Geomorphological processes within the alpine level of Parâng Mountains

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Abstract. The alpine level of Parâng Mountains is situated at altitudes higher than 1800 m a.s.l. over a surface of about 133 km2 (18.3%) of the whole environment covered by these mountains. The present-day relief modelling within this environment is conditioned by the variety of the climatic, bio-pedo-geographic and geomorphologic conditions superposing the lithological and structural substratum – tectonically complex, which induces a diversified morphodynamic potential. The anthropic activity adds to these conditions, representing a determining link in the geographic system of Parâng Mountains alpine level. In the identification and mapping of the present-day geomorphological processes, the genetic criterion was followed. The following types were identified in the alpine level of Parâng Mountains: periglacial processes and landforms (congelifraction, soil creep, periglacial elevation), nival processes (avalanches), wind-induced processes (eolization), gravitational processes (rock collapsing and rolling), pluvial and torrential processes (surface washing, rain-wash, torrentiality), fluvial processes (erosion and accumulation), along with biogenic and anthropic processes. There is a remarkable diversity of the present-day processes and of the resulted landforms, conditioned by altitude and by the morphoclimatic characteristics specific to the high mountains, framing within the level of the periglacial processes.

Keywords: Parâng Mountains, alpine level, potential morphodynamic processes, present-day geomorphological processes

1. Introduction and objectives

The present-day aspect of Parâng Mountains is just a stage in the long-standing evolution of these mountains which have been registering significant modifications along time. Due to the variety of the morphodynamic factors existing within this Carpathian environment, there is a wide range of ongoing geomorphological processes, of which the periodicity and intensity vary largely at regional level.

Mountain area characteristics derive from the general laws of nature and in this regard the altitudinal distribution of the geographical phenomena was imposed as a principle of the research, accessible for analysis of restricted areas or for synthesis of regional areas. The scientific and practical importance of the alpine area determined constantly investigated starting with De Martonne, since end of XIX century up to present-day. This interest for mountain research became more diversified during last 25 years, been connected with modern research techniques.

Two physical-geographical stages imposed by the altitude and morphoclimatic characteristics: the upper Carpathian level/alpine (above 1800 m) and the mean level/forest (800-1800 m), according to most studies regarding the mountains in the Southern Carpathians (Velcea, 1961; Niculescu, 1965; Iancu, 1970; Urdea, 2000; Voiculescu, 2002; Nedelea, 2006; Săndulache, 2007; Săndulache, 2010, Ielenicz and Oprea, 2011; Onaca *et al.*, 2011; Grecu *et al.*, 2011; Voiculescu & Ardelean, 2012; Popescu *et al.*, 2014; Vasile, 2015; Vasile *et al.*, 2014; Săndulache, 2014; Gheorghiu *et al.*, 2015). The recent PhD thesis can be added to the above mentioned studies. The alpine morphodynamic potential analysis is based on the lithological and structural elements, relief energy, drainage density, slope and slope exposure, vegetation, climate and human activity, which are variable in time and space with evolutions difficult to predict. The lithological and structural base, declivity, climatic and biotic factors together with the time lapse (having the role of controlling the relief and responding to the climate change reaction on it) are the key factors for alpine morphodynamic potential determination.

The main objective of the paper represents the inventory, classification and mapping of the actual geomorphological processes, based on in-situ measurements, observations and researches.

The description of the different process stages are presented based on data extracted from thematic maps and climatic data recorded. The final aim is to elaborate the geomorphological processes map that helps stakeholders from different economic sectors: agriculture (pastoral), tourism and construction (mountain resort – Rânca or Transalpina road).

2. Study area

The Parâng Mountain represents the high western part of the mountain group situated between the Olt and Jiu rivers within the Southern Carpathians in Romania. The geographic location (45030'N) determined the temperate continental climate with altitudinal variations (the maximum altitude is 2519 m on Parangul Mare Peak and the minimum altitude about 310 m at Bumbesti-Jiu at the Sadu and Jiu rivers confluence).

The major relief is dominated by the main ridge, oriented from west to east, carried on a length of 33,5 km, where the upper level of the Borascu erosion surface can be found above 2000 m high.

Parâng Mountains are located in the western half of the Southern Carpathians, being framed by Vâlcan Mountains at the west, Căpăţânii and Latoriţei mountains at the east, Şureanu Mountains at the north and Petroşani Depression at the north-west. The boundaries are mainly created by the hydrographic network: at the west – Jiu River, at the east- Olteţul River, Latoriţa, Lotrul and Jieţul at the north, only the southern border being the contact steepness between the mountain area and the Subcarpathian, Oltenia Depression.

The alpine area is approximately between the contour lines on the main and secondary ridges facing north. These morphometric characteristics together with the geographical location are reflected in the main landscape modelling factors.

The alpine level of the Parâng Mountains has an area of approximately 133 km2 (which represents 18.3% of the massif). It occupies about 48 km2 on the northern side (6.7% of the massif) and about 85 km2 on the southern side (11.7% of the massif). The glacial relief represents most part of the alpine level (glacial complexes from the Jieţ and Lotrului springs), extended on corrugated interfluves present in Southern Parâng (Fig. 1a,b).

