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SNOW AVALANCHE ACTIVITY IN PARÂNG SKI AREA REVEALED BY TREE-RINGS

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ABSTRACT. - Snow Avalanche Activity in Parâng Ski Area Revealed by Tree-Rings. Snow avalanches hold favorable conditions to manifest in Parâng Mountains but only one event is historically known, without destructive impact upon infrastructure or fatalities and this region wasn't yet the object of avalanche research. The existing ski infrastructure of Parâng resort located in the west of Parâng Mountains is proposed to be extended in the steep slopes of subalpine area. Field evidence pinpoints that these steep slopes were affected by snow avalanches in the past. In this study we analyzed 11 stem discs and 31 increment cores extracted from 22 spruces (*Picea abies (L.) Karst*) impacted by avalanches, in order to obtain more information about past avalanches activity. Using the dendrogeomorphological approach we found 13 avalanche events that occurred along Scărița avalanche path, since 1935 until 2012, nine of them produced in the last 20 years. The tree-rings data inferred an intense snow avalanche activity along this avalanche path. This study not only calls for more research in the study area but also proves that snow avalanches could constitute an important restrictive factor for the tourism infrastructure and related activities in the area. It must be taken into consideration by the future extension of tourism infrastructure.

Keywords: *snow avalanche, Parâng Mountains, dendrogeomorphology, ski area.*

1. INTRODUCTION

Snow avalanches are common geomorphic processes in alpine and subalpine areas of Carpathians. In these areas, they have a severe impact upon all human activities and existing infrastructure. The railways, the roads, the backcountry recreation areas, the sky areas and even the recreation and public areas can be affected by snow avalanches (Muntán E. *et al*., 2010, Jamieson and Stethem, 2002). In Romanian Carpathians almost every winter some people are being caught by snow avalanches. Since 2004 until 2007, every year more than 20 victims of snow avalanches were recorded (Milan and Flueraru, 2007).

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Parâng Mountains belong to Southern Carpathians, having the maximum altitude in Parângul Mare Peak (2519 m a.s.l.).The geology is dominated by crystalline schists, due to whom the relief is characterized by steep slopes. Between 1400 – 1700 m the average annual temperature is around 2-3^{O}C and the total precipitation about 1000-1200 mm/year. Coniferous belt extents roughly at mentioned altitudes, being dominated by spruce (*Picea abies)* forests. Above 1800 m the average annual temperature drops below 2^{O}C and the average rainfall reach 1200 mm/year, allowing the development of alpine shrubs and alpine grassland (Oancea *et al*., 1987). Crests and steep slopes in these subalpine areas are prone to snow accumulation and avalanche release.

In Carpathians, the tourism infrastructure consisting in ski resorts and hiking trails is sometimes located within areas prone to avalanche activity (Voiculescu and Onaca, 2013). In Parâng Mountains an important ski resort is present on the western slopes of Parângul Mic peak. The ski resort benefits from an ample development project for ski area extension, currently under implementation by Petroșani local council (Agentia pentru Protectia Mediului Hunedoara, 2011). The project aims, among other things, to prolong the existing ski tracks with twelve new ski tracks (12.66 km length) that will reach Parângul Mic Peak (2074 m) and to build three ski lifts that will reach Badea Peak (1935 m) and Piatra Peak (2084 m).

In the historical archives there is a lack mentions about the avalanche activity. Moreover, in this ski area, the snow avalanches were not studied previously. Only one avalanche event is known to have occurred in the 1996-1997 winter and recorded by forestry archives. At that time, large forest areas were affected by the avalanche on the NE slopes of Parângul Mic peak and the timber was extracted in order to clean the area. No destructive avalanche impact on tourism infrastructure is known in this area, but the avalanche activity is supposed to have a restrictive impact upon the future development of the tourism infrastructure.

The dendrogeomorphological approach proved its scientific value for studying the frequency and magnitude of past snow avalanches. It was successfully used in other mountain areas, such as Rocky Mountains (Potter, 1969; Rayback, 1998; Butler and Malanson, 1985; Reardon *et al*., 2008….), Gaspé Peninsula (Dubé *et al*., 2004; Germain *et al*., 2005; Germain *et al*., 2009) Alps Mountains (Schönenberger, 1978; Bebi *et al*., 2009; Corona *et al*., 2010; Garavaglia and Pelfini, 2011), Pyrenees Mountains (Molina *et al*., 2004), Iceland (Decaulne *et al*., 2013). Only few studies addressed to this topic were realized until now in the Romanian Carpathians (Voiculescu, 2005; Simea, 2012; Meseșan, 2013).

