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THE DEEP - SEATED LANDSLIDES CORRELATED WITH THE PRESENCE OF THE VOLCANIC TUFFS IN THE TRANSYLVANIAN DEPRESSION (Rumania)

ABSTRACT: MAC I. & RÎPEANU M., *The deep-seated landslides correlated with the presence of the volcanic tuffs in the Transylvanian Depression (Rumania).* (IT ISSN 0391-9838, 1996).

The Transylvanian Basin, a vast intracarpathian morphotectonic area, is dominated by stratigraphic series and lithologic complexes of Neozoic age. The sedimentary layers include numerous horizons of volcanic tuffs, some of them having very wide extensions and being very thick, and others much more thinner, with an ununiform spreading. These tuffs, together with the petrographic complexes in which they were inserted, have been tectonic affected, thus appearing the domes and the diapir folds. The areas with thick horizons of volcanic tuffs are frequently accompanied by profound landslides. The studies developed in this area lead us to idea that the volcanic tuffs play a special role in the process of landslides genesis, through various aspects: the mechanic behavior of the tuff layers at lithostatic pressures, the internal microtectonization which takes place in the pakets of rocks, the fact that they enable surface waters to penetrate along the fissures toward depth, the presence of the lenticular soluble materials etc. The landslides which appear in the layers of tuffs have many shapes, from which we mention: the shape of blocks phragmented in corpuses, the shape of isolated monticuli and the shape of structural terraces. The landslides corpuses are affected, later on, by microtectonic processes, which stand out in specifis microforms.

KEY WORDS: Landslides, Volcanic tuffs, Transylvanian Depression, Rumania.

RIASSUNTO: MAC I. & RÎPEANU M., *Frane profonde correlate con la presenza di tufi vulcanici della Depressione Transilvanica (Romania).* (IT ISSN 0391-9838, 1996).

Il bacino Transilvanico, una vasta area morfotettonica all'interno della Catena dei Carpazi, è caratterizzato da serie stratigrafiche e complessi litologici neozoici. Le formazioni sedimentarie, includono numerosi orizzonti di tufi vulcanici, alcuni dei quali molto estesi e potenti, altri molto più sottili e con un'estensione irregolare. Tali tufi, insieme con i complessi petrografici che li includono, sono stati interessati da eventi tettonici, cosicché appaiono in domi e pieghe diapiriche. Le aree dove sono presenti gli orizzonti vulcanici più spessi, sono frequentemente interessate da fenomeni gravitativi profondi.

Gli studi sviluppati in quest'area hanno dimostrato che i tufi vulcanici giocano un ruolo speciale nella genesi dei fenomeni franosi sotto diversi aspetti: il comportamento meccanico dei livelli tufitici sotto pressione litostatica, la microtettonizzazione interna delle rocce, la penetrazione in profondità lungo fessure delle acque superficiali, la presenza di materiali solubili lenticolari, ecc. Le frane, le cui superfici di taglio si realizzano nei livelli tufitici, presentano diverse forme tra le quali menzioniamo: blocchi frammentati, collinette isolate e terrazze strutturali. I corpi di frana vengono interessati in seguito da processi microtettonici che si manifestano in specifiche microforme.

TERMINI CHIAVE: Frane, Tufi vulcanici, Depressione Transilvanica, Romania.

THE VOLCANIC TUFFS IN THE TRANSYLVANIAN DEPRESSION

The Transylvanian Depression represents a multiphased morphotectonic unit, formed on the area of a vast Neozoic sedimentation basin. The respective basin was outline at the end of Cretacic (the Laramic Phase), but, it was petrographic and structural built up during the Neozoic. Apparently, it had functioned as a monolithic unit; in reality, both in the period of sedimentation and in the exogene sculptural period, existed territorial differences, imposed, after all, by the ununiform instability of the blocks which formed its own ground.

The sedimentation continuity during the Neozoic, the lithostratigraphic and structural characteristics, the geomorphological specific features of the territory, all these, made this geographic space, to be considered as a reference unit of the European continent.

