

THE SNOW CONDITION, THE AVALANCHES CAUSED AND THE DYNAMIC OF THE AVALANCHES CORRIDORS DURING THE WINTER 2007-2008. CASE STUDY, PADINILE FRUMOASE (PIATRA CRAIULUI MOUNTAINS, ROMANIA)

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Abstract. - **The snow condition, the avalanches caused and the dynamic of the avalanches corridors during the winter 2007-2008. Case study, Padinile Frumoase (Piatra Craiului Mountains, Romania).** In this paper we aim to present in detail the situations generated by meteorological and morphological parameters, which determined the generation of avalanches of different intensities, on five avalanches corridors in the winter 2007-2008. These are situated in the area named Padinile Frumoase, in the north-eastern part of the Piatra Craiului Mountains, which are situated in the central part of Romania and which belong to the Meridional Carpathians. The relief is represented by a calcareous-conglomeratic ridge, in the high part, the peak reaches over 2000 m altitude. Local conditions determine the forming of avalanches, which are oriented on well defined corridors, along the temporary hydrographic network. By studying the evolution of meteorological parameters and their overlapping with local morphological parameters, the existence of some favourable conditions for the apparition of avalanches were detected. There were noticed both active corridors with traces of avalanches, and inactive corridors on which it was not noticed the manifestation of these phenomena. The material adds up to the data base about the avalanches from this massif, being the second situation of analysed avalanches for this mountainous space totally situated in the National Park Piatra Craiului.

KEY WORDS: avalanches, avalanches corridors, snow, meteorological parameters, Padinile Frumoase, Piatra Craiului Mountains

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1. Introduction

This paper analyzes the snow condition and the evolution of meteorological parameters that triggered the avalanches in the Piatra Craiului Mountains (the Southern Carpathians, lying in the central part of Romania) during the winter of 2007-2008. The avalanches are natural phenomena occurring frequently in the Carpathian Mts., reported in various studies (Câmpean, Câmpean, 2010; Constantinescu, 2006, 2009; Covășnianu et al. 2011; Moțoiu, 2008; Moțoiu, Munteanu, 2006; Munteanu 2004, 2009; Munteanu, Constantinescu, 2006; Munteanu, Moțoiu 2006; Munteanu, et. al. 2011 a, 2011 b, 2012; Voiculescu, 2002, 2004, Voiculescu et al. 2010).

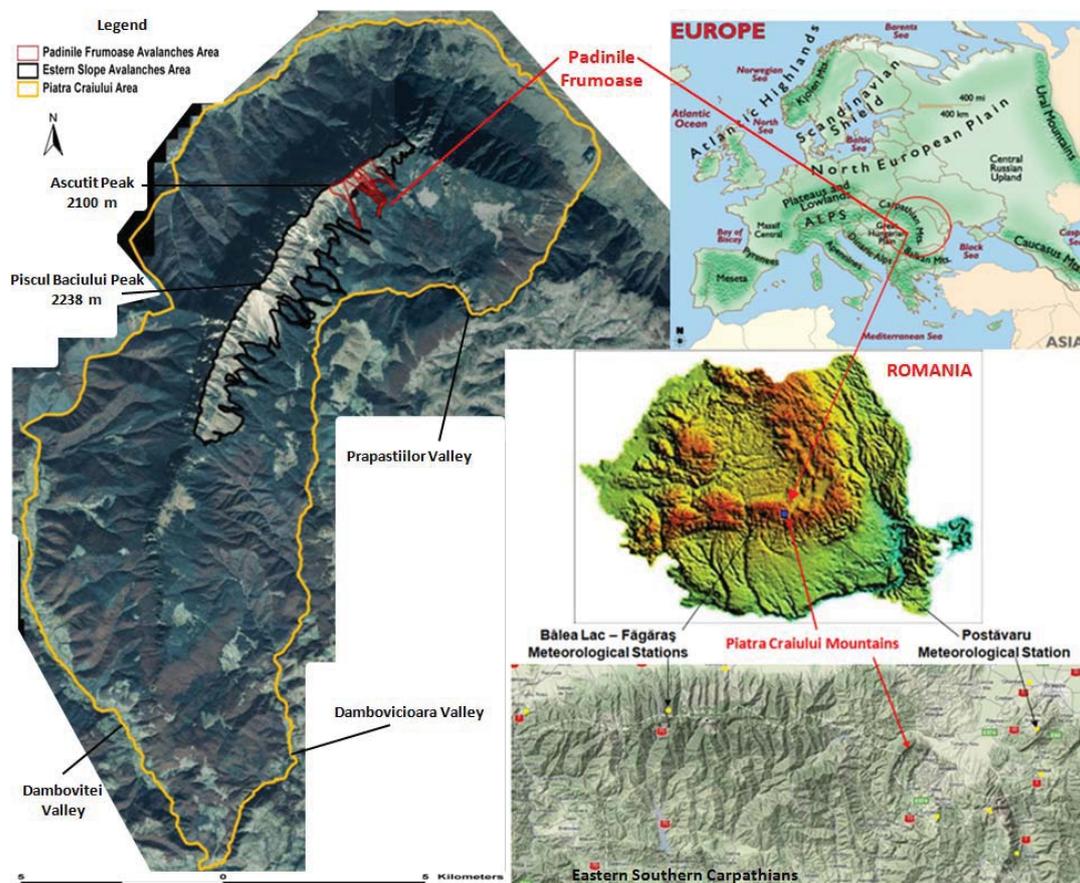


Fig. 1 The location of the study area within the Piatra Craiului Mountains and Bâlea Lac and Postăvaru meteorological stations and within Romania and Europe

