Avalanche terrain exposure classification for avalanche accidents in Catalan Pyrenees

Glòria Martí[1], Laura Trabal[1 2], Joan Manel Vilaplana[2,] and Carles García-Sellés[1]
[1] Institut Geològic de Catalunya, Barcelona, Catalonia, Spain
[2] Facultat de Geologia, Universitat de Barcelona, Barcelona, Catalonia, Spain.

ABSTRACT: Avalanche terrain exposure consists of identifying and classifying areas prone to avalanches taking into account terrain features. From a data set of 190 avalanche accidents in Catalan Pyrenees 17 were selected as well-known accidents due to the existing information in their accident report. We started a pilot study with 9 of this first selection to be analysed using ATES. Due to avalanche terrain specific characteristics of this area an adaptation of terrain parameters of the original ATES was attained. From the previous eleven parameters we didn't take into account glaciers terrain and we added the wind drift exposure since is one of the most relevant feature in this range. The method consisted on the individualized analysis of each parameter for a given track related with accidents. GIS analysis has been applied to accomplish the purpose of this work. Preliminary results show that the accidents occurred in a segment classified as complex terrain. Further step crossing avalanche exposure and danger level rating suggest that the majority of the accidents were during danger level 3 in a complex terrain. The present work represents a first step to know better avalanche accidents in this area regarding avalanche terrain features
KEYWORDS: Accidents, avalanche terrain exposure scale, danger.

1 INTRODUCTION

Avalanche fatalities in Catalonia (NE of Spain) consist mainly on human triggered slabs in backcountry activities. A series of 199 accidents from 1986 to season 2012-2013 have been recorded by the Avalanche team of the Geological Institute of Catalonia (IGC) in collaboration with Rescue team in this area (Bombers de la Generalitat de Catalunya) and the avalanche centre of Val d'Aran (CGA). The typical avalanche accidents in Catalan Pyrenees occurred during a 3 avalanche danger level and consist on a small-medium human triggered slab with a media of 1.5 killed people for a series of 26 winter seasons (www.igc.cat; Rodés, 1999). Avalanche terrain exposure consists of identifying and classifying areas prone to avalanches taking into account terrain features. The first avalanche terrain classification (ATES) was developed by Parks Canada in 2004 with the aim of helping backcountry users assess the severity of the terrain encountered in a given trip (Statham et al. 2006). It has three terrain classes Simple, Challenging, and Complex derived from eleven weighted terrain parameters: slope angle, slope shape, forest density, terrain traps, avalanche frequency, start zone density, runout zone characteristics, interaction with avalanche paths, route options, exposure time and glaciations.

Corresponding author address: Glòria Martí,
Institut Geològic de Catalunya, Barcelona, Catalonia, Spain;
tel: +34 93 5538430;
email: gmarti@igc.cat

During decades avalanche accidents have been analysed from the snowpack structure and cartography point of view (http://www.igc.cat) Following the initiative of our colleagues from the Aran Avalanche Centre using ATES in some itineraries (Bacardit et al., 2011) we applied the ATES to representative accidents in the Catalan Pyrenees (figure1). The aim of the present work is to analyse and classify accidents (fatalities, injured and no damaging events) from terrain features.

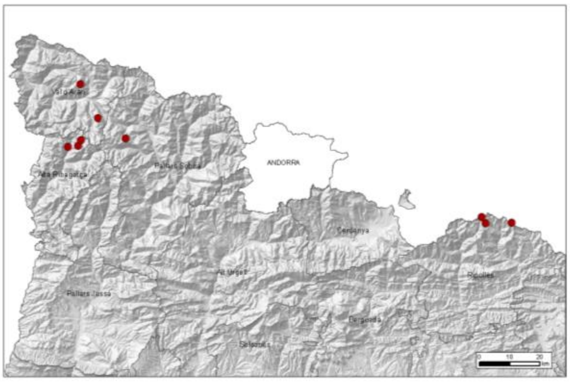

Figure 1: Avalanche accidents selection in the Catalan Pyrenees that were analyzed using ATES. Each accident is represented with a red point.

2 AVALANCHE DATABASE AND SOURCES OF INFORMATION: SELECTION OF ACCIDENTS

In order to analyse and assess accidents from the avalanche terrain exposure point of view we had to select those containing the most detailed information. For that purpose we used all the available information of the avalanche databases of IGC. In addition other on line sources of information were used as well.