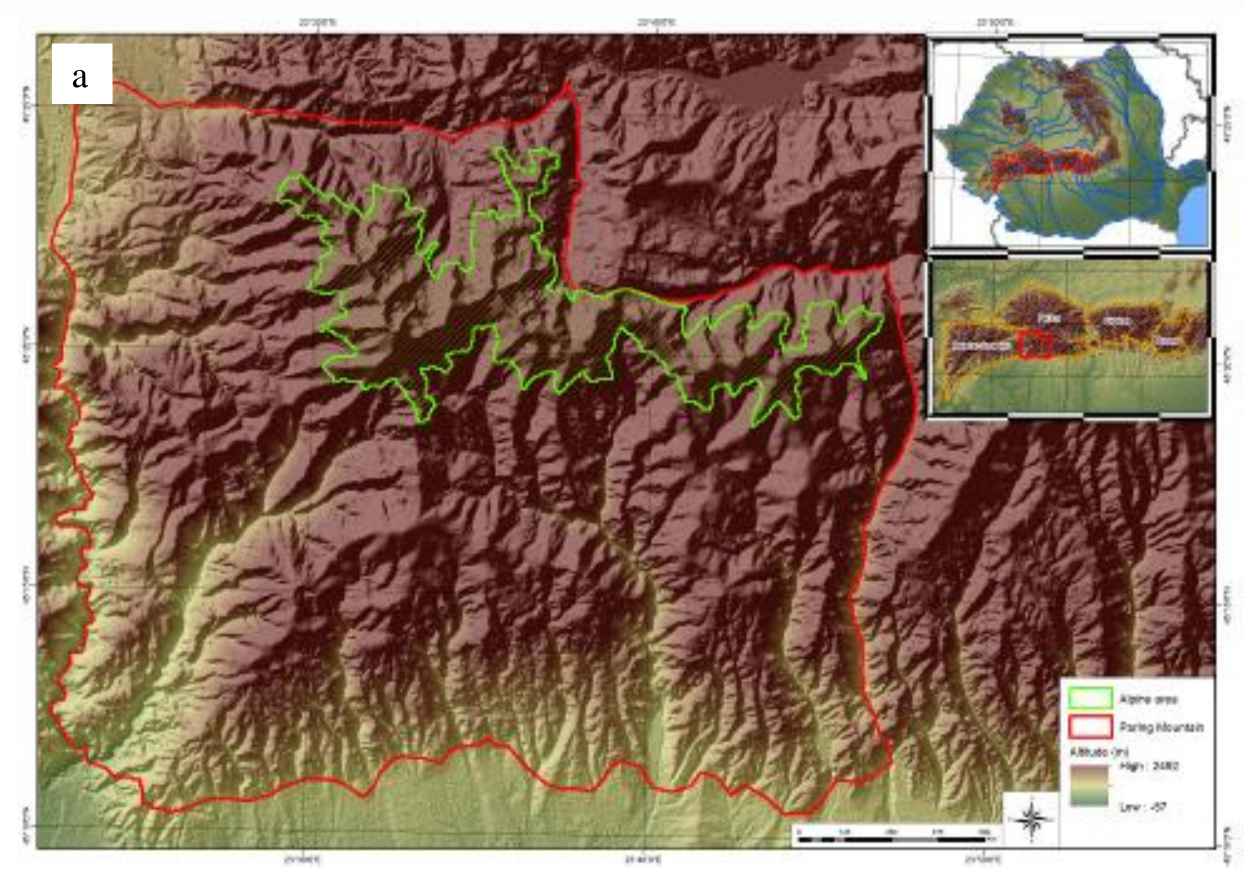


Fig. 1 a. **Geographic location of the Parâng Mountains**

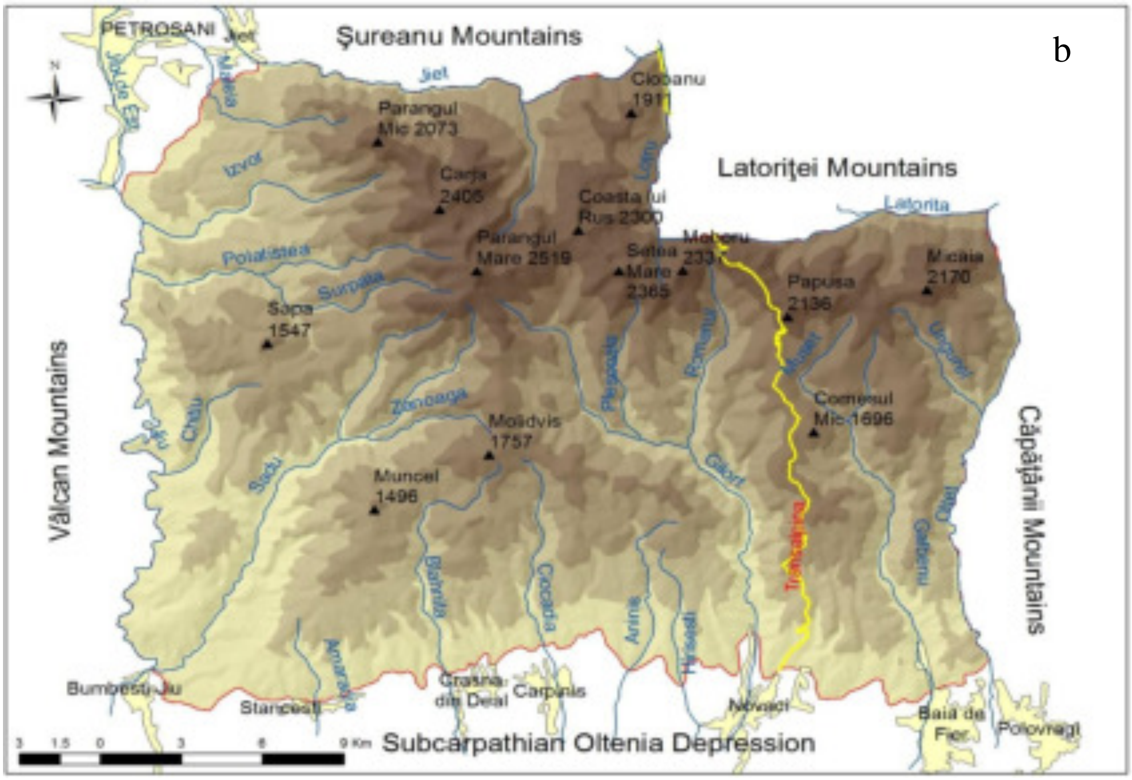


Fig. 1 b. **Geographic location of the Parâng Mountains**.

3. Data and Methodology

Various materials were used for the achievement of this study: the 1:25 000 topographic map, thematic (geological, pedological, vegetation) maps, contour lines extracted from the numerical terrain model (DEM), climatic data over a 20-year interval (1982-2002) from the weather stations in the area or the surroundings existing in the archive of the National Meteorological Administration, 1:5000 orthophotoplanes, tourist maps. The achieved stages aimed at: reading dedicated papers from the specialized literature, analysing the thematic maps, numerous field campaigns during which mapping of the alpine level was performed on the 1: 25 000 topographic map, processing charted elements in the 1:25 000 topographic map were processed using Microsoft Excel, on-field measurements and observations, taking pictures, processing weather data in ArcMap-GIS and Corel-Draw, receiving information from the Gorj and Hunedoara Mountain Rescue teams. The most difficult phase was the fieldwork mapping of the current processes, taking into account the difficult weather conditions at this stage and the physical effort required in high mountain; those have been worked on colour topographic maps at 1: 25,000 (copies, scale 1: 1 thereof) by going through the entire subalpine and alpine area of the mountain, mapping the current geomorphological processes by colour conventional signs; the resulting maps looked like ones in the Fig. 2.

4. Analysis and results

4.1. Morphodynamic potential

Geological factors. From the geological standpoint, in the alpine level of Parâng Mountains, crystalline schist rocks are remarkable (the central-western crest, west of Parângul Mare peak, the eastern summit, east of Păpuşa Peak, Sliveiul Mare glacial cirque within the Jieț complex), granitic intrusions (the central crest, between Parângul Mare and Urdele peaks) and intrusions of crystalline limestones, pegmatite rocks and green tuffogenic rocks (Găuri cirque, within the Lotrului complex) (Fig. 3). Generally, these are hard and semi-hard rocks that may crack and disintegrate in the climatic conditions within the alpine level. The rocks resistance to the action of the external agents is revealed by the rock strength index. These rocks are generally hard and semi-hard, which may crack and disintegrate in the climatic conditions of the alpine area. The crystalline schist, granite, unspoiled and non-cracked limestone are hard rocks with a medium hardness of 5-6 (Mohs scale) and a strength coefficient of 8-15 (Protodiaconov scale), (Stamatiu, 1962). Semi-hard rocks (3-5 hardness) and soft rocks (2-3 hardness) are considered those with an advanced degree of cracking and deterioration.

