The impact of avalanches upon the anthropic activities, on the Western Slope of the Piatra Craiului Massif

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Key words: avalanches, Piatra Craiului Massif, Western Slope, hazard, anthropic activities
Cuvinte cheie: avalanşe, Masivul Piatra Craiului, Versantul Vestic, hazard, activităţi antropice

Rezumat: Lucrarea prezentată îşi propune analiza avalanşelor ca hazard, identificarea arealelor cu potenţial de producere a avalanşelor de pe versantul vestic al Masivului Piatra Craiului, al principalelor caracteristici şi să prezinte impactul pe care îl au asupra activităţilor antropice. Dispunerea straturilor din flancul vestic al sinclinalului „Piatra Craiului" imprimă caracteristicile morfometrice şi morfografice ale acestora, favorabile formării unei reţele de văi torenţiale dense, speculată de zăpada care îndeplineşte condiţiile de curgere. Activităţile antropice din zonele vulnerabile la avalanşe sunt reprezentate de turism, exploatări forestiere şi mai puţin prin cele pastorale. În întregul areal se întâlnesc cinci refugii turistice şi un număr de 20 poteci turistice marcate, iar potecile nemarcate sunt pe majoritatea văilor şi a brânelor. De-a lungul timpului s-au înregistrat aici, 6 victime umane şi distrugerea unor suprafeţe însemnate cu vegetaţie, situate în lungul sau la baza culoarelor de avalanşă.

1. Introduction

The avalanches are spectacular phenomena which fast and with high frequency, having an immediate impact onto the natural elements and upon the human being himself (Voiculescu, 2002). They represent upon gravitational processes snow and ice which slide or roll downhill, increasing their volume, weight and speed (Grecu, 2006), developing a smashing destruction involving force. They result from the interaction of some climat parameters (abundant solid rainfalls, daily temperature variations, snow stratification, wind direction and intensity etc.), which superposes on a specific morphology (nival microdepressions, valley corridors, lithological or structural discontinuities etc.). The avalanches are natural hazards which can be characterized as risk phenomena when the human being and his goods become vulnerable to them. Due to the specific conditions of inaccessible land and to unfavorable weather, it is difficult to establish their distribution (Maggioni, Gruber, Stoffel). This is why it is important to know the morphological characteristics of the area susceptible to this phenomenon.

In Piatra Craiului Massif the occurence of the avalanches is evidenced by the witness tracks of the avalanche corridors (Constantinescu, 1994, 1996, 2006; Moţoiu, Munteanu, 2006; Munteanu, 2004, 2006; Munteanu, Constantinescu, 2006). Although Piatra Craiului seems to be a massif without an increased risk for the human community, as there is no permanent human locality, some anthropic activities with mountain characteristics (tourism, forrestry and grazing exploitations), represent a potential vulnerability through the frequence and the width of the avalanche areas.

The objectives of the study set as target the avalanches in their complexity, as geomorphological hazard, by the identification of the surfaces with an avalanche potential. The main characteristics that have and knowing the impact upon the anthropic activities, in a mountain area with a large number of tourists, are also analysed.

2. Methodology

The basic problem in the prognosis of the avalanche width is knowing the unfolding area and the space distribution of the snow instability. This is difficult to determine, due to the inaccessible lands (McClung, Schweizer, 1993). The Western Slope of Piatra Craiului Massif also presents some morphological peculiarities, which makes it difficult to be crossed, especially on wintertime. This is why we have set up this study using mainly the data from objectives different field campaigns.

Among the most important there were: the morphologic of the mountainside sectors where avalanches, morphometric or functional elements can occur, and especially the localization of the avalanche deposits. We have paid a special attention to the areas where anthropic activities analyses occurs and to the way in which they can be vulnerable to avalanches.

These field data where occurs for drawing the maps, together with the IKONOS–2004 satellite image and ortophoto (provided by the Administration of the Piatra Craiului National Park), airphotogras and topographical maps at a scale of 1: 25 000, tourist maps, photos. The thematic maps (Fig.2) have been ctraun with the help of ArcView program, and in the end we have set up the map of the anthropic activities within the area where avalanches occur (Fig. 3).