The IGC avalanche information consists on: avalanche accidents reports (AR), avalanche mapping and avalanche database (ADB), avalanche bulletins (AB). We also used information of the Cartographic Institute of Catalonia (ICC) to asses some specific ATES parameters.

2.1 Avalanche accidents dataset

From the beginning of the Public Avalanche Forecasting and Prevention Service of the IGC (25 years) avalanche accidents have been recorded recovering not only accidents of the current season but accidents with fatalities and injuries from the past. The current dataset has 199 accidents from 1986. The present work was attained in 2011-2012 with a set of 190 accidents. The level of information is not the same for all the accidents. Obviously those occurred far in the past have less information than the recent ones. As a general rule accidents with fatalities have an accident report associated (AR) which contains detailed information on cartography of the avalanche (1:10.000), nivometeorological data including tests, profiles, danger level and meteorology, avalanche terrain parameters and description, information of the party and the victims and with different level information on the track. The selection of accidents was set up in accordance with the degree of information of the AR, specifically on the track.

2.2 Avalanche Database

Avalanche mapping has been one of the most important branches at IGC from years. Avalanches path maps consist on not only accidents mapping but the systematic observed avalanches mapping during the season and also of the cartography of the whole areas prone to avalanches. This information is recorded together with their alphanumeric information including terrain features and parameters in the Avalanche Database (Oller et al., 2006). The work scale is at 1:10.000 but maps are issued at 1:25.000.

2.2 Avalanche Forecasting

Daily public avalanche reports and associated data like profiles, tests and avalanche danger clues have been very useful to characterize accidents. All this information fulfilled AR and was a source of information for traps parameters i.e. cornices and wind drift as well.

Avalanche danger rating was crossed with avalanche exposure using Avaluator.

2.3 Geographical information

The Elevation Terrain Model at 5x5 meters of the Cartographic Institut of Catalonia (ICC) is available for the Catalan Pyrenees. From that source of information there we derived:

- Slope Maps (figure 2)
- Concave-convex Maps
- Aspect Maps

From IGC we had also Topography and Ortophoto Maps at 1:5.000 scale.

The described information allowed us to select those accidents which had not only specific and detailed avalanche and geographic information but detailed information of the track. From 17 well-known track we selected 9 to attain the avalanche terrain analysis (see figure 1). All the selected accidents were in the most frequented areas and with more accidents in recent decades during winter seasons in the Catalan Pyrenees: Ter-Freser and Aran area at the northeast and north face part of the range respectively and Ribagorçana area in the surroundings of the unique National Park in Catalonia

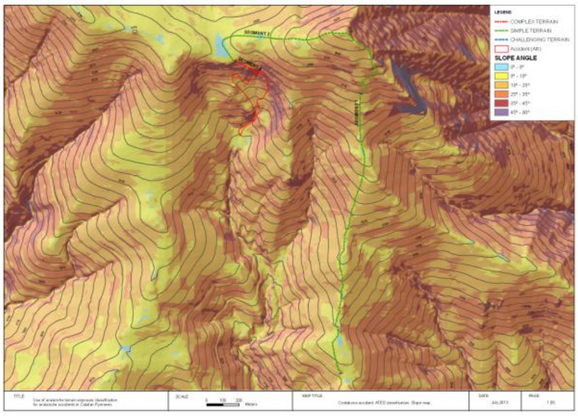

Figure 2: Map of slope angle of Costabona accident. We used intervals of 0º-8º (blue), 8º-18º (yellow), 18º-25º (light orange), 25º-35º (orange), 35º-45º (deep red) and 45º-9º0 (purple)

3 METHODOLOGY

Every accident occurred during a track. Every track was digitized to do the avalanche terrain analysis. These initial nine tracks were divided in segments according with avalanche terrain exposure.

Tracks of accidents resulted in segments with a minimum of 2 segments and a maximum of 5 segments

3.1 ATES parameters modification

From the original ATES Technical Method (V1-04) (Statham et al., 2006) some changes in describing the ATES parameters were

