Spatial Relations in the Recent Evolution of the Deep-seated Landslide from Cheia (Cluj County)

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Abstract. Deep-seated landslides represent the Transylvanian geomorphological landscape features both in magnitude and frequency. The mechanism and the morphology of those deep-seated landslides had such an impact upon researchers that S. Jakab (1981) said that those landslides are "*catastrophic moment in the slope's evolution*".
The landslides from Cheia are deep-seated landslides type, with an area of approximately 4 km^2. The individualization of this deep-seated landslide on the left slope of the Aries River is on the surprising morphology of this landslide. Through our study we plan highlighting the spatial relationships which led to the evolution of the deep-seated landslides morphology. The analysis of multi-temporal cartographic support and the correlation of our data with the field reality allowed us to identify the major changes of the deep-seated landslides forms and also to distinguish two areas that are distinct from the morphological and dynamic point of view.

Keywords: glimee, morphodynamic, Cheia

1. Site Characteristics

The landslide form Cheia is included in the deep-seated landslides category, which is a deep and massive landslide with an area of approximately 4 km^2, a length of 2 km and a width of almost 1,8 km.

This deep-seated landslide is near Cheia village (Cluj County), on the left side of the Aries River (see fig. 1), and is very well individualized by its morphological characteristics of the surrounding landforms: in north there is the alignment of Carierei – Hodinis – Dealul Alb Hills, on east there is Lupilor Hill and the channel of the Aries river in south. The slipped masses during the landslide came to the river bed, altering its course.

Fig. 1: **Localization of the studied deep-seated landslide**

The influence of the lithologic, structural, climatic, bio-pedologic and anthropogenic factors is reflected in the general appearance of the deep-seated landslide, which looks as a well developed and mature landscape.

The region lithology is represented by Pleistocene formations (sand, gravel), Sarmatian deposits (marls, sand, and gravel) and Holocene formations (sand, gravel) (Turda Geological map – 1967, scale 1:200000).

The spatial location of lithological formations has put its mark on both morphology and dynamic of the "glimee" deep-seated landslides.

So, the scarp overlaps the Pleistocene formations, the landslide body is mostly superimposed by the Volhinian-Bessarabian formations and Pleistocene formations that appear only in the south-west part, and the landslide toe overlaps the Holocene formations.

Morphologically speaking we can say that the deep-seated landslide positive forms are conical or rounded, most of them being in very advanced erosion stage.

Due to the subsidence processes, landslides and gulling processes, most of the deep-seated landslide hills are very fragmented, and so many of them are segmented into mounds. The negative forms of the deep-seated landslide – longitudinal and transverse depressions – are well individualized and occupied by temporary rivers or by permanent and/or temporary lakes. Deep-seated landslide area that we have studied has been included to the agricultural system, and so the mounds from the landslide toe are used for crops. Also, in the past, the depressions have been used as orchards.

Just because of the strong dynamics of geomorphological processes that affect the deep-seated landslade, now the land is used for pastures and hayfields in proportion of 90%.

2. Methodology

To analyze the evolution of deep-seated landslide from Cheia we tried to identify those areas which have been most affected by the erosion and accretion processes especially in terms of spatial relation that have worked to shape the morphology of our study area. Methodological, in order to achieve more results we analyzed several cartographic documents represented at different successive temporal referential stages: the Josephine topographic maps for Transylvania (1769-1773), topographic maps, then satellite sceneries and topographical surveys to date. Of course it was assumed that the series of cartographic documents faithfully reflect the reality of the relief from the survey moment.

The morphological changes of the deep-seated landslides has been determinate based on a comparison of states recorded at different times on the cartographic and imaging documents with the present morphology of this deep-seated landslide.

3. Analysis and results

The deep-seated landslide from Cheia is a “glimee” type landslide, atypical for the consequent subtype, because it does not have parallel strings composed by hills, but has hills disposed chaotic. The chaotic disposal of the hills is due to the accelerated blocs’ fragmentation and to the chaotic movement of the blocs on the landslide bed.

