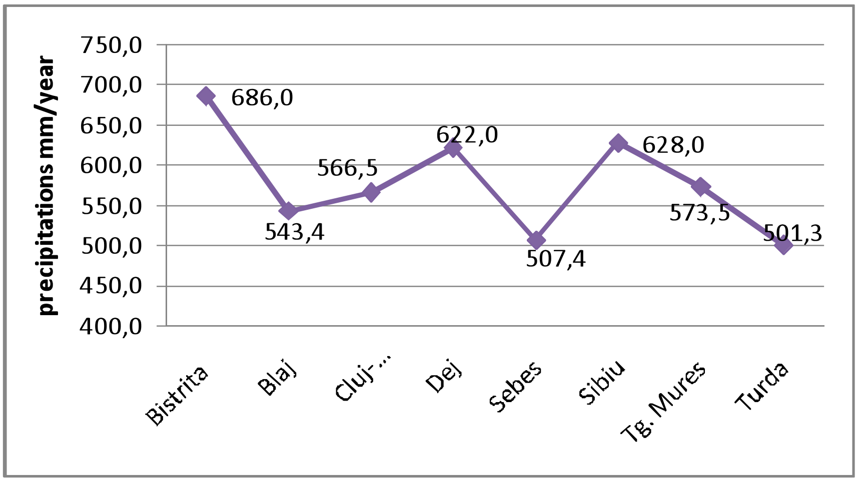


Fig. 2. Average annual values for precipitation during 1961-2000 in the Transylvania Depression (after **Croitoru**, 2006).

Compared to those averages there were recorded deviations considerable higher, so that the highest values frequently exceeded 800 – 900 mm/year, and the smaller drop between 250-260 mm/year. The relationship between rainfall and “glimee” type landslides is highlighted well in literature, been emphasized some areas with “glimee” that were reactivated during the 1970s, when the amount of rainfall has reached record values (fig.3).

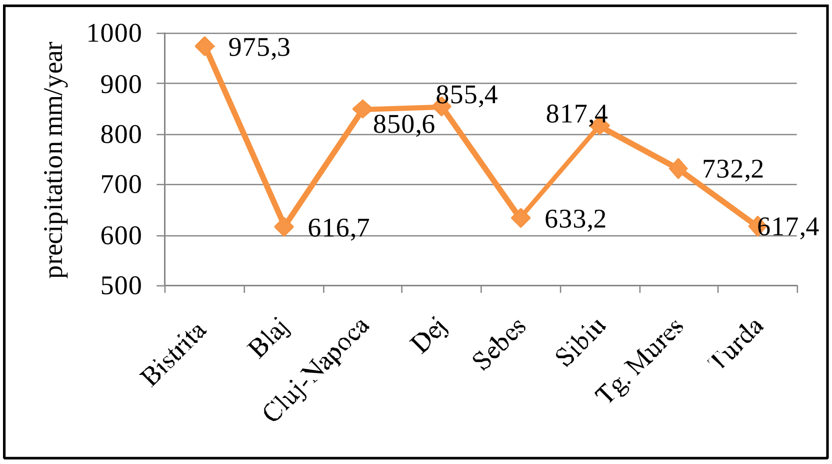


Fig. 3. The annual amount of rainfall (for 1970) recorded for the Transylvania Depression (sursa: **Anuarul meteorologic**, 1970).

Atmospheric precipitation in liquid form usually penetrates the upper layers of the soil. In loose or in the land full of fissures and cracks, wetting is more intense and penetrates deeper. This explains why the deluvial and coluvial deposits are more exposed to landslides. The role of the hydrological network upon the landscape modeling, hence the contribution to development and fragmentation of the "glimee" type landslides, has a triple action, been exercised by the erosion, transport and accumulation. Lateral erosion of the rivers causes instability of the slope, developing massive landslides, as is the case of the Cornățel site, Sibiu County, about which **Grecu** (1997) stated that "*in favorable climatic conditions, when the groundwater circulation was restored, correlated with a possible widening of the Hârtibaciu river, took place a first phase of detachment of one or two rows of mounds. It is a crack-sliding on short distance*".

Regarding the influence of the soil factors and the vegetation, we had taken into consideration only the current role that those factors have upon the "glimee" type landslides morphology, because we do not have data about the type of vegetation or soil that were on the slopes before the sliding process.

Vegetation is one of the factors that act contradictory. This is because, by their roots, the plant are preparing the material for slide, but at the same time their roots can slow down the slip, by setting the deposits. The role depends on the type of the vegetation, the characteristics of each type of the plant (vegetable carpet, wood – type of tree etc.). The forest acts against the slip of the materials on the slope, by elimination the soil moisture by evapo-transpiration and through the root system, which act as a net of protection. Where the mounds are covered with forests the geomorphological processes have a restricted activity, which sometimes is even stopped (the mounds from the Corunca site 2, Saschiz, Cincu, Avrămeşti, Roşiori etc.). Differences arise when herbaceous layer is damaged, either because of the periods of precipitation deficit or surplus, as well as of human activities carried out – such as overgrazing. Referring only to the areas with "glimee" type landslides, the surfaces covered with forests are reduced, being present especially on the mounds, and rarely on the scarp.

Massive deforestation and use of the resulted land for agriculture have contributed to the expansion of the herbaceous carpet, or even replacement with the crops. The cultivated plants (including species that need to be hoes) induce fundamental changes in the processes of wetting of the soil and its resistance to surface runoff, favoring the soil erosion and the linear one.

The sites with “glimee” where there are forests on the scarps (Saschiz, Corunca sit2 etc.) are in a stage of stability, of inactivity, because the scarp activity is “under controls” of the trees. Lack of woody vegetation and strata exposed to erosion contribute to alteration of the scarp (such as at Șoimeni) and can lead to new detachment (such as at Tăureni). On the surfaces affected by “glimee” type landslides the soil genesis processes are under the influence of the morphological conditions that those landslides have, so that in case that those are stabilized, soil can develop, otherwise the soil genesis processes are interrupted by new reactivations. On the surface of the “glimee” forms the soils are unevaluated, because of the instability of the landslides.

However, the soil has its influence upon the morphology of the “glimee” type landslides, even upon the genesis of those processes, due to the fact that infiltration depends on the soil type, in order for the precipitations (whatever their form is) to get to the permeable and then to the impermeable layers. On the “glimee” type landslides that are stabilized the soil had time to develop, being suitable for agricultural use (**Chițu**, 1975).

The anthropogenic intervention upon the morphology of the “glimee” type landslides, especially by deforestation and agricultural crops along the slope, has a major contribution to the intensification of the processes that are shaping the scarps. A prime example is the site with “glimee” landslides from Dâmburile (Someş Plateau) where contemporary landslides have damaged the slope of the scarp, so that now there is a low angle slope, taking the form of a smooth slope. At this process of transformation of the slope’s scarp the anthropogenic influence is evident in the way that the slope is cropped.

The intervention upon the mounds has a more dramatically shape by the intense use of the field, which leads to reactivation of the slope processes (Cornățel – intensive overgrazing) or by leveling the mounds in order to achieve new plane surface used for building houses and the materials extract from them are used for constructions (sands, sandstones, clays, marls – as done at Corunca, Șoimeni). An example is the site with “glimee” landslides from Corunca, where the materials from the mounds are used for constructions and the new plan surface for building. So, where the slope gradient of the fields with “glimee” has low values and the mounds are leveled, those fields are used as support for villages - Roşiori, Corunca, Dâmburile, Aiton, Şăulia-Leorința, Avrămeşti and others.

3. SPATIAL DISTRIBUTION OF “GLIMEE” DEEP-SEATED LANDSLIDES

In Romania this type of landslides is common in hilly areas and Sub-Carpathian with an increase of frequency in the region of Transylvania. Such landslides are present in Moldova’s and Getic’s Sub-Carpathians, but with a reduced growth, as are also those from the Sub-Carpathians between the river Dâmbovița and Trotuş. These processes shaped also the slopes of the Dobrogea Plateau, Getic one and the West Hills (**Morariu, Gârbacea**, 1968).

Although they have a reduced development in those regions, compared with those from the Transylvania Depression, the ones from Conțeşti, Geamăna, Bleici are distinguished according to the authors quoted above. Highest frequency of sites with “glimee” is in Transylvania Plain (Tăureni, Şăulia-Leorința, Mociu, Băița, Archiud, Geaca etc.), in the north of Moldova Plain (Coţuşca, Adăşeni, Flondora etc.) and in Hârtibaciu Plateau (Şaeş, Saschiz, Movile) (**Morariu, Gârbacea**, 1968).

In 1968 **Morariu and Gârbacea** have done the first map of the spatial distribution of “glimee” type landslides for the Transylvania basin, published in the article “*The map of spatial distribution of “glimee” in the Transylvania Basin*”. A new map is done by **Gârbacea** in 1992, been published in the paper “*Map of the glimee from Transylvania Plain*”, in which, according to the author there are “*represented the real forms and areas of the sites with glimee*”.

