THE SECOND WORLD LANDSLIDE FORUM

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The case study of Cancia (Dolomites, Italy), a mountain village threatened by a debris flow

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Abstract The village of Cancia, close to Cortina d'Ampezzo (Italian Dolomites), has been many times hit by destructive debris flows that caused deaths among dwelling people and severe damage to houses and roads; the most recent of these disastrous events happened in July 2009 and caused the death of two people. This study considers the cases of the most calamitous past debris-flow events: the morphological settings of the initiation area are illustrated, along with an analysis of the processes that led to the formation of this dangerous phenomenon. In particular the critical interaction between geological and anthropic systems are examined showing the hazardous effects of the realization of a tourist development in the area. A critical review of the countermeasures so far proposed concludes the study.

Keywords debris flow, hazard mitigation, mountain village, anthropic development

Introduction

Debris flows are a severe natural hazard in mountainous regions and are often cause of people killing and of heavy damage for buildings and other structures, given their high velocity, large volumes and frequent recurrence. The Cancia area and surroundings (Fig.1) is particularly affected by debris flow activity (Genevois et. al., 2000). The hamlet has quite a long record of disastrous events, the oldest of which goes back to 1348 followed by others in 1736, 1737, 1814, 1820, 1868 (year in which the village was hit by a particularly heavy event with an estimated magnitude of 100,000 m^3). After a long period of stability, another debris flow disaster happened in 1957, during big works on the slopes above Cancia for the construction of several cottages (about 400 in 4 successive stages) for a tourist development. The latter event suggests that economic development sometimes can lead to disasters (especially in mountainous environment) when not assisted by scientific knowledge of hazardous phenomena. After the development more and more events occurred, in 1966, 1973 and son on, until 2009, when a debris flow killed two people.

Geological and geomorphological settings

Cancia debris flow is located on the left side of the Boite River valley, near Cortina d’Ampezzo, in the Eastern Dolomites, Italy (Fig. 2), on the western slope of Mt. Antelao (3264 m a.s.l.).

It has a drainage basin area of 1.8 km^2. The upper basin is formed of Upper Triassic to Lower Jurassic massive dolomite and limestones cliff-forming rocks, in the typical stratigraphic sequence of the Dolomiti range (e.g. De Zanche et al., 1993) the rocks are characterized by a high grade of tectonization, that is the source of coarse debris and boulders, accumulating on the underlying slopes with thickness of 10 to 30 m. In this area dolomitic and calcareous walls are high, alternated with morphological benches connected with less competent silty-clayey formations. Faults have modified the geometric relationship among the different formations, especially during the Tertiary era, when different regional tectonic phases of activity occurred. All the structures deriving from these tectonic movements, at lower altitude and in the bottom of the valley, are hidden below thick Quaternary deposits (talus, debris fan, morainic deposits and conglomerates).

The talus in which the Cancia debris-flow channel is incised consists of high permeability, poorly sorted rock debris containing boulders up to 3-4 m in diameter and includes heterogeneous scree, alluvium and old debris flow deposits. Recent alluvial deposits including postglacial sediments blanket the lower parts of the valley. Slope angles below the subvertical dolomitic cliffs range from about 30–40° on the upper parts to10–15° on the lower parts (fan). Since the end of last glaciation the morphology of the area has been remoulded by landslide activity which is still going on and many debris flows are linked to this diffused slope instability.

The debris-flow initiation area is located between 2200 and 1900 m a.s.l.; the channel starts from Forcella Salvella at 2451 m a.s.l. and is incised into the talus, with depths ranging from 3 to 6 m and widths from 10 to 22 m; it is long 2400 m with an average gradient of 20°, ranging from 30° in the upper reach to 15° on the fan where the channel ends in a deposition basin built in 2000 . The channel receives a water contribution from the Bus del Diau torrent; however, this tributary channel apparently does not supply much debris flow material to the main channel. The main morphological parameters of the basin are given in Tab. 1.

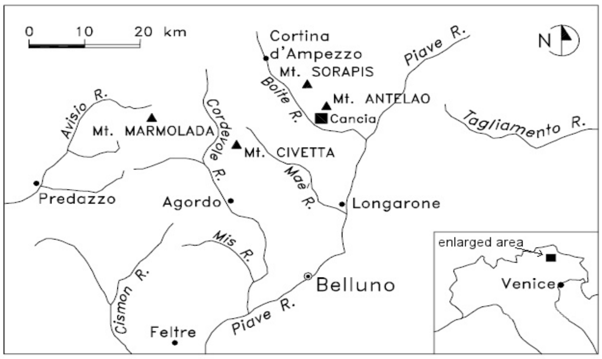

Figure 1. Cancia village location

Table 1: Main morphometric parameters of Cancia debris flow site.

