Geomorphological processes in the Danube Defile
Case study: The Liubotina slide and the Mraconia collapse

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Rezumat. Sectorul analizat se află situat în Defileul Dunării pe malul stâng al fluviului pe rama de sud-est a munţilor Almajului . Localizarea arealul supus analizei din punct de vedere al proceselor morfodinamice actuale, se poziţionează în sectorul Cazanelor, unde după ridicarea S.H.E.N. Porţile de Fier I, sau produs o serie de modificări morfohidrodinamice. *Prăbuşirea din Cazanele Mici* în ordine cronologică este primul proces geomorfologic analizat. Ea sa produs la începutul lunii martie şi este situată la cca. 300 m, aval de confluenţa văii Mraconia cu Dunărea, afectând o porţiune din DN57 Eşelniţa-Dubova prin prăbuşirea zidului de sprijin, până în axul central al părţii carosabile, pe o lungime de cca. 30m. Procesul a avut loc în calcare masive ce sunt afectate de fisuri cu orientare verticală, la care se adaugă o serie de procese ce au contribuit şi aici la declanşarea prăbuşirii, respectiv, o pantă de 90%, oscilaţiile de nivel ale lacului şi aceeaşi metoda neadecvată de construcţie a căii rutiere. Cel de-al doilea proces morfodinamic actual luat în discuţie, este reprezentat de o *alunecare-prăbuşire de tip detrusiv*, ce a avut loc la finalul lunii martie, pe data de 26 martie 2010. Ea s-a produs în amonte de intrarea în Cazanele Mari, mai precis în imediata apropriere a Văii Liubotinei şi este vorba de o alunecare de teren masivă şi complexă, produsă în versantul situat pe marginea drumului rutier DN57 Dubova-Şviniţa la o altitudine abs. de 155-160 m. Pentru stoparea acestor fenomene şi combaterea efectelor, se impun măsuri urgente şi permanente de supraveghere şi întreţinere a drumului rutier strămutat de la baza versantului, unde dinamica proceselor de modelare actuală este variată şi deosebit de activă în anumite perioade de timp precum şi la trecerea de la un anotimp la altul. Executarea unor lucrări de stabilizare a versanţilor, a unor baraje de-a lungul văilor torenţiale, amenajări silvice, etc., precum şi interzicerea autorizaţiilor de construire şi cumpărare a terenului din imediata apropriere a luciului de apă şi a versantului pe care îl străbate drumul naţional.

Cuvinte cheie: dinamica reliefului, procese geomorfologice actuale, activitate antropică.

The sector analyzed is located inside the Danube Gorge, on the left-hand bank of the river, along the South-Eastern face of the Almaj mountains (fig. 1). In terms of the current morphodynamic processes, the area under analysis is located inside the Kazan gorge sector, where the construction of the Porţile de Fier I Hydropower and Navigation Complex (S.H.E.N. Porţile de Fier I) caused later morpho-hydro-dynamic transformations.

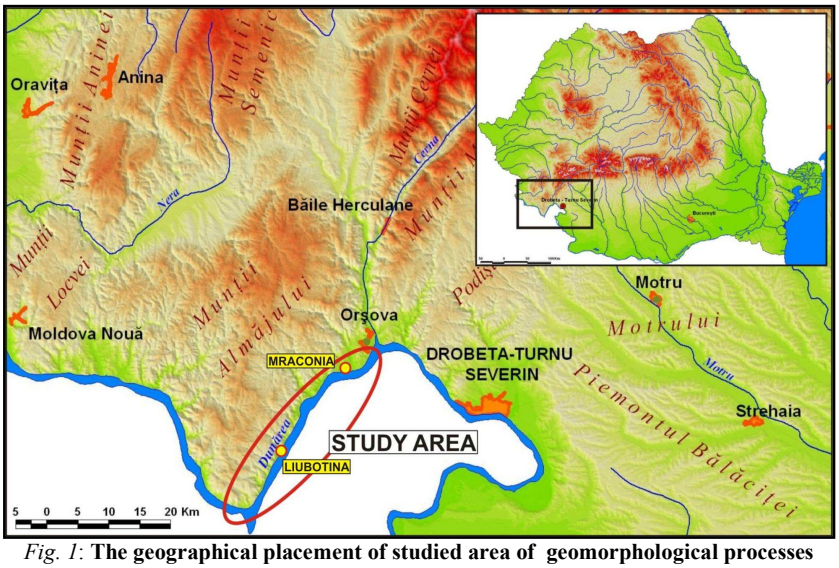

Fig. 1: **The geographical placement of studied area of geomorphological processes in the Danube Defile**