We have also used other data provided by the Mountain Rescue teams of Câmpulung and Zărneşti, by the Administration of the Piatra Craiului National Park, and by the forrestry districts, by the chalet keepers and by the members of some NGO's with activity within this area.

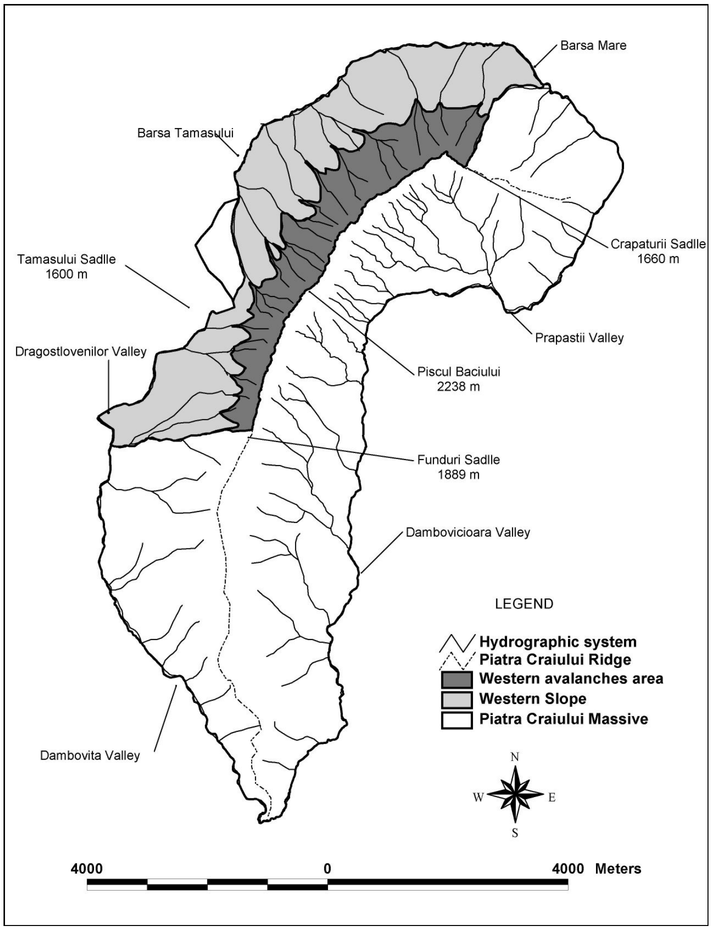

Fig. 1 **The studyed area within the Piatra Craiului Massif**

3. The studied area

Piatra Craiului Massif is situated in the Eastern area of the Southern Carpathians, being formed by a unitary limestone ridge oriented towards NE-SW, with a very steep and asymetrical slope, due to the synclinal structure (Constantinescu, 1996). The ridge of Piatra Craiului represents the highest part of the Western flank of the upstorm drag syncline called "Piatra Mare hogback" (Constantinescu, Piţigoi, 2003) and it is situated between Turnu Peak (1923m) to the North and the Funduri Saddle (1889 m) to the South. It reaches its maximum altitude at Piscul Baciului Peak (2238 m) and it is represented by a series of peaks and mountain saddles, with small basins at the source of the torrential valleys, favorable for the accumulation of snow or for cornices (Fig. 1).

The Western mountainside seems, from any angle, very steep, with structural steps, with a difference in level of over 1,000 m. The limestone rocks (Kimmeridgian – Tithonic) have the strata edges subject to permanent pressure of errosional processes. These rocks are in the upper part, without vegetation, while at the base of the mountainside one can find Cuaternary deposits (Constantinescu, 1994). The whole mountainside is an alternation of narrow valleys with debris flow, sharp edges, steep stops, narrow structural mountain paths, where the current crionival, gravitational, errosional, transport and accumulation processes are very active and dynamic.

On its breadth, there can be evidenced two morphological zones: the North-Western steep slope, between Crapaturii Valley and Umerii Pietrei Craiului, with 15 catchments, each having several tributaries valleys, having a role of avalanche paths. The valleys are deep, and visible from the ridge until the base of the mountainside. Along most of them, or to the contact with the avalanche deposits there are waterfalls, steep parts or ”walls” with a high slope, sometimes vertical.