The study area consists of five avalanche chutes, lying in the Padinile Frumoase area, on the eastern slope of the Piatra Craiului Mountains (Fig. 1). The topography of the massif is represented by a calcareous-conglomeratic ridge, trending northeast-southwest, having two asymmetric slopes, one to the east and the other to the west. The general morphology is given by the location of this area

on the western flank of the Piatra Craiului Syncline. In the upper part, the ridge exceeds 2000 m altitude. The local conditions encourage the formation of avalanches, which slide on clearly defined tracks, overlapping the temporary streams. The length of these tracks ranges from 1150 to 630 m, while the extreme elevations are 2150 m (the Ascuțit peak), lying on the main ridge, and 1330 m, at the base of the avalanche deposition zone. On the entire eastern slope, the avalanche tracks have been numbered from north to south, according to their sequence. Because these valleys do not have names, we have used their corresponding number in this sequence, i.e. from 8 to 12. The area is crossed by a marked tourist trail connecting the Curmătura chalet with the tourist shelter lying on the Ascuțit peak and further with the trail following the main ridge (Moțoiu, Munteanu, 2006; Munteanu 2004, 2009; Munteanu, Constantinescu, 2006; Munteanu, Moțoiu 2006).

During the winter of 2007-2008, the five avalanche chutes experienced a number of avalanches, most of them triggered by the sudden warming recorded in February. By studying the evolution of meteorological parameters (the quantity and structure of snow, temperature, precipitations) and their overlapping with local morphological parameters, the existence of some favourable conditions for the apparition of avalanches were detected. Based on an important quantity of accumulated snow, a period with positive temperatures, of over 10°, was recorded in February, and it created the un-stabilization of snow layers, favouring the producing of avalanches. For this reason, we have made a complex analysis of the evolution of the meteorological parameters along the entire season, making the necessary correlations with the effects observed in the field.

2. Data and methods

Because the Piatra Craiului Mountains do not have a weather station of their own, we have used the data recorded at the meteorological stations Bâlea Lac and Postăvaru, lying in the adjacent mountains. The parameters we have taken into account are the following: the air temperatures recorded at 6 and 12 hours GMT, the maximum and minimum air temperatures, wind direction and velocity, the degree of cloudiness, the daily amount of precipitation (solid and liquid), and the snow thickness. The evolution of these parameters has been integrated in the Geliniv 2.10 software. We have analyzed the weather conditions for the entire winter season, from November 2007 to June 2008, but we paid particular attention to February 2008, when most avalanches discussed in this study occurred.

The data regarding the structure, the thickness and the distribution of the snow cover were collected in the field by the members of the Zărnești Mountain Rescue Service. Most of the snow profiles were accomplished by using the French methodology, simplified for the use of mountain rescuers. We have compared the

structure and the thickness of the snow in the Piatra Craiului Mountains with the more detailed profiles accomplished at the Bâlea Lac and Postăvarul weather stations, located in the Făgăraș and Postăvarul Mountains, respectively. The snow and the weather parameters have been correlated with the Geliniv 2.10 application and the Crocus Mepra PC, developed by CEN Meteo, France.

The synoptic data were drawn from the satellite imagery. For the meteorological diagnosis, we employed the data recorded at the weather stations.

In the end, we have developed a map of the avalanche chutes based on the Ikonos 2004 satellite image. In order to do this, we have relied on our studies in the field, as well as on topographic maps, aerial photographs and the pictures taken during the field campaigns. The use of GIS techniques and analysis has taken into account the existing literature (Barry 2008; Bellaire and Schweizer 2011; Cappabianca and others, 2008; Câmpean and Câmpean 2010; Covășnianu and others, 2011; Decaulne and Saemundsson, 2006; Ludkvist 2005; McClung, 2008; McClung and Schaerer 2008; Pudasaini, Hutter 2007; Sekiguchi and others, 2005; Simenhois, Birkeland 2010; Voiculescu, 2002, 2004; Voiculescu and others, 2010).

For this study, we have also used the information collected from all those who have witnessed the occurrence of an avalanche, i.e. chalet keepers, mountain rescuers, foresters or climbers. On February 28, 2008, the Curmătura chalet keeper managed to witness the development of one of the most important avalanches in the winter of 2007-2008.

