MORPHODYNAMICS OF THE CHIRLEŞTI MUDFLOW (BUZĂU MOUNTAINS)

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Morphodynamics of the Chirleşti mudflow (Buzău Mountains). The paper undertakes a morphological and morphodynamic assessment of a 1,350 m-long mudflow, followed up in various phases since its occurrence that poses a great danger to one of the main Trans-Carpathian roads in Romania. The study relies on large-scale geomorphological mapping and on aerial photos obtained over several time sequences (1977, 1992 and 2005), total station and DGPS surveys and laboratory analysis of some sliding plane rock variables. Assessments were aimed on highlighting the morphological, morphometrical and morphodynamic characteristics of the mudflow functional sectors. Mudflow reactivation episodes over the above-mentioned time interval alternated with periods of intense gully erosion and reactivations of upper sector slides.

INTRODUCTION

Previous studies conducted in the Curvature Carpathians and Subcarpathians of Romania (Bălteanu 1974, 1976, 1983; Ielenicz 1984) revealed the important role played by mudflows in the modelling of steep slopes developed on Palaeogene Flysch and Neogene molasse deposits. The movement of materials takes on a visco-plastic form, depending on the quantity of water and of available material in the source-areas, the petrographic properties of the rocks, the morphology of pre-existent relief and landform shaped by intense, pulsatory mudflow activity. The above-mentioned studies have pointed out the presence of three types of mudflows: flows with fixed source-areas (in a state of dynamic equilibrium, with reactivation of small amplitude along the main scarp or flow-track slopes); partially reactivated mudflows (reactivation movements triggered during excess rain intervals, moving along segments in terms of structure, texture or thickness of the deposit) and active flows (marked by a general movement that entails all the three functional sectors).

The international literature includes many studies on quantitative mudflow assessments, countries like Italy, France, Switzerland or Austria having a rich practical experience in this type of processes. The above-mentioned examples put forward how that obtaining a 3D representation of a mudflow process enabling its numerical modeling based on future hypothetic scenarios (Flageollet *et al.* 2000, van Asch, Begueria 2007) means passing through several stages such as rock state parameters analysis and their correlation with climatic parameters e.g. temperature or precipitation (Parise, Guzzi 1992; Varnes, Savage 1996). Subsequently existing data will be completed with information supplied by air and satellite images (Gilli *et.al.* 2000, Malet *et.al.* 2002), valuable for a more efficient quantification of the morphodynamic characteristics of these fast-going processes.

Previous studies on the Chirleşti mudflow have evidenced its early-stage morphology (Badea, Posea 1953) as well as some morphographical aspects (Constantin 2002).

The present paper makes a detailed assessment of the morphological and morphodynamic features, underlying further and in-depth hazard and risk studies.

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STUDY AREA

The mudflow covers an area on the righthandside slope of the Buzău River mountainous sector, close to its confluence with the Cătiaşu Brook (Fig. 1), within a broader contact area between the Carpathian Palaeogene Flysch and the Subcarpathian Miocene molasse, termed by some authors "*the Carpathian-Subcarpathian transition strip*" (Niculescu 1971, 1974), a sector affected by a wide diversity of slope mass movements.

The mudflow has developed along a reverse fault, on Palaeogene Flysch deposits of brittle sandstone with intercalations of argillaceous schists and marls (according to the geological map 1:200 000, Covasna sheet). In its upper sector, the flow intersects lines of hydrostatic discharge of an active shallow aquifer essentially contributing to the overmoisturing of colluvial deposits.

The 1,350-m long mudflow, unfolding along a north-east consequent valley (*Curătura*), between 615 and 350 m relative altitude, has three well-outlined dynamic and functional sectors: source area, flow-track and terminal accumulation fan.