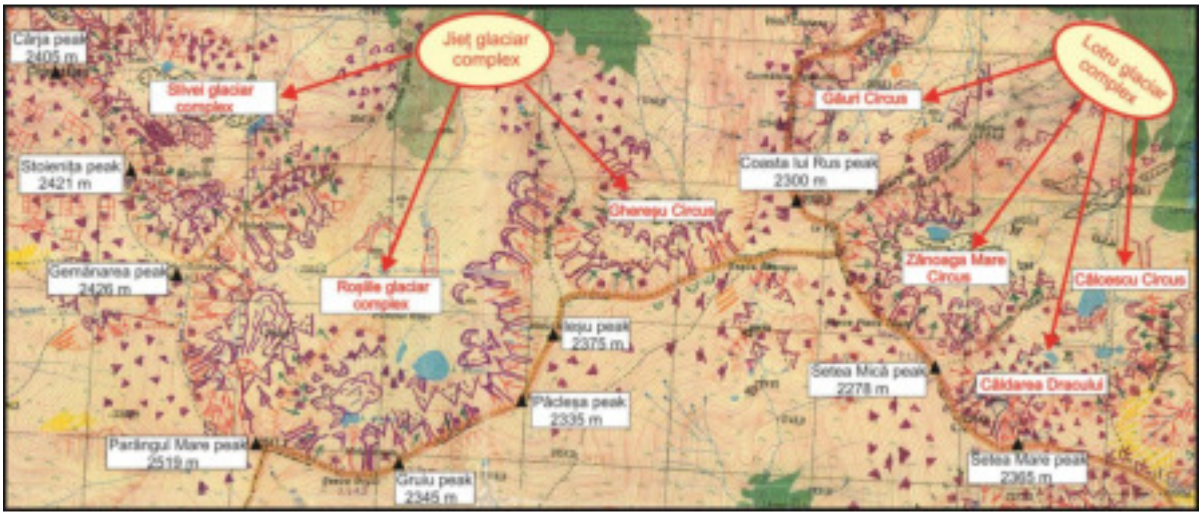


Fig. 2. **Topographic map in the fieldwork phase**

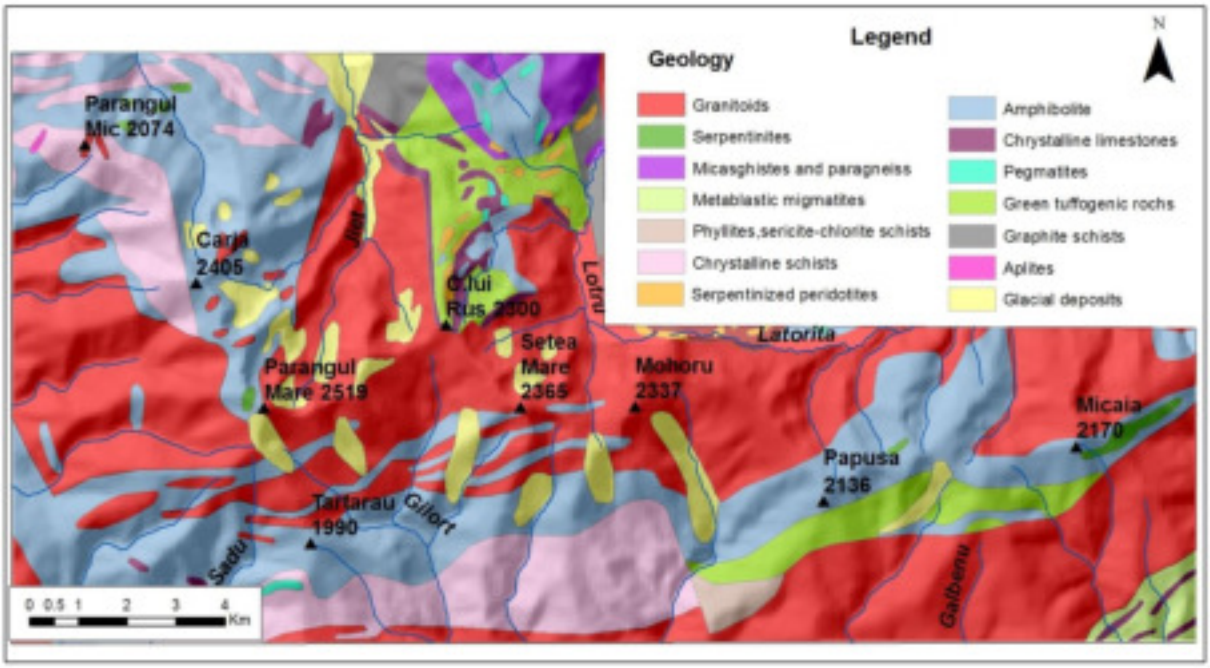


Fig. 3. **Geological map of the alpine level within Parâng Mountains (after the Geological Map, scale 1: 200 000, sheet 26 Orăştie and sheet 33 Tg. Jiu, 1968)**

Geomorphological factors. From the geomorphological standpoint high relief energies are remarkable of 300 – 400 m and over 400 m (in the central and western part) but also of 200 – 300 m (in the eastern part). The fragmentation density keeps high, more than 8 km/km2, within the glacial complexes Jieț and Lotru, displaying values of 6 – 8 km/km2 and 4 – 6 km/km2 towards the borders of the alpine area, both in the west and in the east. This is an indicator expressing the capacity to drain the water from precipitation in a shorter or longer time interval, which induces a high morphodynamic potential. Slopes are steep, reaching 20 – 30º and over 30º (on one side ad the other of the main crest and on the mountain sides of the glacial cirques), with slopes less than 15º steep (along the interfluvial summits and on the bottom of the glacial cirques) (Fig. 4). The declivity of the mountain sides influences the present-day morphodynamic potential, favouring the prevalence of certain processes or others. Thus, the steep inclines favour the activity of the cryogenic agents, while the mild inclines – the nival modelling. The slope is one of the determining factors in the acceleration of some present-day geomorphological processes, like avalanches, collapses and rock falling.

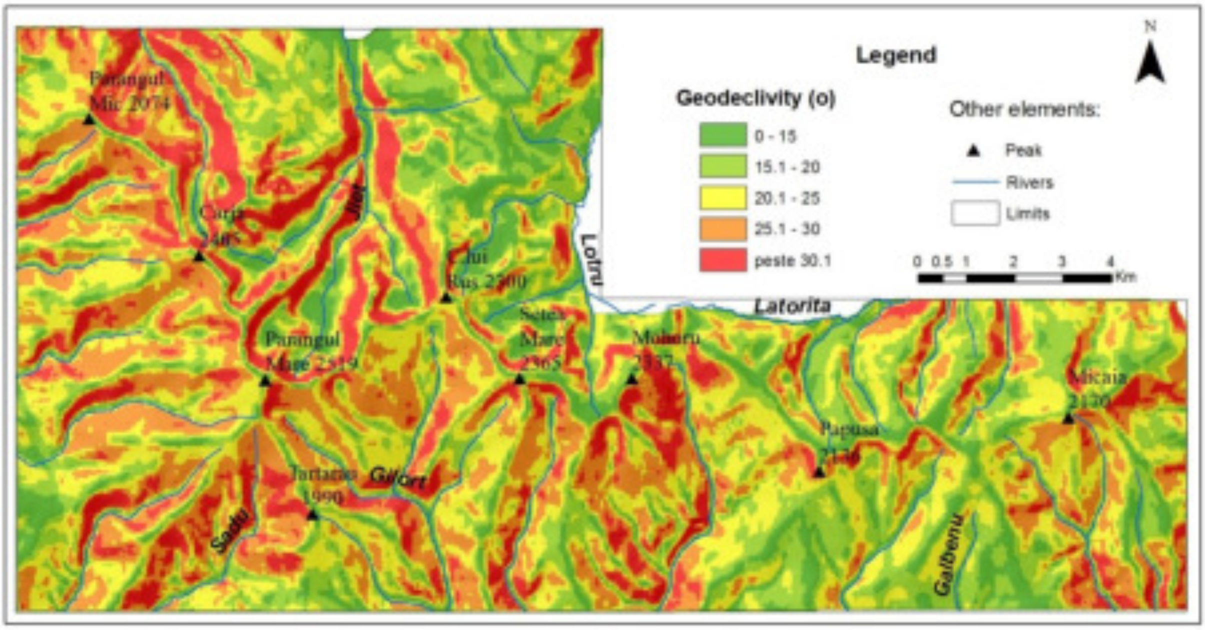


Fig.4. **Map of geodeclivity in the alpine level of Parâng Mountains**

Climatic factors. The analysed area unfolds in the circumstances of the alpine climate, within one cold and one very cool thermal stage and at the same time in one moderate-nival and one nivo-pluvial precipitation level respectively. In order to analyse the climatic parameters that condition the start, rhythm and intensity of certain present-day geomorphological processes, we used climatic data from the N.M.A. Archive and from three weather stations located in the Southern Carpathians, over a 20-year period (1982-2002) (Table 1).

Table 1. **Main climatic parameters characterizing the alpine level of Southern Mountains**

Weather station	Altitude/ exposure	Mean annual temp.	Min. abs. Temp.	No. of freezing days	Mean annual precip. mm	No. of days with rain
Omu Peak	2504 m/-	-2.3oC	-35.5oC	254	1136	55.2
Bâlea Lake	2038 m/ Northern	0.3oC	-27.4oC	208	1134	99.7
Parâng	1585 m/ South-Western	3.6oC	-23.5oC	160	938	86.6

Weather station	Altitude/ exposure	Max. precip. in 24 hrs.	No. of days with snow	No. of days with snow layer	Snow layer depth (cm) Mean/Max
Omu Peak	2504 m/-	83.5	111	220	32 / 132
Bâlea Lake	2038 m/ Northern	195.6	108	223	60.7 / 158
Parâng	1585 m/ South-Western	70.2	65	151	15.7 / 52

**data processed from the N.M.A. Archive (1982-2002)*

The role of the climatic factors is very important in the evolution of present-day dynamics, since they influence the type and intensity (rhythm, magnitude and duration) of every process, the climatic factors being considered initiating factors of many processes (congelifraction, avalanches, surface washing, streaming, ravine-formation, torrentially).

Analysis of the Peltier (1950) diagrams applied at weather stations situated at various heights in the Southern Carpathians (Voiculescu 2001; Grecu *et al.*, 2011), shows that the stations located above 2000 m (Omu Peak – 2505 m and Balea Lake – 2038 m) are within the area the most exposed to gelifraction, mass displacements and eolization and also within the area where alteration and fluvial erosion occur with a moderate/ weak intensity. Thus, it is proved that the intensity and periodicity of those geomorphological processes are direct influenced by the climatic factors. Experiments and temperature data sampled in the alpine area within the Bucegi, Făgăraş and Retezat Mountains in places with diverse slope and exposition show that the thermal values display function of slope and exposition (Vasile *et al.*, 2014, Vasile, 2015).