Towards the Western and the North-Western, of the limestone mountainside, there are, on the main interfluves, a series of erosion remnants, developped at altitudes of 1400-1600 m, where there avalanches also occur. Between Umerii Valley and Urzicii Valley there the Western Steep Slope develops, where 6 hydrographic basins and 13 main avalanche corridors occurs. Here, the valleys slightly define their shape towards the lower part of the mountainside, at the base of the large walls that are immediately under the ridge (Cristea, 1984), being well sketched in the deposit of debris flow and downhill from that.

4. Results and Discussions

The morphological and morphometric features of the whole mountainside provide with favorable conditions for the avalanches. The slopes have average values of more then 35^0, often reaching more then 70^0 or even 90^0 or there are overhung areas (Fig.2).

Due to the slope high declivity, there is no possibility for the snow to accumulate. Only in small basins at the springs of the valleys and in confluence areas, located in narrower sectors there are good conditions. This is why the slope is the one of the factor which allow the avalanche development, even during the snow falling, especially if they are accompanied by winds, when the snow not having enough place to deposit. When the snow quantity is to large to keep its equilibrium, the ridge cornices and edges break, also during the melting period. The exposition is predominantly Northern and North-Western in the Northern half, and Western in the Southern half. Due to this feature, there are differences. Where the Northern and North-Western exposition exist, the snow gathers at each snowfall, as there is not enough time to melt, only at surface. Large avalanches occurs especially on springtime, because the temperature does not sufficiently allow the change of snow quality, especially because of the warming of the base stratum, which generates the bottom avalanches. Meanwhile, in other areas with predominantly Western aspect, avalanches can occur all along wintertime. Due to morphological conditions, the smaller avalanches form on other secondary valleys or around all Western isolated remnants. They can start from any wall, even where forrest vegetation exists. The anthropic activities can develop in or next to areas with an avalanche risk, thus becoming vulnerable to avalanches (Hervas, 2003; Armaş, 2006).

An important peculiarity of the avalanches is that, they develop from the ridge towards the foot of the mountainside, because the declivity and the morphology favours the fast movement of the snow, along the valleys. The intermediary small basins that are generally small and have a $35\text{-}45^0$ slope stops the energy of the smaller avalanches. During spring avalanches, once started, the snow reaches higher and higher speed and it only stops when the slope profile changes, meaning only when it reaches onto the colluvium deposits from the slope foot (Constantinescu, 2006). Due to the narrowness of the valleys (about 2-3 m breadth), the avalanches develops all along the mountainside (an average of 600-700 m difference) and have a big amplitude in height. The transported snow reach over 100 m height, especially where the valleys are narrow towards the thalweg. Such tracks have been encountered on Vâlcelul Spălat, tributary to Ciorângăi Mari Valley, from Padina lui Râie Catchment, where an avalanche that occured in 2005-2006 also left visible marks on the slope. Because the valley has in the transport sector a very narrow thalweg, of 2-3 m, the snow coming from the acumulation area had a height of approximately 100 m, flying over the level of the neighboring interfluves.

The transported materials can move within the forrest zone and be deposited up to altitudes of 1,100 m to the North and 1,300 m to the South. This emphasizes the morphological differences between the two subunits. The reduced vegetation development or even its lack from the corridors, indicate the frequency of the avalanche occurrence.