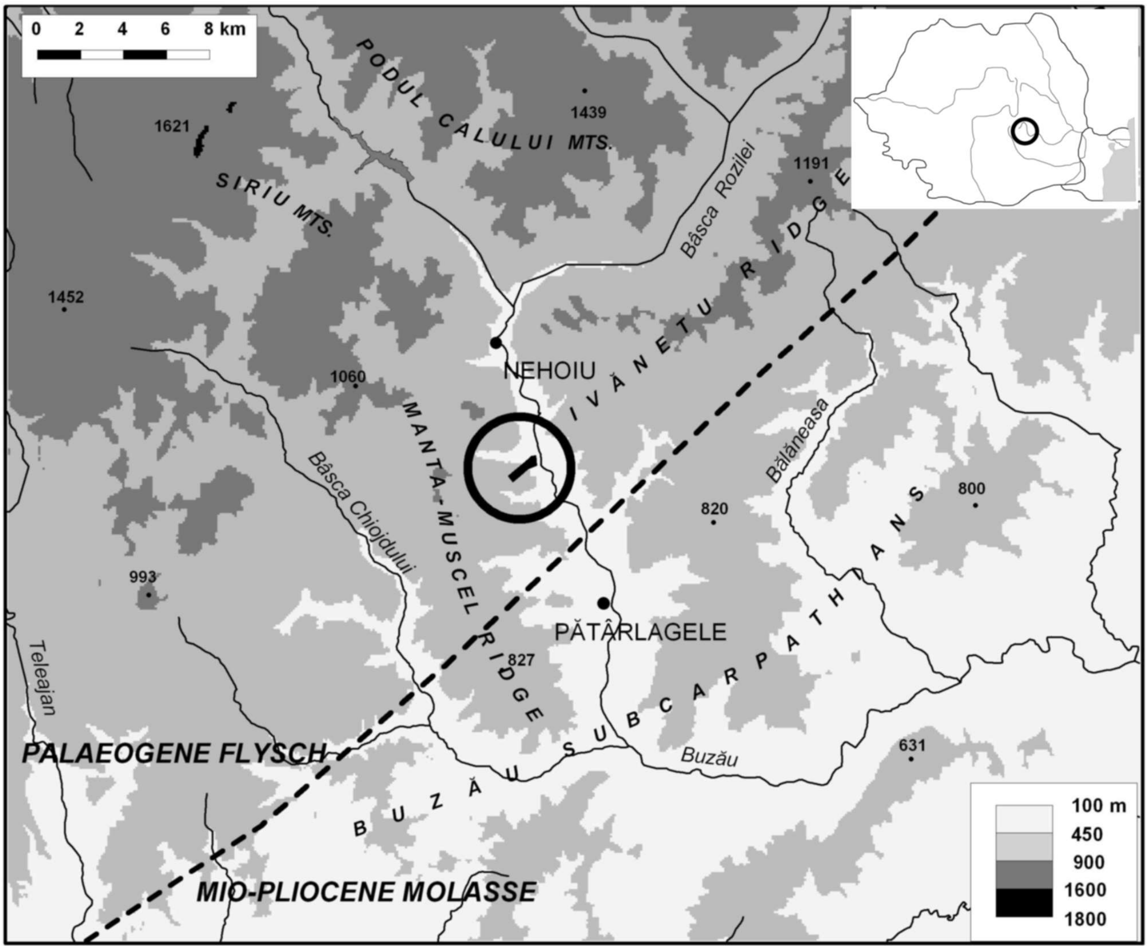

Fig. 1 – Study area position.

The phenomenon was first documented in 1953, right after its reactivation caused that year by a rainy spring associated with snowmelt, the substrate being already overmoisted by the abundant precipitation fallen in the autumn of 1952 (Badea, Posea 1953). The authors quoted above point to the steep slopes, structure and lithology (heterogeneous formations of marls and clay-marly schists) as the main natural factors favoring the occurrence of the process. At the same time, the authors present details of morphology and morphometry, the three functional sectors and the damage incurred in the lower sector.