3. Results and discussion

In order to understand the context in which the avalanches in the Padinile Frumoase area occurred, we further present the evolution of the meteorological parameters during that winter season.

The evolution of weather parameters and the snow condition during the winter of 2007-2008 (October 2007-June 2008), in the area of the Făgăraș and Postăvarul mountains

The Postăvarul weather station

The first snowfalls of the 2007-08 winter season occurred on 12-13 and 20-22 October, when snow cover reached 2 cm and 16 cm, respectively, but melted rapidly away in the next few days. From November 4 until November 20, the sky was generally overcast and it rained; consequently, the snow thickness grew progressively, from 10 cm in the first day to 88 cm on November 21, which actually was the highest value recorded that month. The most important snow amount (37 cm) accumulated from the afternoon of November 18 until the next morning. This white blanket lasted until May 12, 2008, the date that marked the

end of the snow season. The maximum thickness of the snow cover was 130 cm, a value recorded in the first decade of April (Fig. 2).

The lowest air temperatures dropped to 21.2°C below zero in the second decade of February, while the maximum ones rose to 15.4°C in the second decade of October. This winter has seen significant variations of the air temperature in a very short time (1 or 2 days) (Fig. 2).



Fig. 2 The evolution of nivometeorological parameters for the period December 2007-April 2008 at Postăvarul weather station (Geliniv application)

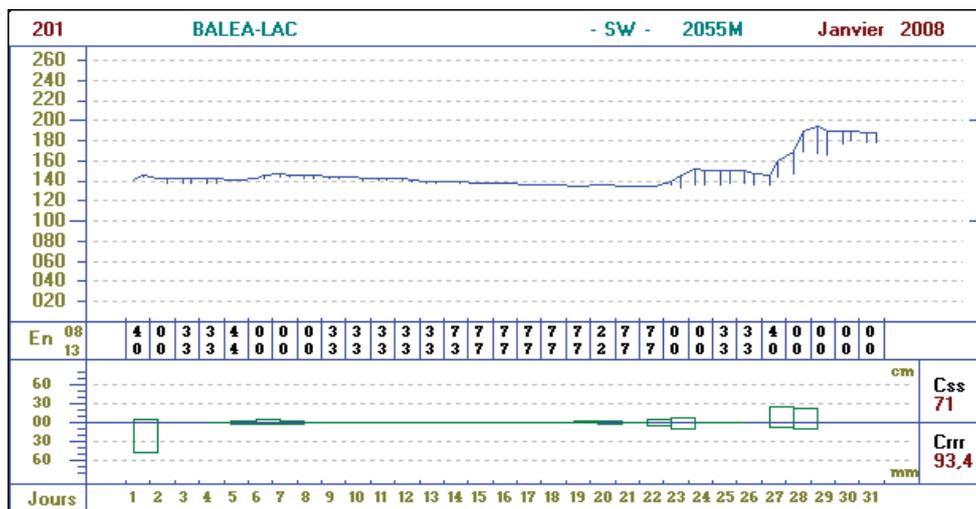


Fig. 3 The evolution of nivometeorological parameters for the period December 2007-April 2008 at Bâlea Lac weather station (Geliniv application)

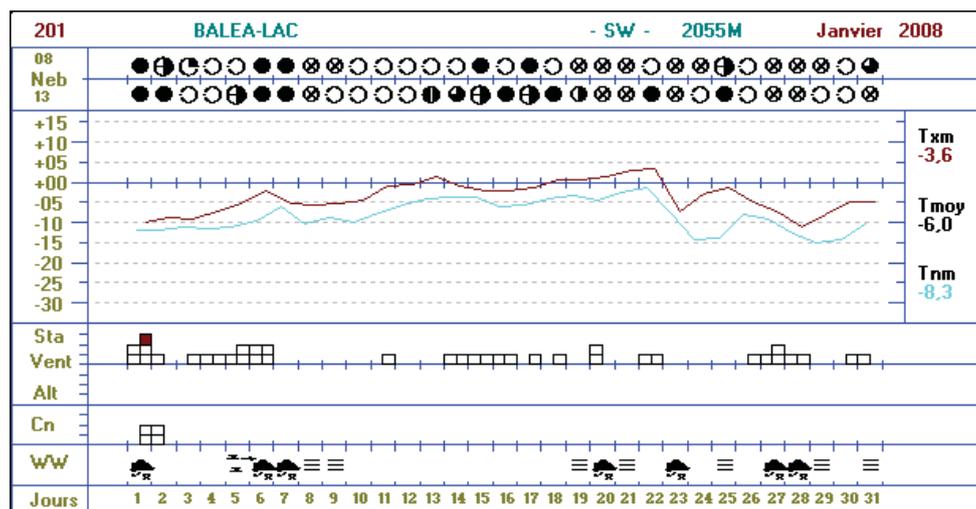
The Bâlea Lac weather station

The first snowfalls of the 2007-08 winter season were recorded on September 8, when the snow cover reached 8 cm; until September 13 the thickness grew to 25 cm, but during the next three days all the snow melted away. Two other

