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Geomorphological map of the surroundings of Cortina d'Ampezzo (Dolomites, Italy)

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Geomorphological investigations in the area of Cortina d'Ampezzo (Dolomites, Italy) have been carried out since the 1980s mainly within national and European research projects. This has enabled the researchers to define, on the one hand, the geomorphological evolution of the area and, on the other hand, the spatial and temporal occurrence of landslides, that are the most spread geomorphological feature of the studied area.

A detailed geological and geomorphological survey was carried out at a scale of 1:10000 and a geomorphological map at a scale of 1:20000 was produced following to the Italian geomorphological mapping methodology (Gruppo …. 1994). The survey was combined with multitemporal aerial and ground photograph analysis. The examination of archive photographs (late XIX and early XX century) was especially significant for the slope evolution to be evaluated thanks to the low degree of human activity in the area, together with the scarce extension of woodland.

The Cortina d'Ampezzo valley, situated in the eastern Dolomites, is surrounded by high mountain groups such as Tofane, Lastoni di Formin, Croda da Lago, Faloria, Cristallo and Pomagagnon. The valley is crossed in a N-S direction by the Boite torrent, a right tributary of the Piave River.

From a climatic point of view the Cortina d'Ampezzo area is quite varied. This is mainly the result of the wide altitudinal range. The climate corresponds to the Alpine type, from cold to temperate, with variably cold winters and mild summers. The pluviometric regime reflects the typical pattern of an Alpine climate with two maxima of rainfall, of which the main one is late spring-summer and the other in autumn. As regards snowfall, the period of permanent or almost permanent snow normally begins in December and lasts until April. In the higher zones naturally this period lasts for a couple of months longer.

The geological structure of the area, characterised by an alternation of dolomitic rocks and successions of prevalently pelitic components, has markedly conditioned the morphological evolution of the slopes after the retreat of the LGM glaciers (Pasuto et al. 1997). The stratigraphical sequence outcropping in the area of Cortina d'Ampezzo covers a period of time ranging from Middle and Upper Triassic to Lias. The Quaternary deposits, mainly deriving from landslide phenomena, are widespread inside the valley, masking the substratum and making the recognition of tectonic elements along the valley bottom particularly difficult. The Triassic rocks outcrop especially in the peripheral parts where the highest mountain groups are located

The slope morphology is softly degrading in the medium and lower parts where pelitic formations outcrop, while at higher altitudes subvertical dolomitic walls rise up, eventually interrupted by typical ledges, thick scree slopes, located in correspondence with more erodible formations. The whole area has often been affected by landslide phenomena of various types and of sometimes notable dimensions, some of which are still active today. As

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a result of the favourable morphological conditions, the area has witnessed progressive urbanisation, which has also been tied to an intensive tourist development. Because of this intense urbanisation and the interest which this region holds for tourism, the presence of some active landslides and of a large number of dormant landslides makes this area particularly vulnerable and subject to a high geomorphological risk (Soldati 1999; Pasuto, Soldati 2004).

The valley of Cortina d'Ampezzo during the Würm glaciation was almost completely covered by ice masses reaching thicknesses of 1000 m; only the highest dolomitic peaks emerged above the glaciers. At that time several glacial tongues converged in the valley from the surrounding mountain groups, forming a thick glacial tongue which met the Piave glacier near Pieve di Cadore (about 35 km valleyward of Cortina d'Ampezzo). Thus the slope evolution and the setting of the surficial deposits of the studied area mostly date from the post-Würmian period. As regards glacial deposits, only a few outcrops datable to late glacial stadial phases were found. The scarcity of such deposits, in contrast with other dolomitic areas, is related to the numerous and extensive landslide movements which occurred after the retreat of the glacial masses (Panizza et al. 1996; Soldati et al. 2004).

The Cortina d'Ampezzo area appears to have always been prone to instability phenomena for the following different reasons. First of all the structural conditions of the valley must be taken into account. The stratigraphic succession is, in fact, characterised by an alternation of dolomitic rocks showing a brittle mechanical behaviour (Dolomia Cassiana, Dürrenstein Formation and Dolomia Principale) and rocks with a ductile mechanical behaviour (San Cassiano Formation and Raibl Formation). This situation has favoured the development of mass movements and deep-seated gravitational slope deformations; the latter, which were widely recognised in the area, may have favoured themselves or induced the occurrence of several landslides (Soldati and Pasuto 1991).

Furthermore the incidence of tectonic activity is also significant as regards landsliding; in fact, the dolomites were affected by an intense jointing in correspondence with the principal faults, thus creating discontinuities which became potential sliding surfaces and preferential seepage zones for water which could reach and moisten the underlying marly and clayey formations. In addition, tectonic activity might have favoured landsliding giving a diffuse presence of the San Cassiano Formation in the middle-lower part of the slopes as a result of partial doublings of the stratigraphic sequence due to overthrusting (Pasuto et al. 1997).

The effects of glacier retreat on the slopes must not be overlooked. It is likely that the pressure of ice on the valley sides determined rock deformations in correspondence with surfaces of structural discontinuity, favouring the formation of sliding surfaces.

An effort has been made to assess which of the numerous radiocarbon dates collected in the study areas of Cortina d'Ampezzo are related to events of a type or magnitude that might be indicators of Holocene climatic changes (Soldati et al. 2004). The first phase of marked slope instability is observed in the Preboreal and Boreal (about 11500 to 8500 cal BP) and includes, on the one hand, large translational rock slides, which affected the dolomite slopes following the withdrawal of the Lateglacial glaciers and the consequent decompression of slopes and, on the other hand, complex movements (rotational slides and flows) which affected the underlying pelitic formations and were probably favoured by high groundwater levels resulting from an increase of precipitation and/or permafrost meltdown. A second concentration of landslide events is found during the Subboreal (about 5800 to 2000 cal BP), when slope processes, mainly rotational slides and/or flows, took place in both the study areas. These slides may be considered as reactivations of older events linked to the phase of precipitation increase, which has been documented in several European regions during the mid-Holocene period. On the other hand, during the Little Ice Age, the scarce number of landslides dated in the study areas does not enable an increased frequency of landslides to be detected.

The recurrence in time of landslide activity since the Lateglacial was certainly also influenced by non-climatic factors. Among these, the influence of human activity, which is proved to have been crucial for other Alpine areas at least since the mid-Holocene, seems to be almost irrelevant in the study areas where only seasonal or isolated settlements were present before the Middle Ages. Nevertheless, the present state of the investigations does not allow the assessment of the degree of influence of this and other possible non-climatic causes, which might have "disturbed" the climatic signal identifiable in the landslides studied.

In the geomorphological map of the area surrounding Cortina d'Ampezzo landforms are depicted according to the Italian mapping methodology. This methodology pays particular attention to the genesis of landforms (glacial, periglacial, gravitational, alluvial etc.), that are distinguished using symbols of different colours, and their degree of activity, marked with more or less intense colouring. Morphometric aspects are also represented on the map by specific symbols. The outcropping of geological formations and tectonic elements are mapped, too. In the specific case of the Cortina d'Ampezzo area, this is of fundamental importance to understand the past, present and future evolution of the relief, because the structural control on landforms is relevant.

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