The internal tectonism and the tectonism from the periphery with the adjacent Carphatian units, induced both an intrabasin volcanism and a peribasin volcanism, of Neozoic age. This fact is illustrated by the numerous volcanic tuffs horizons, inserted in a sedimentary column of more then 3000 meters in thicknes. Taking into consideration the spatial repartition and the stratigraphic position, these tuffs have an uniform value: a general or basinal value (the case of the tuff of Dej), a regional value (the tuffs of Borsa-

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Apahida, Ghiris, Hadareni, etc.), and a local value (different levels of tuffs which exist on small areas).

In a brief characterization, the volcanic tuffs from the Neozoic, present in the Translvanian Depression are:

- the tuffs of Dej (rhyodacitic) marks the debute of the Neozoic volcanic activity (the Stiric Phase); it is characterized by an immense volume of cineritic materials, a wide spreading, a greenish colour and a little bit bigger resistence than of the other types. From the cronostratigraphic point of view it is situated at the bottom of the lower Badenian formation;

– the tuff of Borsa-Apahida (dacitic) has a regional spreading and it is situated at the limit between Badenian and the Lower Volhinian (Buglovian);

– the tuff of Hadareni (dacitic) is a representative level, attached to the Lower Volhinian Level formations, having a white colour and considerable thickness;

– the tuff of Ghiris (andesitic) is considered to be the cartographic limit, between Buglovian and Sarmatian, and considering the spatial point of view, it covers a sufficient vast territory, in the western part of the Transylvanian Basin (MÂRZA, 1962);

– the tuff of Sarmasel (dacitic, rhyodacitic/andesitic) is defined by a white colour with a chalk aspect and a pelitic - aleuritic vitroclastic structure, strongly zeoliticed (up to 90%) (VANCEA, 1960);

– the tuff of Urca (dacitic) dating from the Lower Besarabian, has a vitroclastic composition and variable thickness (1-2 m);

– the tuff of Rîciu (rhyolitic), situated at the upper part of the Lower Besarabian, presents slender vitroclastic features;

– the tuff of Bazna (andesitic) is spreaded in the central part of the basin and has an unclear stratigraphic position, Panonian-Meotian.

Besides the above mentioned horizons there are, also, numerous local levels, which have a limited spreading, inserted in the Sarmatian and Panonian sediments (tab. 1).

TABLE 1 - The main horizons of volcanic tuffs in the Transylvanian basin - Geological Characteristics (after MÂRZA & MESZAROS, 1991)

Tuff of	Geological Age	Zone (nanno) (E. Martini, 1971)	Stratigraphic Value	Local Names	Mineralogic and Petrographic Characteristics	
					Petrographic Type	Alteration Phenomena
++ Gidfalău	Medium Pleistocene				Andesitic	
++++	Romanian					
+++	Dacian			Ighis		
++	Pontian			Vama Seacă		
++ Bazna	Panonian (Meoțian)		Meotian	Somârtu (D. Ciupagea, 1829)	Andesitic	
++ Sincai	Lower Besarabian			Band, Sînpetru de Câmpie, Rîciu, Bozed, Oarba de		
++Urca++		NN9		Mureș, Group Of Urca Tuffs		
					Dacitic	Zeolitization
++ Sărmășel						
++Ghiriș	Upper Volhynian	NN8	Upper Volhinian	Colina (Iris)-Cluj-Napoca, Zau	Dacitic (Ryodacitic)	Zeolitization
		NN7/8	Lower Volhynian (=" Buglovian) the end of it	Rotbav, Grănari, Jilbert	Andesitic	Bentonitization, Zeolitization
++Hădăreni	Lower Volhynian			Băița, Gădălin,	Dacitic	Bentonitization,
+++		Nn7/upper		Cara, Ocna Mureș	Zeolitization	
+++						
++Borșa Apahida	Upper Badenian	Nn6/upper	The limit Badenian Lower Volhynian	Iclod, Bunești, Cata, Merești, Sânpaul	Dacitic	Zeolitization
Σ						
+++Dej	Lower Badenian	Nn5		Orman,Tioc, Păglișa Mirșid, Perșsani	Ryodacitic	Zeolitization, Silification
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00000000			Basal Conglomerates transgressive			
	Ottnagian	NN4/upper				

THE PREMISES OF LANDSLIDES DEVELOPING

A very small number of papers (VANCEA 1960; MARZA & MESZAROS, 1991) deals with the idea of a connection which exists between the landslides and the volcanic tuffs, in the Transylvanian Depression (MAC, 1966).