METHODOLOGY AND DATA

The morphodynamic assessment of the Chirleşti mudflow is based on repeated large scale (1:5,000) geomorphological mapping. The 5 m/pixel DEM (representing the mudflow sector and the surrounding areas) was obtained based on 2005 aerial photos, while a DEM of 1m/pixel for the terminal fan was obtained based on total station (Sokkia 610) and DGPS (Thales Mobile Mapper) surveys. At the same time, in order to determine a series of variables like grain-size distribution, plasticity, consistency and colloidal activity indexes, samples were collected from the *in situ* rock and the disturbed material (4 samples/sampling point, in order to calculate the standard deviation of the determined values).

The mudflow's morphodynamics assessment will state its numerical modelling, in the light of several hypothetical scenarios permitting the quantification of associated risks. Having in view specific risks (to people, households, electrical network, rail and road traffic), a quantitative deterministic approach, considered to be relevant to this kind of process (Soeters, van Westen 1996, Glade *et al.* 2005) will be made further on in order to highlight areas likely to be covered by variously thick materials from the terminal cone.

RESULTS AND DISCUSSIONS

Mudflow morphology

The mudflow's three functional sectors are well-individualized in the relief. The material is heterogeneous and moves on a plane consisting of marls and grey clays (Fig. 2) that contains a fine pellitic, psephytic, seldom psammitic matrix which envelops a centimetric skeleton of menilites and disodiles in a high proportion.

Grain-size fractions are not very well sorted out in longitudinal profile, preserving their heterogeneous character both in the source areas and along the flow-track. The surface of the cone is marked by mineral and vegetal debris fragments (remnants of tree-trunks, materials provided by the retrogressive failure of the main scarp and less often from the flow track). The geotechnical property are outlining a sliding surface formed predominantly out of grey marls and clays showing very high plasticity (I_p) and medium-to-high consistency (I_c).

The source-area (Fig. 3), which covers 3.36 hectares, is elongated in shape and presents active scarps, separated by sandstone spurs and a head depression filled with colluvial materials. It is 540 m long, up to 60–80 m wide, with delevellings of 5–20 m and declivities of 40–50°. Accumulated colluvial mass represents the outcome of medium and deep-seated slumps, shallow slides and granular topples. The colluvium undergoes sheet wash, rill erosion and superficial slides. Several fissures, parallel to the main scarp, develop behind it, sometimes having up to 1–2 m in length and 30–40 cm in depth, suggesting an amplitude-reduced but continuous scarp retreat. Extremely heterogeneous rocks (sandy clays, rich clays, marls and sands) as well as the very large extent of the main source area favor the swift infiltration of water from precipitation and from the local water tablets. The overmoisted colluvium then starts to move in form of a visco-plastic fluid, reaching the flow-track.