Corroboration of the endogen processes, exogenous ones and the anthropic activities led to activation and reactivation of some geomorphological processes, such as: landslides, rock fall, collapse, denudation processes, torrential ones, weathering. Those processes concur to the degradation of the scarp, the hills and the depressions between the hills, having as result the badlands fields (fig. 2).

Starting with the analyse of the Josephine maps – the topographic survey of Transylvania (1769-1773), than with the topographical maps from 1962 and 1984, scale 1:25000, and 1973 scale 1:5000, we were able to observe majors differences regarding the degree of fragmentation.

Those observations caught our attention and we started some researches on the dynamic of the geomorphological processes, which shaped the deep-seated landslide up to today morphology.

Fig. 2: **Mounds from Cheia “glimee” deep-seated landslide affected by weathering, erosion and rock fall**

After analysing multiple longitudinal and transversal profiles over the deep-seated landslide, made on the cartographic documents, images and topographic surveys up to date, we identified the areas that have been major modified during time. Using the longitudinal profiles we could analyze not only where are located the parts that are highly shaped during time, but also to estimate by what processes and how were “transformed”. As seen in the fig. 3, there are hills that are affected by landslides and others are affected by human actions, being prepared for agriculture use.

The morphology of the “glimee” was deeply modified by erosion processes and mass movement ones, in such a way that today the hills are fragmented in several pieces (called mounds) (see fig. 4). The depressions are filled with the materials that are detached from the slopes, and so the elevation of the depressions in increasing and of the mounds is decreasing. On the other hand there are some depressions that are shaped by gulling processes, so their elevation is decreasing and the elevation of the mounds is increasing.

Sometimes the two forms (depression and mounds) are decreasing at the same time, so that part of the “glimee” is getting closer to get flatten.

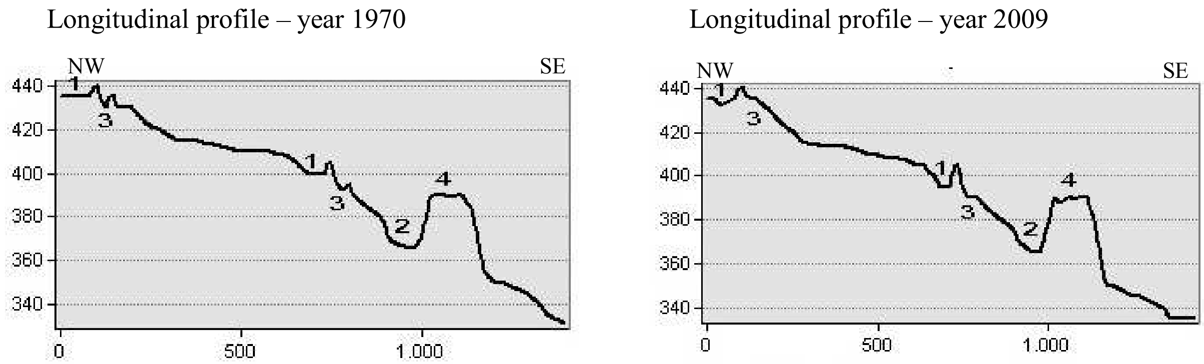

Fig. 3: **Longitudinal profile over the Cheia deep-seated landslide.**
Evolution of the relief forms due to the geomorphological processes (studied period 1973-2009)
1. Depressions that were clogged by materials that were coming from the slopes because of landslides, collapse;
2. Depression affected by gulling processes; 3. Hills shaped by landslides, collapse and erosion processes;
4. Hill shaped by human activities – agriculture lands.

Fig. 4: **Fragmented hill from the deep-seated landslide body** (2009)

Comparing the data from the topographical map, scale 1:5000 (1973), with the data from the topographic survey (2009), we identified parts that were affected by geomorphological processes that fragmented the hills (see fig.5.), and filled the negative forms.