Therefore, our researches, carried out in a number of areas with massive landslides (*glimes*), led us to the idea that there are direct connections between certain levels of volcanic tuffs and the landslides processes. Consequently, the premisis which provide such connections are of different kinds:

The supergene weathering phenomena, associated with the volcanic tuffs

Depending on a wide range of conditions, the volcanic tuffs are submitted to strong diagenetic processes, which permanently modify not only the chemical composition, but also the physical features, as well as the mechanical behaviour. The support of these modifications is represented by the volcanic glass (GHERGARI & *alii*, 1991), which, in conformity with its composition, with the environment's chemistry, is submitted to the following phenomena: bentonitization, zeolitization, dolomitization, calcitization and silification. While the first two processes (bentonitization and zeolitization) affect the great majority of the tuffs (BEDELEAN & STOICI, 1984), the other processes affect only the tuff of Dej (dolomitization and silification), and the tuff of Borsa-Apahida (calcification) (GHERGARI & *alii*, 1964).

The argilisation process starts from the bottom of the tuff horizons, in optimum conditions, when the support is constituted by impermeable rocks, like marls and clays. The impermeable support mantains a hydrochemical regime in which takes place the argilitic transformation of the volcanic glass. This phenomenon explains the vertical decreasing of the bentonising's intensity suffered by the volcanic. The process of bentonitization may, partially or totally, affect the horizon of tuff. The process is enabled especially when the «roof» of the tuffs horizon is made of permeable rocks (sands, sandstones, conglomerates).

The minerals identified in the clay fractions are different, however dominating the following: montmorillonite, illite, baidelite, crystobalite and calcite (the tuffs of Ghiris, Hadareni). It is well known that those minerals, in conditions of wetting, sustain the landslide process (GHERGARI & *alii*, 1991).

The relationship with the adjacent deposits

The volcanic tuffs belong either to some complexes of strata, or they separate different cronostratigraphic series. For this paper, the following aspects are important:

– the volcanic tuffs nead have a roof of strata on a considerable thickness in order to transmit a lithostatic pressure to the horizon of cinerites;

– the strata of the roof must be permeable, assuring, thus, the penetration of the weathering waters toward depth;

– the subdjacent strata must be impermeable ones, in order to sustain the supergene processes from the horizons of tuffs, helped by the infiltration water, reached to the level of contact between these and their support.

Such conditions are extremely obvious for the tuff of Hadareni (the bottom of Buglovian), the tuff of Ghiris (from the bottom of Sarmatian) and for the tuff of Bazna (the Lower Pliocene), which are frequently covered by thick packets of sands, conglomerates and sandstones, or, are inserted between sandy marls and they lean upon marly facieses. For the genesis of the gravitational processes, in the areas with volcanic tuff it is estremely important that immediately above the horizon with volcanic tuffs should come sands or sandstones, even if, over these, are coming in succession strata of marls and clay, with different other insertions (sandstones, sands, limestones).

The characteristics of tuffs' sedimentation

Only the tuffs present in thick strata (4-10 m) may enable profound gravitational movements. Then, the packets of volcanic tuffs with a slender stratification and varied petrographic features (compact marly, tough sandstone, friable sandstone aspect, slender, tuffy sand, and others) are, all, uniform subjected to the microtectonizations processes. That is the reason why, the strata with tuffs are frequently fissured, dismembered in sequences of various dimensions, having the aspects of «blocks», easy to detach from the common packet.