However, the periglacial processes vary in surface function of the rock type and vegetation cover degree, according to our in-situ observations and mapping.

Biotic and pedological factors. The vegetation of the alpine summits is not unitary, displaying differentiations with respect to the environment conditions between the upper and the lower parts of those sectors, which trigger the existence of totally different vegetation within the sub-alpine and alpine level respectively. The main components of the sub-alpine vegetation are: the alpine bushes made up of boreal-alpine and alpine shrubs, (mountain pine or juniper, dwarf juniper, mountain alder, snow rose), shrubs (blueberry bushes, cranberry), lawns made up of graminaceae.

The alpine level shelters the vegetation situated on the highest summits and peaks of this mountain massifs, displayed as islands at altitudes higher than 2200 – 2300 m a.s.l. (in fact, the lower limit of this level is the line up to which the juniper – Pinus montana – climbs in isolated samples. This level is characterized by dwarf shrubs and alpine lawns (association of small-size grass, dwarf wooden plants, sub-shrubs and associations of plants grouped in spherical shapes) (Fig. 5).

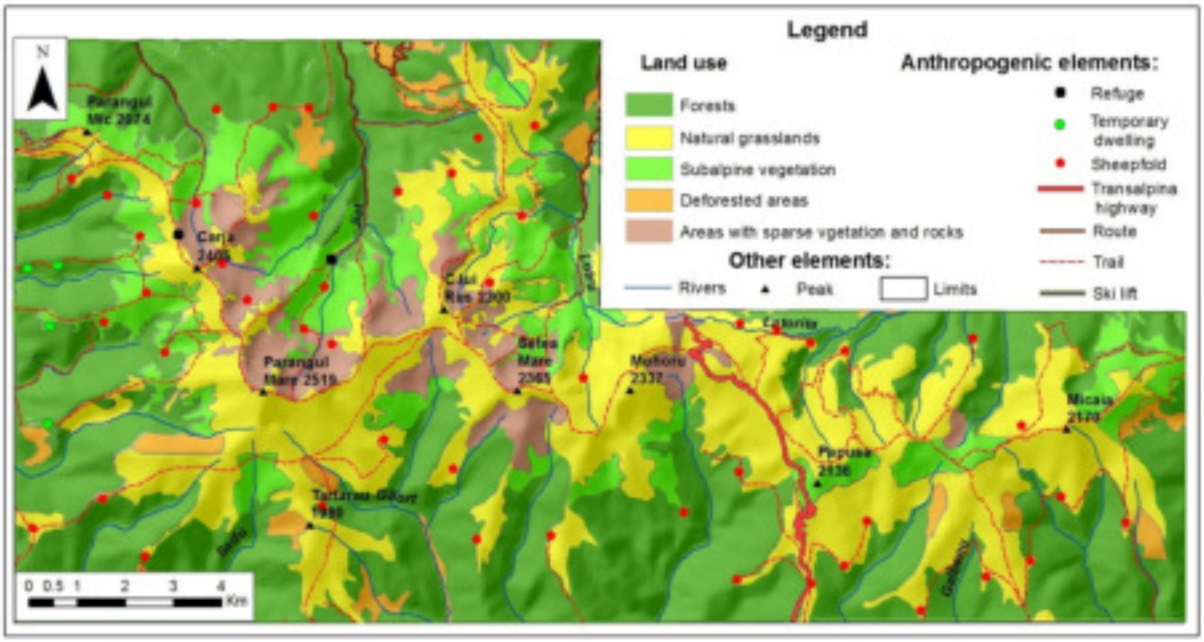


Fig. 5. **Land cover / land use map (after CLC, 2000) and the anthropic impact in the alpine level of Parâng Mountains**

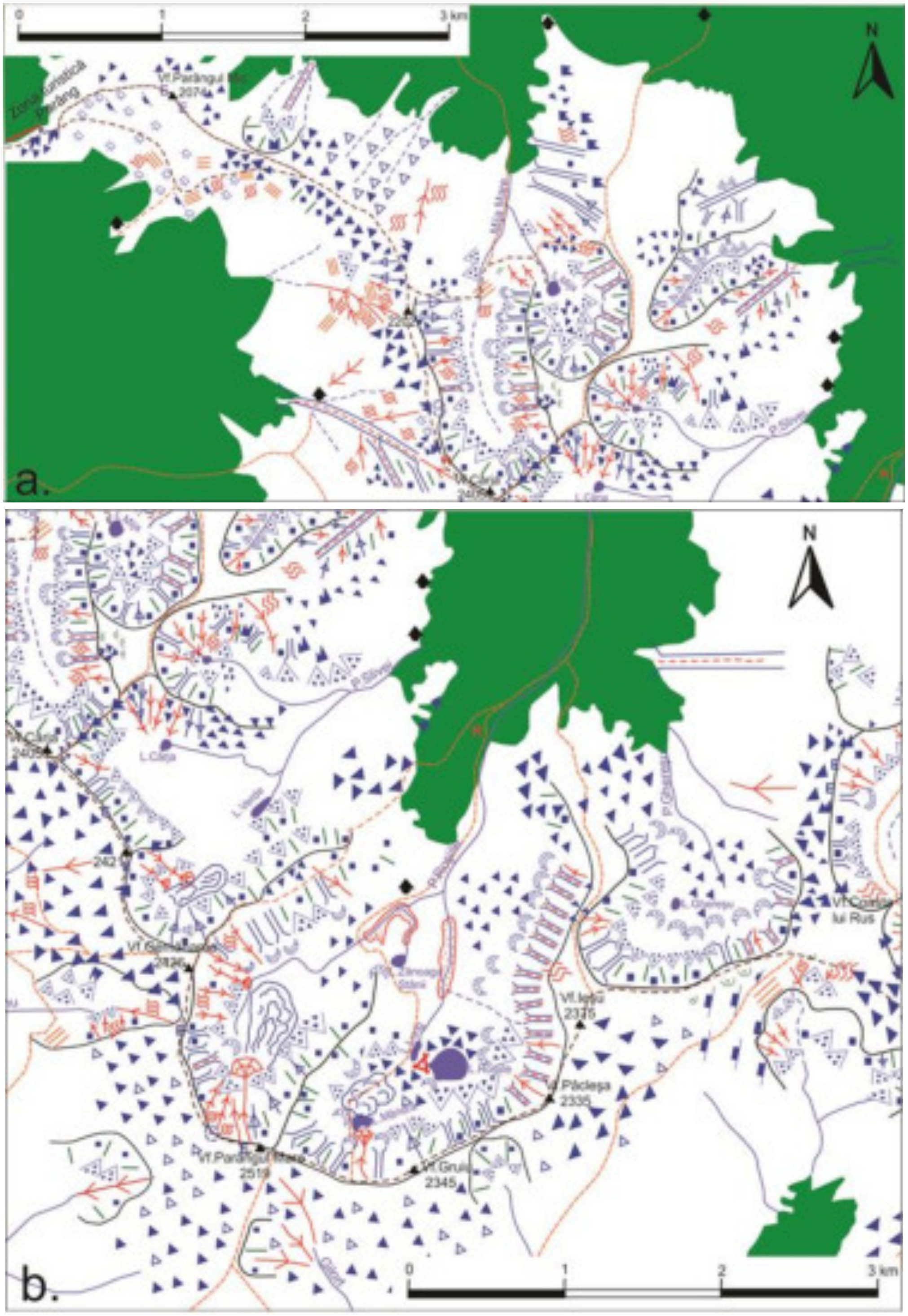
The soils within the analysed mountain environment belong to the spodosols class (represented by podzols developed under the resinous forests vegetation, at their upper limit, or under the juniper associations, from the lower alpine stage), umbrisols (represented by humico-silicatic soils, developed under the vegetation of the alpine lawns and primitive soils (represented by lithosols, thin soils undergoing the initial formation stage, on the heavily inclined mountain sides, on recent detritus, on steepness areas, in the upper part of the narrow summits and along the crests).