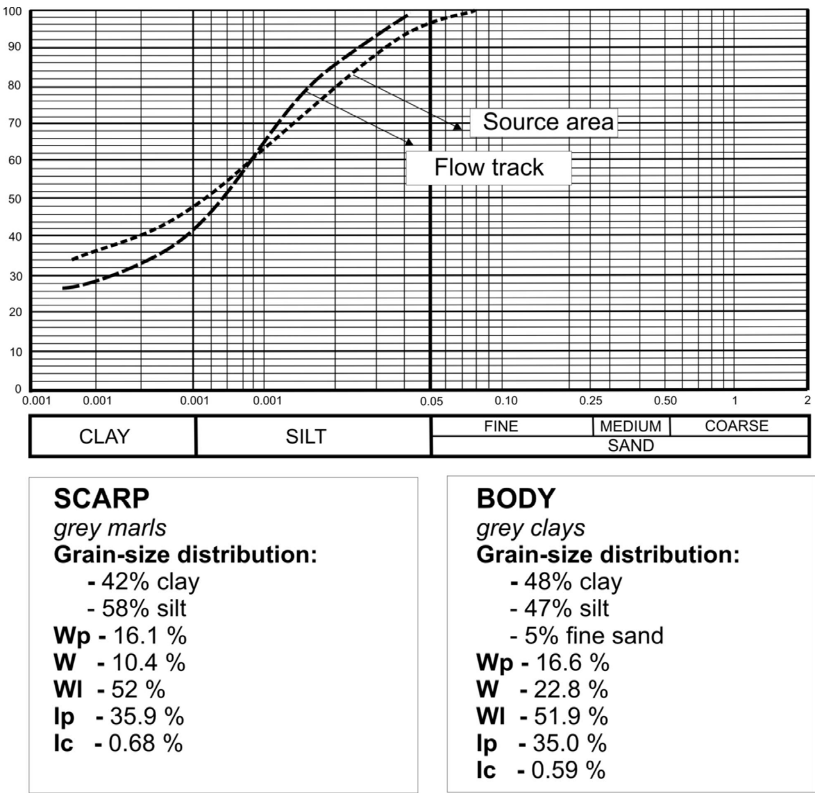

Fig. 2 – Rock parameters (clay and marl from the main source area; 2004; laboratory analysis: National Institute of Research and Development for Land Reclamation "ISPIF" Bucharest).

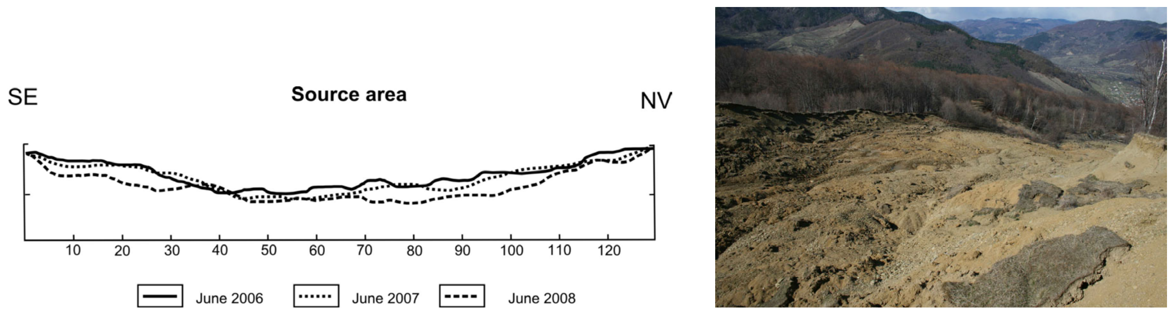

Fig. 3 – Cross-profiles in the main source area.

The 750 m-long flow track (Fig. 4) develops downhill from a narrowed sector situated just below a structure-controlled threshold bordering the source area. Along this sector, the mudflow reaches 5–15 m in width, being limited throughout its length by a 1–2 m-high lateral pressure ridges. In a few widening sectors, the track is bordered by secondary lateral scarps, formerly active during various phases of reactivation. The reactivation of some lateral colluvium, fissured during 2007–2009, can supply even higher quantities of materials in the future. The flow-track material is 1–3 m thick and consists of a sandy-marly matrix which contains a skeleton of menilites, disodiles and schistose sandstone (10–15%) up to 20–30 cm in diameter. The lateral pressure ridges which border this sector are being permanently refreshed and reconfigurated at the contact with the track. However, on the outside, they preserve the mark of some previous pulsations, illustrated by the layout of several parallel rows (2–3 sometimes), only along the righthandside slope (the left one being very steep).