The presence, in the mass of some tuffs, of the lime concretions, and of the gypsum lenticles, provide the chemical disolutions, the formation of gaps and the dismembering of the deposits' mass unity (BARBAT & MARTON, 1989).

The tuffs' positions in the Neogene structures

The volcanic tuffs together with the other geological formations, are associated with monoclinal structures, with the simple folds' structures and with the domes' structures, specific in the Transylvanian Basin. The inclination of the slopes varies a lot, from 2-5' to 55-65', having different mechanical effects. The strong inclined strata and the surface position, enables the gravitational movements. The presence of the tuffs strata in the upper horizons of the folds' top, in the cuesta's outface and in the fronts of the faults, assures the fissuring and the tearing of same compartments of land, toward the negative erosional areas (valleys, «wealds», etc.) (fig. 1).

In conformity with the above mentioned premisis, appear gravitational processes, in the tuffs of Borsa-Apahida, Hadareni and Ghiris, which belong to the stuctures situated in the north-western part of the Transylvanian Depression (fig. 2).

THE FEATURES OF THE LANDSLIDES

The morphologic elements present some distinct notes:

– the scarp is high (10-70 m) and strongly inclined, developing on big lengths;

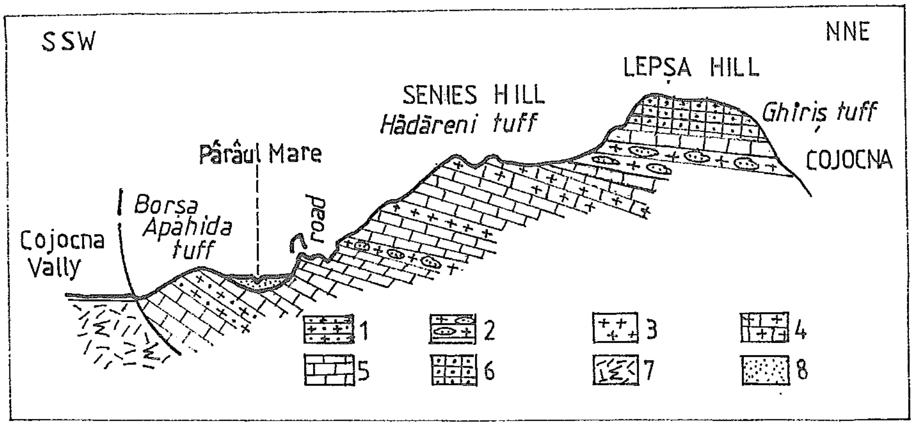


FIG. 1 - Synthetical geological profile through the Senies and Lepsa Hills at Cojocna. Horizons of the outcropping volcanic tuffs: 1) Borsa-Apahida tuff; 2, 3), local tuff horizons; 3) local tuff horizons, 4) Hadareni tuff; 5) Other formations; 6) Ghiris tuff; 7) Salt; 8) Alluvia.