Having those maps (done by **Morariu and Gârbacea** (1968) and **Gârbacea** (1992),) the topographic maps (at scale 1:5000 and 1:25000) and the aerial images (2002-2005) we have done an inventory of the sites with “glimee” (this was done with the financial support from the project IDEI 2465/2008). After that we validated our work by going in the field. So we have got to a 480 number of sites with “glimee” (here are only the sites that we have validated, and we thing that there are much more). Based on this research we correlated the distribution of the sites with several parameters:

- morphological units of the Transylvania Depression;
- types of deposits;
- actual altitude of the scarps;
- aspect of the slopes;
- actual slope degree.

By those correlations we tried to identify the main characteristics of the “glimee” type landslides, the differences and the common parameters that those have, in order to do a classification of them. Regarding the spatial distribution of the “glimee” landslides according to the morphological regions of the Transylvania Depression, stands out the high frequency in the Transylvania Plain (59,2%, of the total number), than in the Hârtibaciu Plateau (11,3%) and Someş Plateau (9,3%). In other regions the number is very small, there for there is a total percent of 20,2 for all the remaining regions (table 1).

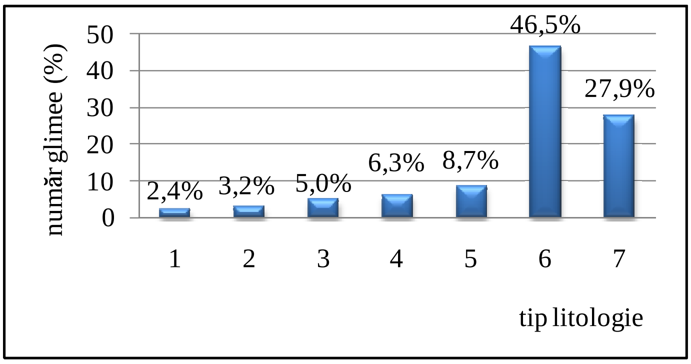
Morphological unit	**Percent “glimee”/ total nr.**	**Morphological unit**	**Percent “glimee”/ total nr.**
Transylvania Plain	59,2%	Târnavei and Târnavei Mari Hills	3,6%
Hârtibaciu Plateau	11,3%	Secașe Plateau	1,2%
Someș Plateau	9,3%	Turda - Alba-Iulia Corridor	1%
Transylvanian Sub Carpathian	7,1%	Sibiu Depression	0,2%
Târnavei Mici Hills	7,1%		

Table 1. Spatial distribution of “glimee” type landslides according to the morphological units of Transylvania Depression

The Transylvania Plain has a morphology with slow slopes and a medium altitude of 450 meters. In the paper "Transylvania Plain" by Manciulea (1944) it is said that this region has slopes that present a landscape that is disturbed by "those lifting of the small peaks, some of which have very steep slopes, almost vertical, while others have a pronounced asymmetry". Those forms are named by the locals as "țigle or țiglaie", been known today under the general name of "glimee".

The deposits in which the Transylvanian Plain morphology is shaped are mainly Miocene – with clays, marls, sands and intercalations of tuffs and salt. Those are suitable for the activity of erosion and mass movements. For "glimee" type landslides those deposits are the most favorable. The main characteristics of this unit are the altitude between 500-550 m on the hills and 250-300 in the valleys. The climate is in present days specific for depression, with a medium temperature of 8,5 - 9^0 C, and the precipitations have values between 550-600 mm – in the Turda – Alba-Iulia and Mureş Corridors, 600-700 mm – in the Plain part and 700-800 mm in Unguraşu Hills and in the transition part toward the mountain (**Savu**, 1980). We consider that those values have favorites the dynamic of the "glimee" type landslides. In those parts of the Transylvania Depression where the natural factors aren't favorable for the development of the "glimee" landslides such as in Turda – Alba-Iulia Corridor the frequency of these landslides is low. The petrography mosaic of the depression is one of the mainly factor that have an important role for the genesis and dynamic of those landslides. Alternating layers of permeable and impermeable deposits allow the rivers to shape the relief, and also the circulation of the atmospheric waters towards the impermeable layers – to clays and marls.

It is remarkable the fact that a high number of "glimee" type landslides is developed on formations with alternative layers of marls, sands and sandstones (**Morariu and Gârbacea**, 1968, **Grecu** 1993.). From our analysis it is obvious that a value of 46,5% of the total "glimee" sites that we validated are developed on marls, sands and gravels (fig. 4), which highlight the importance of the alternant deposits of permeable and impermeable layers, that have significant thickness.



1. Sands, gravel (Holocene); 2. Clayey marls, sandstones, salt, tuffs (Badenian); 3. Conglomerates, sandstones, marls (Helvețian); 4. marls, tuffs (Buglovian); 5. Clay marls, sands (Pannonian); 6. marls, sands, gravels (Volhinian-Bessarabian); 7. "Glimee" landslides developed at the contact of two or more deposits.

Fig. 4. Frequency of the "glimee" type landslides according to the lithology.

Spatial repartition of the "glimee" landslides in the Transylvania Depression was correlated with the actual altitude of the scarps of those landslides, in order to determine the altitude values in which those landslides are developed. We have considered the scarp as the main element or this analysis because we consider the scarp as a source of materials for the development of those landslides. This is the element that can lead to a new detachment that can then be shaped into mounds. Rom our analysis results a total o 50% from the number of the sites with glimee that have the scarp situated at an altitude of 400-500 meters. The landslides ("glimee" type) that have the scarp at over 550 meters in altitude have areas that exceed 450 ha, there or in this category are included some of the largest and typical "glimee" from Transylvania Depression - Şaeş–1 650 ha, Movile–1 100 ha, Saschiz–785 ha, Daia–769 ha.

If we correlate the spatial distribution of "glimee" landslides with the aspect of the slopes we can find some information regarding the genesis and dynamic of those landslides. The geomorphological processes that are connected to the water circulation (such as linear erosions, mass movements, mad flows etc.) and the type of the vegetation are under the influence of the aspect of the slopes. A high frequency (41.8%) of the "glimee" on the sunny slopes indicates the importance of the alternating periods of wetting – drying and freeze – thaw. The most frequently "glimee" type landslides are on the south oriented slopes, with over 23% (table 2).

	Slope orientation							
	N	NE	E	SE	S	SV	V	NV
Frequency (%)	5.7	5.0	12.7	8.1	23.6	18.2	20.6	6.1

Tabelul 2. Frequency of "glimee" according to the slope aspect.

Based on the results from the correlation between the aspect of the slopes and the areas of the sites (the present ones) we found that the largest sites are developed on the western slopes ("glimee" from Şaeş – 1 650 ha) and south-west ("glimee" from Movile – 1 100 ha).

An important element is the angle of the slopes on which are developed the "glimee" landslides and from our analysis results a value of 87.5% from the total number that is on slopes with an angle of inclination with values of 3-17^0 (fig. 5). Those figures lead us to conclude that, for the development of such landslides it is required a reduced slope. There for we consider that this influences the fragmentation of the materials during the slip process.

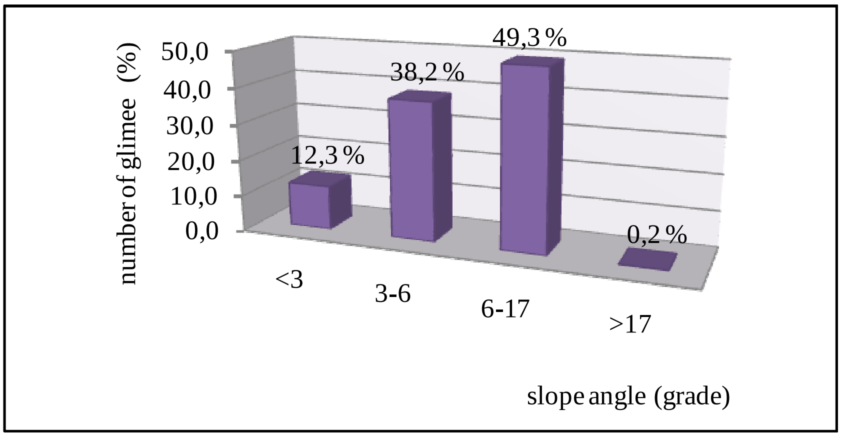


Fig. 5. Frequency of "glimee" according to the slope angle.

4. “GLIMEE” DEEP-SEATED LANDSLIDES ROM TRANSYLVANIA DEPRESSION. CASE STUDIES

4.1. Morphological aspects of “glimee” deep-seated landslides

“Glimee” landscape has positive and negative forms, disposed parallel to the scarp. The mounds (the positive forms) have different shapes – cones, pyramids and truncated pyramids or cones, been the result of the activity of linear erosion and mass movement that shaped them. Those positive forms can have a tubular, structural aspect; such are the ones from Bozieş and Aruncuta from the Transylvania Plain (**Gârbacea**, 1996).

Regarding the morphology of the “glimee” type landslides this is the result of the processes that have shaped them. During the slip of the materials on the slopes, there were cracks in their bodies, which were subsequently transformed by modeling processes in areas that currently separate the mounds. Those areas are current depressions, modeled by geomorphological processes such as linear erosion and mass movement, and widening or clogging with materials transported from the slopes of the scarp and of the mounds. There for the actual processes have a dual action, by destruction of the primary morphology and by shaping them.

Referring only to the “glimee” type landslides’ morphology, of course at the present one that is in the field, we have analyzed each element of the landslide / the scarp, the body and the toe.