The scale of the current geomorphological processes along the Danube valley has increased in the recent period, especially where the conditions for their emergence and development were highly favorable (high fragmentation, steep slopes, forests on limited surfaces, developed weathering crust, etc.). Representative instances for these situations include erosion processes, tied to the local conditions, where hillsides generally suffer because of washing and rain-washing, alongside ravination processes, which mainly occur in the context of steep slopes, with a high rate of rock alteration, or the absence of vegetation, due to a superficial soil layer. Gravitational processes – consisting in landslides, slumps and mobile slope deposits – are equally important. Landslides and slumps occurred because of brittle deposits with argil interstices, and where tougher rockmass is dominant (lime, sandstone, the crystalline schist of the Getic plateau), rock decay resulted in mobile slope deposits (detritus, rockslides and adobe deposits). The structural and mineral complexity of the Danube gorge brings about a large variety of processes and types of landscape (The "Porţile de Fier" comprehensive atlas, 1967).

The Cazanele Mici slump is (fig.2), chronologically speaking, the first geo-morphologic process discussed. It occurred in early March, on March 9, 2010, and is located circa 300 meters downriver from the Mraconia valley confluence with the Danube; it damaged one section of the DN57 Eşelniţa-Dubova national road, as the parapet collapsed, all the way to the median line of the road, on a distance of around 30 meters. The slump is 20-meter high from waterline to the road level; the rebuilt parapet is 8-meter high.

The process occurred inside a lime rockmass which featured vertical faults, alongside several processes which were partially the cause for the onset of the slump, that is a 90-degree declivity, lake water level fluctuations and the improper means used in road construction. A relevant argument in favor of acknowledging and protecting the environment is that on the right-hand bank of the river, in Serbia, the responsible approach to works on the road linking Kladova and Golubac meant no processes similar to those on the left-hand bank of the Danube occurred, although the geological and mineral conditions are similar.

The second recent morphodynamic process considered consists in a *detrusive-type landslide* (fig. 3), slump that occurred late in March, on March 26, 2010. It occurred upstream of the Cazanele Mari, more exactly in the near vicinity of the Liubotina valley; it consisted in a massive and complex landslide on the versant located alongside the DN57 Dubova-Şviniţa national road, at an absolute altitude of 155-160 meters.

Fig. 2: **The collapse of Mraconia**

Fig. 3: **The landslide of Liubotina**

The distance from the slump rim to the toe of the slope amounts to around 200 meters, which means the landslide involved a huge mass of dislocated material, which impacted on the entire mountainside, blocking and wrecking the national road surface on a 130-meter section. The volume of the rockmass displaced is estimated at 100,000 cubic meters; part of the flow coming down the slope collapsed into the Danube river.

The morphodynamic process that crested the premises for the emergence and onset of the massive landslide caused a series of micro-forms of relief: the slump ravine, the body of the flow and the toe of the slope.

The *ravine* is semicircular-shaped, with steep, even vertical walls, reaching up to 15 meters in height in the central section; it marks out, in a clear and continuous line, the jagged mass of the flow. The slump funnel is also clearly marked out on its

lateral sides, by means of 5-to-10–meter-high steep slopes, angling downwards.

The *body of the flow* features several microreliefs– jumbled piles, gradations and curves caused by the flow mass molding onto the ragged contour of the bedrock slope. The slope's visible sections have an abraded look, especially on rockfaces and along the alternating bands of clay, as the result of friction between the moving mass of rock and the rock in situ. The mirror-like look is even more obvious when bedrock was dragged along in the landslide. The flow mass consists in a mixture of uprooted trees, detritus and an important amount of weathering crust. A part of the flow mass descended over the national road and into the Danube river, creating a sizeable mass of alluvia.