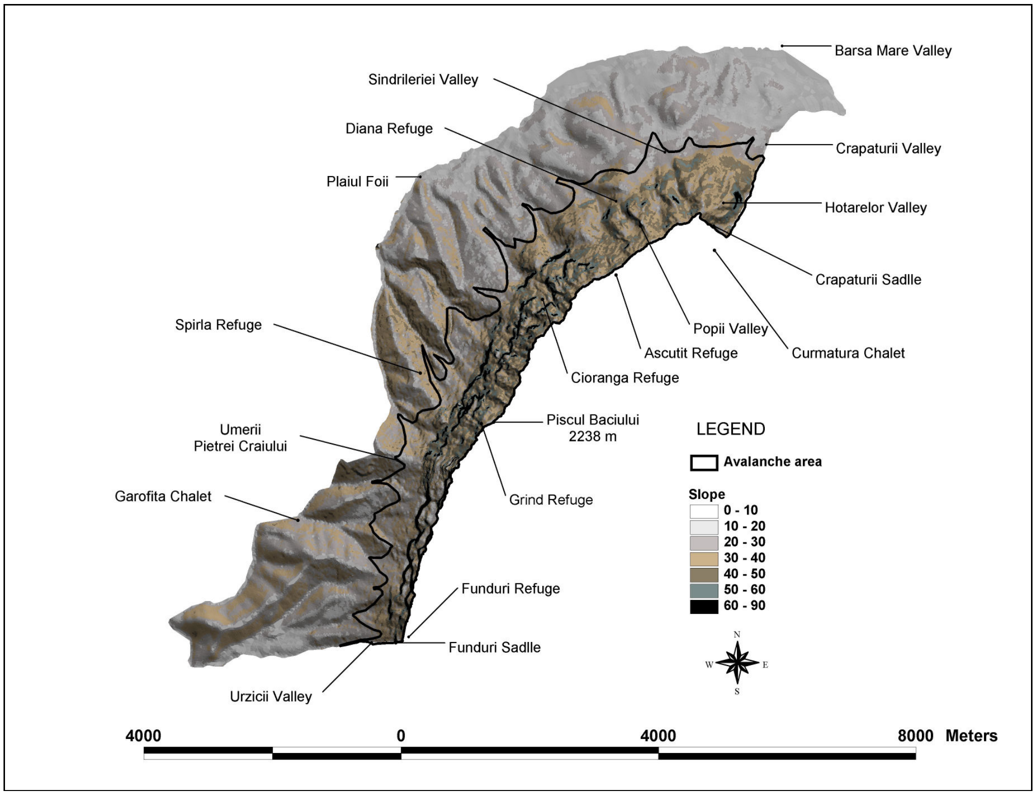

Fig. 2 **The Western mountainslope of Piatra Craiului Massif – Slope Map**

The main modelling of the valleys is a predominantly nival one. The flow of the surface waters is has a torrential regime. The largest part of the water from rainfall infiltrat in the limestone strata or in the debris deposits. All the valleys have the role of avalanche corridors. On each of them, there can be differentiated three typical sectors for avalanches (Ancey, Charlier, 1996; Moţoiu, 2005):

- the sectors with snow accumulation and avalanche release (starting zone) are located, in the majority of cases, within the superior part of the corridors, immediately near the ridge line and are represented by the upper basins at the source of the valleys. The majority are large, with several affluent threads, which confluent right above the place where the valley gets narrower. Fen exceptions are on the Western Steep Slope, Southern from Padina Lăncii Valley – the area of the Marele Grohotiş (Big Debris) and many other surfaces with over 60^0 slopes, where snow accumulates within the upper part of the steep areas and flows due to gravity, independently from the valley track.

- the transport sectors of the avalanche materials are located along the valleys and follow their tracks. Within the North-Western part, they reach over 1,000 – 1,400 m length, being narrow (can reach only 2-3 m breadth) and steep (over 40^0 slopes). To the South-West they are shorter, of about 400-500 m, with over 60^0 slopes, on the mountainsides located in the accumulation sector next to the ridge and the base of the colluvial deposit.

- the deposit sectors are located on the base of the corridors and are overlapped upon the Cuaternary deposits and the active scree rivers from the lower part of the mountainside. They generally occur when the mountainside slope changes, and decreases under 20^0 and can take different lengths, according to local morphology and amplitude. These are easy to be noticed through the transported material and the tracks they leave. The snow destroys the trees it finds on its way, in places where the deposits located at the base of corridors have been fixed by vegetation. Such trees torn off by avalanches appears on the majority of the valleys, which make the avalanches to become an indirect risk factor, in for accidents during summertime due to trees also growing onto the tourist tracks. In summer 2007, such a lethal accident died occur, at the base of Padina Închisă Valley.