The *scarp* is represented by a slope that has different values regarding the inclination of it, with heights that can vary from10 to 50 meters; in the situations in which the slopes are more slow those values are due to the modeling processes that have installed post sliding. Depending on the degree of shaping the profile of the scarp has a series of shapes, being present on it a series of “steps”, which highlights the work of contemporary processes such as landslides and erosion. At the base of the scarps’ slope is the accumulation of the detritus resulted mainly due to landslides and erosion. There for at tha base of the scarps are so called accumulation glacis, which makes the transition towards the first groove – the one that separates the scarp from the mounds. The action of the geomorphological processes had an important role to “maintain” the layers to date, so we can observe the alternations of conglomerates, sands, clays, marls and sandstones.

The body of the landslides. The detached blocks and then slide on the slope are under the influence of the geomorphological processes that are installed almost immediately, being transformed into mounds of various shapes: oblong, pointed, conical or pyramidal. Regarding the distribution of the mounds in the field they are disposed parallel to the scarp, forming strings or not. In scientific literature are presented those slides as having up to seven to eight parallel rows – Saschiz site presents six strings (**Gârbacea**, 1964), Movile site has “the sliding body disposed in seven – eight rows” (**Grecu**, 1997), “glimee” landslides from Pădureni (Țop), have five to six rows (**Buz et al.**, 1997) etc. There are also situations where we cannot identify rows, such are the landslides from Cheia, Câmpeneşti etc. this is due to the genesis mechanism, which is different from the ones that present mounds that form rows, disposed parallel to the scarp.

Regarding the negative forms from the upper part of the landslides those present lakes – temporary or permanent, meanwhile the ones near the toe of the site are more flattened and are used for agricultural purpose. Delimitation of the area that corresponds to the toe is rather difficult for “glimee” type landslides in our opinion. This is due to the fact that those landslide are very old and the reality on the field from now is the result of many types of processes that act on their surface (some of them are still active). Considering the reality from the field we consider the toe of those landslides as the front part of it, which is represented by a sliding glacis.

Based on the morphology of the “glimee” landslides we can group them in three categories, each representing an evolutionary stage of the “glimee”. The first category in which the relief is presented well individualized in the surrounding landscape, and the slide blocks have relatively large bodies (with amplitudes over 25-35 m). Those are well preserved and poorly degraded – e.g. Şoimeni, Saschiz, Apold, Corunca, Vultureni. The areas of those landslides are used for hay and grazing. The second category includes slides which have a morphology “strewn” with mounds strongly shaped by geomorphological processes (such as landslides, linear erosion, subsidence etc.). There are updated opening and slopes with gradients of more than 32^0 – Tăureni-Fundătura, Suatu, Cheia, Urmeniş, Satu Nou etc. The micromorphology of those sites with “glimee” looks kind of badlands, and there or the lands are not cultivated, exception for grazing in some parts. The last category consists of those sites with “glimee” whose mounds are flattened, rouded, with low amplitudes (under 10-15 m), thus showing a faint morphology. “Glimee” type landslides from this category - such as Roşiori, Ranta, Triteni-Hotar, Movile - are used as proper space to expand settlements and related fields are included in the agricultural use.

4.2. Evolution of “glimee” deep-seated landslides. Case studies

In the subchapter 4.2 we have directed our analysis on what we have observed on the field, and on the correlations between the data extracted from the cartographic documents. Our research is referred only to 12 sites with “glimee” deep-seated landslides, which we consider as representative for our purpose. We hope that from those studies will get to a general idea about the dynamic of “glimee” type landslides. The detailed sites are developed on different lithological deposits, present different evolutionary stages, have a specific morphology for this type of landslides. Diverse geomorphological processes are shaping those areas, but it is also evident the anthropogenic intervention. Those determine different shapes of the mounds, as well as of the scarp.

Regarding the dynamic of the slopes on which are situated the “glimee” landslides, this is dependent of the position that those landslides have in the profile of that slope, and for this reason we can distinguish the following situations:

- Slopes affected on the entire profile by “glimee” landslides – in this case the dynamic of the slope is the same with the landslide, and any change that appear in the landslide morphology is reflected in the slope profile;

- The slopes affected only partial – at the superior or inferior part. Here the changes generated by the slope processes present a series of differences. If the “glimee” landslide is in the inferior part of the slope there can be two direction of development – a) towards the top o the slope – and in this case the slope can become a “Saschiz type” and b) the scarp can be “destroyed” which leads to equilibrium of the slope, and the “glimee” type landslide ceases it activity.
- A situation rarely present is the one in which the “glimee” landslides affect the slopes of the same hill (**Grecu**, 1993). This situation is at Aiton (**Mac**, 1996) (Cluj Hills), Heria, Păucea - **Josan**, în 1979, (Târnava Mică Hills).

The present dynamic of the system of “glimee” landslides is under the control of the climatic oscillations. Studying those landslides leaded us to the highlight of the importance of the geological structure, of the lithology and of the response to different variables and to their regime (such as the climate, hydrology, vegetation, soil etc.).

Later after the slide process, through the activity of geomorphological processes, are done some changes in the “glimee” relief. Those changes are sometimes major, such as the “elimination” of the scarp or the fragmentations of the blocks and even mounds, or the changes upon the depressions. This opinion – that the post sliding processes can determine major changes into the morphology of the “glimee” landslides – is not accepted by all researchers; some of them say that the post sliding process “can produce only secondary changes to the morphology of those landslides” (**Morariu, Gârbacea**, 1968).

The morphology of the “glimee” landslides is the result, in our opinion, of the post sliding modeling, and that the processes that are shaping the forms resulted – such as recent landslides, linear erosion – are the main “actors” in determining “what we can see today on the field”. Therefore we conclude that:

- The evolution of the “glimee” landslides is dependent of the scarps state. According to this the dynamic of the landslide can lead towards evolution (Cheia, Aiton, Tăureni, Cornățel, etc.) of the landslide or can stop its activity. When the scarp is active there is a possibility or reactivation of the landslide, and can take place new detachments, such as it happened at Tăureni.
- The processes that are shaping the “glimee” landslides tend to restablich the equilibrium of the slope. For this we consider that there are three major stages in the modeling of those landslides – elimination of the scarp, degradation the mounds and leveling the depressions.
- The processes that are shaping the element of the landslides (scarp, body and toe) are having a different dynamic. The differences are due to the position of them on the slope, due to the climatic factors, vegetation, human intervention etc.

A question whit which we have started our study was connected to the dynamic of the “glimee” landslides – “how did/does the mound form?” The answer to this came along with the research stages, been revealed by the field study. The form of the mounds and their position in the landslide body and to the scarp leaded to a more detailed study of this. We consider that the morphology from the present is the result of very long periods of modeling, been the result of fragmentation of the blocks pre detached. There are exceptions from this, when the mounds are not included into a sliding process, but are the result of fragmentation of hills or interfluves (sites from Cheia, Boju - figure 6, Cornăţel etc.), and there is no sliding process. Another way in which mounds can be individualized is by new slides from a pre-individualized block (such is the case of Urmeniş).

Fig. 6. The way in which the mounds from Boju have formed.

For our case studies we have done a morphological sketch, several profiles on different cartographical maps and on the field. Or some sites – such as for Boju, Cheia, Aiton, Suatu sau Satu Nou – we analyzed the changes of the mounds and of the scarp, and for others we have analyzed the morphology of them as a system.

4.2.1. "Glimee" deep-seated landslides from Tăureni (Transylvania Plain)

The site with "glimee" from Tăureni is situated in the Pârâul de Câmpie basin, on the south slope of the Triciu Hill. The Pârâul de Câmpie basin is shaped by over 80 sites of "glimee" landslides, which represents over 12% of the total surface of the basin.

The genesis of this landslide seems to have taken place at the beginning of the 1970 (according to the cartographic documents), been the result of the heavy rainfall in that period. The slope on which the landslide is has a convex form, with absolute altitude of 472.6 m and a slope degree of about 15^0.

What is interesting about this landslide is that the last detached block dates from 2008 (according to local people and the cartographic maps). As a result, we can delineate or this area several evolutionary stages. Due to their morphology and position of the mounds we consider that in each evolutionary stage it is possible that there have been detached several blocks at the same time, but with no connection between them, been situated in different parts of the site. Their different position within the site determines the association of the mounds in rows, but this doesn't necessarily mean that they are parts of the same block. The evolutionary stages of the mounds highlights the "order" in which they were formed, starting from the toe towards the scarp of the landslide, and considering the ones near the toe the “oldest”.

The scarp of this “glimee” landslide (fig.7) has an altitude of 400-410 meters, being shaped by geomorphological processes, such as linear erosion and mass movements. Those geomorphological processes “maintain” the shape of the scarp – which resemble as a steep slope (over 42^0) at the upper part, while at the lower part of the slope are accumulated materials, which give a slower slope of it. This part is considered to be an accumulation glacis, which has the shape o steps. This glacis is formed from deluvial deposits with clays and sands. Because of it recent age it still presents a net of cracks (with opens over 30 cm), which is due to stress caused by the slip.

On the scarp line are several springs, due to which, on its steep, gullies are formed, and at its base in the depression area, that separates the newly detached block from the scarp, are developed lakes (fig.8) which are fed by those springs and by rainfall.