In an attempt to check if trees from Parângul Mic area recorded in their rings the past avalanche activity, we analyzed 42 samples (11 stem discs and 31 increment cores) gathered from 22 Norway spruces (*Picea abies (L.) Karst*) located in the upper part of Scărița valley avalanche path (fig. 1).

Usually, the dendrogeomorphological studies of past avalanches are based on a larger number of samples. Corona et al. (2012) suggest that a sample size of approximately 100 trees is required to obtain avalanche reconstruction in an avalanche path. In this study we don't aim to accomplish avalanche reconstruction along the entire mentioned avalanche path, but only to test if trees in this area are suitable for a further dendrogeomorphic reconstruction.

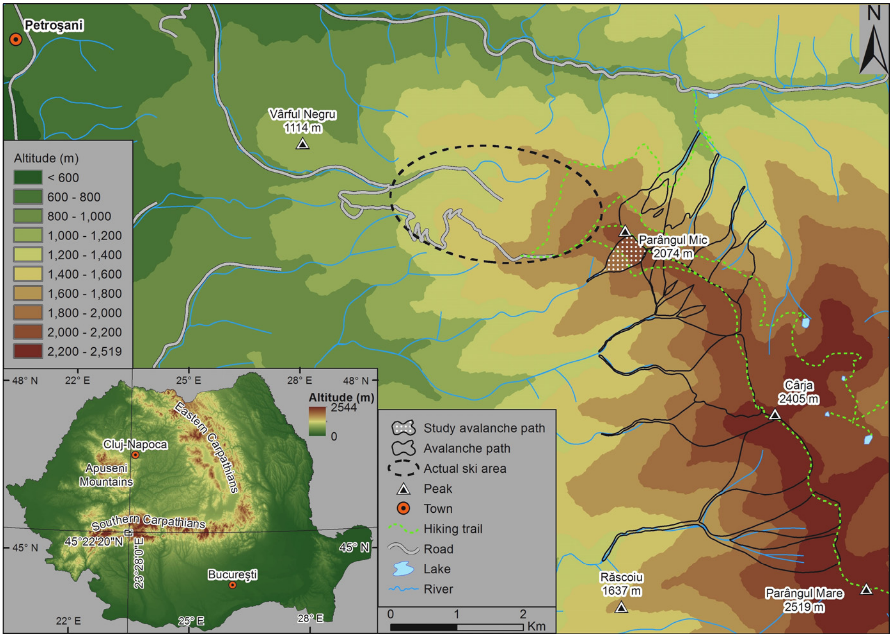

Fig. 1. Study area location

2. MATERIALS AND METHODS

The occurrence of geomorphic processes, including snow avalanches, may disturb the trees located in the area affected. The most important disturbances left by snow avalanches in trees are stem tilting, scars, tree decapitation, broken branches (Butler and Savyer, 2008; Stoffel and Bollschweiler, 2009a; Luckman, 2010). Correlated with those disturbances, the trees record in their internal structure the effects of the mechanical impact by developing growth anomalies, such as tangential rows of traumatic resin ducts, compression wood, growth suppression (Wilford, 2005; Stoffel and Bollschweiler, 2009a). They are stored in the annual ring(s) formed after the impact and represent a reliable natural archive suitable for reconstructing past avalanche activity with annual resolution (Stoffel *et al*., 2010).

The tangential rows of traumatic resin ducts are formed in coniferous trees after insect or fungal attack, fire damage or mechanical wounding (Bollschweiler *et al*. 2008). As a defensive mechanism, the tree develops a network of resin ducts that lead the resin to the place where wounding occurred (Nagy *et al*., 2000).

The compression wood is formed as a consequence of stem tilting induced by the exerting of a pressure upslope like in the case of an avalanche. In order to regain its vertical position, the coniferous trees produce downslope cells with thicker walls that will make the rings darker and larger than normally (Warensjö, 2003; Stoffel and Bollschweiler, 2009a). In the case of avalanches impact, the compression wood anomalies usually last many years, even more than 10, depending on the severity of the impact.

The growth suppression consists in one or more annual rings narrower than the previous. It affects the entire ring(s) if the tree was decapitated or only a portion (usually upslope) if the roots were partially damaged. In this case, the water and nutrients supply is reduced in the affected side of the tree (Stoffel and Corona, 2104).

The scars are the result of a strong mechanical impact that destroys a portion of the bark and the below layers of wood. In time, the tree will grow more intensely from the edge of the injury in order to close it (Stoffel and Bollschweiler, 2009a).