From a typological point of view (Voiculescu 2002, 2004; Mititeanu, Mititean, 2004; Moţoiu, 2005), the avalanches met in this sector of study belong to several types:

- *powder avalanches,* when the snow is fresh, starting when the wind or the abrupt warming of the weather "shakes" the unstable snow (especially that from rocks or vegetation), occurring right after the snowfall, generally having reduced proportions;
- *plate avalanches*, which occur on broken, flowing on well defined plans, if the snow has been laid on several layers, especially by the wind and if there exists a producing cause for the plate failure (tourists, chamois or its own weight);
- *snowball avalanches* gradually increase volume during sliding down and fall on wintertime, but especially at the immediate melting of the fresh snow, from the rocks or vegetation, reaching small dimensions;
- *moist avalanches* occuring especially on springtime, once the warming and melting of snow stars, appearing on the whole source surface and reaching variable dimensions;
- *corridor avalanches* occurring on the corridors formed by torrent valleys;
- *bottom avalanches,* triggering the whole snow layer existing in the starting sector, unvealing the vegetation and the rocks, occurring mainly when the temperatures grow on spring, sometimes until late April or May;
- *cornice or terrace avalanches* are formed through braking the ridge cornices, on the edges, or to the margins of structural steep areas. The cornices dislocate and fall down, triggering the snow laid on the mountainside, which can flow in large quantities.

The anthropic activities developed within areas featuring an avalanche risk are represented by tourist, grazing and forestry (Fig.3).

The tourism in Piatra Craiului has reached a distinct amplitude, by setting in 1932 of the Plaiul Foii Chalet (849 m) in the North-Western part of the massif, as well as the setting of some tourist tracks and refuge cabins. Southern from the Tămaşului Ridge there is Garofiţa Pietrei Craiului Chalet (1,100 m), built at the beginning of the 70's by rearranging a forestry district cabin (Cristea, 1984). To the South, there is another forestry cabin, on the Ivan Valley. There are 6 refuge cabins, from which 2 at the base: Şpirla (1,400 m) and Diana (1,510 m), 3 along the ridge: to the North – Ascuţit Peak, (2,150 m), at half ridge, in Grind Sadlle (2,210 m) and to the South one within Funduri Sadlle (1,850 m). On the mountainside, there is the refuge cabin of Ciorânga Mare (1,685 m), close to the place where the former cabin of Ascunsă was built, this being the only one built in an area with only unmarked tracks (Ionescu-Dunăreanu, 1986) (Fig. 3).

There are 20 ***marked tourist tracks*** on the Western mountainside (Fig.3), of which 7 cross the mountainside from the slope base to ridge, 12 being link tracks to the mountainside base and one of them being a ridge track (Ionescu-Dunăreanu, 1958). Due to the morphology of the mountainside, all tracks leading up ridge have parts that cross avalanche corridors or avalanche deposits. In table 1, there are their morphometric feature. All of these tracks are closed on wintertime by the Mountain Rescue team, due to the risk faced by those tourists that cross them. This is why only the base tracks are appropriate for mass tourism, for which the access is unrestricted, guided by signs and tourist tracks, on which the avalanche risk is being specified. There are also tourists who neighs these warnings. Unfortunately, during the last 30 years since Mountain Rescue service exists, there have been registered 6 casualties (3 on Călineţ Valley and 3 at La Lanţuri). The marked tracks can be grouped in three areas, depending on their position:

In **the Northern area** there are 8 marked tourist tracks: along *Crăpăturii Valley* there is a 1,500 m track which is considered relatively safer and easier than others (630 m difference). Due to the fact that it represents a short link track between Zărneşti town and Curmătura Chalet, it is used in wintertime, as well. It has a morphology with favourable conditions for avalanches both on slope and on the 12 tributaries, the deposits of which stop on the thalweg of the valley (Munteanu, 2006). The *Padina Hotarului Valley* is narrow (20-50 m) and along all its length and unitary slope (over 40^0), has a well defined main corridor. *Padina Şindrileriei Valley* has a large source and a narrow corridor (below 10 m). On both valley, the tracks are along the thalwegs. *Brâna Caprelor* and *Padina Popii Valley* are entirely exposed to avalanches (which occurs differently, according to exposition) because they have their tourist tracks along some structural narrow paths which crosses a series of corridors from the affluent valleys. The base tracks between *Crăpăturii Valley – Colţul Chiliilor –Diana Refuge –Urşilor Valley,* crosses the avalanche deposits of the corridors. There can also form avalanches from the errosion witnesses from the exterior of the mountainside, on a total length of 2,100 m. In the summer of 2007, between Diana Refuge and Colţul Chiliilor a lethal accident occurred, for a tourist who tried during the night to make a detour from the avalanche deposits.