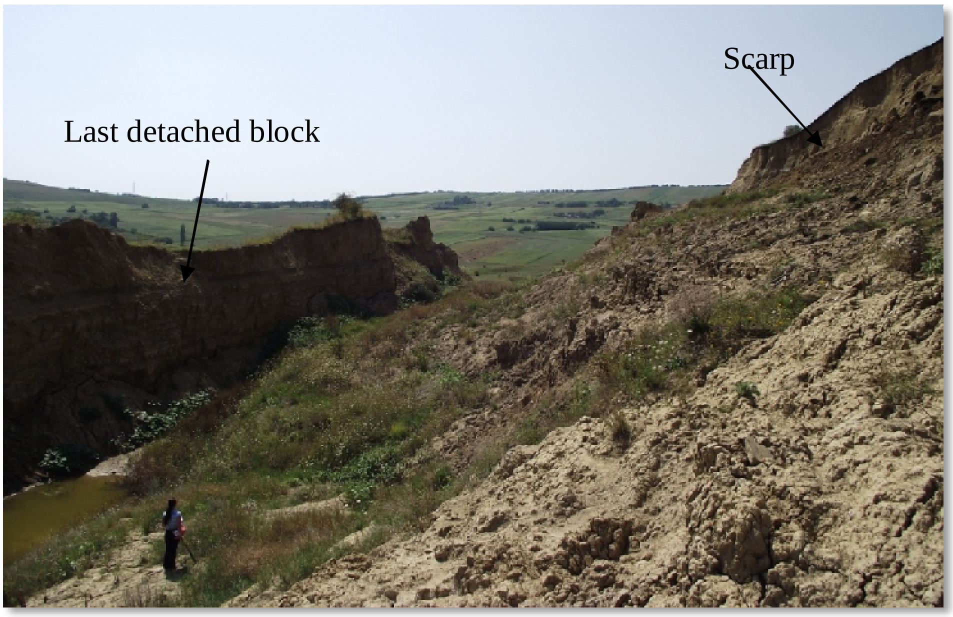


Fig. 7. The morphology of the latest slide at Tăureni
(Transylvania Plain) (August 2011).

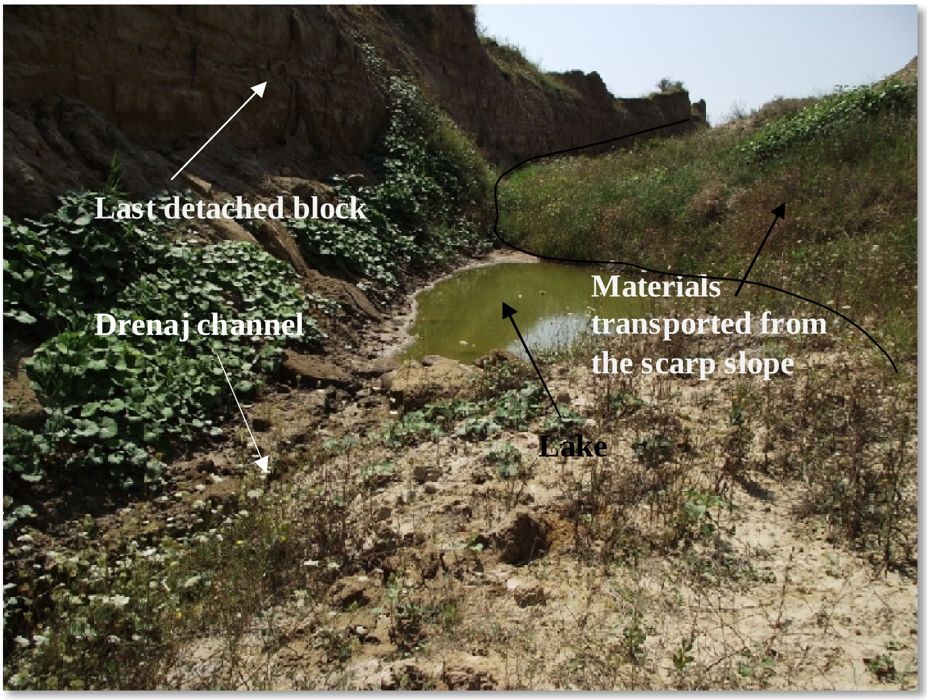


Fig. 8. The newest depression of Tăureni site, with the specific morphology (august 2011).

The last evolutionary stage identified on the field is represented by this last slide, which took place in 2008 (according to the information that we have from the cartographic documents and from the local people. This last block is still not fragmented, being positioned in the central part of the site and not on its hole width. This supports our opinion that the detached and slide block don't have to be as width as the landslide and that they can be situated in any part of the site.

The morphology of this last block is also a support or our opinion in which we express the importance of the fragmentation during the slip (when cracks are formed) and of the one post slide, done by the geomorphological process that act on the cracks places. The north slope of this block has a steep shape, with the deposits opened, where we can identify them. By comparing the positions of the deposits from this block with the ones from the scarp, we can see that there is no deference, and that those strata are not much disturbed, except of a slight balance towards the scarp of the strata from the block, due to the sliding process.

The existence of fissures and cracks in the area between the scarp and the upper part of the slope, leads us to believe that the area with "glimee" will be extended.

4.2.2. "Glimee" deep-seated landslides from Boju (Transylvania Plain)

This site is situated at the limit of two hydrographical basins – the Zăpodie and the Boju. This site is composed from two landslides, which have shaped the interfluves between the two basins. The "glimee" landslide from the eastern slope has two major evolutionary stages, and the one from the northern slope has only one detached block, which is not yet fragmented into mounds. Unlike other sites with "glimee", the result of the fragmentation of the interfluve is not lower area, but has been turn into mounds. This is not as it happened at Aiton, where instead of the interfluves now it is a low area, resembling to a depression.

At the beginning of our thesis, we highlighted the fact that some “glimee” as mounds can be developed by fragmentation of the interfluves, not only by a slide process. There for, this site can be a model for the development of the mounds (which we call “glimee”). Here some of the mounds are the result of the sliding processes and some have resulted because of the fragmented interfluve. So, in this case there were individualized the mound from the north side by a slide process (nr. 1 in fig. 10), and also the mounds from the eastern slope (areas noted with no 2 and 3 on fig. 10). The mound noted as 4 in figure 10 is the result of fragmentation, without been involved in a sliding process. It is the result of the suffusion and recent landslides that shaped the main hill on which the “glimee” landslides are (fig. 9). This fragmentation is rather recent, because after studying the cartographic document (scale 1:5000) and the aerial imagines we can conclude that it must have taken place during this period, because on the topographical map it does not appear.

This site can be considered as a model for the “glimee” landslides, but we do not consider it a general one for all the area with “glimee” landslides.

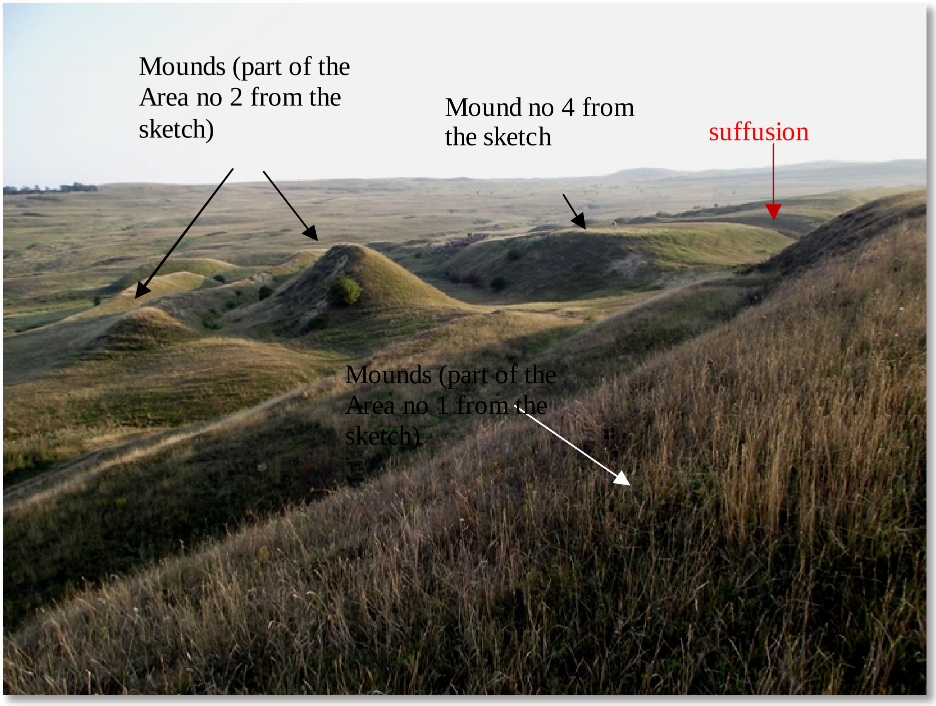


Fig. 9. Panorama over the south area of the “glimee” landslide from Boju (august 2011).

