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Goeohazards mapping in Catalonia

Summary:
This paper presents the different lines of work being undertaken by the Geological Institute of Catalonia (IGC) on geological hazard mapping. It describes the different map series, scales of representation, methodologies and its expected use.

Keywords: hazard mapping, geohazards, Catalonia.

Introduction

The Parliament of Catalonia approved, by Law 19/2005, the creation of the Geological Institute of Catalonia (IGC), assigned to the Ministry of Land Planning and Public Infrastructures (DPTOP) of the Catalonian Government.

One of the functions of the IGC is to “study and assess geological hazards, including avalanches, to propose measures to develop hazard forecast, prevention and mitigation and to give support to other agencies competent in land and urban planning, and in emergency management”. Therefore, the IGC is in charge of making official hazard maps for such a finality. These maps comply with the Catalan Urban Law (1/2005) which indicates that in those places where a risk exists, building is not allowed.

The high density of urban development and infrastructures in Catalonia requires geo-thematic information for planning. As a component of the Geoworks of the IGC, the strategic program aimed at acquiring, elaborating, integrating and disseminating the basic geological, pedological and geothematic information concerning the whole of the territory in the suitable scales for the land and urban planning. Geo-hazard mapping is an essential part of this information. Despite some tests having been carried out with wide land recovery (Mountain Regions Hazard Map 1:50000 [DGPAT, 1985], Risk Prevention Map of Catalonia 1:50000 [ICC, 2003]), at present the work is done mainly on two scales: land planning scale (1:25.000), and urban planning scale (1:5.000 or more detailed). These scales imply different approaches and methods to obtain hazard parameters used for such purpose. The maps are generated in the framework of a mapping plan or as the final product of a specific hazard report. These different types of hazard mapping products are explained below.

Geological Hazard Prevention Map of Catalonia 1:25.000 (MPRGC25M)

The most important mapping plan is the Geological Hazard Prevention Map of Catalonia 1:25.000 (MPRGC25M). This project started in 2007. The MPRGC includes the representation of evidence, phenomena, susceptibility and natural hazards of geological processes. These are the processes generated by external geodynamics (such as slope, torrent, snow, coastal and flood dynamics) and internal (seismic) geodynamics. The information is displayed by different maps on each published sheet. The main map is presented on a scale of 1:25000, and includes landslide, avalanche and flood hazard. Hazard level is qualitatively classified as high (red), medium (orange) and low (yellow). The methods used to analyze hazards basically consist of geomorphological, spatial and statistical analysis.

Several complementary maps on a 1:100000 scale show hazard caused individually by different phenomena in order to facilitate the reading of the sheet and understanding of the mapped phenomena. Two additional maps for flooding and seismic hazards, represented on a 1:50000 scale, are added to the sheet. The map is intended to enable government and individuals to have an overview of the territory, with respect to geological hazards, identifying areas where it is advisable to carry out detailed studies in case of action planning. At the same time a database is being implemented. It will incorporate all the information obtained from these maps. In the future it will become the Geological Hazard Information System of Catalonia (SIRGC).

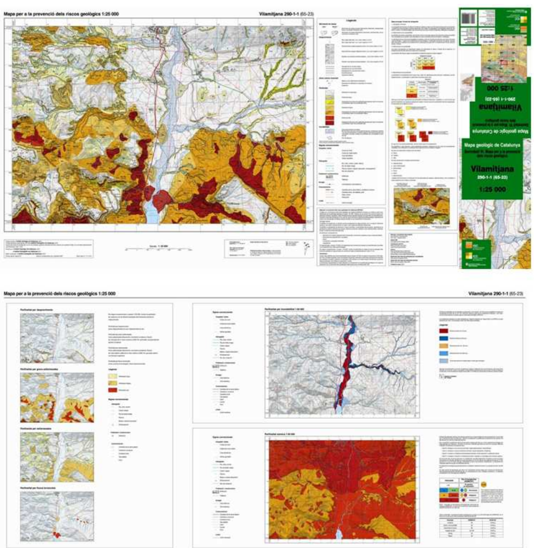

Fig. 1: First published sheet, Vilamitjana (65-23), in 2010.