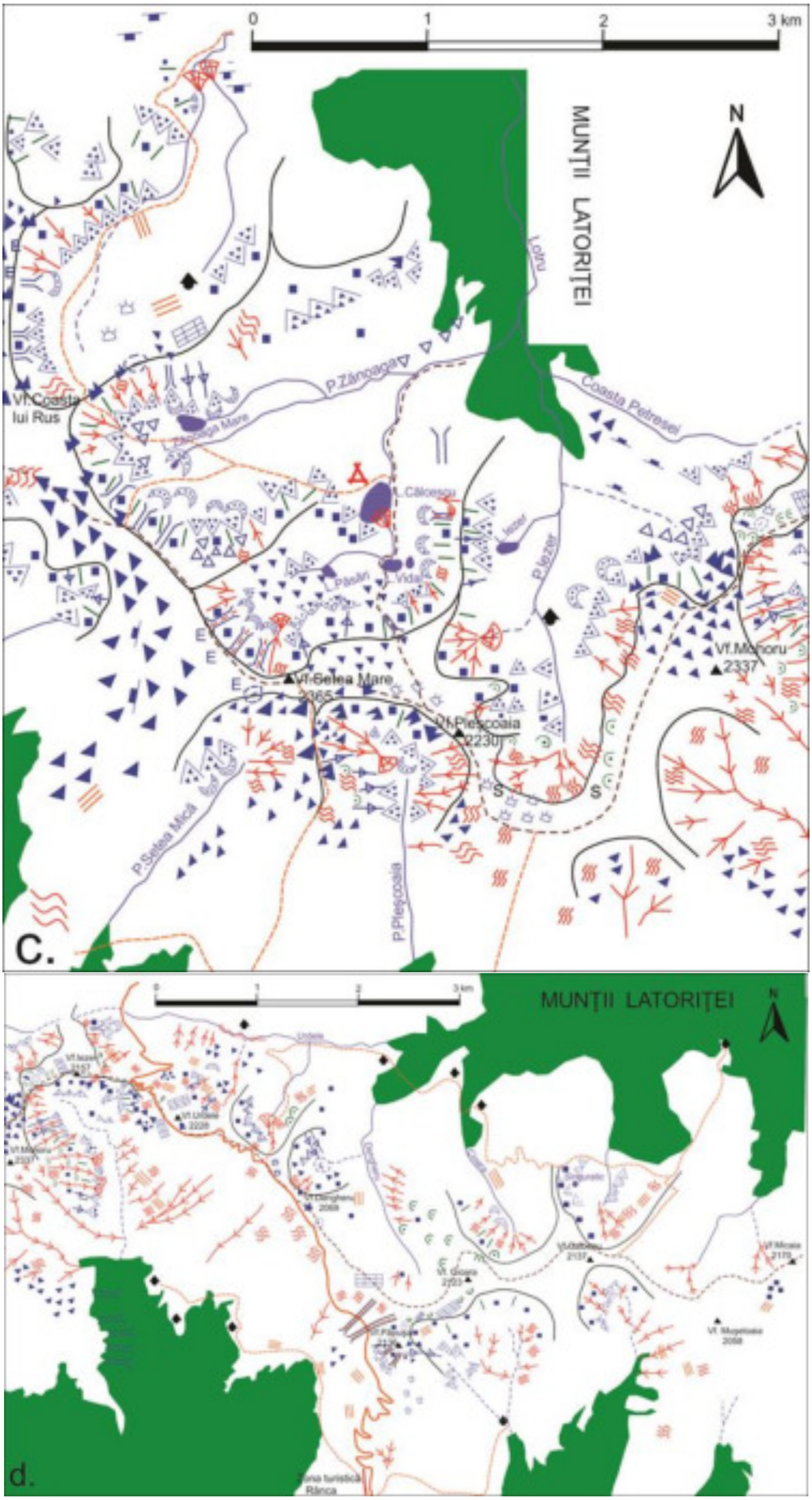
Anthropic factors. The anthropic activity is a determining link in the geographic system of the Parâng Mountains alpine level. The involvement of man in morphogenesis through its multiple and diverse activities influences the present-day morphodynamic, being also a morphogenetic agent (Urdea, 2000). In the alpine level of Parâng Mountains, the anthropic activities which cause imbalance within the environment are tourism and grazing (Fig. 5).

Excessive grazing marks its results through centres of erosion (in Dengheru, Iezer and Urdele Mountains) and through the destruction of the vegetal carpet. With respect to the other forms of aggression on nature, tourism acts through enhanced construction activity in Rânca – Corneşul Mare and Parângul Mic sections, uncontrolled rock exploitation in Păpuşa – Dengheru section which triggers imbalance in the mountain sides, acceleration of the erosion along the paths and their deepening, some of them becoming ravine-like juniper cutting for fire etc. Building communication ways and especially the Transalpina main road negatively impacts the environment. To cut such roads through, clearing necessarily takes place along with destabilizing the base of the mountain sides and activating much more active morphodynamics oriented to streaming, torrentially, collapses and landslides.

4.2. Geomorphological processes – identification and mapping

In identifying and mapping the present-day geomorphological processes and the resulting landforms, we tracked the genetic criterion (Grecu, 2007; Grecu & Palmentola, 2003). We thus have identified in the alpine level of Parâng Mountains the above types of processes and landforms: periglacial and nival, wind, gravitational, pluvial and torrential, fluvial, biogenic and anthropic (Fig. 6 a, b, c, d) (Săndulache, 2010).

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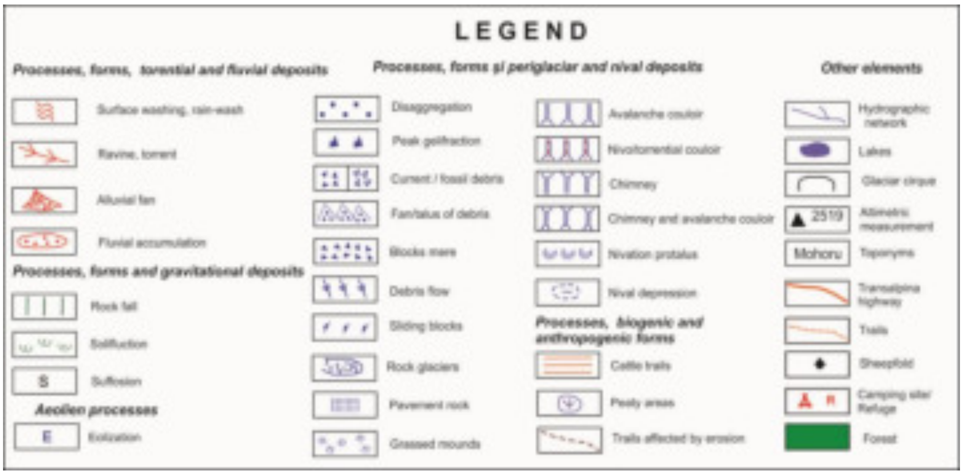

Fig. 6. **Present-day geomorphological processes in the alpine level of Parâng Mountains: a. Western section; b. Jieț glacial complex; c. Lotru glacial complex; d. Eastern section (Săndulache, 2010)**

4.2.1. Periglacial processes

These processes encompass phenomena connected to the action of freezing and thawing and act through gelifraction, periglacial elevation and soil running. The periglacial morphogenetic environment is encountered there where the influence of the freezing –thawing oscillations prevails (Tricart, 1963).

Congelification is the process caused by the freezing and thawing of the water in the cracks of the rocks and by insolation. It is conditioned by the oscillations of the temperature through 0ºC. Such oscillations act intensely in frost-cleaving rocks. As a result, gelifraction occurs, *i.e.* the mechanical process of rock fragmentation (disintegration), as more than 125 congelification cycles occur yearly in Parâng Mountains (Urdea & Vuia, 2000) (Fig. 7).

”At present, frost-cleaving processes act with a lower intensity and affect the crests and the high summits. During the Pleistocene, those processes were affecting a wider area, in the lower part of the mountain, the proof being the old detritus from the foot of the mountain, now covered by vegetation. Therefore, the disintegration forms take the aspect of ***residual relief*** (*sharp crests* – Cârjei indentation, Silveiului crest, the main crest between Cârja – Stoienița – Gemănarea – Parângul Mare – Gruiu – Ieşu – Setea Mare peaks, *pyramid-shaped peaks* – Cârja, Parângul Mare, Gruiu peaks), or ***accumulation forms*** represented by detritus resulted from the accumulation of big-sized materials. The main landforms resulted through the disintegration process are the gelifraction mountain sides (Piciorul Tecanului), *rivers of rocks, torrents of rocks, detritus trains* (Circul Mija) (Fig.8), widespread all over the high area of Parâng Mountains” (Săndulache, 2010, pag. 60).