Mechanical properties of the rocks that are in composition of the mounds (marls, sands, gravels) and the structure of those, allow the water to pass through their fissures, and so the water gets to the materials such as clays and silt, which are at the bottom, and new landslides and other processes are activated. This led to the today morphology, with many mounds that are reshaped continuously.

The geomorphological processes that shape the deep-seated landslide tend to flatten of the "glimee" landslide. Their action on the scarp of this landslide determinate the uplifting of the scarp to the interfluves, and at the same time they reduced the slope inclination.

These actions are leading to the elimination of the scarp. Today it can barely be distinguished, because it is affected by new landslides and the depression that one's was between the scarp and the first hills wade is almost hills by landslides that affected the scarp and the hill's slope.

Cooperation between lithology, climate and human activities has an important influence on the dynamic of the geomorphological processes.

Where are Sarmatian deposits, or at the contact between those and the Pleistocene deposits, the fragmentation is higher that where are Holocene formations. On those two parts of the "glimee" deep-seated landslide even from a morphological point of view they are different.

There for we can set bound for two areas that have different aspects regarding the morphology and morphodynamic (fig. 6).

The part that is over the Sarmatian deposits and over the contact between the Sarmatian and Pleistocene formations, represent the scarp and the most part of the landslide body. From a morphologic point of view this part is dominated by mounds, with rounded or conical shapes. Those mounds are shaped by weathering, landslides, creep, rock fall, subsidence processes and erosion processes.

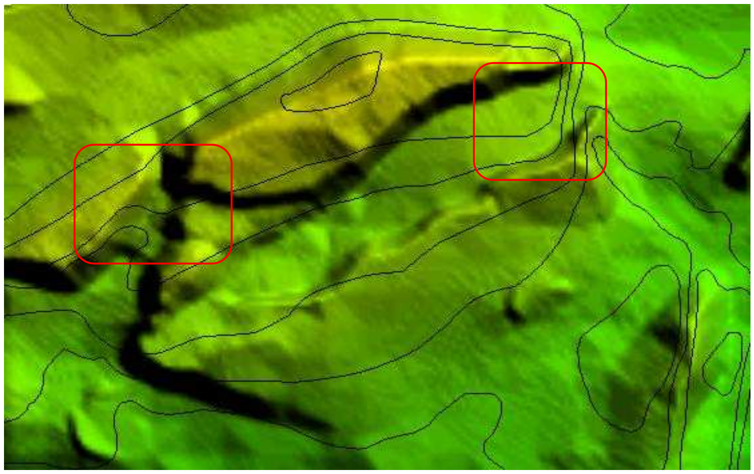

Fig. 5: **Extract of the DEM from 2009 on which are overlaid the contours from 1973's map. The rectangles show the parts that were fragmented during almost 30 years**

