THE AVALANCHE CARTOGRAPHY OF CATALONIA. A PRELIMINARY EVALUATION OF THE SPATIAL AVALANCHE DATA.

Pere Oller (1), Jordi Marturià (1); Juan Carlos González (2) and Pere Martínez (1)

(1) Institut Geològic de Catalunya. Parc de Montjuïc s/n 08038 Barcelona. pereo@icc.es
(2) Institut Cartogràfic de Catalunya. Parc de Montjuïc s/n 08038 Barcelona. jcgonzalez@icc.es

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INTRODUCTION

The growth of tourism in recent decades, in the Catalan Pyrenees (figure 1), has resulted in an increase in building, opening of mountain roads in the winter, and related infrastructures. As a consequence, exposure to natural hazards has increased and so has the risk. Risk and hazard maps are basic documents for land planning, management and disaster prevention. In 1986, the Geological Survey of Catalonia (SGC) began an ambitious avalanche mapping plan 1:25.000 of all the Catalan Pyrenees. In 1996, the first Avalanche Paths Map (MZA) was published by the Cartographic Institut of Catalonia (ICC), and the last one, the 14th, was published in 2006.

Figure 1 - Location of the Catalan Pyrenees (red area, enlarged in figure 4)

During the realization process of the MZA a great deal of avalanche data was compiled. An avalanche database (BDAC) was created for storing and managing all this information. The aim of the Avalanche Database of Catalonia (BDAC) with the Avalanche Data Server (SDA) is to be the reference site for anyone interested in this information. The information has been stored according to three mapping concepts: avalanche path (AP), avalanche inquiry (AI), and avalanche observation (AO).

The aim of this paper is to present this cartography, how the information has been stored, and to remark on the importance of every avalanche mapping concept and its limitations.

THE AVALANCHE PATHS MAP

The MZA (figure 2) is a susceptibility map which represents areas potentially affected by avalanches. It is based on the French "Carte de Localisation Probable des Avalanches" (CLPA; Pietri, 1993). It is suitable for land planning at a regional scale. This information was compiled through terrain analysis, witness inquiries and winter avalanche activity surveillance. The map shows a synthesis of all the gathered information. Orange represents the areas mapped from terrain analysis and violet represents a synthesis of the information gatherd from inquiries and winter surveillance. The cartography was made on the ICC 1:5.000 digital bases (topography, ortophotos, and DEM; Martí et al, 2000).

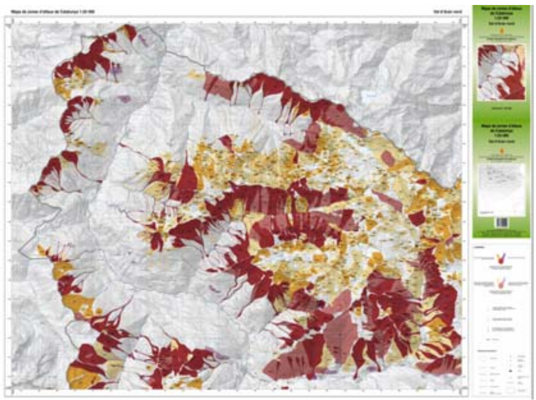

Figure 2 - First published Avalanche Paths Map: "Val d'Aran Nord" (1996).

An extension of 5.092 km^2 was surveyed. During this process 17.518 AP were mapped (figure 5).

One result was the continuous avalanche map of the entire range (Figure 4). The area potentially affected by avalanches covers 1.257 km2. It represents 3,91% of the Catalan territory, and taking into account the Pyrenean territory it affects the 36% (Oller et al, 2005). As can be seen in figure 3, the western part of the range (from

Andorra to the west) is the most affected part, representing 78% of the total affected surface.