Rock basin area (km^2)	0.16
Total basin area (km^2)	1.18
Basin maximum elevation (m s.l.m.)	3066
Upper basin outlet elevation (m s.l.m.)	1900
Upper basin mean slope (°)	30
Total cannel length (m)	2400
Mean channel slope (°)	20
Start of deposition area elevation (m s.l.m.)	1020
Valley bottom elevation (m s.l.m.)	880
Deposition area mean slope (°)	7

Climatic and hydrological setting

Heavy rainfall thunderstorms are typical for the Alpine region during summer and they can be caused by frontal weather systems or by local convective processes (single-cell thunderstorms). The topography of the area, in particular the Sorapis-Antelao range with high rock walls (up to 1000 m) arranged in a North-South line fosters the rapid uplift of air masses travelling from West to East with frontal systems (which are at the same time slowed down by a barrier effect of the high walls themselves) easing the formation of storm cells.

From the climatological point of view the average annual rainfall of the area is around 1000 mm, concentrated in summer and autumn, winter snow normally covers the whole area from November to late May.

Given the high permeability of the scree, in normal conditions there is no water flow in the main channel, while some liquid discharge (normally modest) is present in the Bus del Diau torrent. The debris-flow season goes from late May to the beginning of October; snow is present on upper slopes from May to July (period length depending from temperature and amount of snow) and the snow melting constitutes an important factor for debris-flow triggering as it can keep the water table at high level in sediments and even saturate the superficial layers of potentially mobilizable material in the initiation area. The triggering mechanism is related to the possibility that the upper layers of sediment in the initiation area (where the slope gradient is around 30°) are saturated with water (Takahashi 1991) this condition, given the high permeability of scree in this area, requires very high rainfall intensity values) with some amount of flowing water on surface (Innes, 1983).

Nevertheless, the state of humidity in the debris-flow-prone sediments can be modified, up to complete saturation, by snow melting (as said) and by an antecedent long duration and low intensity rainfall in this case, even a low intensity rainfall can destabilize the upper layer of sediments (Deganutti et. al., 2000).

The latter fact, in particular, makes the possibility of the implementation of a debris-flow warning system very difficult for the unavoidable occurrences of many false warnings since it should be calibrated on the lowest triggering rainfall, but such precipitation threshold is normally exceeded many times per year with no debris flow triggering (Bacchini and Zannoni, 2003).

Moreover some small-scale debris-flow events were originated by a remobilization of previous debris masses that had stopped along the channel.

Past events

As said, debris-flows of Cancia have been a recurrent phenomenon during the last centuries. Information about disastrous debris flow events go back to 1348. Unfortunately not much data are available for past events in Cancia area.

The earliest documented event is dated 1868: the debris flow deposited more than 100,000 m^3 of material over an area of 203,000 m^2 (Fig. 3 and 4); it claimed 12 lives and destroyed 13 buildings.

In the last forty years several events occurred, involving volumes from 15,000 m^3 (1987) to 50,000 m^3 (1996 and 1999), causing property damage in the settlement as well as interruptions of a State road. In 1966, a debris flow of 25,000 m^3 damaged the Cancia village and temporarily dammed the Boite River. The most recent event occurred on July, 18th 2009. In the night, a flow of more than 20,000 m^3 swept away the debris basin bank and flooded the village, damaging numerous building and causing two deaths.

Available data on past Cancia debris flows are presented in tab. 2; in many cases of old events only the event occurrences are reported in local records.

Anthropic evolution

As it is possible to observe from tab. 2, after 1957 the recurrence frequency changes abruptly, with 20 events in 50 years versus 9 events in the previous 6 centuries!