Fig. 7. **Rock disintegration process (Culmea Stăncior) (August 2008)**

Fig. 8. **Detritus trains in Mija Circus (August 2005)**

Soil creep is a periglacial process that takes place in the area bordered by the annual isotherm of 3ºC, *i.e.* as a rule at an altitude higher than 1600 m a.s.l. (Voiculescu, 2000 b). The occurrence of characteristic landforms are *solifluxion terraces* (Parângul Mare – Mândra, Pleşcoaia – Mohoru Summit) and *solifluction lobes* (encountered in the western mountain sides in the Piatra Tăiată – Setea Mică, Urdele – Dengheru – Păpuşa, Galbenu – Pristosu sections).

The ***periglacial elevation*** consists in the upward pushing of the blocks stuck in the over-moisten soils due to the freezing-induced tensions, which direct those blocks with the long axis in the vertical (Băcăuanu *et al.*, 1974). This process is involved in the genesis and evolution of the *periglacial pavement, reptant blocks* (Fig. 9) and of the *periglacial mounds* (Fig. 10) (Urdea *et al.*, 2002). "Grassed mounds are present on the summit between Setea Mare – Pleşcoaia – Mohoru peaks, on Piciorul Păpuşii, Dengheru – Urdele section, under Dengheru saddle. North of Păpuşa peak typical periglacial pavement develops, and reptant blocks are widely spread in the upper level of Parâng Mountains" (Săndulache, 2010, pag. 61).

Fig. 9. **Sliding block in Găuri Circus (August 2008)**

Fig. 10. **Grassed mounds (Mohoru – Setea Mare saddling) (August 2008)**

4.2.2. Nival processes

"These processes are favoured by the snow persisting over long intervals (more than 200 days in a year in the high area, with a thickness exceeding 7-8 m in the sheltered zones). Snowfalls are a climatic phenomenon recorded in this mountainous environment from September (with a snow depth of 3-10 cm in the first 10-day period of October) to the spring months (between 13 and 23 cm in the first 10-day period of April), with a maximum depth in December – March, when the snow layer is deeper than 65 cm, even reaching 100 cm).

There is no date of the first snow in the alpine and sub-alpine level respectively. Its occurrence is probable even in the summer months. At altitudes higher than 1900 m a.s.l. the snow layer persists until later than the first half of May being present during 180-200 days annually. The areas with a northern exposure within the alpine domain preserve snow patches persisting from one year to the following. There, the snow accumulates non-uniformly because of the landforms and the wind. There are sections (crests) almost devoid of snow or sectors (sheltered areas, nival micro-depressions, lacustrine cuvettes), where the blizzard causes the snow to accumulate with depths that may reach even 7-8 m. The modelling action of the snow acts through ***slow nival settling and erosion processes*** which create *nival micro-depressions* (Fig. 11) (beneath Setea Mare peak, on the summit between Ieşu and Piatra Tăiată peaks) and through ***fast nival erosion processes*** materialized in avalanches. Their occurrence is favoured both by characteristics of the landforms (the existence of couloirs and slopes more than 30º steep) and by the climatic conditions (abundant snowfalls, duration and depth of the snow layer). Repeating year after year, avalanches favour the formation of *avalanche couloirs* and lead to the formation of specific accumulation micro-relief - *clout-shaped nival accumulations* (nival moraines) through the accretion of the eroded material at the foot of the mountain sides (Fig. 12). Avalanches are widespread throughout the high area of Parâng Mountains, on the mountain sides of the glacial cirques. When avalanches are massive, they exceed the upper limit of the forest, which avalanches modify, creating couloirs in the forest, through uprooting trees (Ţapu, Slivei, Roşiile summit)" (Săndulache, 2010, pag. 61).

In the alpine level of Parâng Mountains, the most frequent avalanches occur along slopes with a 20º-50° incline, existing in most of the mountain sides within the glacial cirques and valleys but also along the largely open mountain sides, where avalanches are wide and display surface features (beneath Coasta Păpuşii, on Piciorul Tecanului etc). The territorial distribution of the snow layer is non-uniform, varying function of the peculiarities of the active surface (mostly the presence or absence of non-homogeneities) and of the wind (owed to its intensity and direction). The snow layer is very deep, especially in the negative landforms, whereas on the convex surfaces it is much thinner.

Fig.11. **Nival depression west of Parângul Mare peak (June 2005)**

Fig. 12. **Avalanche couloir and nival protalus in Câlcescu circus (August 2008)**

"The above-displayed characteristics of the snow layer can be synthesized in three examples of nival profiles obtained on 15 February 2009 around 13.00 LT in the area of Parângul Mic Summit. This summit is west-east oriented, with altitudes in excess of 2000 m a.s.l., being characterized by the existence of the two mountain sides (with a northern and southern orientation respectively), prone to wide avalanche occurrence in the upper part, channelling however along certain couloirs when they exceed the upper limit of the forest"(Fig. 13).

The summit is crossed by a touristic crest path and by an alternative which crosses the median part of the southerly-exposed mountain side, along a contour line situated at altitudes of 1850 – 1900 m a.s.l.

Profiles were performed at various altitudes and exposures, after a three-day spell with precipitation: profile no. 1 (Fig.14), profile no. 2 (Fig. 15) and profile no. 3 (Fig. 16).

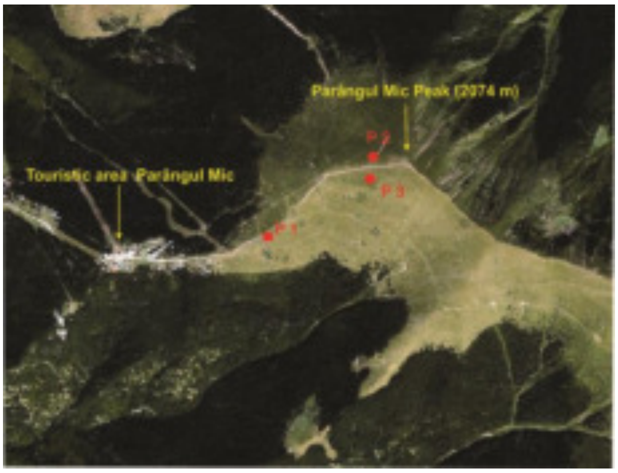

Fig.13. **Location of the nival profiles performed on Parângul Mic summit on a satellite image (www. wikimapia.org)**

Fig. 14. **Nival profile no. 1 (Săndulache, 2010)**

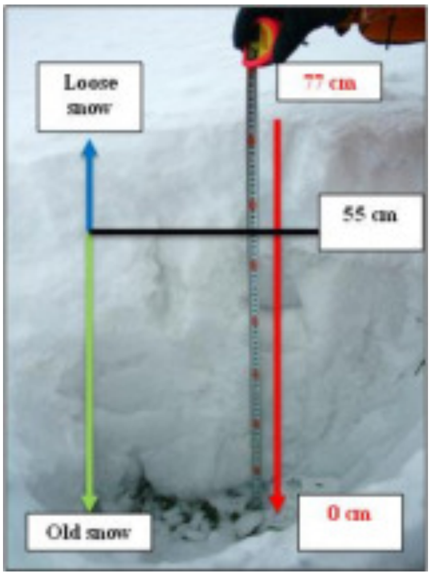

Fig. 15. **Nival profile no. 2 (Săndulache, 2010)**

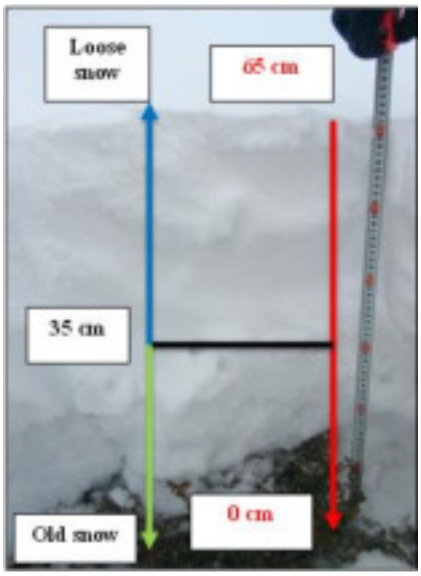

Fig. 16. **Nival profile no. 3 (Săndulache, 2010)**

Nival profile no. 1 was performed on the interfluve, at an altitude of about 1830 m a.s.l. situated lee-side, with a southern exposure. The snow layer was 110 cm deep, exclusively made up of fresh, loose snow.