snowfall episodes occurred on October 14 (the snow melted away in two days) and October 19, when the thickness of the accumulated snow was significant (14 cm during the first day and a maximum thickness of 40 cm on October 22). Because of the rising temperatures, this snow layer also melted away progressively until November 1. The snowfalls recorded on November 5 gave birth to another snow layer (28 cm on the first day), which lasted on the meteorological site until June 10 (Fig. 3). The maximum thickness of the snow cover was 286 cm (on April 17), a value recorded at 00 hours UTC. For two and a half months, the snow was thicker than 200 cm, and for 20 days it exceeded 250 cm (Fig. 3).



a The snow layer thickness and the amount of precipitation in January 2008 at Bâlea Lac weather station



b The extreme temperatures, the wind and the meteorological phenomena

Fig. 4 The nivometeorological synthesis for January 2008 at Bâlea Lac weather station

The evolution of weather parameters and the snow condition at Bâlea Lac weather station in January and February 2008

January 2008

Except for the interval January 3-5, during the first decade of this month, the weather was generally cloudy, snowfalls have been scarce and fog was common. During the interval January 10-18, the weather was generally fair and the temperatures rose as high as 0.8°C. From January 19-23, the weather was warm (maximum temperature 3.2°C), but cloudy; fog was a common phenomenon, while the amount of precipitation was low. Then, the weather got cold (minimum temperatures as low as 15°C below zero) and during January 26 and 27 it rained heavily (45 cm of wild snow) (Fig. 4). The maximum thickness of snow layer was 194 cm (on January 29) (Fig. 4 a).

The sounding of January 24 undertaken on a southeastern-facing slope showed a high instability of the snow layer. On the surface, there was a wild snow layer, about 15 cm thick (created by the snowfalls of January 22-23), which was underlain by a wind slab structure, 10-15 cm thick; beneath there were 15 cm of snow having a very low resistance. Further to the base, the layer kept compact, having a high resistance and a significant volume. It was made up of fine particles, with faceted crystals with cup-shaped base (Fig. 5 a).

The measurements of January 29 were made on a southeastern-facing slope. They highlighted a complex structure of the snow layer, as follows: on the base, layers consisting of cup-type crystals; in the middle part, fine crystals with plane facets, alternating with thin crusts; and to the surface, a consistent wild snow layer, about 30-40 cm thick, accumulated in the aftermath of the snowfalls of January 22-23 (Fig. 5 b).

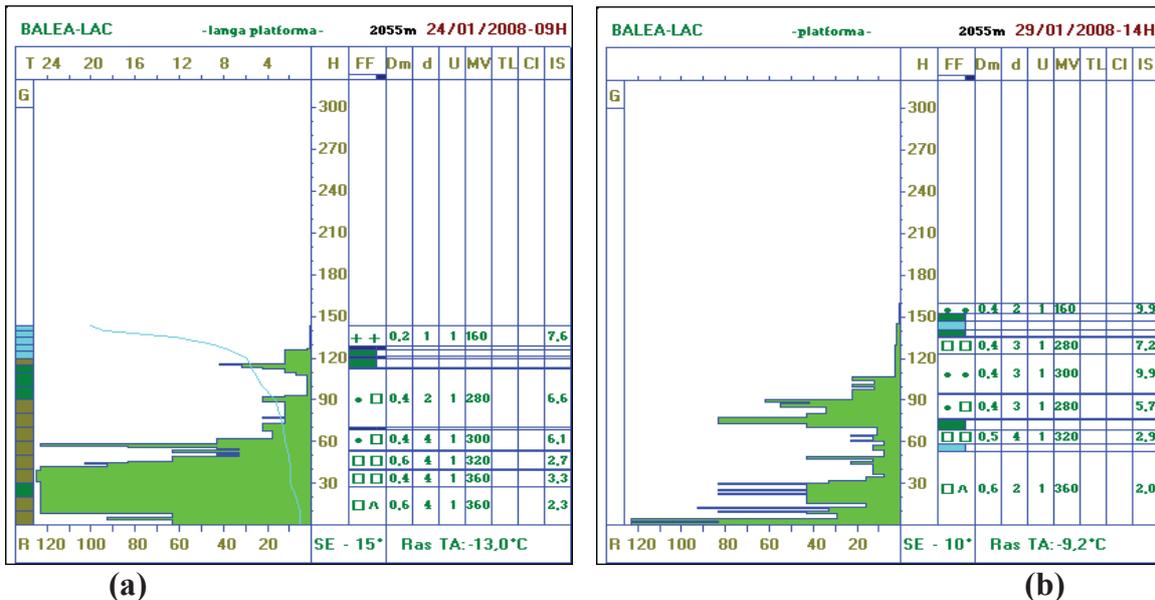


Fig. 5 a, b The snow layer structure for January 2008 at Bâlea Lac weather station

Resistance and stratigraphic profiles accomplished on February 2008 at Bâlea Lac

In comparison with the previous sounding, the gradient of the temperature inside the snow layer was medium and high, thus encouraging the formation of cup-type and plane-faced crystals. The sounding made on February 5 showed that although the snow density increased, the first 30-35 cm from the surface continued to have a low resistance, which made the layer highly unstable (Fig. 7 a).