The central area comprises 5 tracks: *Plaiul Foii – Şpirla Refuge*, where 400 m of the tracks lay along the deposit of Spirla valley; *Şpirla Refuge – Grind Saddle* is one of the first equipped tracks in the massif and the most exposed to avalanches, which leads to the ridge, called *La Lanţuri* or *Drumul lui Deubel* (after the name of the one who equipped it, a teacher from a Brasov highschool, in the 19th century)(Cristea, 1984) and which crosses over 1.000 m length, a series of corridors from the source of Spirla Valley. In the winter of 1987, an avalanche occurred there, having 3 casualties; *Şpirla Refuge – Umerii Pietrei Craiului* has the aspect of a narrow path which crosses by the base of the limestone mountainside, at an average altitude of 1,550 m and crosses along the 1,000 m length, 4 avalanche corridors come from the ridge and other 3 from the South-Western part of an errosion witness from the exterior of the mountainside; *Plaiul Foii –Tămaşului Ridge* tracks and from there to *Garofiţa Pietrei* Craiului Chalet, where avalanches can occur only in deforested areas, on the forest exploatation channels, but with no connection to those from the limestone slope.

In the Southern area there are 6 tourist tracks leading to Umerii Pietrei Craiului: only one climbs up the ridge (Şaua Funduri), along *Urzicii Valley*, being totally exposed to avalanches; a track links *Umerii Pietrei Craiului* to *Urzicii Valley*, through the base of the limestone mountainside, at an average altitude of 1,650 m, crossing all avalanche corridors from Tamasului valleys, Padina Lăncii, Marele Grohotiş, Stanciului, Ivan; between *Garofiţa Chalet* and *Marele Grohotiş* there is a track crossing, on over an 1,000 m length, the base and Southern limit of the active deposit of scree slope, which coincides with the avalanche deposit. Another track, appeared as a solution to avoid walking on the active scree river, crosses on over 700 m through the potential avalanche deposit area in Cerdacul Stanciului. From *Grănicerului Cross* to *Tămăşelului Sadlle* there is another track, parallel to the base of the limestone slope, at an average altitude of 1,400 m, crossing the deposit sector from 3 avalanche corridors.