Surely there is an effect of change in historical recording attitude with time, but it is as much sure that the tourist development built from the mid 1950s takes a big responsibility on the debris-flow frequency increasing that followed its realization for the big modifications of the previous natural setting of the fan. Before the construction of the tourist chalets, Cancia was a very small mountain village which comprised only a few dozen houses. After the disastrous events of the late 19th century the fan at the end of the debris-flow channel was left free from buildings and debris flows could spread freely on the fan (Fig. 6) for as long as almost 70 years. In particular, the development comprehends many cottages and a large common structure; the construction started in the mid 50s and continued till the first 70s and the buildings are located mainly in the debris-flow deposition area (areas 2 and 3 in Fig. 5). Only the northern-most channel was left, while the others (visible in Fig. 6) were buried to build the first group of about 65 cottages; the resulting channel was narrowed and deepened, the curvature radius of the two bends on fan were reduced with the final consequence to shift down the deposition area of debris flows, much closer to the historical settlement of Cancia and just above it (Fig. 7). The memory of the disasters of 70 years before was lost.

After the numerous events of late 90s (tab. 1) in the year 2000 a debris basin was built at the end of the channel, but the magnitude of the probable debris-flow surge was underestimated and, as a consequence, the capacity of the basin was too small and the retention bank too low. The result, during the 2009 event, was the breaching of the bank and the overflowing of the debris mass with the destruction of some houses in Cancia centre and the death of two people.

Now a different debris-flow countermeasure is under study: a new channel that should be dug on the left side of the existing one and a large debris basin before its confluence in the Boite river; the realization of this very big project implies the demolition of tens of cottages in areas 2 and 3 in Fig.5: a high cost for community and also a kind of "nemesis" of the tourist development big mistake.

Figure 2 Cancia debris flow site. (Google Earth image, acquired in 2004).


Figure 3 Photograph of Cancia village after the 27 July 1868 debris-flow event.

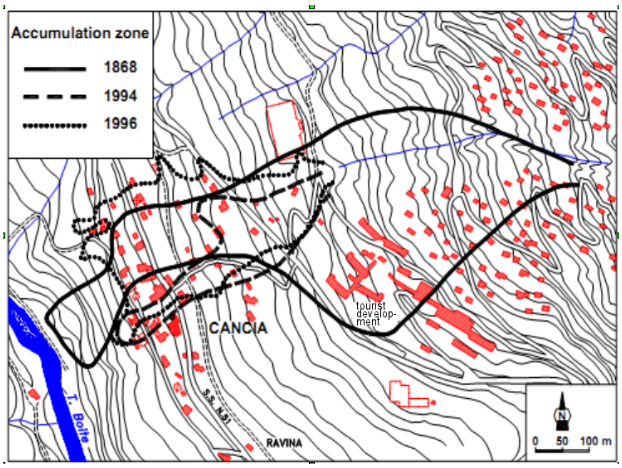

Figure 4 Debris flow flooded areas in the years 1868, 1994 and 1996 (modified from Mantovani et al., 2002).

Table 2 Debris flows, damage and estimated volumes. Blank fields indicate unavailable data.

Date	Damages (when available)	Volumes
1348, 25th Jun	Houses swept away, numerous deaths	
1736, 19th Jun	Debris flow deposits buried the village of Sala	
1737, 7th Jul	Damages in the villages of Sala and Resinego. 7 deaths	
1814, Oct		
1820, Oct		
1868, 27th Jul	12 deaths and 13 destroyed buildings	>100,000 m^3
1888		
1957, 27th May		
1966, 5th Nov	Severe damages to the Cancia village, interruption of the N.R. 51 and temporary damming of the Boite River	25,000 m^3
1973, 12 Aug	Debris flow rests at the end of the channel	
1987, 19th July	Damages to one building and road cuttings	15,000 m^3
1987, 25th Aug	High-water-content event	
1992, 4th Oct	Debris flow confined within the channel	
1993, 20th Jul		
1993, 26th Jul	Debris accumulation within the channel	
1994, 2nd Jul	20 damaged buildings and road cuttings	30,000 m^3
1994, 14th Sep	Debris accumulation within the channel	
1995, 18th Jul	id.	
1996, 8th Jul	id.	
1996, 7th Aug	Several damaged buildings and road blocking	50,000 m^3
1997, 12 Jun	Debris accumulation within the channel	
1998, 14th Jul	id.	
1998, 25th Jul	id.	
1998, 5th Sep	id.	
1999, 16th Aug		7,000 m^3
1999, 20th Sep		50,000 m^3
2009, 18th Jul	Breaching of the debris basin bank and two deaths	20,000 m^3

Conclusions

The dramatic story of Cancia is paradigmatic: an inhabited area threatened by a natural hazard where a wrong concept of development increased the territory vulnerability, leading to disasters with loss of human lives.