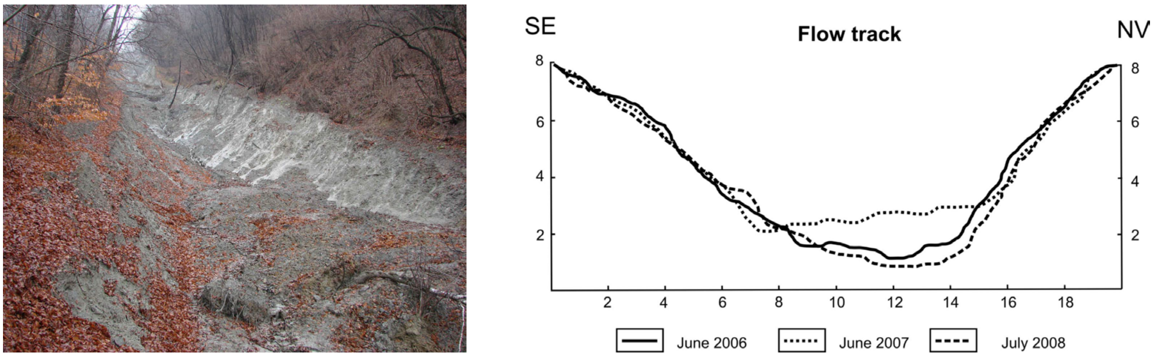

Fig. 4 – Flowing track (left) and cross-profiles (right).

Along the contact between flow-track and slopes may be seen small stepped slides (up to 1 m high), deep fissures and small, temporary water accumulations. Towards the end sector, the movement regime is slightly modified morphologically, showing a viscous-to-plastic transition, favoring occasionally the growth of grass and buckthorn bushes. These microforms are completely changed with each mudflow pulsation.

The lower sector (accumulation fan) (Fig. 5), which is the one to have a major direct impact on households and road-and-rail traffic routes, is obviously the most important one. It covers 1.7 ha and displays numerous virgating cones superposed on the 10–12 m Buzău River terrace. Successive accumulations of material and their effects are seen in the destructions caused over time, e.g. ten households in 1953, one in 2006 and two in 2010.

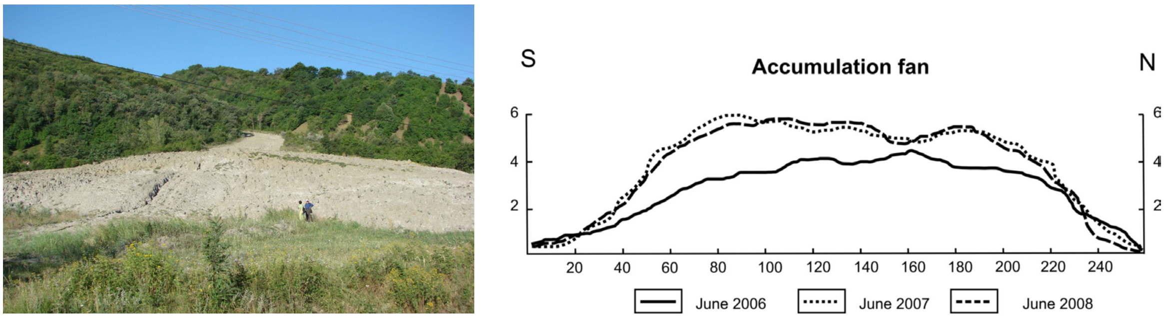

Fig. 5 – Terminal fan (left) and cross profiles (right).

In 2010, the accumulation cone length was 170 m, its 2–5 m high front (Fig. 5) being severely fragmented by rills and gullies, swiftly deeping in its unconsolidated material. The cone exhibits frequent piping funnels and underground channels with collapsed ceilings, reflecting the major role played by underground drainage and piping processes in the dynamics of the end sector.