The procedure followed in the main map consists of three steps:

1.Catalogue of phenomena and evidences
2.Susceptibility determination
3.Hazard determination

The catalogue of phenomena and evidence is the base of the further susceptibility and hazard analysis. It consists of a geomorphologic approach and it comprises the following phases:

1.Bibliographic and cartographic search: the information available in archives and databases is collected.
2.Photointerpretation: carried out on vertical aerial photos of flights from different years (1957, 1977, 1985, 2003, etc.). The observation of the topography and the vegetation allows the identification of areas with signs of instability coming from the identification and characterization of events that occurred recently or in the past, and from activity indicators.
3.Field survey: checking and contrasting on the field, the elements identified in the previous phases. Field analysis allows a better approach and understanding, and therefore identifying signs and phenomena not observable through the photointerpretation.
4.Population inquiries: the goal of this stage is to complement the information obtained in the earlier stages, especially in aspects such as the intensity and frequency. It is done through a survey to witnesses who live and/or work in the study areas.

In a second step, areas susceptible to be affected by the phenomena are identified from the starting zone to the maximum extent determinable at the scale of work. Their limits are drawn taking into account the catalogue of phenomena, geomorphological indicators of activity, and from the identification of favourable lithologies and morphologies of the terrain. This phase includes the completion of GIS and statistical analysis to support the determination of the starting and run-out zone. It can be extensively applied with satisfactory results with regard to the scale and purpose of the work.

Finally hazard is estimated on the basis of the analysis of the magnitude and frequency (or activity) of the observed or potential phenomena. Susceptibility areas are classified according to hazard matrix represented in Figure 2. Hazard zones are represented as follows: areas where no hazard was detected (white), zones with low hazard (yellow), medium hazard zones (orange), and areas with high hazard (red).

		FREQUENCY/ACTIVITY		
		Low	Medium	High
INTENSITY	Low			
	Medium			
	High			

Fig. 2: Hazard matrix (based on Altimir et al, 2001).

In order to obtain an equivalent hazard for each phenomena, an effort was made to equate the parameters that define them. The same frequency/activity values were used for all phenomena, but magnitude values were adapted to each of them.

Each hazard level contains some considerations for prevention (Figure 3). These considerations inform about the need for further detailed studies and advise about the use of corrective measures.

	PREVENTION	
HAZARD	DETAILED STUDIES	HAZARD MANAGEMENT
Not observed	-----	-----
Low	Recomendable	Necessary in certain cases
Medium	Indispensable	Necessary in many cases
High	Indispensable	Necessary in most of the cases

Fig. 3: Prevention recommendations.

Hazard from each phenomena is analyzed individually. The main challenge of the map is to easily present the overlapping hazard of different phenomena. A methodology identifying that this overlap exists has been established with this objective in mind. It indicates what the maximum overlapped hazard is (Figure 4), but in any case, without obtaining new hazard values.

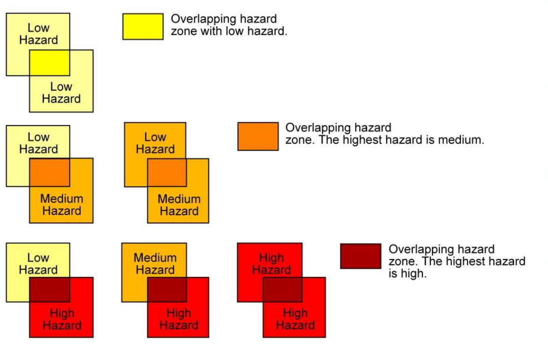

Fig. 4: Multi-hazard representation.

To identify what is the hazard level and the phenomena that causes it, especially in overlapping areas, an epigraph is assigned (Figure 5). This epigraph consists of two characters, the first in capital letters, indicates the value of hazard (A for high hazard, M for medium hazard and B for low hazard), and the second, in lower-case, indicates the type of phenomena (e for large landslides, s for landslides, d for rockfalls, x for flows, a for avalanches and f for subsidence and collapses). The higher the overlapping is, the longer the epigraph will be.

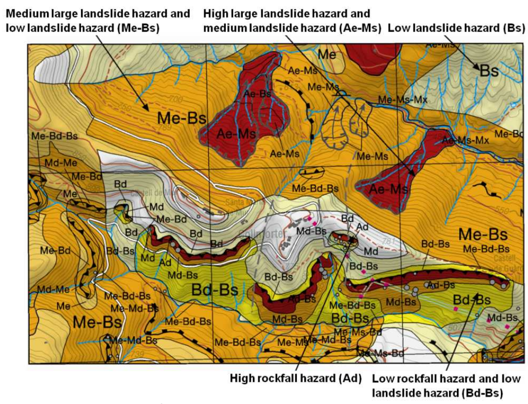

Fig. 5: Example of multi-hazard representation.