The *toe of the slope* ended up in the lake water, around 100 meters from the roadside. As a result of the resilience of the body of water as well as the pressure exerted by the flow mass on the move, the toe of the slope shaped up like a breakwater. The contributing factors also included the momentum of the flow, and the milder slope grade close to the riverbank; the milder slope combined with the thickness of the landslip to preserve the vertical position of the trees dragged along, visible from mid-altitude at the lake's 65-meter absolute altitude.

Potential causes and triggering factor:

As in any geomorphologic process, the fundamental causes are: rock, gradient and water. In the situation analyzed, one must point to the thick layer of slope deposits, especially in its lower third, deposits consisted in matter with a high rate of plasticity, as the result of alternating bands of clay. These deposits lie on top of serpentine soil, magnesian slate, with a high content of chlorite, talc and chrysotile, in various stages of weathering. The alternating bands of clay combined with the steep gradient – an average 45-degree angle – and the existing faults and crevices easing infiltration and excessive water accumulation to create the premises for the process trigger.

Fig. 4: **The collapse of Mraconia and the landslide of Liubotina**

The very important role played by human activities, both direct and indirect, has to be acknowledged: the direct cause was interference with the natural balance of the gradient, when building the road linking Orşova and Moldova Nouă. The manner the road was built was just as harmful, as it involved blasting the mountainside and shoveling the excavated material into the lake water. The blasts caused new crevices in the mountainside mass and enlarged the existing ones. Indirectly, the 5-meter-plus fluctuation of the lake waterline, undermined the cohesion of the underlying mountainside by means of alternating moistening and air exposure; road traffic is also one of the preliminary causes, in terms of the vibration it causes.

Triggering causes:

The extremely arid weather of the summer of 2009 was followed (tab. 1, fig. 5), late that autumn, by abundant rainfalls, which continued throughout winter. The above-mentioned existence of crevices, perpendicular on the direction of traffic, allowed rainfall water to infiltrate and accumulate throughout the deposits, which led to over-moistening them. It was only a matter of time because the landslide began, which occurred in March 2010.

Table 1. **Monthly and annual mean atmospheric precipitation** (mm)

Staţia meteorologică	Perioade	LUNA													
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II
Dr.Tr.Severin	2009-2010	77.6	60,9	33.9	15.4	26.4	103.6	25.6	20.2	19.0	109.2	101.6	135.2	66.1	94.6

Staţia meteorologică	ANUL								
	2001	2002	2003	2004	2005	2006	2007	2008	2009
Dr.Tr.Severin	501.0	677.2	672.6	700.5	846.4	714.1	740.0	640.4	728.6
Berzesca	550	642.4	513.9	689.7	857.4	687.0	708.1	536.4	745.2

Berzesca	2009-2010	73.9	82.3	63.5	3.2	41.6	79.8	51.8	44.2	20.4	110.6	94	79.9	59.4	87.3

Source: processed ANM data

Work is now being done to consolidate the mountainside at the road level, but the existence of crevices in the higher reaches makes it likely to ease further landslides, in the long run, as the respective location remains an active one. Work to consolidate the mountain slope in the area of a previous landslide in the vicinity also contributed to destabilizing the mountainside.