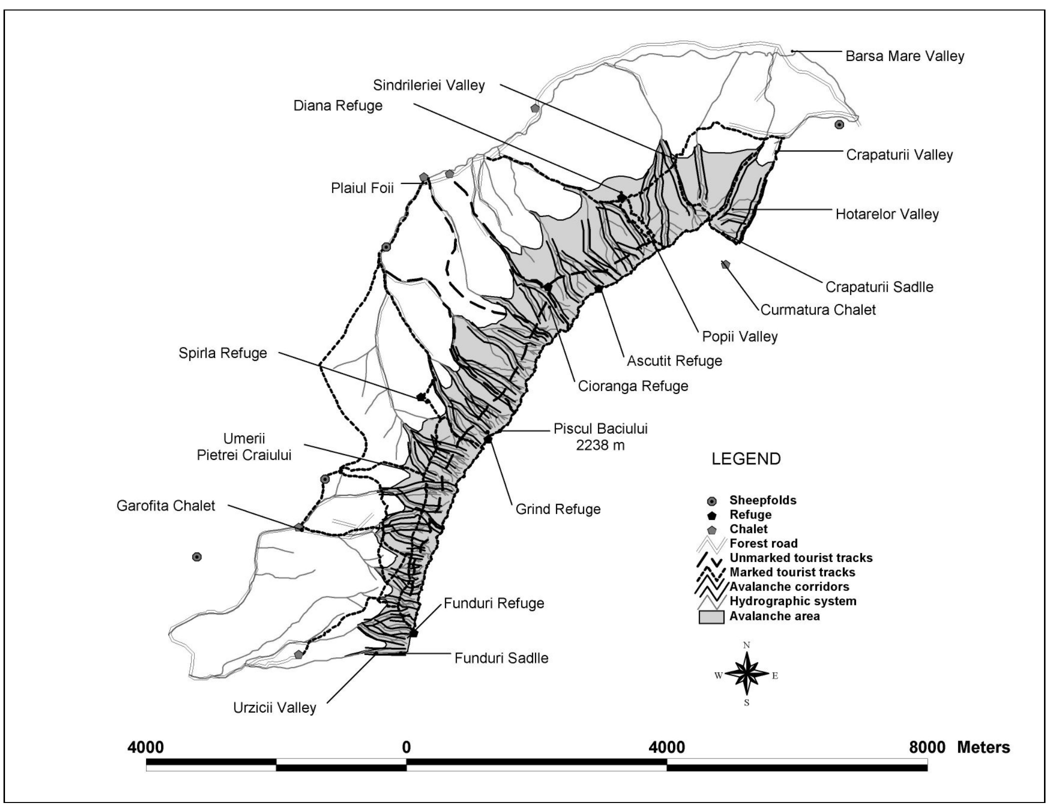

Fig. 3 **The map of the anthropic activities from the avalanche occurrence area**

The ridge is crossed all along its 8,500 m by a track between Turnu Peak (1,923 m) - Piscul Baciului (2,238 m), sector called the *Northern Ridge* and respectively from there to Funduri mountain saddle (1,889 m), meaning the *Southern Ridge*. The track generally follows the ridge line, represented by an alternance of peaks, mountain saddles, horns, and sharp edges. Most of the time, where the Western part has over 60^0 of slopes and is more exposed. The track is on the Eastern mountainside, crossing the source areas of the avalanches from the opposed mountainside. It can also be crossed on wintertime, on a track strictly following its highest altitudes, often different from the summer one, as there form cornices, which by breaking, can lead to the launching of avalanches.

The unmarked tourist tracks are almost on all of the main and secondary valleys, as well as on the structural mountain paths. These are used especially by those who wish to reach the wilder areas of the massif or the hiking tracks. The access is not controlled, although the new recommended of the National Park Administration dictate to limit the tourist number on these unmarked tracks. Because these tracks are within strictly protected scientific areas and because these are not tourist tracks or arrangements, the risk of producing accidents is much higher. A large part of these tracks cross avalanche corridors. Among some of the most popular tourist paths we mention Padina lui Călineţ Valley (where, in 1970, an avalanche killed 3 hikers), Podurilor Valley, Ciorânguţa, Padina Lăncii Valley, Brâul de Mijloc, Brâul de Jos, Brâul Roşu.

The grazing and forestry activities have a much lower development compared to those similar from the Eastern mountainside (Moţoiu, Munteanu, 2006), because of the unfavourable natural conditions. The sheepfolds can be met only on the sencondary Western edges – Tămăşel, Plaiul Mare, Plaiul Foii or in Bârsa Mare flood plain, the grasslands being far from the surface affected by avalanches. The forestry activities can reach the base of the avalanche corridors, like for exemple in the area of Lăncii Valley – Tămăşelului Valley, where in the last 4 years there have been complete deforestations, thus reaching the base of the deposition sectors of material transported by avalanche. Thist can further lead into the future to enlarging the deposit surfaces of the avalanches.

5. Conclusions

The Western mountainside of the Piatra Craiului Mts.is strongly used by people, although it doesn't seem, due to its morphology. Nevertheless, it is exactly this unique morphology that attracts many tourists which follows both marked and unmarked tracks and paths. It presents an area where the avalanches can occur depending on the geomorphological and climate conditions. The tracks and the effects left behind along years, emphasize the presence of more then 30 corridors. Their impact can reach the anthropic activities: tourists, forestry and grazing exploitations. There are important tourist tracks, chalets, refuge cabins, sheepfolds, a centenary forestry fund, all differently vulnerable to avalanches.

Because they represent a reality that needs to be known, it is necessary to study the avalanches as complex processes and to catalogue the corridors. The raising of awareness among those undertaking anthropic activities in the area, to avoid risk exposure and negative impact is another objective.

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