Nival profile no. 2 was performed on the windward mountain side having a northern exposure, at an altitude of about 1960 m a.s.l. The total snow layer depth was 77 cm, being made up of old, hard snow between 0 and 55 cm and of fresh, loose snow between 55 and 77 cm (22 cm).

Nival profile no. 3 was performed on the southern mountain lee-side of the summit, at an altitude of about 1930 m a.s.l. The total snow layer depth was 65 cm, 35 cm of which being hard, old snow (between 0 and 35 cm) and 30 cm of fresh, loose snow (between 35 and 65 cm).

It can be noticed how the above-presented elements considered triggering factors for avalanches are found in the analysis of these profiles: the different exposure makes the depth of the frozen snow higher on the northern slope (50 cm) than on the southern one (35 cm), where the solar radiation is more intense, which causes the snow to melt. Also, on the days before performing the profiles and on the very day of the activity precipitation fell and the prevailing wind was northerly, which caused the snow to be drifted on the northern, windward mountain side, and fresh snow layer accumulated, 22 cm deep, whereas on the southern mountain side, 30 cm of fresh snow accumulated. However, under such circumstances, fresh snow avalanches could occur irrespective of the mountain side exposure, given that the snow was more than 20 cm deep and the slope in question is steeper than 30º. Yet, there was no significant risk of avalanche occurrence" (Săndulache, 2010, pag. 124-126).

4.2.3. Gravity processes

Rolling and collapses belong to the category of brisk motions developing from the inclined landforms, being accountable for the displacement of disintegration products towards / at the foot of the mountain sides. Such events are favoured by very steep mountain sides (inclination in excess of 40º) of the glacial circuses devoid of vegetation. They are frequent in Groapa Seacă a Mijei and Mija, Slivei, Stoieniţa, Gemănarea, Mândra, Roşiile, Zănoaga Mare, Găuri, Căldarea Dracului, Urdele glacial cirques and not only (Fig. 17).

4.2.4. Pluvial and torrential erosion processes

These processes are determined by large precipitation amounts and contribute to the detailed modelling of the landforms through processes of *surface washing* (pluviodenudation) and *rain-wash*. Those are the most common of the present-day processes which occur over most of the mountain environment. *Torrential processes* are based on rain-wash and its effects and represent a widespread present-day geomorphological process, whose results are easily noticeable in the landscape. They are determined by rich precipitation during the summer months and by the slow melting of the snow accumulated in the torrential reception basins which cause the formation of nivo-torrential bodies.

Fig. 17. **Roşiile glacial circus wall affected by numerous scars resulted from the detachment and collapse of disintegrated blocks (August 2008)**

"Areas with diffuse erosion (surface washing, rain-wash) are very frequent in the area of Parâng Mountains, typical sections being encountered on Muntele Scurtu – Parângul Mic, on the mountain sides of Mija I cirques, of Lacul Înghețat, Zănoaga Gemănării, Zănoaga Mare – Gâlcescu, Setea Mică – Pleşcoaia, Iezer, Mohoru (Fig. 18 a), Cioara, Bălescu (Fig. 18 b), beneath Ghereşu saddle, beneath Coasta Păpuşii, etc.

In the surface erosion process, the analysis of certain climatic parameters is very important, especially the precipitation-related ones, which are the triggering factor for this process. In this sense, we analysed the number of days with rain, the number of days with certain precipitation amounts and the Angot index. The number of days with rain and the number of days with certain precipitation amounts are indicators of the erosion processes intensity, contributing to the fragility state of the systems. We used climatic data from Bâlea Lake weather station, located in similar conditions with respect to those from the alpine area of Parâng Mountains (Fig. 19 a, b).

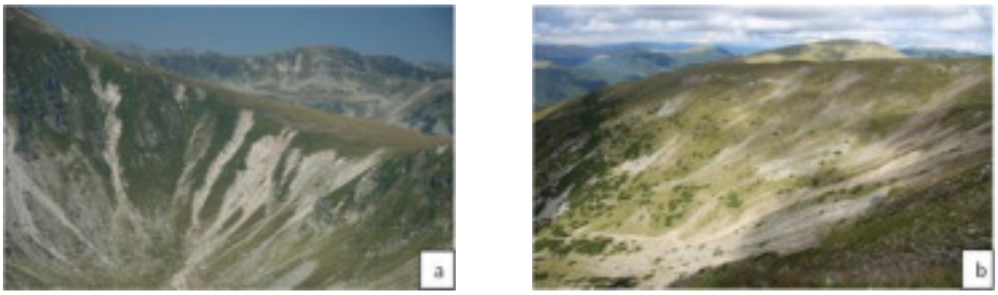

Fig.18. **Surface washing, rain-wash and ravining in***:*
(a) Gaura Mohorului and (b) Bălescu Circuses (August 2008*)*

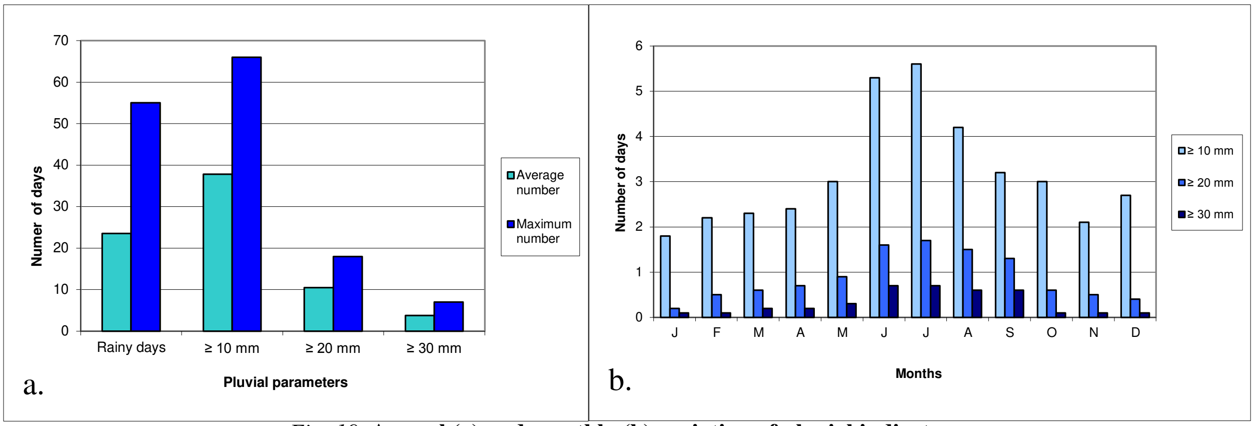

Fig. 19. **Annual (a) and monthly (b) variation of pluvial indicators**
(data processed from the N.M.A. Archive 1982-2002)

It can be noticed that the highest number of days with rain and various precipitation amounts is recorded in the summer months (June – August).

Another indicator of the precipitation regime, important to the modelling process and to the various economic activities specific to the mountain area is the value of the *Angot precipitation index* which helps us determine the rainy or droughty character of each month taken apart. Values greater than one point at rainy months, whereas the sub-unit ones point at droughty months. Months displaying values close to one may be considered normal with respect to moisture. Figure 20 a. discloses that the rainiest months are the summer ones, from the May – August interval in the high area of the massif, which causes pluvial erosion to enhance and induce disturbances in the summer seasonal activity within this mountainous environment (tourism, grazing etc.) This is also ascertained by fig. 20 b., which renders the Angot precipitation index computed over the warm interval (May – October) against the cold one (November – April).