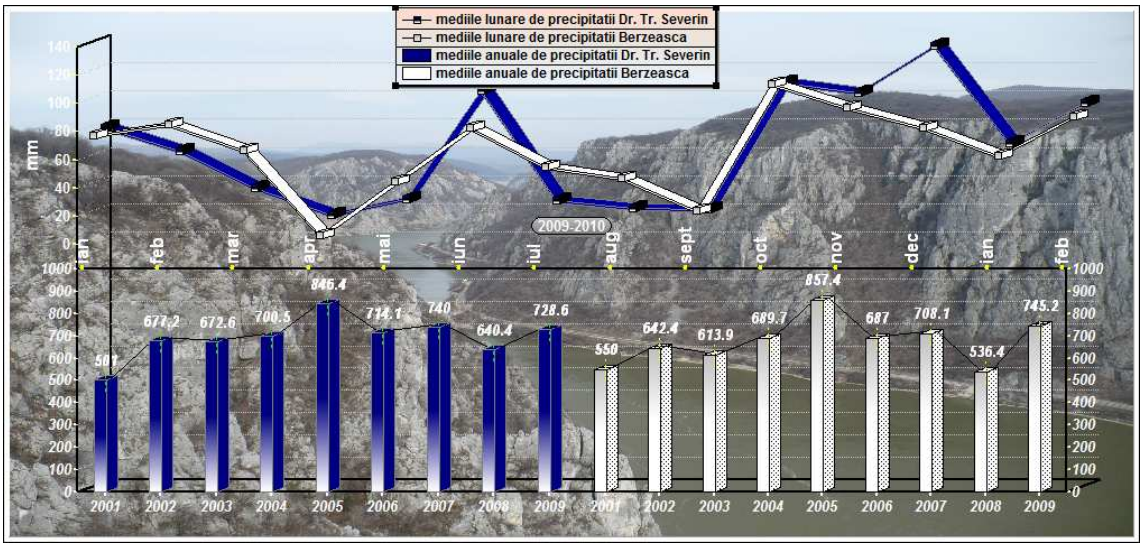

Fig. 5: **Monthly and annual mean atmospheric precipitation** (mm)

The current evolution of this sector of the Danube gorge is influenced by several transformations and present morphodynamic processes such as riverbank abrasion, landslides and slumps, deposition, silting, etc., which raise several practical and theoretical matters pertaining to

Danube gorge landscape dynamics in the wake of the construction of the Porţile de Fier I reservoir.

Several factors such as gradient, lithology or infiltration water which causes over-moistening of the rock can create the premises for landslides and slumps. Morphodynamic factors to be mentioned may include climate and human-action factors, which play an important part in this case study.

Climate factors

Most Earth crust-shaping processes are due to climatic agents or agents originating in certain meteorological phenomena. As far as the climate is concerned, the alternation of arid periods and rainy periods leads to the loss of rock cohesion. The increasingly abundant nature precipitation in the rainy seasons, combined with the higher percentage of precipitation amounts in the past few years, have brought about the recrudescence of landslides and slumps and the acceleration of erosion processes.

Water coming from precipitation and snowmelt becomes an important geomorphologic agent, especially in those areas with limited forest vegetation or areas subject to deforestation. In its action to shape and trigger various geomorphologic processes, water benefits from the assistance of preliminary factors such as slope declivity, the composition of the sublayer, etc. In areas where woods have been deforested and the slope declivity was modified by human action, the incidence of current shaping processes (erosions, slumps, landslides, etc.) registered a strong increase.

Human-action factors

Humna involvement in current morphogenesis is analyzed in terms of both the influence man exerts by his actions, and the fact he can serve as a morphogenetic agent.

The construction of the reservoir involve in the construction of the Porţile de Fier I hydro power plant meant the reconstruction of the communication routes and mountainside consolidation construction work, which led to slope-cutting, especially in the lower thirds of the mountainsides, which diminished the stability of the versants and triggered various geo-morphological processes.

Current geo-morphological processes now occur on a large scale in the Danube gorge, thanks to the favorable conditions for their emergence and development (steep slopes, high landscape fragmentation, thick weathering crust, deforested areas or areas of little vegetation, leasing the water surface and the land beneath the DN 57 embankment, operations which brought about the landslides, etc.).

In *conclusion*, the region analyze features an intense dynamic, with current geo-morphological processes occurring on a large scale, favored by natural factors (geologic, geomorphologic, hydrologic, climatic factors, etc.) and enhanced by human action (the approach to road construction, the heavy traffic, more or less authorized private construction work), which contributed to destabilizing the land.

Urgent and permanent measures have to be taken to monitor and maintain the national road, re-routed from the foot of the mountainside, where the current dynamic of shaping processes is varied and exceedingly active at certain times as well as during the changes of seasons. Work should be done to consolidate the mountainsides, to erect dams along gullies, to improve forestry management, etc., as well as ban construction or buying land in the proximity of the waterline and close to the mountainside traversed by the national road.

The lesson learned is that in a battle against the environment, man always stands to end up on the losing side, which makes it an imperative task to act with the utmost care, respect and responsibility to all elements in the supporting and nurturing environment.

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