Mudflow morphodynamics

After 1953, the mudflow had several periods of reactivation (1969, 1975, 1977, 1990, 2004, 2005, 2010, 2011), associated with expansion of the source areas and accumulation of the lower sector (Fig. 6). Active flow periods alternate with intervals of relative stability, dominated by gullying, rapidly eroding the colluvial materials in the flow track and enhancing imbalances in the source area. In the lower sector, this alternation shows up in the superposition of the accumulation cones formed during the active flow period. The periods of gullying-induced modelling process are visible in the presence of some young soil strips existing in the lower sector. Applying *the medical illness concept*, we would say that this mudflow is a chronic geomorphic process featuring acute periods (Diaz, Murnane

2008), and alternates in the slope modelling regime mudflow and gullying (Bălteanu 1976). Acute intervals, randomly occured in time have affected the Buzău-Braşov National Road 10 and two groups of Chirleşti village households. In periods of maximum activity, the dominantly plastic movement turns into a viscous one, increasingly more fluid and rapid, with sideways expansions. This type of movement corresponds to periods of rich precipitation in spring (associated or not with snowmelt), or torrential summer rains. After it stopped raining, the movement gradually returns to a state of plasticity which may last for one-two weeks.

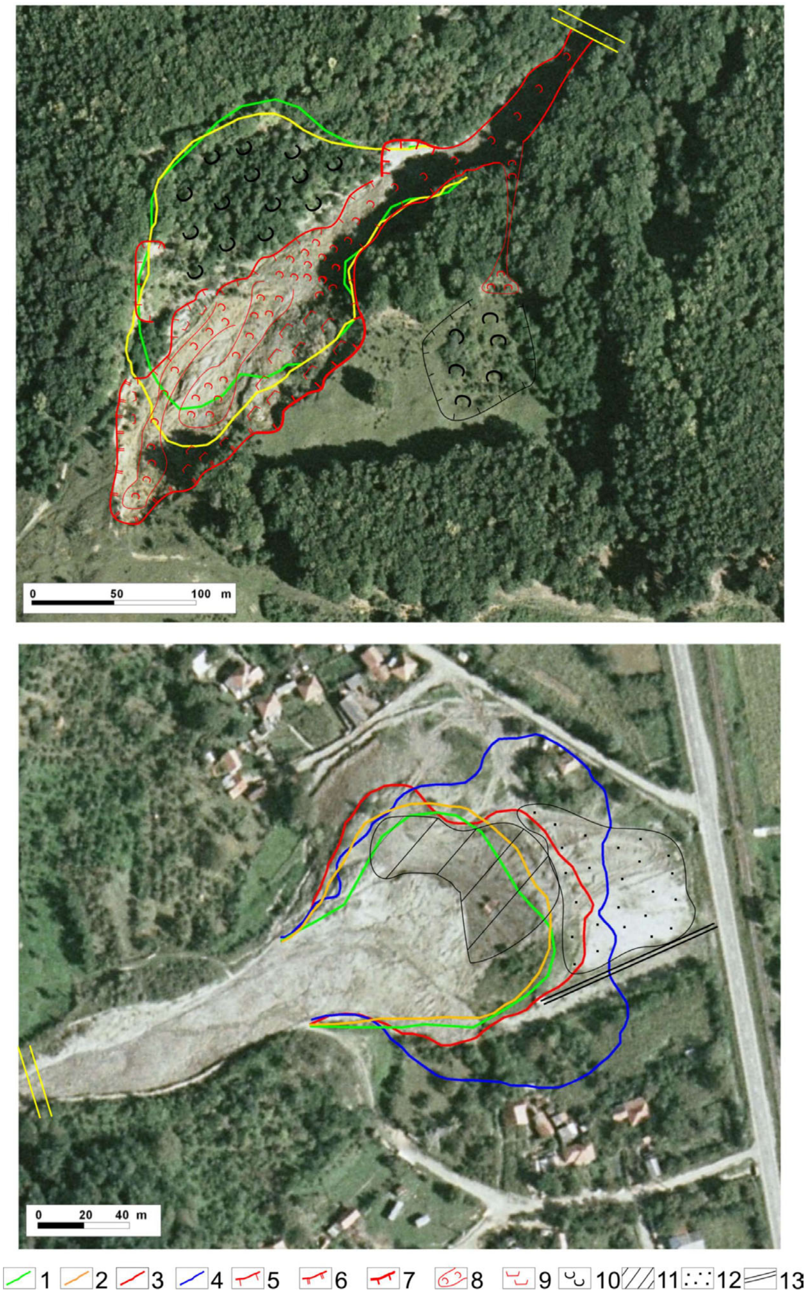

Fig. 6 – Geomorphological sketch of Chirlesti mudflow (2008): 1. limit in 1977; 2. limit in 1992; 3. limit in 2005; 4. limit in 2008; 5. active scarp (under 2 m); 6. active scarp (2–5 m); 7. active scarp (more than 5 m); 8. mudflow; 9. rotational landslide; 10. dormant landslide; 11. anthropic relief ; 12. “outwash plain”; 13. drainage channel.

The annual regime indicates accentuated activity in spring and summer, related especially with a scarp retrogressive development and a terminal accumulation, both in size of colluvium thickness. The summer's end-to-autumn features no major changes, the main processes being the consolidation of lateral pressure ridges and temporary accumulation of colluvial material along the flow track. In winter and in early spring a stage of temporary equilibrium is reached, when the quantity of precipitation, basically the main triggering factor, is diminishing. The freeze-thaw process generates small accumulations (0.2–0.5 m in height) at the base of the main scarp, formed of materials toppled due to dilation-contraction process.