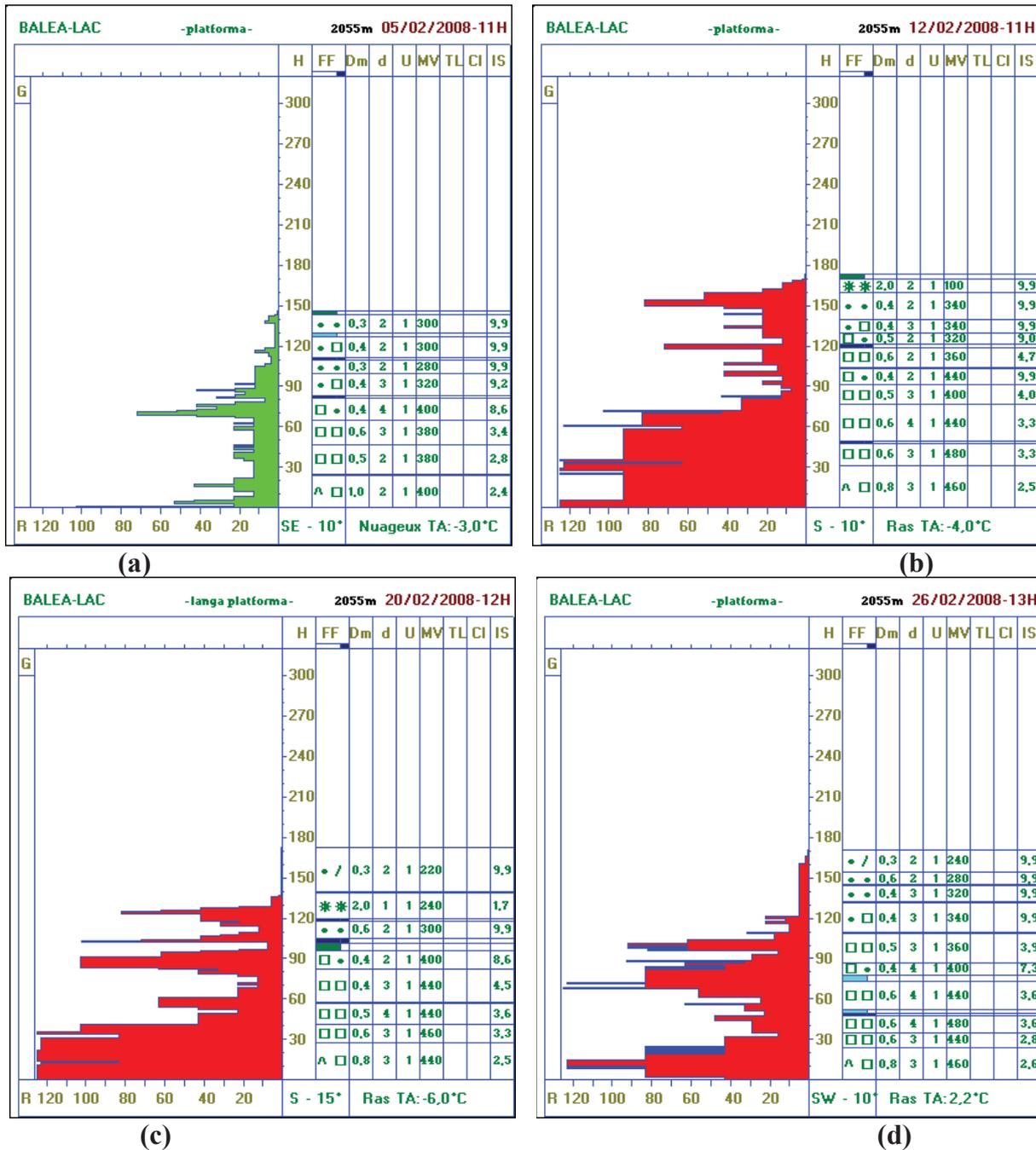


Fig. 7 a, b, c, d The snow layer structure for February 2008 at Bâlea Lac weather station

The precipitation fallen during the interval February 8-11 resulted in the accumulation of 8 cm of wild snow, covered with a thin layer of snow grains. Daytime temperatures reached 2⁰C on February 6 and February 7, and consequently the liquid water percolated the upper layer. Thus, in the first 60 cm, the alterations induced by the low and medium gradients encouraged the formation of fine pellets and plane-faced crystals. Below this layer, the soundings indentified the structures revealed by the profile accomplished on February 5 (on the southeastern slope), which were responsible for the formation of a low resistance area lying at a depth of about 90-100 cm from the surface. Due to the high thickness and the huge snow mass, the layer did not turn into a potential instability plane (Fig. 7 b).