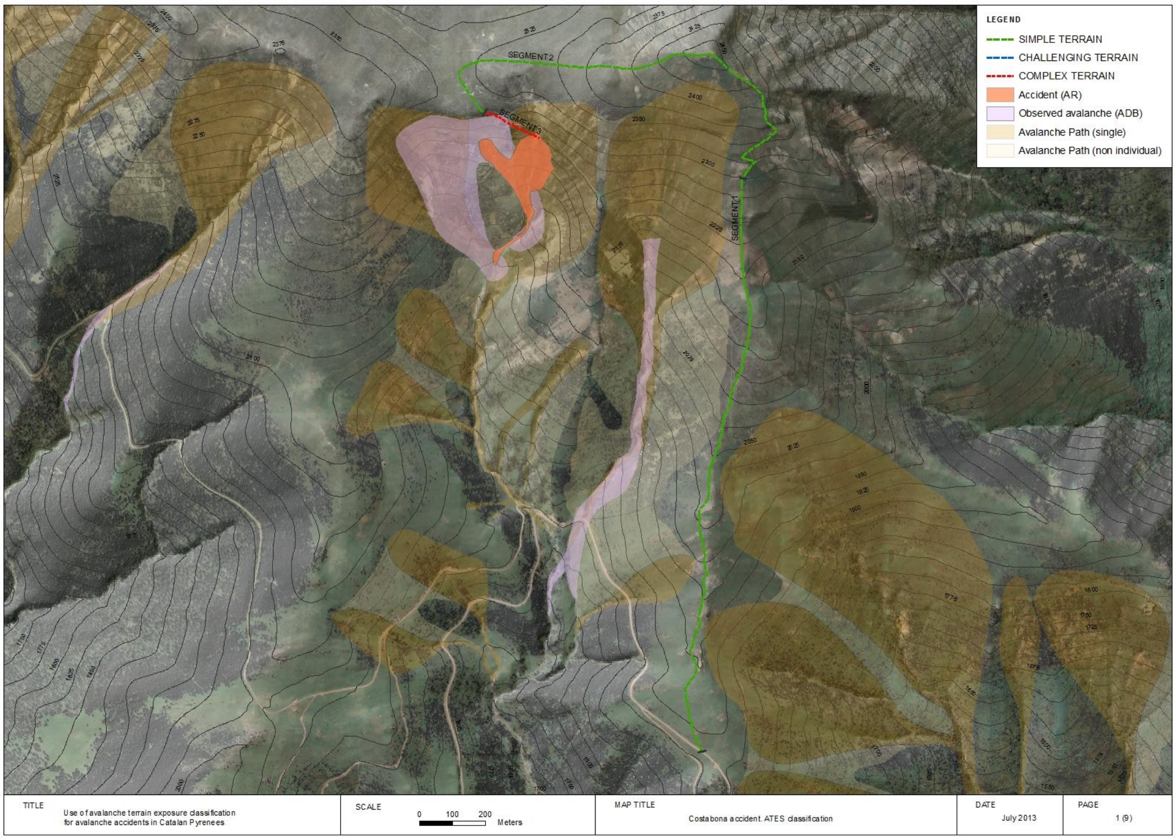

Figure 3: Map of Costabona accident with avalanche terrain classification: the two first segments of the track were classified as simple and the last one as complex, being this last one the place of the accident. In red colour we mapped the avalanche of the accident. As a background layers there are ortophotomaps and observed avalanches (in light violet) and avalanche paths in light orange, from ADB.

introduced with the aim of reflecting specific issues of the accidents and data and due to the terrain characteristics of the study area.

Avalanche glaciers in the Pyrenees are reduced to north face of the range or very scarce in the south face. Specifically in the Pyrenees of Catalonia (mostly south faced) they do not exist. For this specific reason we did not analysed this parameter in this work.

Forest density, avalanche frequency, route options and exposure time descriptions were kept as the original ATES Technical Method.

Some of the tracks of the selected accidents started in ski resorts where although the slope is above 30 degree, on season works and treatment of the slopes is different from out of bounds areas. For this reason we included as simple terrain those slopes above 30º in ski resort areas (figure 2).

Convoluted terrain in slope shapes was described as those areas with abrupt changes in aspect and concavity and convexity.

We included groups of trees acting as obstacles in challenging terrain traps.

In the description of simple terrain of the start zone density, runout zone characteristics and interactions with avalanche paths, we added the “areas not affected by avalanche paths” since no level 0 was included in the scale (Campbell et al., 2012). Furthermore we include the interaction with non-individualized avalanche paths of ADB in challenging terrain and individualized avalanche path in the complex terrain, for the interaction with avalanche paths. These two specific categories of avalanche paths maps allowed us to categorize a little bit more these parameters.