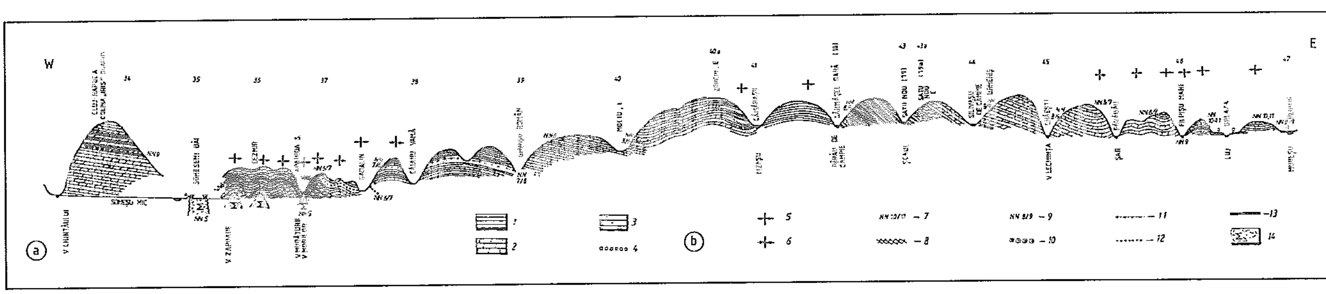


FIG. 2 - Synthetical East-West geological profile of the Transylvanian Basin: 1) clays; 2) marls; 3) sandstones; 4) quaternary deposits; 5) anticline; 6) syncline; 7) NN 10/11 Ponoṅian; 8) NN9 Sincai-Râciu-Sabed tuff; 9) NN 8/9 Upper Volhinian-Lower Bessarabian tuff; 10) NN9 Sarmasel-Colina tuff; 11) NN 7/8 Ghiris tuff; 12) NN 6/7 Hadareni tuff; 13) NN6 Borsa Apahida tuff; 14) NN5 salt.

– the bodies of the landslides have the shapes of flat «blocks», which, due to the denudation, become monticular; the edges of the shifted masses present strong inclinations, all around, due to the tuff's resistence, present in the slided bodies (fig. 3);