Until the date of the next sounding (February 20), the weather got gradually cold and it snowed. Consequently, snow layer grew by 33 cm after the snowfalls recorded during the interval February 14-20. The first 40-50 cm showed a low resistance, being especially formed by fine and visible pellets, underlain by older wind slabs. The layer lying at the contact with the soil showed many cup-type crystals (Fig. 7 c).

The gradual increase of the air temperatures until February 26 encouraged the slight increase of the cohesion between the wild snow grains identified in the upper part of the layer at the previous sounding; down below, the snow structure remained the same (Fig. 7 d).

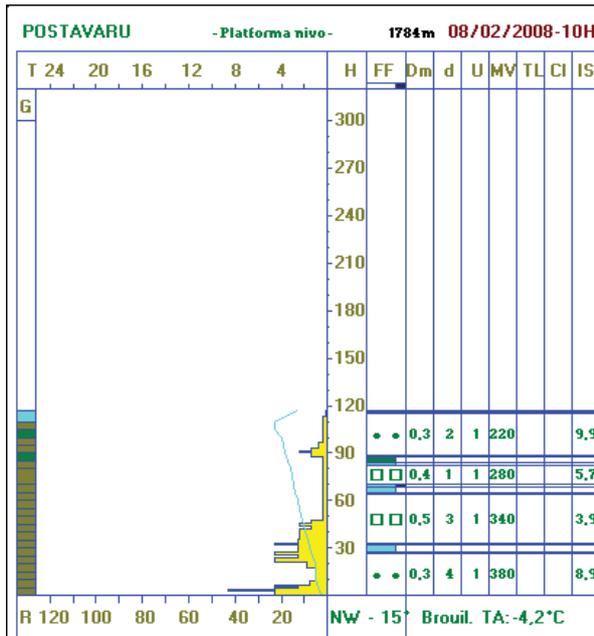
The evolution of the weather parameters and the snow condition at Postăvarul weather station in February 2008

The first week was characterized by a generally fair weather, with relatively high maximum temperatures (positive values as high as 3.9⁰C), but with low minimum values during the first nights (-10⁰C). Then, the weather began to cool and during the interval February 8-11, it snowed (3 cm of wild snow). The temperatures continued to drop in the third week of the month as well and, consequently, the weather became frosty; the thermometer sank as low as -16.2⁰C (maximum value) and -21.2⁰C (minimum value); during the interval 14-19 it snowed, the wind gained strength (12-20 m/s) and the pulver snow layer was 10 cm. During the last week, the weather was fair and air temperatures began to rise significantly (maximum values of 8.7⁰C in two nights and slightly positive minimum values); the snow layer thickness decreased from 106 to 84 cm. The maximum thickness of the snow layer was 108 cm (during the intervals February 1-4 and 19-20) (Fig. 8).

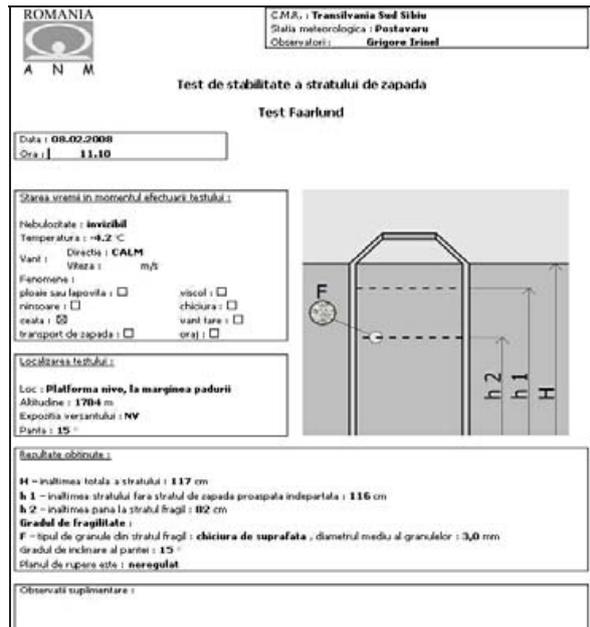
Resistance and stratigraphic profiles accomplished on February 2008 at Postăvarul

The first sounding of the month was performed on February 8. The layer showed a low resistance in the first 60 cm, being made up of 1 cm of wild snow,