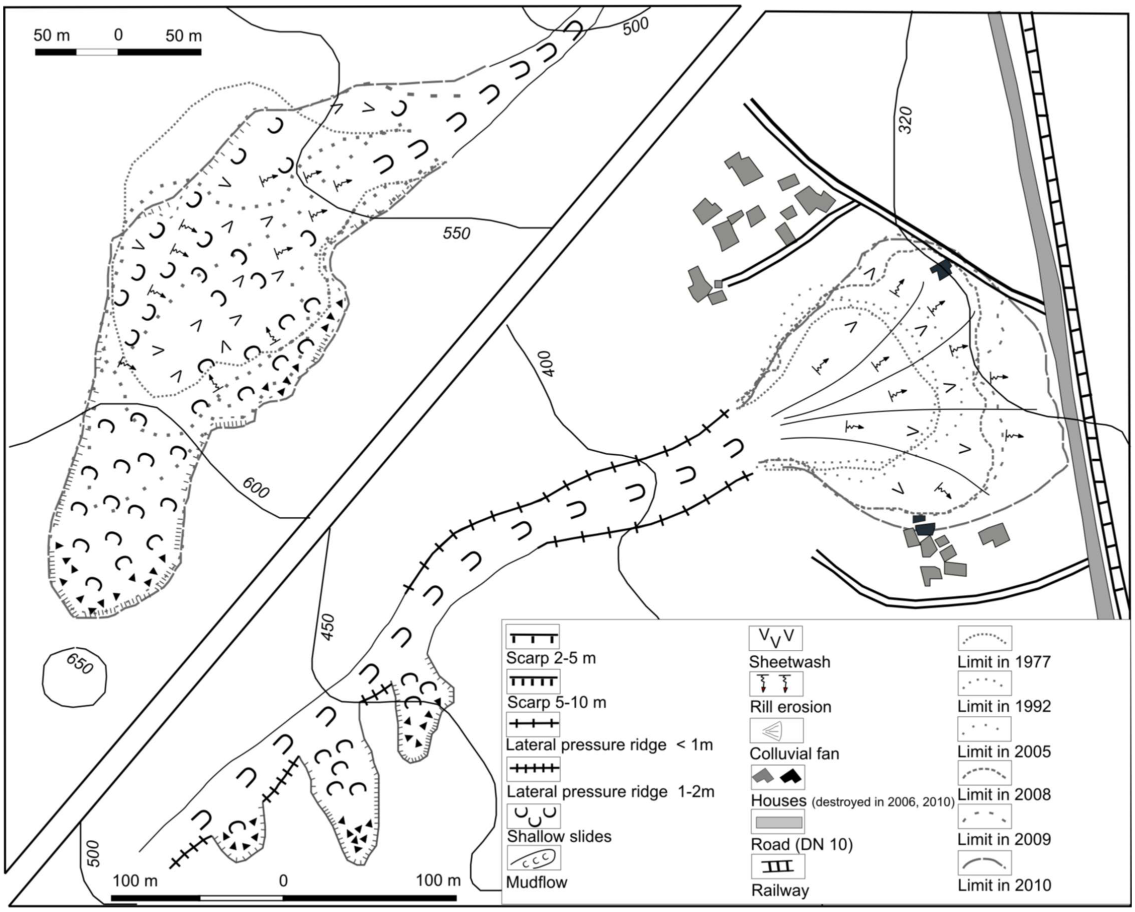

Fig. 7 – Chirleşti mudflow geomorphological sketch (2010).

The most important changes during the study-interval occurred in the source area, namely the scarp migrated towards the watershed according to the steepest slopes. For example, on June-July 2006, 5,731 m^2 (some 29,000 m^3) slide from the main source area. A special case was the year 2005, the rainiest one in the region after 1975. Beginning with the end of spring and throughout the summer, major changes occurred, which cumulated with those of the summer of 2006 led to the enlargement of the source area by some 11,000 m^2 and of the cone area by some 5,500 m^2 (about 15,000 m^3). As described by Micu *et al.* (2011), the year 2010 was also considered extremely important for the morphodynamics and future behavior of the mudflow, since a switch from a single source area to *multiple source areas* occurred. During February 2010, caused by fast-rising temperatures which melted the snow, the water infiltrated rapidly throughout the main source area lead to a general reactivation causing intense lateral erosion all along the flow track. The immediate effect was the reactivation through retrogressive evolution of dormant landslide deposits situated at the confluence with 2 lateral tributaries (Fig. 7). This process formed two major (area: 400–500 m^2; volume: 500–1,500 m^3) and two linked minor (200–400 m^2 and 200–800 m^3) secondary scarp areas.

As a matter of fact, those extremely wet intervals reflected in the morphology and morphodynamics of the mudflow will constitute the groundwork in the numerical modelling of the flow, in the attempt to assess, quantify and manage associated risks.

CONCLUSIONS