The first step in our research was to analyze the cartographic material available and to choose an avalanche path where the trees show external disturbances related to past snow avalanche activity. For the present study, we selected an avalanche path located on Scărița valley, which is included in the existing development projects of future ski infrastructure extension (fig. 2).

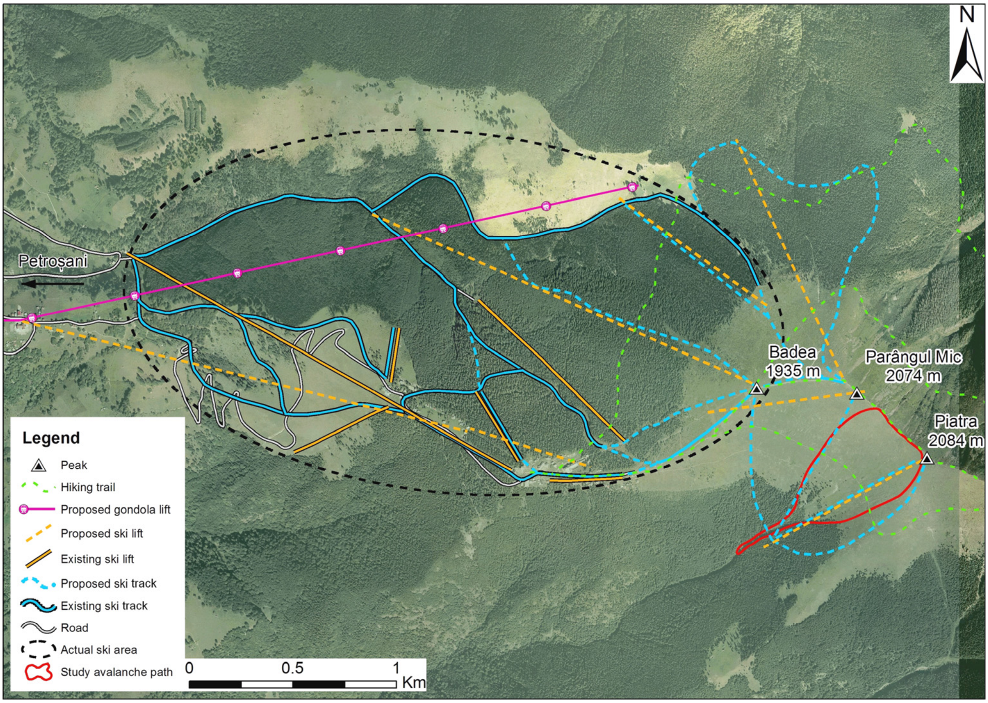

Fig. 2. Existing and proposed tourism infrastructure in the study area

During the field campaign (summer 2014), the trees located in the upper part of the avalanche path were visually analyzed and those showing severe disturbances as a consequence of past avalanche impact were sampled. Eleven trees were sampled using Pressler borers and 2-4 increment cores were extracted from each tree. Other eleven trees were sampled using a saw in order to extract a stem disc from every tree.

The sampling method was adapted according to the tree disturbance. The core sampling orientation was described by Stoffel (2005): A – left, B – right, C – upslope, D – downslope. The trees with tilted stems were sampled at the height of the maximum curvature of the stem. Two increment cores were extracted form tilted trees, one upslope (C) and another one downslope (D) (Bollschweiler *et al*., 2007; Corona *et al*., 2010).

From the trees presenting scars, a core was extracted next to the scar (Stoffel and Bollschweiler, 2008; Stoffel *et al*., 2010) and another core was extracted from the oposite part of the trunk or downslope. The decapitated trees were sampled few centimeters below the decapitation level and two cores were extracted, one upslope and another one downslope. In the case of the sawed trees, a stem disc was cut at the mentioned level.

The increment cores were glued on wood supports. The samples (discs and increment cores) were then air dried and sanded using abrasive belts (80, 240, 360 grit), in order to show clearly the anatomical details. Later, the annual rings were counted in every sample and marked with a pencil as Phipps (1985) recommends (one point for the years finished with „0", two points for the years finished with „50" and three points for the years finished with „00").

For ring-width measurements we used the LINTAB 5 system that includes a binocular microscope and a mobile table, connected to a computer with TSAPWin Professional 0.55 software (Rinntech, 2006).