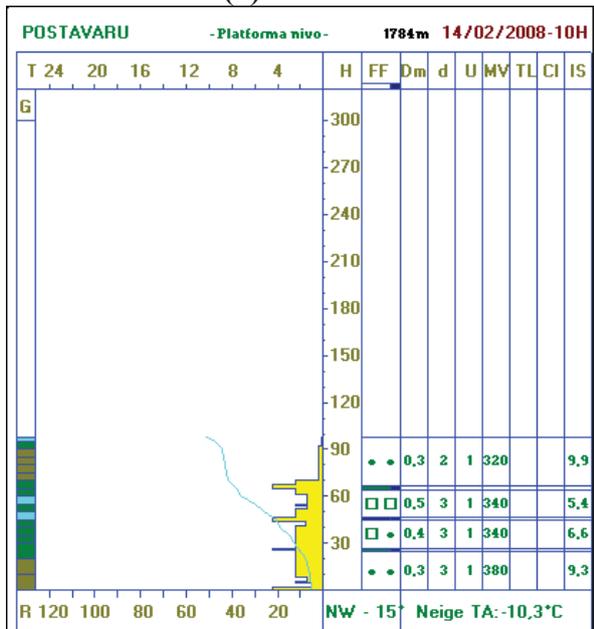
On February 21, the surface layer (30 cm), made up of a relatively recent pulver snow cover, deposited during the snowfalls that had occurred in the previous days, and a layer of fine pellets, showed a low resistance. Beneath this layer, there was a crust that acted like a sliding plane for the overlying snow. Deep down, as low as the soil level, the sounding revealed the presence of several thin crusts and layers made up of fine pellets (Fig. 9 d).



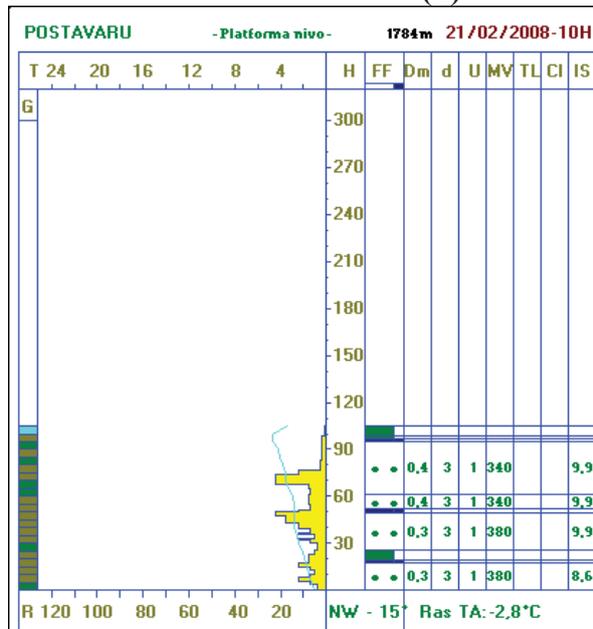
(a)



(b)



(c)



(d)

Fig. 9 a, b, c, d The snow layer structure for February 2008; test of stability at Postăvarul weather station

The estimation of avalanche risk for the area of the Făgăraș Mountains in January and February 2008

For January 2008:

- At elevations higher than 1800 m, the avalanche risk levels 5 and 1 were not estimated; the other risk levels were estimated to have the following percentages: risk level 4 – 9.7%, risk level 3 – 16.1% and risk level 2 – 74.2%
- At elevations lower than 1800 m, the avalanche risk level 5 was not estimated; the other risk levels had the following contribution: risk level 4 – 9.7%, risk level 3 – 16.1%, risk level 2 – 71.7% and risk level 1 – 3.2%.

Until January 24, due to the gradual increase of air temperatures, which however remained negative, and the lack of precipitation, the snow layer became stable; the estimated risk was moderate (2). Yet, during the last days of the month the avalanche risk increased because of the higher amounts of precipitation and the significant temperature variations (of 10-15⁰C in 24 hours). Consequently, the avalanche risk was estimated at 3-level and later at 4-level.

For February 2008:

- At elevations higher than 1800 m, the avalanche risk levels 5 and 1 were not estimated; the other risk levels were estimated to have the following percentages: risk level 4 – 3.5%, risk level 3 – 72.1% and risk level 2 – 24.4%
- At elevations lower than 1800 m, the avalanche risk level 5 and 1 were not estimated; the other risk levels had the following contribution: risk level 4 – 3.5%, risk level 3 – 16.1%, risk level 3 – 35.5% and risk level 2 – 6.2%.

The avalanche risk gradually declined from high (4) in the first day of the month, to moderate (2), and then it grew again to 3 (significant) after the snowfalls of February 16 and stayed so for the rest of the month, because the temperatures became positive.

The avalanches in the Padinile Frumoase area

Due to the meteorological context described above for the winter season 2007-2008, avalanches occurred on each of the sliding paths mentioned previously. On the avalanche chutes number 8 and 11, the snow sliding was encouraged by the warming intervals of February, while on the tracks 9, 10 and 12, which did not experience avalanche phenomena in February, one could note small melting avalanches in March and April, which were also due to the warming weather (Fig. 10 and 11).