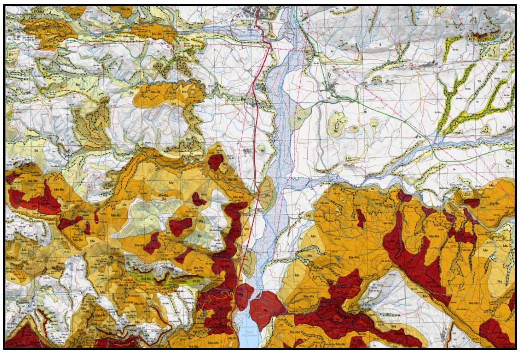

Fig. 6: Main map 1:25000, which includes landslides, avalanches, sinking and flooding according to geomorphologic criteria.

Complementary maps

Complementary maps represent the hazard established for each individual phenomena at 1:100000 scale. The purpose of these maps is to facilitate the interpretation of the main map. Depending on the type of phenomena identified in the main map, the number of complementary maps can vary from 1 to 6.

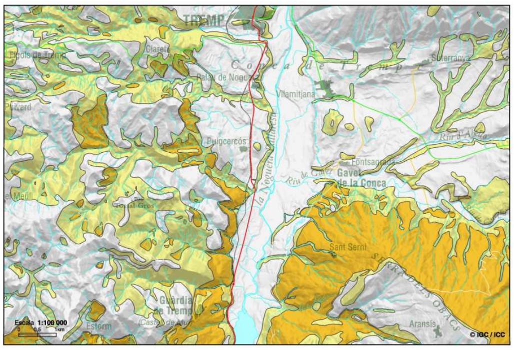

Fig. 7: Complementary map of surface landslide hazard.

Seismic Hazard Map

This map was obtained from the map of seismic areas for a return period of 500 years, for a middle ground, and considering the effects of soil amplification.

To take into account the amplification of the seismic motion due to soft ground, a geotechnical classification of lithologies from the Geological Map of Catalonia 1:25000 into 4 types was carried out: R (hard rock), A (compact rocks), B (semi-compacted material) and C (non cohesive material). This classification is based on the speed of the S-wave through them (Fleta et al., 1998). The proposed amplifications were assigned to each group of lithologies. For types R and A no additions of any degree of intensity were made, but for types B and C, there was an addition of 0.5 degrees of intensity.

The final map (Figure 8) also represents the values of the basic seismic acceleration of the compulsory "Norma de Construcción Sismorresistente Española" (NCSE-02) for a placement in rock, and the intensity of the seismic emergency plan (SISMICAT).

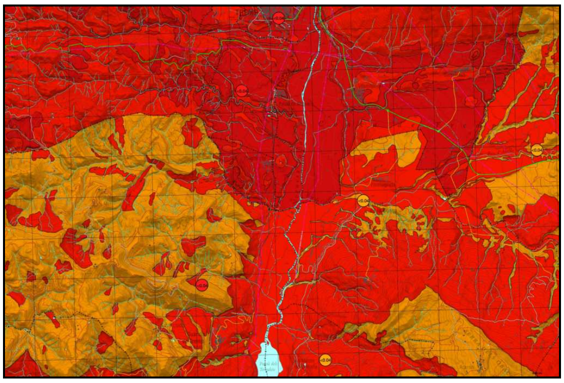

Fig. 8: Seismic hazard map 1:100000.

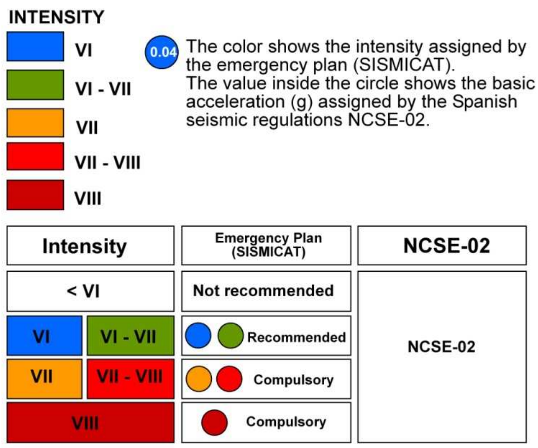

Fig. 9: Seismic hazard map symbology.

Flooding hazard map

The flooding hazard map 1:50000 scales shows the limits of the hydraulic modeling for periods of 50, 100 and 500 years provided by the Catalan Water Agency (ACA). A flooding map according to geomorphologic criteria was done in those streams were hydraulic modeling was not performed.

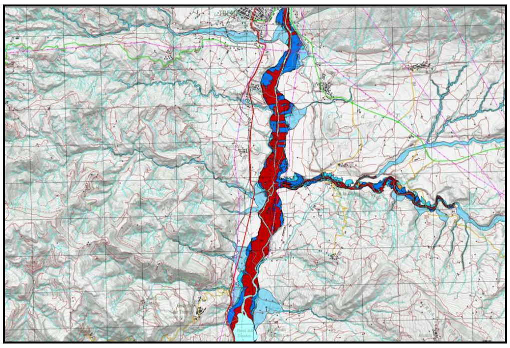

Fig. 10: Flooding hazard map 1:100000 based on hydraulic modeling.