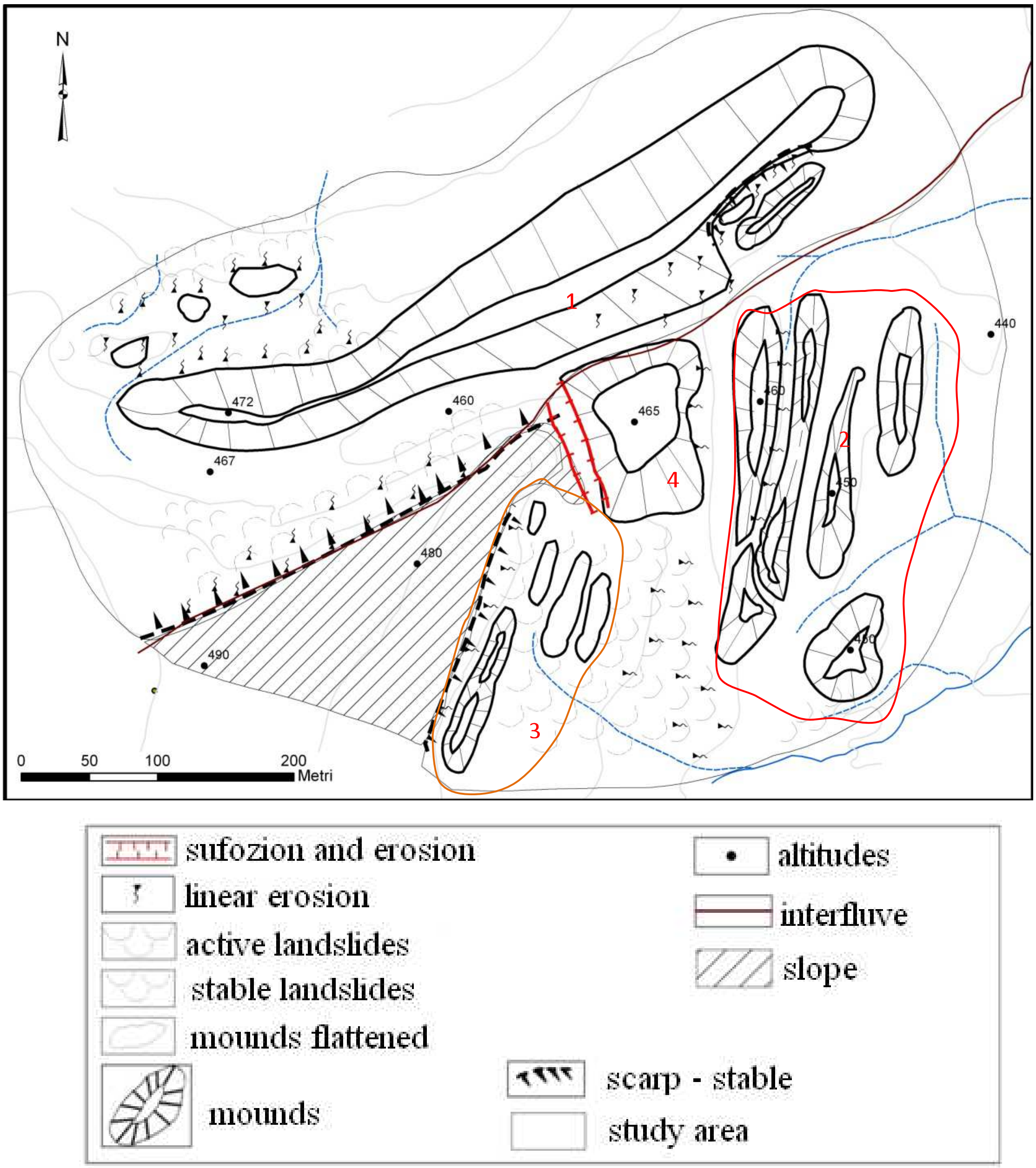


Fig. 10. The morphological sketch of the “glimee” landslides from Boju (Cluj County).

4.2.3. “Glimee” deep-seated landslides from Urmeniş (Transylvania Plain)

The “glimee” landslides from Urmeniş are situated in the eastern part of the Transylvania Plain, being thereby conferred to it some specific characteristics of this region. The morphology of this site shows that these landslides have a step genesis, having mounds in different evolutionary state. The ones near the toe of this area have slow slopes, being at the same time strongly fragmentized. This reflects an intense activity of the geomorphological processes such as landslides, linear erosion and suffusion.

There are also different morphological features in this area regarding the mounds. Those are shaped by recent landslides and by linear erosion, with the differences that on the slopes oriented towards the toe the dominant processes are the landslides, and on the ones towards the scarp the dominant process is the linear erosion.

It is currently undergoing a fragmentation of a mound from the central part of the landslide (fig. 11) by suffusions, landslides and linear erosion. This highlights the role of the post sliding processes that shape the landslides element, and transform them on a major scale. The mound that is now in a developing state was detached from another mound, through a sliding process, not as in the most cases through fragmentation due to linear erosion. We could consider this process as a “glimee” type landslide but a minor scale, at the subsystem of the mound.

In conclusion the mounds can be developed from others mounds already individualized. In figure 11 the main mound is noted with no 2, and the one that was detached from this with no 1.

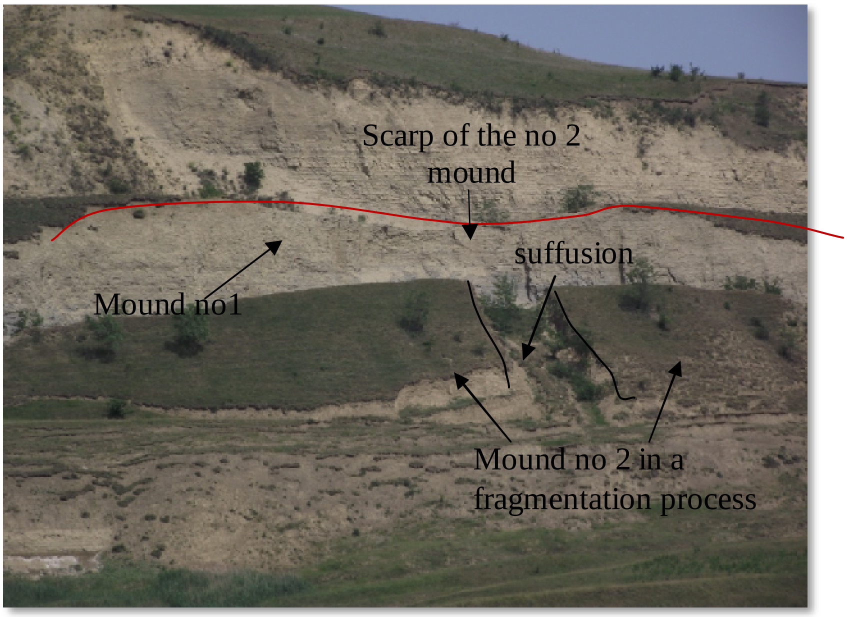


Fig. 11. The fragmentation o the mounds from Urmeniş “glimee” landslides (June 2011).

4.2.4. “Glimee” deep-seated landslides from Şoimeni (Someş Plateau)

The landslides from Şoimeni are situated on the right slope of the river Şoimeni, in the Cluj and Dej Hills (Someş Plateau). This site presents mounds with cone forms, been well individualized in the surrounding landscape. A detailed study of this are with “glimee” has shown that there can be distinguished two smaller areas with different features. On the diagram below (fig. 12) we can see how the mounds are grouped in the north and northwest part of the area. The two areas with “glimee” present distinct features from a morphological and evolutionary view.

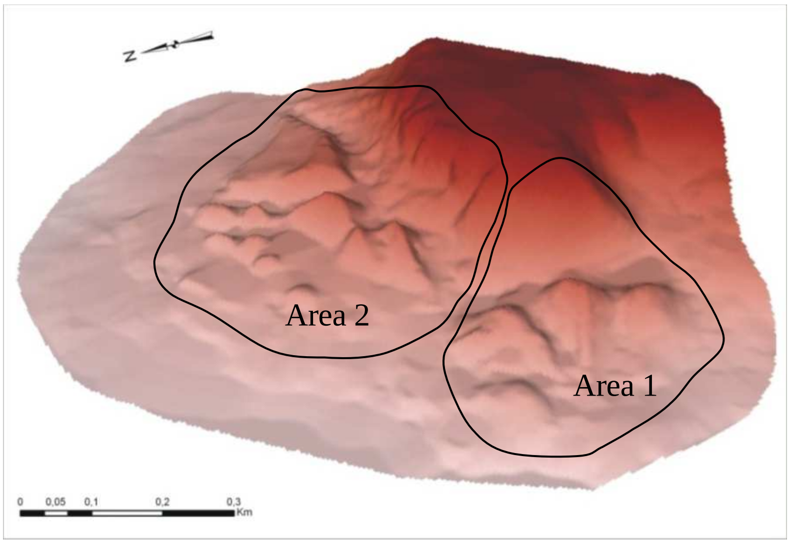


Fig. 12. Bloc diagram of “glimee” landslide from Şoimeni
(the vertical exaggeration is de 1,5).

4.2.5. “Glimee” deep-seated landslides from Cheia (Transylvania Plain)

“Glimee” deep-seated landslides from Cheia are situated in the western part of the Transylvania Plain, on the left slope of the river Arieş, near Cheia and Mihai-Viteazu villages (Cluj County), having a specific morphology and well individualized in the landscape nearby.