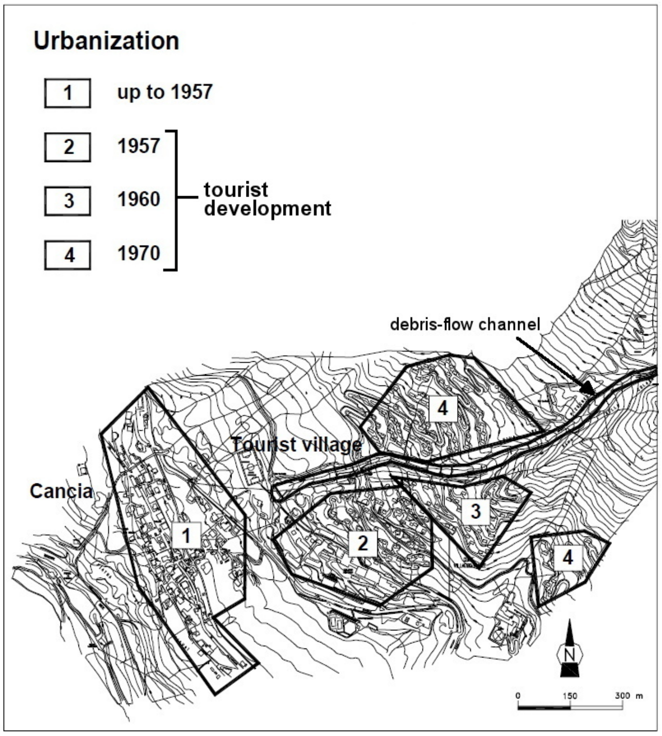

Figure 5 Successive stages of development in Cancia area. (modified from Bacchini and Zannoni 2003).

Probably in the 50s of last century technical competence and social sensitivity towards geological hazards were much lower than the push for economic growth. The works done to the channel and on the fan in the attempt to reduce the hazard for Cancia have been realized with no specific knowledge of debris-flow peculiarities. Such measures generally followed usual mountain torrents stabilization philosophy based on old-fashioned water-sediment dynamics criteria only and so proved to be almost useless to the aim they were done for, as the numerous and heavy damage reported after many events from 1957 to 2009 demonstrate. Eventually Cancia denizens now know the measures taken so far in order to mitigate the debris-flow hazard for their village are far from sufficient to assure safety.

On the other hand in that area the interaction between geological and anthropic systems is complex and human values and psychological issues are highly involved. So, studies and design of new solutions, along with a deep knowledge of the dangerous natural phenomenon, must take into account also the expectations and the rights of the people living there: the cost of the demolition of a tourist cottage can be much lower than that of a smaller and older house of a Cancia citizen once the "social costs" are taken into account along with the material value of the involved properties.

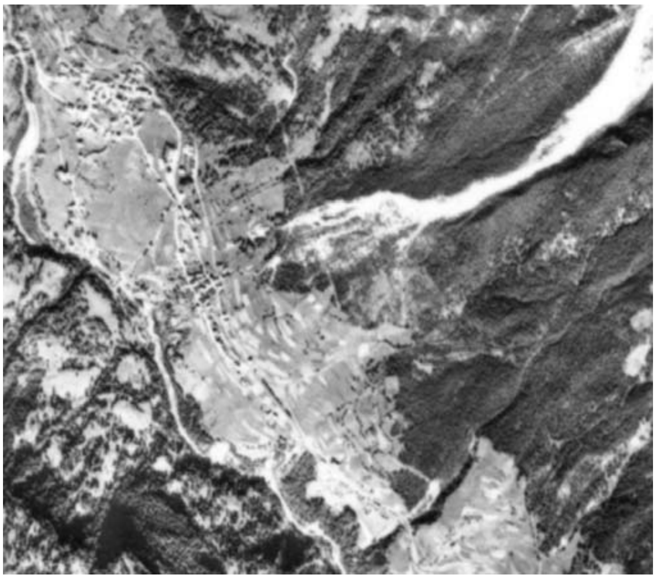

Figure 6 Cancia aerial photograph taken before the construction of the tourist cottages (1954).

Figure 7 Same area as Fig. 6, photo taken in 1973.

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