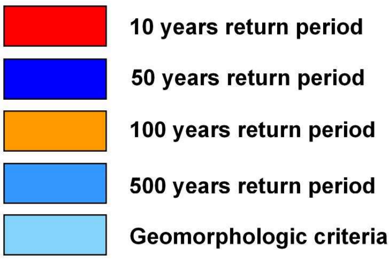

Fig. 11: Flooding hazard map symbology.

Avalanche Paths Map (MZA)

A second mapping plan, already finished, is the Avalanche Paths Map (MZA). It was begun in 1996 and finished in 2006. An extent of 5092 km2 was surveyed. During this process 17,518 avalanche paths were mapped. This is a susceptibility map on a scale of 1:25.000, useful for land planning in the Pyrenean areas. The methodology is based on the French “Carte de Localisation des Phénomènes d’Avalanches” (Pietri, 1993). On this map, the avalanche paths, mapped from terrain analysis (photointerpretation and field work), are represented in orange, and the inventory information (witness surveys, historical documents, field surveys and dendrochronology) is represented in violet.

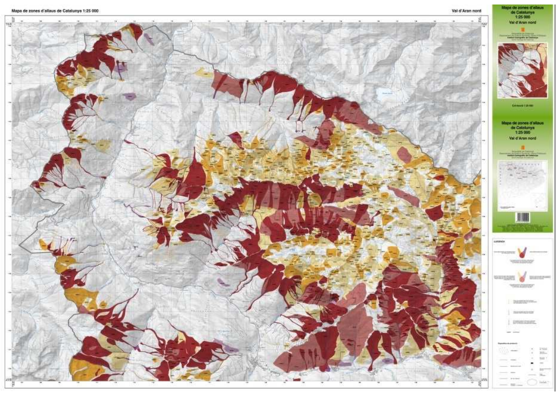

Fig. 12: First published Avalanche Paths Map, “Val d’Aran Nord”, in 1996.

The termination of the MZA allows a first global vision of the avalanche hazard distribution in this region. The area potentially affected by avalanches covers 1,257 km2. That is at 3.91% of the Catalan country, and considering the Pyrenean territory, it affects a 36%.

At present, all the avalanche information is stored in the Avalanche Data-base of Catalonia (BDAC). New events, coming from avalanche observation, are added to this database. The information is available via the Internet at: http://www.icc.cat/msbdac/.

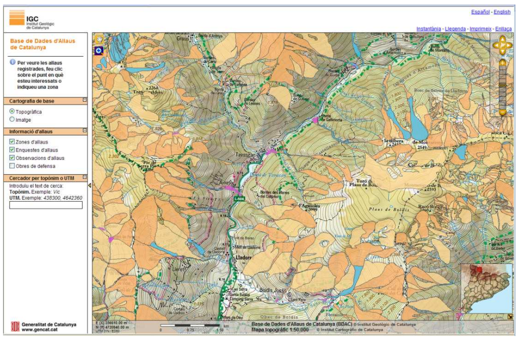

Fig. 13: Interface of the avalanche data server

Hazard maps for urban planning

At present, for all the municipalities that want to increase their building limits, the procedure is, first of all, to make a preliminary hazard map on a 1:5.000 scale. This element is, in fact, just a map of “yes or not”, which states if hazard exists or not. If the municipality decides not to develop in hazardous areas, the process finishes. In the case that the municipality wants to build in the hazard-zone areas, more detailed studies have to be completed. These studies include complex data collection, usually via drilling specific boreholes, other geotechnical work, and advanced modeling. The phenomena taken into account are landslides, rock falls, sinking and snow avalanches. In these maps, the hazard mapping is obtained from frequency/intensity analysis. Advanced modeling analysis is performed in order to obtain the most accurate results, and to support the observational data and expert criteria. Up to the present day, there is no standard methodology. The current challenge for the IGC is to prepare guidelines for such a goal in order to guarantee the standards of quality and homogeneity.

There are preliminary studies of a hazard mapping plan 1:5000 for snow avalanches. In this map terrain is classified into high hazard (red), medium hazard (blue) and low hazard (yellow). Urban planning implications regarding hazard have not been defined yet. An analysis of the MZA, supported by the statistical □-□ model, resulted in the identification of 24 urban areas to be mapped. The mapping methodology includes terrain analysis, avalanche inventory, nivometeorological analysis and numerical modeling to complete the information.

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