– together with the big bodies of the landslides are also present smaller bodies of landslides, detached from the bigger ones, as a proof being the petrographic and structural common elements (fig. 4);

– the bodies of the landslides are permanently affected by microtectonic processes, which divides them into phragments and creates microforms (prolongued depressions, fronts of microfaults, scarps of secondary landfalls, denivelations of unhook, and others) (fig. 5);

– the big height and the striking denivelations, in comparison with the negative surfaces (interbody depressions, depressions at the back of the last landslide wave) are connected with the landslides' profoundness and with the material's consistency, from the bodies of landslides;

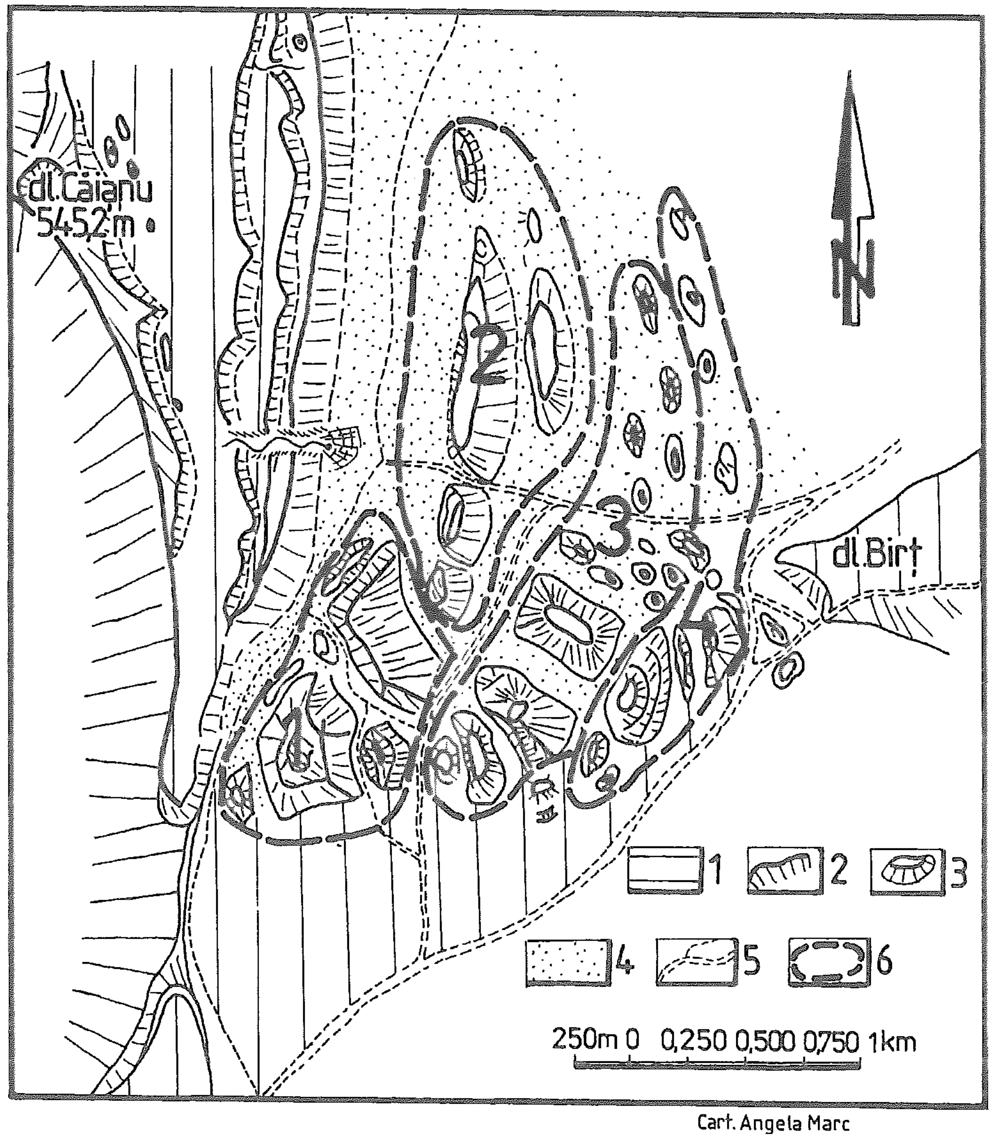
– the surface of the landslide area has un obvious semicirculary and trapezoidal geometry.