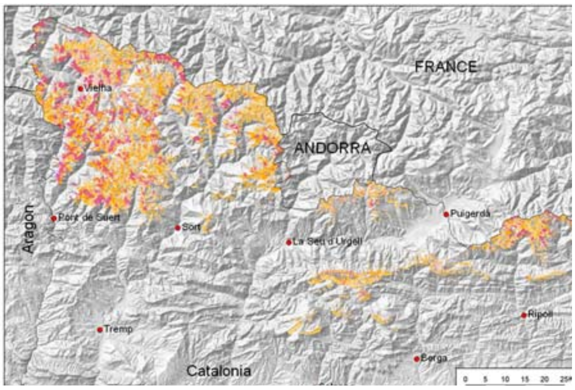

Figure 3 - Avalanche Paths Map of the Catalan Pyrenees.

THE AVALANCHE DATABASE OF CATALONIA

With the design and implementation of the BDAC an important step was taken in systematically storing the large amount of information generated by the MZA mapping process. The goal was to have an efficient system for data managing, analysis and actualization of the information.

The information stored in the BDAC is both graphic and alphanumeric. Avalanche mapping concepts are represented by polygons (graphic) and a set of attributes describes its characteristics (alphanumeric). The mapping concepts are the following:

- Avalanche Path (AP): area exposed to avalanche phenomena. Inside the avalanche paths, avalanches occur with different frequencies and dimensions. The AP limits are mapped from expert observations of terrain characteristics and vegetation indicators. The associated information is the terrain characteristics, type and state of the vegetation and potential damage to human beings. They were systematically mapped throughout the entire region.
- Avalanche Inquiry (AI): area where an occurrence has been observed in the past. This information is obtained from local inquiries. The AI limits are based on these descriptions. The associated information come from the description to witnesses to the event. Some relevant characteristics such as date of occurrence, runout distance or damage, are pointed out. They were mapped near inhabited areas, where they interfere with human activity.
- Avalanche (AO): area where an avalanche has been observed. Their limits are mapped from the direct observation of the avalanche. The associated information consists of the date, nivometeo conditions, type, physical characteristics, damage and victims. They are mainly being mapped in populated areas, roads and ski resorts, but also in unpopulated areas.

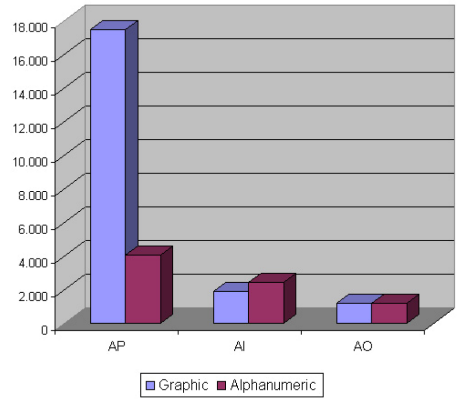

Figure 4 - Data obtained in the MZA mapping process and updated in the BDAC.

THE NEED OF COMPLEMENTARY INFORMATION

The reason why this information was kept separate is conceptual. An AP is an area where avalanches can occur, defined by expert criteria. Its limits depends on the existence of avalanche evidence, and on expert experience. AI and AO describe avalanche events. The difference between them is the spatial precision of the data. In general, AI is more imprecise and incomplete, but it provides information from the past century; AO is more precise and complete, but its information was only collected during the last 20 years. So, the three avalanche mapping concepts provide complementary information and provide more knowledge about avalanche phenomena. Therefore it also improves the knowledge of basic parameters for hazard evaluation: runout distance, frequency and intensity.

The contribution of AI and AO to AP is shown bellow. The AP is the mapping concept from which AI and AO were compared. First, the increment of mapped surface from AI with respect to AP was calculated. Later, the AO increment with respect to AP was obtained. Finally the AO increment was compared with the addition of the AP+AI mapped surface, taking into account that in the mapping process, the AP was mapped first, after was the AI, and the AO are still being mapped.

Figure 5 shows how the increment of the AI mapped area with respect to AP was 1.647 Ha (1,3% of the total surface). Comparing AO with AP the increment was notably lower, 0,3% (232 Ha). The third value, the AO mapped surface with respect to the AP plus AI information was slightly lower than the previous (260 Ha, 0,2%). These results show that AI provided more spatial information than AO, but AO spatial increments were registered mainly on avalanche paths where there is no AI information. It reveals that AO mapping is more widespread over the territory, whereas AI is more concentrated in populated areas.