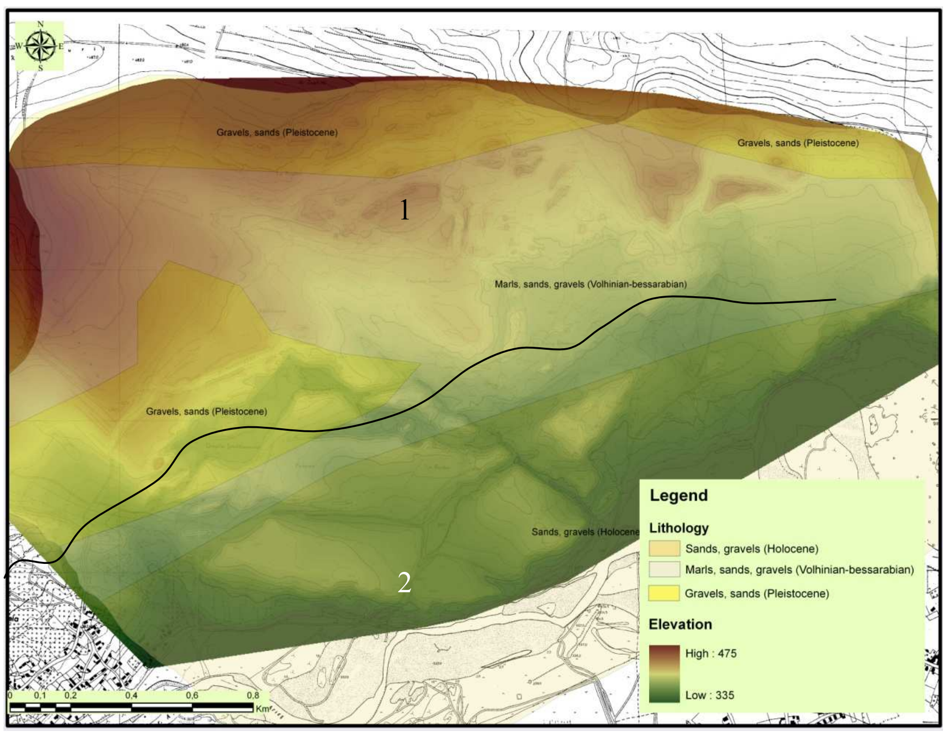

Fig. 6: **Lithological sketch of the deep-seated landslide from Cheia. The limit between the two areas that have different characteristics:**
1. Area with high fragmentation, on Sarmatian and Pleistocene deposits;
2. Area with low fragmentation, on Holocene deposits.

The slope inclination has values between 30-90^0, and where the inclination is very high the strata are brought to daylight (fig. 7).

The depressions from this area are narrow, occupied by temporal and/or permanent lakes, and are clogged with the material coming from the slopes.

The area that is over the Holocene deposits is part of the landslide body and especially the toe, which has reached the Aries riverbed. This area presents big blocks which are fragmented by gulling processes. Those gullies are now filled by permanent and temporary lakes. Comparing with the first area here the fragmentation is less high, and the hills are used in agricultural system. The geomorphological processes are not so active, and only a few landslides affect the ridges of the hills.

Because this part of the deep-seated landslide is used as agricultural land, the geomorphological processes are less active, and even stopped (fig. 8).

Fig. 7: **Mounds fragmented that are situated in the first area, at the central part of the landslide body**

Fig. 8: **Hills that are less fragmented, on the toe of the landslide**

Because of their morphology, this type of landslide (deep-seated landslides) has been included to the agricultural system. Regarding the evolution of land use, we observed the shift from hay land use category to vineyard category or to orchards and pastures. In the 80's, the areas of this deep-seated landslide that were suitable for arable crops have been transformed into arable land, but those which have been very affected by the geomorphological processes have been included to pastures.

So, the fact that this deep-seated landslide from Cheia is used in agricultural system can be understood like a good thing by slowing the geomorphological processes and also can be understood as a bad thing by excessive grazing which accentuates the erosion processes.

Most recent climate changes represent a favourable factor for modelling the deep-seated landslides, especially in terms of flattening the slope affected by this kind of landslide.

4. Conclusions

By analysing the evolution of the deep-seated landslide from Cheia we identified several parts of it that are modified by different geomorphological processes, having as cause the natural and anthropic factors that pull together in order to have the morphology from nowadays. Through comparing the cartographic materials and the satellite images we can affirm that there are some parts of the deep-seated landslide that are active. The lithology plays an important role for the dynamic of the geomorphological processes, there for we were able to distinguish to different part from a morphological and morphodynamic point of view. The way in which the deep-seated landslide evolves and because of the active processes that shape the forms of "glimee", the villages that are nearby this area might be at risk. The infrastructure that they build (in 2005) on the deep-seated landslide is already affected by active landslides, so this deep-seated landslide can be reactivated.

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