One growth curve vas obtained for each increment core. The discs were measured on 4 directions (A, B, C, D) obtaining 4 growth curves for each disc. All growth anomalies identified were also noted. The growth curves were cross-dated by checking visually the pointer years (Schweingruber, 1996). The years when at least 2 trees with grow anomalies were considered as avalanche event years. An exception was made for the year 1935 when only one of the sampled trees was alive, but its growth anomalies clearly indicate an avalanche event occurred in that year.

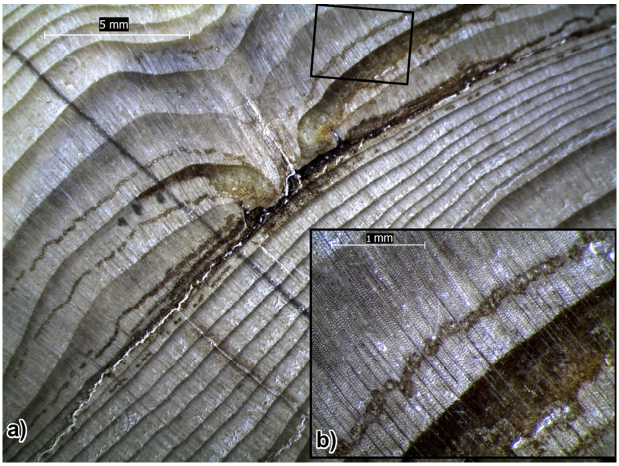

Fig. 3. a) Closed scar produced in 1999 associated with tangential rows of traumatic resin ducts;
b) detail of the ring with tangential row of traumatic resin ducts formed in reaction to mechanical impact of snow on the tree stem

RESULTS AND DISCUSSIONS

The analysis of the 22 trees sampled along Scărița avalanche path revealed a minimum of 13 avalanche events occured between 1935 and 2013: 1934-1935, 1986-1987, 1988-1989, 1990-1991, 1994-1995, 1996-1997, 1998-1999, 2002-2003, 2003-2004, 2004-2005, 2007-2008, 2009-2010, 2011-2012.

This avalanche activity reconstituted using tree-rings records represents a minimum frequency (Reardon *et al*., 2008; Luckman, 2010; Corona *et al*., 2012). There may have been more avalanches that were not recorded in the sampled trees.

The centralization of the growth anomalies allowed us to make a comparison between the information provided by the increment cores and those sampled by stem discs (fig. 6). This comparison show that the discs contain more information than the increment cores and point out more avalanche events. Also, the discs provide more diverse information than the cores. For one event, on the stem disc one may easily identify all the mentioned anomalies: tangential rows of traumatic resin ducts (fig. 3b), compression wood (fig. 4), growth suppression (fig. 4), scars (fig.3a), because it allows the investigation of the entire circumference of the ring.

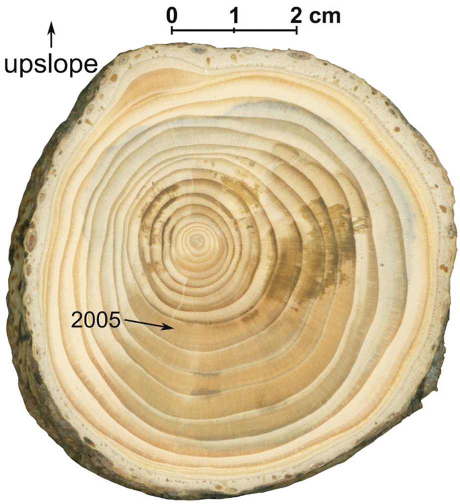

Fig. 4. Compression wood sequence downslope 2005-2009 and growth suppression upslope 2005-2006