Finally we added wind drift exposure as a new parameter. The proposal classifies as simple terrain those tracks crossing areas with null or scarce wind drift, as challenging tracks crossing areas with frequent wind drift and finally as complex terrain those areas crossing very frequent wind drifted snow deposits and cornices. This information is available both in ADB and in Avalanche forecasting.

The method consisted on analysing the track using these parameters. We also analysed the accidents from original ATES and compared the results.

The tracks were divided in segments as a result of the ATES classification (simple, challenging and complex). In case of significant differences in classifying a variable the track was also divided.

4 RESULTS AND DISCUSSION

From the original 9 tracks, two were divided in 2 segments, four in 3 segments, two in 4 segments and one in 5 segments according with avalanche terrain. In all of them the final segment corresponds to the part of the track where the accident occurred. In figure 3 an example of the resulting with the segments classified with ATES are shown.

4.1 Terrain description of the tracks using ATES

A summary of the main features of the accidents using the proposal pointed out in the methodology is represented in figure 4.

Coll de la Marrana accident resulted in two segments. The first classified as simple terrain because of flat or low slope angle areas crossing on-piste areas. The second part was a complex terrain out of bounds with steep terrain affected very frequently by wind drifting and cornice formation. In a similar way but with three segments was the Costabona accident (figure 3). This track has two simple terrain fragments with some cornices in the second one and a third complex segment due to steeper terrain with several interaction with avalanche paths and recurrent wind drift problems due to slab formation.

In the same area there was the Bastiments accident that was divided into 5 segments: 2 classified as simple, 1 challenging and 2 complex. The most problematic ones are those parts of the track with steep terrain with well-known high avalanche frequency and wind drift and cornice problems.

The both Punta Alta accidents (1 and 2) had some common segments classified as complex terrain mainly because frequent exposure to starting zones at the end of the track. Punta Alta 1 was classified as 1 simple, 1 challenging and 1 complex and Punta Alta 2 has 1 simple and 2 complex segments.

A particular accident in comparison with the rest of the sample but at the same time with common features with avalanche fatalities in the study area was the Cavallers accident. It occurred while several parties were climbing in a gully. The majority of the parameters in the accident segment were described as complex, specifically terrain traps and the other segment as challenging. Lo Teso de Son has a simple starting terrain that increases in complexity due steeper terrain with cornices, traps and overlapping with paths. The classification was 1 segment as simple terrain, 1 challenging and 2 complex.

The Tuc dera Pincela accident was divided in three segments with a first simple one and two complex terrain in the other two segments. The main characteristics of the complex terrain in this accident were large open terrain, numerous overlapping paths and frequent exposure to starting zones.

Finally the Malh Blanc accident is in an area with recurrent accidents. This particular track was divided in 4 segments being the fourth the more complex one and where the accident occurred. The others were classified as simple in the first segment and 2 challenging.

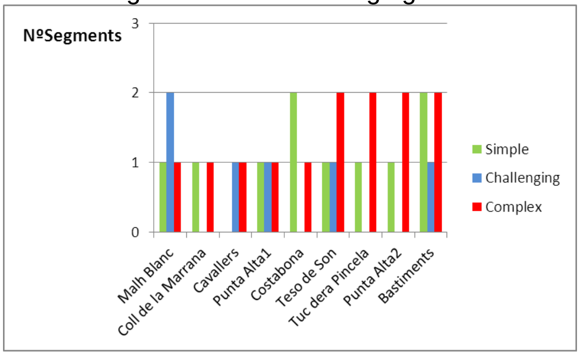

Figure 4: Frequency of avalanche terrain exposure ratings for all the tracks and segments analysed.

We also did the original ATES analysis resulting in non-essential changes and definitively the same rating. As a general rule when we had a complex terrain due to wind drift in the proposed parameters, there were cornices in terrain traps so having both the same rating at the end.

4.2 Segments of tracks with accidents

For all the tracks the most complex rating was for the segment where the accident occurred, being classified as complex terrain for all.

Focussing on the rating of each parameter, we found that forest density and exposure time parameters were completely ranked as complex terrain, followed by slope angle with 8 from 9, interaction with avalanche paths and wind drift exposures with 6, traps and route options with 4, slope shape and runout characteristics with 3, start zone density with 2 and avalanche frequency with 1 (figure 5)

The parameter with more challenging ratings is the starting zone density with 7, followed by route options with 5, slope shape with 4, interaction with avalanche paths and terrain traps with 3 and runout zone characteristics and slope angle with 1 (Figure 5).