This site with “glimee” is “unusual” for this type of landslides, especially for the consequent subtype, because does not present rows formed from mounds. The mounds of these landslides are in a chaotic spatial distribution. This chaotic distribution, we consider as a result due to many factors, among which: the genesis by a single block in the first stage; the existence of a chaotic network of cracks, there or a chaotic drainage net; second detachments of several blocks, but from the one already slide (new detached ones by a slide process and not because of erosion influence).

The slope processes - landslides and linear erosion – and the lateral erosion of the Arieş River are shaping the morphology of the “glimee” landslides from Cheia. We have observed areas here because of linear erosion and recent landslides slide blocks are fragmented and transformed into mounds (fig. 13) and mounds are leveled. At the same time the depressions are leveled by illing them with the materials transported from the mounds and scarp slopes.

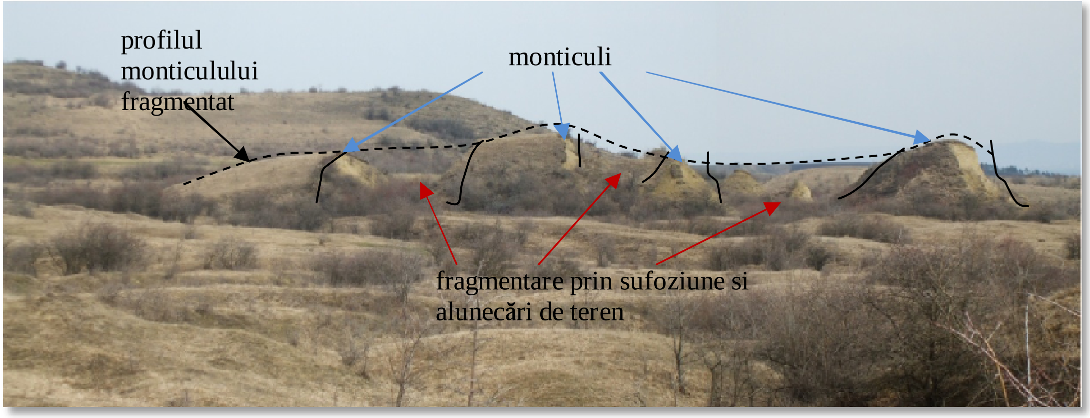


Fig. 13. The ragmentation of the blocks at Cheia landslides.

As for other sites here too we can distinguish two major evolutionary stages. The morphology of the mounds leads to consider detachments of large-sized blocks, in which during the slide process cracks appeared and alter that they were fragmented by geomorphological processes.

On the morphological sketch (fig. 14) of this landslide is obvious the chaotic distribution of the mounds, which confers to this area the aspect of badlands.

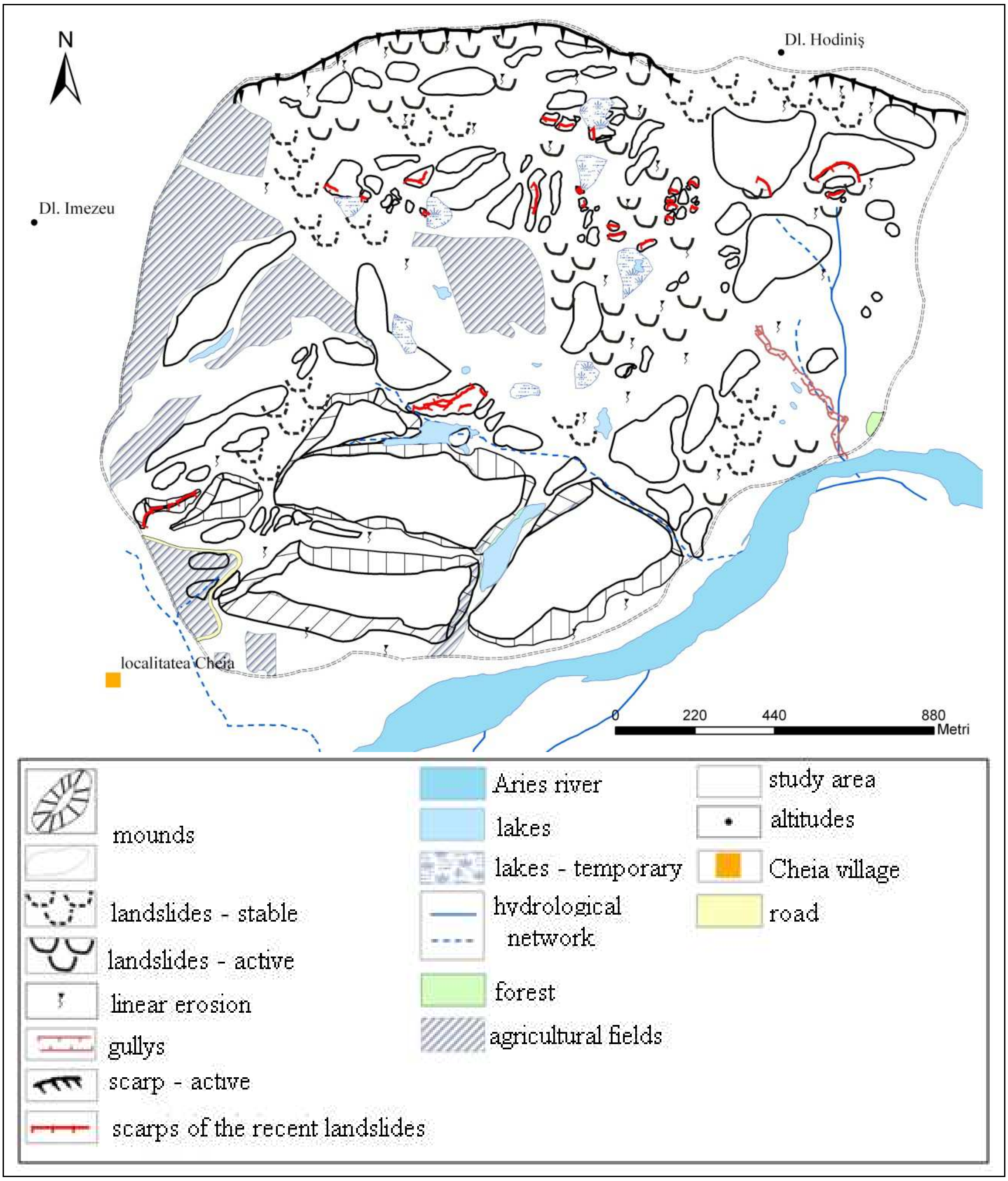


Fig. 14. Morphological sketch of the "glimee" landslides from Cheia (Transylvania Plain).

4.2.6. "Glimee" deep-seated landslides from Satu Nou (Transylvania Plain)

In Transylvania Plain, on the Şes valley, a tributary to the river Pârâul de Câmpie, has developed a small "glimee" type landslide, with little over 7 ha, but which through it characteristics represent a distinguished area in the nearby landscape. From a geomorphological point of view this landslide has only three mounds disposed parallel to the scarp. Those mounds appear to be part of the same block (fig. 15).

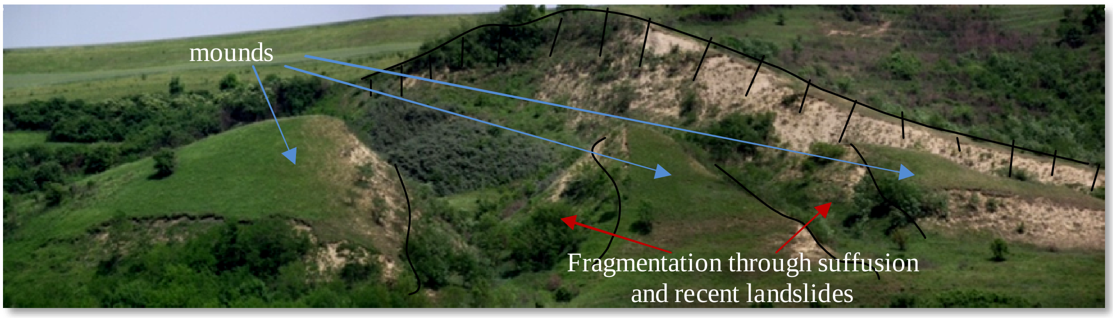


Fig. 15. The "glimee" landslide from Satu Nou.

This site is an example that confirms the importance of the post sliding modeling. The individualization of the three mounds took place as a result of the suffusion processes, linear erosion and recent landslides. Those processes have been installed where the crack due to sliding were (fig. 16).

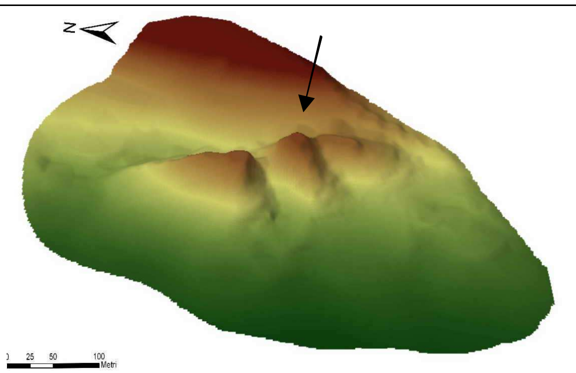
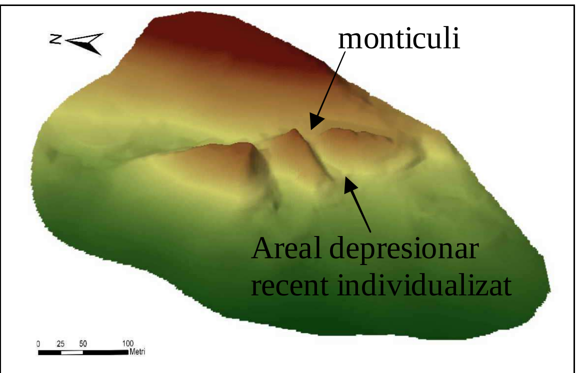
	
Elevation model or the "glimee" landslide from Satu Nou, done after the topographic map from 1973 (scara 1 :5000).	Elevation model or the "glimee" landslide from Satu Nou, reprezenting the reality from the ield in present time.