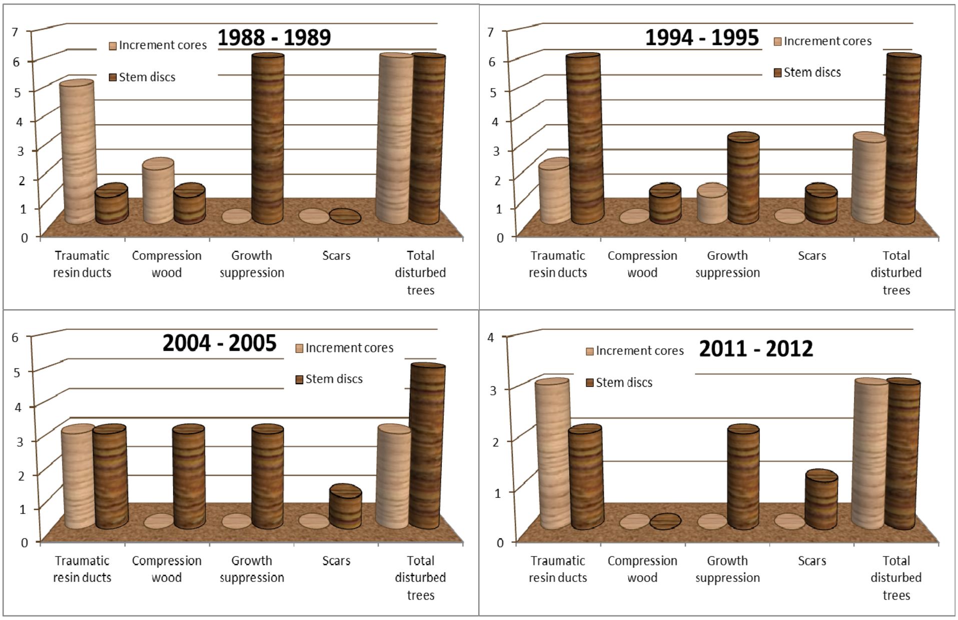

Fig. 5. Comparison between the number of gowth anomalies identified in the trees sampled by increment cores and stem discs for several winters when avalanches occured

Instead, the increment cores present more often traumatic resin ducts, compression wood and/or growth suppression reactions and just accidentally scars, because only a small part of the ring is available for analysis. Moreover, the reaction type found in increment cores strongly depends on sampling technique.

The increment cores are easier to prepare for analysis because they get dried quicker than stem discs. The most important disadvantage of stem discs extraction is that it represents a destructive sampling technique, causing the death of the tree, excepting the case when below the sampling level alive branches remain and could renew the axial growth. The increment cores extraction removes this drawback leaving the tree unharmed (Stokes, 1996).

In our study area, the snow avalanche impact on the tourism infrastructure is not a destructive one but a restrictive one. In the case of Parâng ski area there was not yet severe damages on the tourism infrastructure caused by avalanches, as it happened in other areas of the Carpathians (Moțoiu, 2008; Munteanu *et al*., 2012). Instead, we were able to identify an intense avalanche activity that was not previously known in the area.

It is expected that the expanding of tourism infrastructure resulting from all the development projects will attract a lot of skiers in the ski resort and will allow them to reach very easy Parângul Mic Peak or Piatra Peak in order to ski downslope. Is well known that *„the popularization of extreme sports impels more and more people to trespass out of the marked boundaries of the ski slopes”,* in order to practice free ride snow sports (Arlettaz *et al*., 2007). In this context, *„some skiers and snowboarders at ski areas now seek out extreme terrain”* (Jamieson and Stethem, 2002). Such terrain will be found near by the two peaks, above tree line, in the starting and track zones of the avalanche paths and therefore the uninformed skiers will risk triggering more snow avalanches that commonly occur under natural conditions.

As described in the development project, one of the proposed ski lifts will link the Scărița area with Piatra Peak area, expecting to have the transport capacity of 1200 persons per hour. In addition, other 4 ski tracks will arrive at its base. They will be built as far as 80% of their surface on alpine grassland and they will pass through the Scărița avalanche path. The development project contains only two measures for avalanche release prevention:

a) installation of coastal fences and avalanche stoppers;
b) plantation of *Pinus mugo* saplings and other local shrub species.

In our opinion, even if these prevention measures will be conscientiously applied, it will be insufficient to protect future infrastructure and the tourists.

As it was demonstrated in the case of past debris flows (Stoffel and Bollschweiler, 2009b), the past events reconstruction based on a small number of samples *„may yield valuable data on past events”*. The weakness of such a study are an incomplete frecvency due to unidentified past events and the lack spatial extension for identified events.

Further it is necessary to analyze more samples from the entire avalanche path located on Scărița valley, in order to do accurately reconstruct the avalanche activity history along the entire Scărița avalanche path. The dendrogeomorphic reconstruction could be useful for the avalanche hazard zonation in the studied area.

3. CONCLUSIONS

As a result of our study we affirm that certainly 13 avalanches were produced in Scărița avalanche path even the historical records mention only one event.

We want to warn the tourists and the infrastructure owners or developers about the fact that the avalanche activity is an intense one in this area so it must be seriously taken into consideration in the deployment of all winter tourism activities.

For the following studies, the sampling must be extended. A complete dendrogeomorphological study must include both types of samples, increment cores and stem discs in order to get the utmost information possible. The discs provide the maximum information and the cores complement them efficiently.

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