On track 8, an avalanche occurred on February 2, 2008. This was the first to occur on the northernmost of all the five avalanche chutes of the Padinile Frumoase area. This valley exhibits a gorges sector, cut into conglomerates, downstream of which there are debris fans made up of elements from collapses and older avalanches. The gorges have the appearance of three short narrow bends (6-9 m wide), the thalwegs of which shelters scree particles of various sizes. Upstream

the gorge, the valley widens (50-60 m); here, one can see a large talus cone, developed at the base of a structural threshold lying in the long profile of the avalanche chute. Upstream the threshold, the valley is wide (40-60 m) and is flanked by patches of forest. It is formed by the junction of two main valleys originating in the avalanche-starting zone. The valley is more than 600 m long and the vertical difference between the headwaters and its mouth is more than 450 m (1950-1500 m).

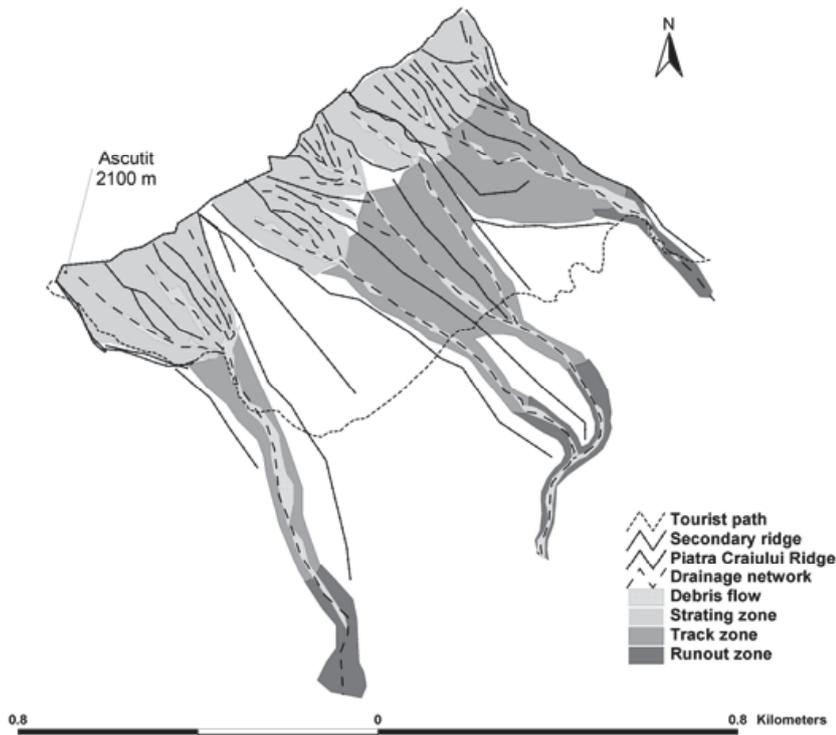


Fig. 10 The Padinile Frumoase area – The general map showing the avalanche chutes and the location of the investigated plots



Fig. 11 The traces left by the avalanches that occurred on February 2008 along the tracks number 8 and 11

The avalanches occurring along this valley are seasonal. There is at least one every winter, the size of which differs according to the specific meteorological conditions of the respective year. The one that occurred during the analyzed span of time affected only the bottom of the valley. It started in the catchment area, transported the dislodged material along the sliding track and deposited most of it at the base of the talus cone lying upstream the gorges. A small amount managed to advance even downstream the gorge sector (Fig. 10).

Another avalanche that occurred in February affected track number 11. This avalanche chute is represented by a main valley, which to the headwaters splits into several small and flat-bottomed valleys. It develops between 2070 and 1470 m altitude, on a vertical difference of 600 m, having a length of about 700 m and mean widths of 60-70 m (Fig. 10).

The tracks number 9, 10 and 12 are bigger, but the avalanches that occurred here during the analyzed interval were less significant, being represented only by melting avalanches, which did not impact large areas, as it was the case with other years, too (Moțoiu and Munteanu, 2006) (Fig. 10).

The situations discussed previously show the relationship that exists between avalanche occurrence and weather conditions. The avalanche risk must necessarily be taken into account because the sliding snow can take by surprise the tourists that follow the existing trails. At the same time, the avalanches have a devastating effect on the forest vegetation.

Conclusions

The analysis of the meteorological parameters for the entire winter season 2007-2008 shows synthetically how their evolution affected the avalanche occurrence. A major feature of that winter was the alternation of snowfalls and warm spells. The local morphology of the five avalanche chutes encourages snow deposition. Avalanches may be triggered by the rising temperatures, provided that the snow cover and its structure are adequate. The investigated profiles suggested that the snow layer had a typical evolution that was conducive to avalanche occurrence. But even though such conditions are present throughout the area, the avalanches do not occur simultaneously on all the valleys, and their size differs.

The study brings its contribution to the improvement of the meteorological database regarding the winter of 2007-2008, as well as to the understanding of the avalanches occurring in this mountain massif, which lies entirely on the territory of the Piatra Craiului National Park.

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