Processes and mechanisms

The landslides' genesis and dynamic may be deduced from the structural, petrographical and morphological elements of the affected formations. As far as the structures is concerned, there are two situations, of concordance and discordance.

On the wide monoclines, or, on the folds' flanks, where the inclinations vary between 50' and 80', appear translational, consequent landslides; under the impact of the lateral tractions (toward neighbouring basis levels) detach «blocks», extended and of big thickness (30-60 m), which slide on short distance. This phenomenon may be monophasic (Suatu), or polyphasic (Dâmburele). In the first case, only one compartment is detaching and is moving, which, lately, is divided into phragments in smaller parts,

FIG. 3 - The «glimee» of Dâmburele. Morphologic sketch: 1) upper part of the slope; 2) zone of detachment; 3) landslide bodies; 4) small depression; 5) roads; 6) area with the main landslide bodies.



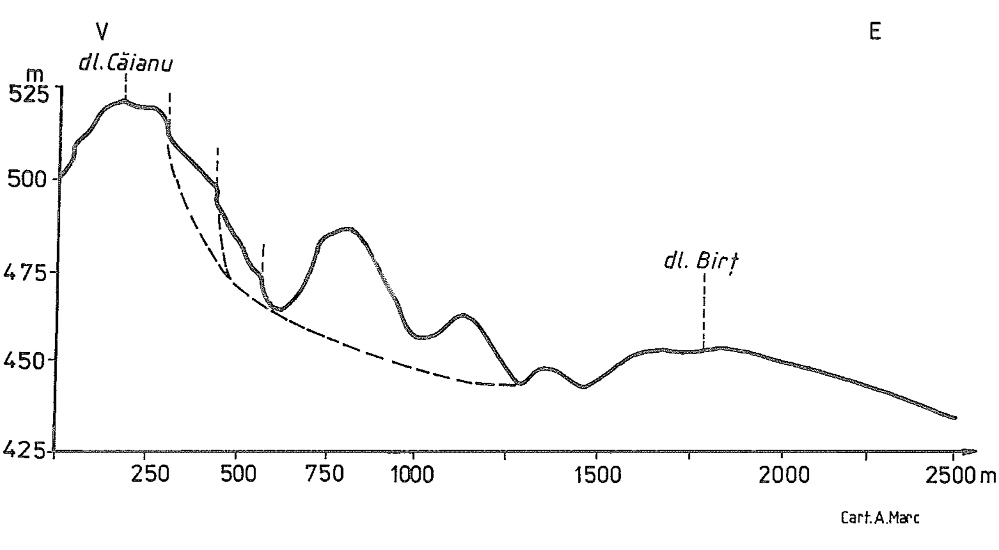
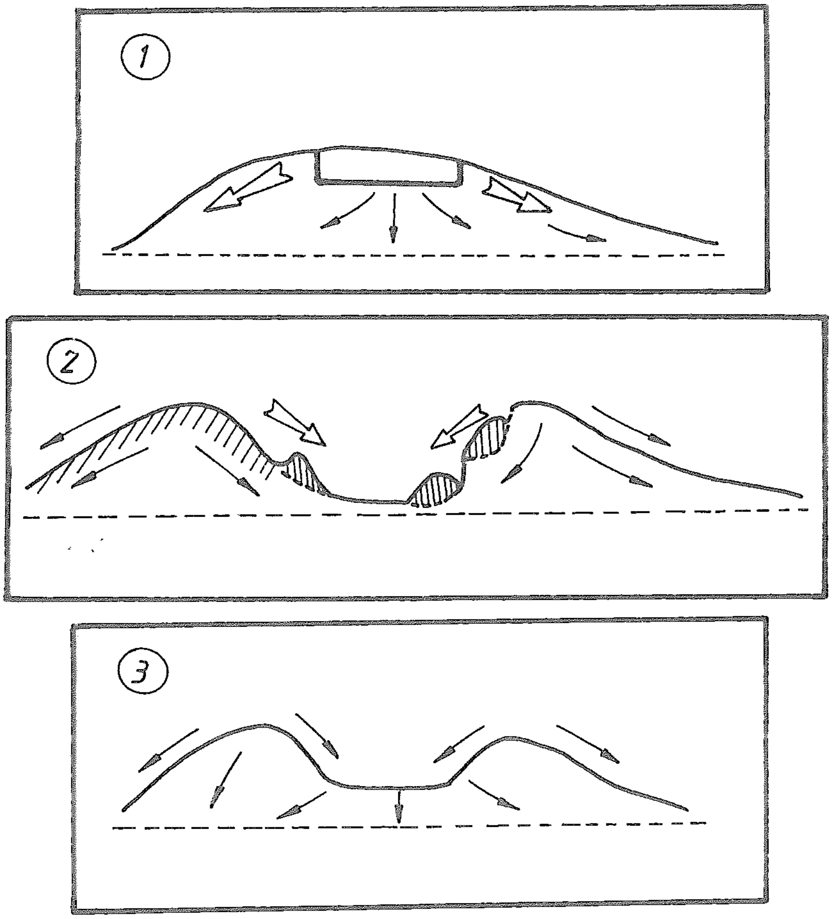


FIG. 4 - The «glimee» of Dâmburele; cross section between Caianu Hill and Birt Hill.



Cart. A.Marc

FIG. 5 - Evolution of the «glimee» depressions caused by microtectonics. The arrows point the forces of traction and the movement of the fragments.

by microtectonic processes. These phragments keep the structure and the physiognomy of the initial block. In the second case, the detaching begins in the neighbourhood of the basis level, and then, goes on in stages, toward the interstream areas. The resulted bodies mark the successive stages of detaching and movement.

The support of the movement may be different: a ground horizon of the package of tuffs, strongly argilised, which, in contact with water, is swelling and creates instability; a stratification level, from the package of tuffs; a subdjacent sedimentary stratum, of marl or clay, strongly moistured. Therefore, in certain situations, massive landslides can be born without an unusual fetch of water.

On the abrupt fronts (including the cuesta), the movement's mechanism is connected with the lithostatic decompensations. The process begins with the creation of a «splinter» in the upper part of the edge, where the volcanic tensions are maximum. Lately, a mass from the cuesta's front is falling to the ground, and, simultaneously is sliding on a short distance. Thus, is forming a «wave of glimee».

This phenomenon is representative and may appear in more rows of monticular bodies, separated by prolongued microdepressions. The later evolution of the slided bodies stays under the command of the exogene factors.

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