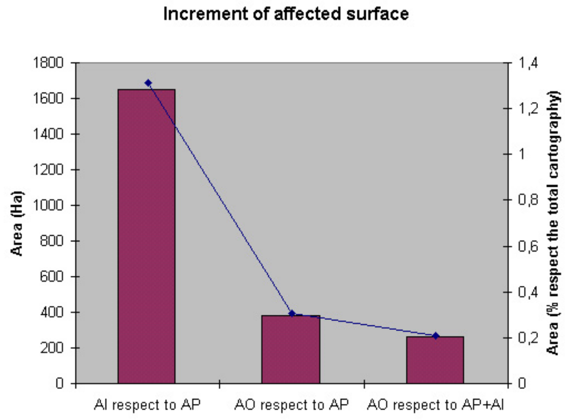

Figure 5 - Increment of affected surface.

The resulting values are not very high but they are important because the majority of these increments are mapped in the runout zone of the avalanche. In many cases human infrastructure is located in these zones.

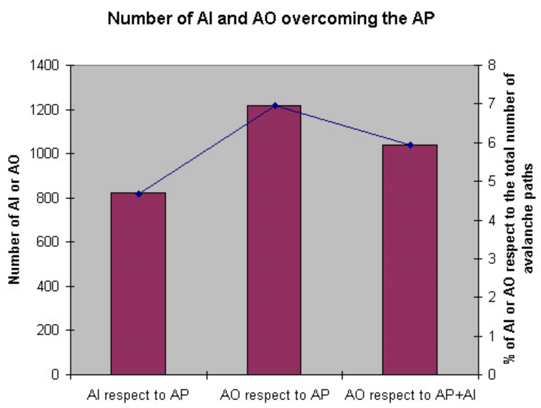

Figure 6 - Increment of avalanche paths.

In figure 6 the number of AP, in which increments where registered, is shown. In this case, there are more AP with AO increments than with AI increments. This graphic explains that in the case of AI, the information depends mainly on witnesses, who are restricted too in populated areas. In general, AO, is more widespread throughout the territory. It exceeds the AP+AI limits, but with short distances, because of the short observation period, in which the mapped increments are lower.

In figure 7 the avalanche paths are classified in function of the incremented surface. In the case of AI, the majority of cases have increments from 0,1 to 10 Ha, and in the case of AO, the increments are lower than 1 Ha. This confirms that AI contributes with an important increment to the mapped surface, and AO contributes with fewer increments, but these increments are observed in more avalanche paths.

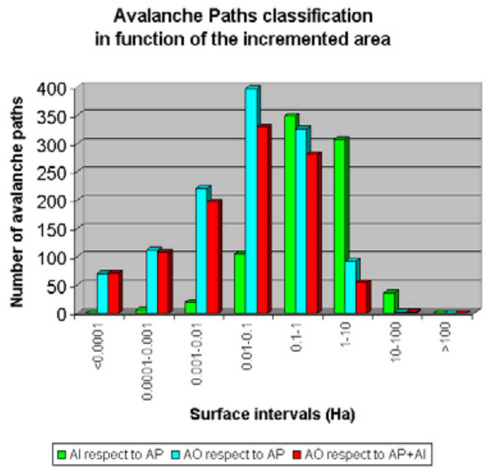

Figure 7 - Classification of the avalanche paths in function of the incremented area.

CONCLUSIONS

The Avalanche Database of Catalonia is a basic tool for storing, updating and managing the information gathered during the Avalanche Paths Map mapping process and present avalanche surveillance. Avalanche phenomena affects 4% of the Catalonian surface and 36% of the Pyrenean regions. The structure of the avalanche information in Avalanche Paths, Avalanche Inquiries, and Avalanche Observations, is very reliable for further analysis. The mapping concepts are different and they represent different degrees of precision.

The improvement of the cartography in the runout zone is basic for hazard analysis. Avalanche Inquiries provide an approximation to major avalanches and therefore a significant increase of mapped surface. Avalanche Observations provide a lower increment of mapped surface, but this increments are observed in more Avalanche Paths.

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