Concerning simple terrain there are four parameters: forest density, exposure time, slope angle and interactions with avalanche paths, without any simple rating (Figure 5). Avalanche frequency was rated mainly as a simple. In this particular parameter we used the ADB information with a series of 18 seasons with regular avalanche observation in the Catalan Pyrenees which is not enough to characterize this particular parameter.

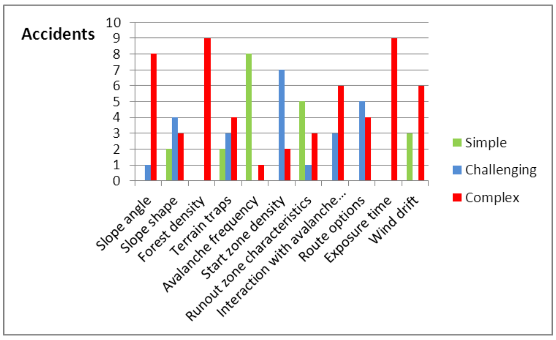

Figure 5: In this graphic it is shown the frequency of parameters concerning the avalanche terrain exposure ratings for the segment with accidents.

4.3 Crossing avalanche terrain rating with avalanche danger: Avaluator

From avalanche bulletins we got the danger level for every accident. All the accidents happened with a danger level 3 of the European Avalanche danger Scale except Cavallers and Lo Teso de Son with danger level 2.

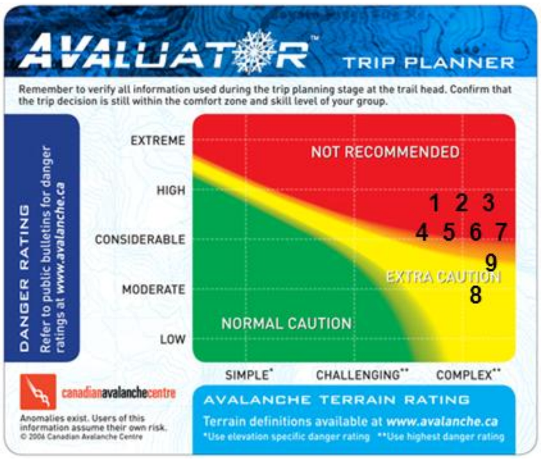

Figure 6: Avaluator card with avalanche accidents represented with numbers: 1 Punta Alta1, 2 Bastiments, 3 Costabona, 4 Malh Blanc, 5 Tuc dera Pincela, 6 Punta Alta2, 7 Coll de la Marrana, 8 Cavallers and 9 Lo Teso de Son.

The Avaluator Trip Planner combines current snow and avalanche conditions -danger rating- and the terrain of the intended trip -ATES rating- (Haegeli et al., 2006). Crossing both ratings provides the user professional recommendations about training and experience required for safe travel ranked as: normal caution, extra-caution and not recommended. As seen in figure 5, six accidents were in the not recommended area and 2 in the extra-caution recommendation indicating that in those terrains and with those snowpack state avalanche accidents are very frequent and the current conditions are primed for avalanche accidents.

5 CONCLUSSIONS

The selected accidents occurred in the most crowed backcountry areas and at the same time with more accidents in the recent decades. For this reason the analysis of this sample becomes a good representation of avalanche accidents in Catalonia. However, enlarging the sample with more study cases (at least until 17 of the previous selection) is needed to deep in terrain analysis results.

For a given avalanche danger level, accidents occurred in a segment of the trail classified as a complex terrain even though there were segments classified as simple or challenging in all the nine tracks analysed.

Eight trails had at least one simple terrain before the occurrence of the accident so meaning that there other choices to do some activity with less risk.

Recurrent accidents with fatalities in Catalan Pyrenees are those inside gullies and in specific while performing climbing activities. In this kind of terrain there are few options to avoid accidents even when there are moderate instability of snowpack. Thus special efforts has to be attained like warning people in this particular terrain in avalanche bulletins as it has been done in recent seasons. Avalanche frequency has been the most difficult parameter to analyse due to the lack of information. In this particular issue further research on avalanche frequency like systematic field observations in the most frequented tracks has to be attained in order to improve results.

The use of ATES is a powerful tool to better describe avalanche accidents. The implementation the original ATES classification will improve accidents reports.

Crossing avalanche terrain with avalanche danger is very useful in special for the user but in our particular case because of the danger level comes from European Avalanche Danger Scale, we would suggest to perform deeper analysis on how to adapt with Avaluator.

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