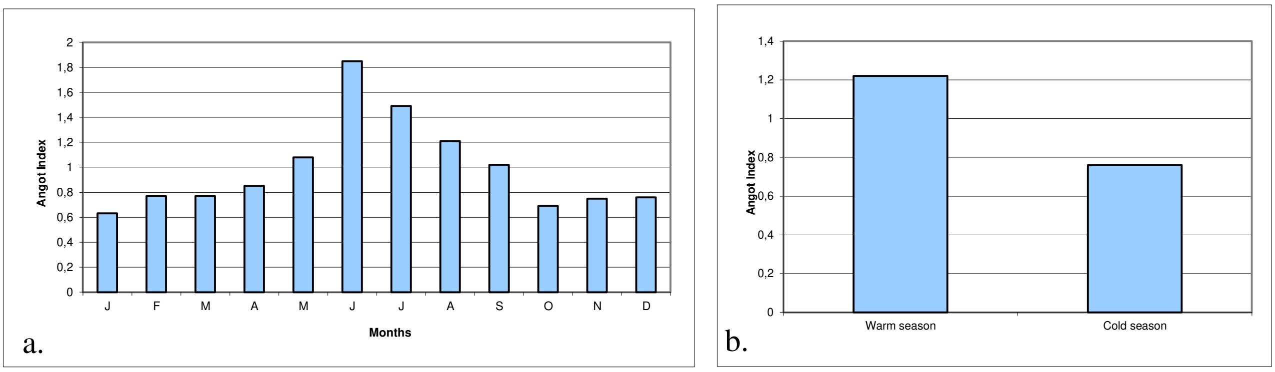

Fig.20. **a. Mean monthly values of the Angot precipitation index, and b. Mean seasonal values of the Angot precipitation index** *(data processed from the N.M.A. Archive 1982-2002)*

When rain-wash enhances evolved forms take shape (*ravines, ruts, torrents*) concentrated on the mountain sides with erosion glacis, on the mountain sides with friable rocks devoid of vegetation at the springheads of every valley. Some of those display large sizes, like the ravine located at the springheads of Iezer brook (Fig. 21): lengths of about 250 m, widths of 30 – 50 m (with a maximum of 55.3 m) and depths of about 15 m. They are located in the wall of Iezer circus, at 2150 m a.s.l. being the unique case in Parâng Massif of the hydrographic network expanding upstream the wall of a glacial circus, a phenomenon reported by Emm. de Martonne in 1907 (Iancu, 1970).

Fig. 21. **Ravines at the springheads of Iezer brook (August 2008)**

Torrential processes are active processes, acting during rainfalls of above-average intensity (torrential rain). "In the alpine environment, torrential rainfalls exceeding 30 mm in 24 hrs. frequently occur, reaching 195 mm (on 3 June 1988 at Bâlea Lake weather station). The highest intensity of torrentiality is specific to the summer season " (Săndulache, 2010, pag.148-150).

Within the torrential bodies, the erosion and transport power is high, and when other processes, especially nival, aggregate, large size debris cones are formed. Although the possibility that the torrential network develops exists everywhere, except for the surfaces covered by seas of blocks, torrents are mostly concentrated on the mountain sides of the glacial cirques and valleys. Torrents on the rocky mountain sides develop there where the declivity is in excess of 40º with lengths greater than 100 m, as are those from the central high area, devoid of vegetation or only barely covered by it. There, torrents display a leaking channel, with a V-shaped transversal profile (Răboj, 2009).

4.2.5. Other geomorphological processes

Eolisation acts having the wind as agent, occurring in any season but most efficiently in winter (especially from December to February) but also during the months with scanty precipitation (March – April, October – November and to a lesser extent September) (Mihai, 2005). It contributes to enhancing disintegration and to *rock pavements* formation.

Fluvial processes act continuously, with different season to season intensities, with a highlight on both the ***in-depth and lateral erosion*** and ***accumulation*** however not remarkable through severe effects in the morphodynamics of the alpine geomorphological landscape of Parâng Mountains. The fluvial erosion has a small overall intensity in the alpine stage. All the rivers within the upper reach, characterized by steep slopes, markedly erode moraine deposits from the bottom of the valleys then become fainter when reaching the tough substratum. Accumulation is only possible in the narrow sections of the silted glacial stairs, where small meadows are created, where the river gets meandered (Zănoaga Stânii, Slivei and Găuri brooks).

Animal paths are 10-30 cm wide stair-shaped micro-landforms. The most typical of those are encountered in the eastern part of the massif (Culmile Urdele, Dengheru, Păpuşa, Bălescu, Muşetoaia) but also in the western part (Scurtu – Parângul Mic Section).

Anthropic processes act through eroding and deepening the touristic paths and as a result of constructing the Transalpina highway in the high area of these mountains.

5. Conclusions

The way present-day geomorphological processes act, their intensity degree and frequency are determined by altitude, which yields the climatic staging, by the climatic conditions, the morphometric and morphogeographic characteristics of the relief, by lithology and geological structure. The elaborated cartographic materials and the in-situ observations show that the geomorphological agents and processes are spatially associated, with differentiated action, function of the mentioned factors combine, an important role being held by the dynamics of the climatic elements. A direct relationship is noticed of the spatial extent of the periglacial with the upper limit of the forest. Thus, the periglacial stage is situated beyond the upper limit of the forest are stretches in the altitude up to the higher mountain crests (Răboj and Codreanu, 2008). As regards the mean annual air temperature, the 3ºC isotherm delimitates the periglacial stage, closing the areas with periglacial processes. This thermal value delimitates the maximum expansion of the periglacial domain, at its contact with the forest domain (Voiculescu, 2000 a, 2002). On the northern slopes, the upper limit of the forest reaches altitudes of 1800-1900 m.a.s.l., which causes the periglacial stage to expand less with respect to surface compared to the southern slopes, where the upper limit of the forest is situated at 1600-1700 m.a.s.l.

The analysis of the maps highlights the high frequency of the periglacial processes on the northern slope, spatially determined by the quaternary glacial relief, more precisely by the complexes of the glacial circuses from the springs of Jiet and Lotru rivers.

Periglacial relief forms are frequent, *e.g.* the disintegration forms represented both by sharp crests and pyramid peaks (the main crest between Cârja and Setea Mare peaks but also secondary crests like the Cârja or Slivei ones) and accumulation shapes (cones and detritus trails) present at the basis of Mija, Slivei, Mândra, Ghereşu, Găuri, Zănoaga Mare, Pleşcoaia and Gaura Mohorului glacial circuses. Soil running, grassed mounds and reptant blocks are present in the central part of the massif, on the Parângul Mare – Mohoru summit but also in the eastern part, on the Urdele, Dengheru, Păpuşa and Galbenu summits. Rock pavements are encountered in the eastern section of the massif, nearby Iezer, Urdele and Păpuşa peaks. Avalanche couloirs are very widely spread, being present in glacial circuses. Some of them are markedly expanded, reaching the forest limit (below Cârja peak, the western mountain side of Mija Mare valley, Mohoru summit).

The pluvio-torrential processes and shapes are imposed by the marked precipitation regime within the summer season, when the sum of the fallen amounts reaches 350 mm at Parâng weather station in the June – August interval. Pluvio-torrential shapes are represented by the areas with diffuse erosion (surface washing and streaming), frequent on the southern mountain side of the main summit, between Curtu peak and Cârja, along Pleşcoaia-Mohoru and Păpuşa-Urdele summits but also within the glacial circuses within the eastern section of the massif (Dengheru, Cioara and Galbenu). More evolved shapes (ravines, tracks and torrents) are frequent both in the areas of the central glacial circuses (Slivei, Zănoaga Mare, Gaura Mohorului, Iezer and Găuri) and along the milder summits from the central-eastern part of this mountain massif (Galbenu-Micaia Summit), favoured by the lack of forest vegetation and the intensity of pasture activities. From the in-situ measurements and observations, the amplitude of the torrential shapes reaches lengths of 100-200m for certain torrential corridors analysed within Căldarea Dracului and Găuri circuses and 250 m for the ravine within Iezer circus, situated at an altitude of 2150 m.a.s.l.

Gravity processes imposed by the slope are frequent within the glacial circuses and in the upper part of the glacial valleys, on the mountain sides steeply inclined and devoid of vegetation, where disintegration processes are remarkable. Rock falling and rolling from the mountain sides of Mija and Slivei are frequent, developed on amphibolites, but also in Mândra, Roşiile, Zănoaga Mare and Căldarea Dracului circuses, developed on granitoids. At the basis of the circuses, detritus foot or cone shapes are formed (very much expanded being those from Mija Mare Circus, Gemănarea, Roşiile, Găuri and Căldarea Dracului).

The dynamics of the present-day processes is the support for the occurrence of certain geomorphological hazards that act because of the conditioning between the environment elements and components.

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