Fig. 16. The evolution model for the landslide at Satu Nou (Transylvania Plain).

4.2.7. "Glimee" deep-seated landslides from Suatu (Transylvania Plain)

The site from Suatu is on the western part of the Transylvania Plain, being part of the Botanical Reservation Suatu. The "glimee" landslides from here have mounds that are in an advanced stage of degradation, having the strata at sight. From the cartographic documents we did not see any changes in the evolution of this site, which leaded us to the conclusion that the age of this landslide has to be very old. The mounds that are now present on the field are the remaining parts of what must have been. This site is a good example regarding the importance of lithology upon the morphology of the “glimee” type landslides.

Fig. 17. Panorama on the “glimee” type landslides at Suatu.

4.2.8. “Glimee” deep-seated landslides from Fânațele Clujului (Cluj Hills)

The site with “glimee” from Fânațele Clujului resembles with the one from Suatu, except that it has a larger area, a different lithology and has more complex morphology. The landslides from Fânațele Clujului is developed on the let slope of the valley o Pârâul Valea Caldă, on the south side o it. This site is nearby Cluj-Napoca city, at a distance of only six kilometers.

The dynamic of the site is dominated by recent landslides, which are active on the most part of the area, and because of this the morphology of the scarp resemble as having steps. Within this area we can distinguish two different areas, with differences regarding the morphology of them. There for, we consider that there are at least two distinct stages that contributed to the genesis of this “glimee” landslide.

4.2.9. “Glimee” deep-seated landslides from Dâmburile (Transylvania Plain)

The landslides from Dâmburile are shaping the slope of the eastern part of the Căianului Hill, from the Pârâul Suatu basin. At this site we can observe differences morphometric features between the mounds from the upper part of the site and of the ones near the toe. The ones near the toe of the landslide are much smaller than the ones situated near the scarp. This fact we consider that is due to the different evolutionary stages that took part in the genesis of this landslide.

The scarp of this “glimee” landslide is strongly shaped by the geomorphological processes – especially by recent landslides, which had lead to the “elimination” of it, and transformed into an accumulation glacis. There for, this flattened surface is used for agricultural crops. This is not favorable for the stability of the scarp, because the crops are done along the slope, which has a contribution to the activity of the geomorphological processes.

This area with “glimee” can be considered a model for the landslides that have their mounds flattened, there for are in an advanced evolutionary state. The morphology is a flattened one, the depressions are large, and the fields are included in the agricultural use or used to extend localities.

4.2.10. “Glimee” deep-seated landslides from Cornățel (Hârtibaciu Plateau)

The “glimee” area from Cornățel is situated in the Hârtibaciu Plateau, on the left slope of the river Hârtibaciu, been developed on the entire length of the slope. According to the morphology of these landslides we can distinguish here two different areas, which have different features regarding the evolutionary stage. The first one is on the south part of the slope, been in an advanced evolutionary stage, and it is represented by a “landslide glacis” shaped by torrential organisms (**Grecu**, 1997). The second area is in the north part of the slope, and has well individualized mounds in the landscape nearby, with amplitudes from 5 to 35 m. this sector is shaped by recent landslides, torrential processes and linear erosion. The spatial distribution of the mounds from this part is on four rows, which are parallel to the scarp line. From those mounds the ones near the scarp have the amplitudes near 35 m, and the ones near the toe of the landslide are in more flattened. The slope degree for the mounds in the upper part of the site is between 17- 32^0 (fig. 18), been shaped by recent landslides. Those are covert by grass.

Fig. 18. Mounds at Cornățel - shaped by recent landslides (October 2010).

4.2.11. “Glimee” deep-seated landslides from Aiton (Someş Plateau)

The area with “glimee” from Aiton is situated nearby Cluj-Napoca city, at only 15 km, been developed on the south-western slope of the Cioltu Mare Hill (718 m), at the contact between Feleacul Hill and Transylvania Plain. Morphological, this site presents a scarp that has a length of over five kilometers, and the mounds have low amplitude comparing to other sites with “glimee”. Those mounds are not so well individualized in the landscape of this region, giving the slope a waved morphology. The special feature of this site is given by the influence that this landslide has upon the slope dynamics. Here we can distinguish several sectors with “glimee”, which we consider as part of the same area, but because of the drainage network, the mounds have been separated, and now it gives the impression of different sites.

This area has therefore several evolutionary stages, which shows a stage genesis. The evolution of these landslides is driven by climatic factors and anthropogenic intervention, that working together can trigger or stop the activity o some processes, such as mass movements or linear erosion. It is evident at this site the influence of the human activities upon the morphology of this landslide, which by the agricultural land use leads in flattening the mounds. This site, along with the one from the north-western slope of the same hill can be included at the category of the "glimee" landslides that are shaping the interfluve (fig. 19). If this "glimee" type landslide is reactivated, the interfluve is susceptible to the degradation, and on its place can form a low area, such as at the Cheia site, or example.

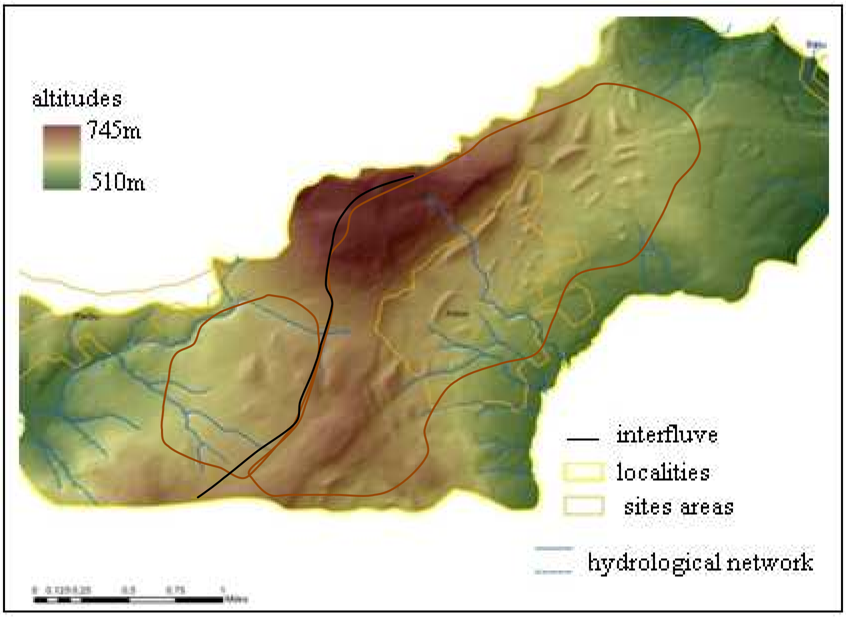


Fig. 19. The elevation model for the "glimee" landslides at Aiton.

4.2.12. "Glimee" deep-seated landslides from Corunca (Târnava Mică Hills and Corridor)

A more special case is the one from Corunca, where the "glimee" landslides are situated on the right slope of the Vatman Valley, in the eastern part of the Târgu Mureş city. The feature that makes this area different is given by the anthropogenic influence upon the morphology of this landslide, especially upon the mounds.

If in the 80s human intervene in order to level the mounds for new field to be cropped, in the last 5-10 years at Corunca they are leveling the mounds in order to extend the village area (fig. 20).

Fig. 20.mound leveled by human intervention at Corunca (September 2010).

Comparing the topographic documents and the aerial images (the ones from 2005 and 2009) we observed a major extend of the village, in the eastern sector, on the area of the landslide. In order to be leveled they use the material that are extract from the mounds to level the depressions between the mounds. For our study we have highlighted the areas there human have a major influence upon the morphology of the landslides, and we observed that the most affected mound is the one near the scarp, on which recent landslides have been active.

4.3. “Glimee” deep-seated landslides and their role in the slope modeling

Landslides are a characteristic of the modeling in the Transylvania Depression. The morphology, dynamic of the landslides and the evolution o slopes is in relation are in relation with:

- Geological substrate – predominant of sand and clays, in which the permeable layers are alternating with the impermeable ones;
- The preexistent morphology, generates in previous modeling cycles;
- The evolution of the climate from the Pleistocene until now, with the evidence of the favorable periods or landslides genesis in subatlantic and boreal;
- The land use.

Landslides have been a significantly influence in modeling the landscape, and the deep-seated ones have imprinted on slopes morphology the forms that are even now as part of this morphology, been seen as witnesses of the past events.