The Chirleşti mudflow is one of the most relevant mudflows examples in Romania. Similar to other such phenomena in the Curvature Carpathians and Subcarpathians (Apostului Valley, Murăturile, Viei Valley, Cuculeşti), the seasonal distribution of precipitation, considered to be the main triggering factor, shapes the flowing-sliding characteristics, further controlling the morphology of the entire process.

In the active periods, the material moving with the flow has a seasonal characteristic, the rich precipitation falling at the end of spring and in summer being associated with major pulsatory movements, rapid flow over short and medium distances (up to 50–100 m), developing shortly after rains have stopped. The three functional sectors, well illustrated in the relief (Fig. 7), show distinct morphodynamic features. Since the end of summer and in autumn, the intensity and duration of precipitation are changing; the mudflow's movement is shifting too, basically from viscous to plastic decreasing the flow speeds. The movement is now continuous and uniform, as revealed by some lateral friction lens visible along the flow-track and in the upper sector of the accumulation cone. In the cold season, once the quantity of precipitation is diminished the water in the surface layers of the colluvium is freezing, movement speed slows down. After 2008, the mudflow intensified in relation with a bigger volume of main source area material sliding and moving faster along the flow track, finally accumulating in the end sector. This morphodynamics was enhanced by the emergence, and potentially growing development of new lateral source-areas, likely to facilitate future large colluvial quantities, apparently fixed by forest, enter the flow-track.

The large possibilities of study (morphodynamics, hazard and risk analysis) make this site, unique in Romania by his amplitude, suitable to be considered a geomorphosite and protected accordingly.

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