The relief of “glimee” landslides is an element of the landscape of the Transylvania Depresion, both by the frequency and by magnitude of the process. The average values of the “glimee” surface is between 30 – 250 hectares, and the biggest are over 650 hectares – Saschiz 780 ha, Aiton 950 ha, Movile 1100 ha, Şaeş 1650 ha. Those landslides are formed in sedimentary deposits, with low angles or slightly folded, presenting an alternation of permeable and impermeable layers.

The oldest landslides, including here the “glimee” type, have been shaped by processes that have “erased” the morphology created at the moment of the sliding. However, by the magnitude of those events, in the slope morphology we can distinguish both the forms of destructions and the ones o deluvial construction, namely the mounds. Those forms are frequently in the Transylvania Depression, especially in the Transylvania Plain, Hârtibaciu Plateau and Someş Plateau.

Specificity and prevalence of slip processes in the Transylvania Depression led to the identification of the process with the slope morphology, and therefore in the scientific literature are three types of slopes (named landslide slopes), among which the Saschiz one – proposed by de **Gârbacea** (1964) and the Măgherani – detailed by **Tovissi** (1970).

Pleistocene – Holocene landslides (**Irimuş**, 1998) have paved the way to current development of the morphodynamics, by developing a diverse palette of shapes, which not only changed “the slope surface” – landslides valley, sliding amphitheatres, solifluxional areas – but its profile too – by alternating the concave sectors with the convex ones.

This type of landslides has contributed to the degradation of the interfluves, by developing the low areas instead on them and by generating some new ones at the top of the springs: Alecuş, Lunca, Giuleşti, Păucea, Valea Sărată etc. development of delapsiv landslides is conditioned by the withdrawal of the scarp towards the top of the slope (such as at Româneşti).

Therefore the morphology of the slopes displays the mark of the Pleistocene modeling, with amphitheatres of landslides, such as those from Saschiz, Corunca, Porumbeni, which demonstrate a specific feature – a high geomorphological potential risk. This risk is due to the type of movement, the depth of it and the fact that they overlap areas with synclinals, with a more evident diapirism from Pliocene towards today (**Ciupagea**, 1972).

4.4. The typology of “glimee” deep-seated landslides

“Glimee” sliding type classification is done based on various parameters, including:

- The relation with the structure;
- The relation with their position on the slope;
- The morphology of the scarp;
- The evolutionary stages.

At those parameters we can add the genesis mechanisms, the morphology of the landslides, the areas that they have and others.

4.5. The age of the “glimee” deep-seated landslides

Special research on the age of the “glimee” type landslides have been done since 1932, by Pop (quoted by **Pendea**, 2005), which made the first pollen analysis of a peat deposit in a depression resulted from a “glimee” landslide (at Sălicea, Cluj County).

In 1986, **Buz et al.,** have analyzed palynological the peat of lake “Tâu fără fund”, from the site with “glimee” at Pădureni, Transylvania Plain, in order to identify the age of the slides. After analysis the authors summarize: “*we are not wrong saying that the sliding process was triggered well before the stratification process of the peat, process that is linked … with the appearance of a wet ecotop, triggered, with sufficient probability, by the climatic conditions from the subatlantic in its initial phase*”.

The studies from literature indicate more favorable intervals for the “glimee” landslides trigger, from Late Glacial till Subatlantic, with the possibility that some of them have occurred since the time of Eemian (**Pendea**, 2005). So, “… *we cannot say that there is a general valid age for all the glimee landslides. Both in Pleistocene and Holocene were moment – and not periods – with specific conditions favorable to trigger large-scale landslides*” (**Jakab**, 1981).

Although the opinions of the researchers are divided regarding the triggering of this type of landslides in the present time, the reality from the field leads us to believe that those landslides can extend nowadays, I the specific conditions are fulfilled – the temperature and precipitation with extreme values. The detachment of the last block at Tăureni is an argument for this opinion, because in 2008 were recorded high quantities of precipitations, been considered “a year excessively wet” (according to data from www.mmediu.ro).

5. DEVELOPMENT MECHANISM OF “GLIMEE” DEEP-SEATED LANDSLIDES

Until now, regarding the development of “glimee” deep-seated landslides, in scientific literature, has not been assigned a unique concept on the genesis and evolution of these specific landslides. Considering the “glimee” deep-seated landslides as relatively stabilized or stabilized (**Morariu, Diaconeasa, Gârbacea**, 1964), had as a consequence the fact that most of the studies were concentrated on a descriptive morphological approach, rather than focusing on the trigger mechanism and later development of these landslides.

“Glimee” deep-seated landslides formation and later evolution of relief follows different and complex patterns in “glimee” deep-seated landslides family; each one of them has its own specific way of evolution, being influenced by its own lithology, and climatic, bio-pedological, anthropogenic factors. The trigger mechanism can be seen as an important variable which affects the subsequent evolution of the landslide.

Jakab (1981) considers that these landslides are formed by the undermining of the slope, due to loss of balance. The slide „*is preceded by the formation of cracks over the sector undermined,…, the mass movement occurs through a slide movement, with a slight tilt in the direction of movement of sliding block, without disturbing the original stratigraphy. Slided block may break into segments, which, with further modeling, acquired more of the actual rounded mound shape*”. The effect on the slope of this type of landslide is represented by a strong subsidence, which „*in an advanced stage of evolution turns into a glacis, as a consequence of epigenetic processes of gradual erosion of „ glimee ” deep-seated landslides and filling of depressions with erosion material, resulting a balancing surface profile…*” (**Jakab**, 1981).

Based on the theory of sliding waves, **Surdeanu** (2008) develop a possible model of development of these landslides, calling it „evolution model wave by wave”. Thus, it is considered that the first mounds, which belong to the toe of the landslide and are in fact in an advanced stage of modeling, are the first blocks moved on the slope. Then comes the following rows of mounds until the last row (looking from the toe of the landslide to the scarp), considered as the youngest „ landslide body”.

In our opinion, the development of this type of landslides can take different directions, one being by a block movement and its fragmentation during the transaction slide to the base of the slope, other being a repeated detachment of the blocks who form the body of the landslide and a fragmentation which occurs during the movement and later on, due to modeling processes. The present morphology is the result of combination between the slide process and the later modeling processes. This fact is explained by:

- the position of the mounds at the same altitude on slope, which has relatively the same amplitudes;
- different evolution stages between different rows of mounds;
- according to the genesis mechanism, one can differentiate between different landslide waves, of different age;
- the deepness of debris deposits which fills the depressions between mounds - the smaller the deposits, the smaller is the geomorphological activity and youngest the depression.

From field analysis, the “glimee” deep-seated landslides which have lakes in the depressions from the upper part of the site have a recent age and a young morphology, still under the morphological processes modeling activity; instead, old landslides (especially those dated in Pleistocene) do not have lakes, the depressions are leveled with debris deposits from the slopes of the mounds or o the scarp, and the angle of mounds slopes are smaller.

The “glimee” landslide site from Tăureni is representative for the successive trigger mechanism of blocks detachments, being differentiated in the landslide morphology four evolutionary stages, in which the last detached block is very recent (2008). This status leads us to consider that dethatched blocks can fragment or not during the transitional movement on the landslide slope. This last detached block from Tăureni landslide is not fragmented (fig. 21), and has the north slope vertical, and undisturbed stratigraphy.

Fig. 21. Recently detached block from “glimee” deep-seated lanslide at Tăureni (august 2011).

CONCLUSIONS

By our study, called ”*Glimee deep-seated landslides from Transylvania – a geomorphological study*” we have analyzed problems such as: the meaning o the “glimee” notion; distribution of “glimee” deep-seated landslides in the studied area; the influence of same parameters upon the “glimee” landslides triggering and dynamics; “glimee” landslide morphology, their genesis, evolution and development mechanisms. The “glimee” landslides analyzed in this study present different stages of development and evolution, with important changes concerning their morphology, changes which occur as an answer to the forms resulted from the mass movement and the modeling action of contemporary geomorphological processes.

The existence in the same area with “glimee” landslides of a multitude of generations of shapes, determined us to conduct an evolutionary analysis approach. Starting from field research, we tried a “reconstitution” of landslide waves, in order to find the number of rows, respectively the number of successive detachments.

In our analysis, difficulties appeared even in the early stage if implementation, because of the lack of cartographic documents, which proved to be a major issue. By this reason the number of field cases was somehow restraint to those areas which were “covered” from cartographic point of view. Extremely important is the position of the “glimee” landslides on the slopes, because as much as they are positioned on the inferior part of the slope, as much it has a greater potential for later development. This fact is strongly underlined by the “glimee” landslide of Tăureni, which being positioned on the inferior part of the slope, is still in development and most probably –as proof we considered the cracks from the superior part of the slope- moments such as 2008 will occur for sure.

The intervention of modeling processes on the morphology of “glimee” landslides is best reflected on the evolution of mounds. These are fragmented, degraded and present different stages of evolution, even in the same landslide wave. Mounds’ different evolutionary stages reflect the intensity of denudational processes, which tend to re-establish the slope equilibrium.

The individualization of mounds can be realized by many means: the detachment by a slide movement of a landslide wave; the fragmentation of the landslide waves; the fragmentation of heights, but without being implied in a slide process.

The evolution of “glimee” deep-seated landslides presents some common characteristics: the fragmentation of heights, the modeling by contemporary landslides or by erosion and the apparition of conical mounds- but every site has its own identity, by modeling processes.

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