Landforms and Quaternary deposits in the UNESCO Dolomites: past, present and future studies.

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The landforms and deposits of the Quaternary are closely related to each other. Indeed, many landforms are generated by the accumulation of debris coming from the weathering processes of the bedrock (accumulation landforms), others are generated by erosive processes (erosional landforms).

The Dolomites are recognized by the widespread outcrop and favorable exposure of carbonate rock formations, which provide a unique and spectacular view on the marine life during the Triassic. Moreover, the numerous vertical peaks and the valleys covered by Quaternary deposits present a variety of extraordinary landforms, linked to the morphoselection processes. Pinnacles, spiers and rock towers with contrasting horizontal surfaces such as ledges, crags and plateaus, rise abruptly from extensive talus deposits and from gentle and undulating hills.

The Dolomites have always attracted a multitude of geologists from around the world, thanks to their easy accessibility and the clarity with which the geological phenomena can be observed. On the other hand, there are no unified and integrated overviews taking into consideration the quaternary evolution of the Dolomites region. Information is often spread in a multitude of geological works and case studies, and is therefore discontinuous and lacking in-depth analysis.

A first geomorphological topic that in the past interested Italian and foreign scientists was the inherited morphology of the dolomitic groups. This issue, that still deserves investigation, came from the observation that the current peaks share an uniform top heights, regardless of their shape and structure, which suggests the existence of an ancient landscape with smoothed relief, in contrast with the current one.

Regarding the Quaternary deposits, various authors mostly investigated the glacial ones, which are particularly widespread and the most useful from a chronological point of view. The first attention on Quaternary deposits date back to the first decades of the 20th century. It mainly regards studies on single mountain groups, frequently included in more comprehensive geological works. A significant advance in the study of Quaternary deposits came from several geomorphological works that began towards the end of the last century, with new significant insights starting from the 1970s. These works are often accompanied by detailed geomorphological maps, and investigate the genesis of the deposits, refining their chronology with the help of absolute and relative dating methods. In some specific areas, the dating of deposits allowed to reconstruct an articulated evolutionary framework of the landslides and slope stability phenomena. Unfortunately, these works are sparse and do not provide a full coverage of the entire territory of the Dolomites.

Further advances in Quaternary study came at the end of the 1980s, with the start of the CARG Project, aimed at producing the national geological map at the scale of 1: 50,000. One of the most qualifying and innovative aspects of this project was the importance given to the Quaternary deposits in both their surveying and their cartographic representation. These Quaternary formations, formerly considered as debris coverages that prevent the observation of the underlying bedrock, were finally considered of the same importance as the geological substrate. Unfortunately, in many cases these deposits were classified according to different criteria (e.g. litostratigraphic, allostratigraphic, or using the "unconformity-bounded stratigraphic units"), due to the lack of a uniform methodological approach. Recently, the advent of new remote sensing techniques (such as airborne, high-resolution LiDAR) enabled to better map and understand landforms and deposits, surveying, for example, complex landform assemblages masked by vegetation. In addition to the traditional ^{14}C dating techniques, new types of chronological investigation methods have been developed, but they are still rarely applied in the Dolomites.

Consequently, if on the one hand the genesis of the various Quaternary deposits in the Dolomites UNESCO World Heritage are in most cases well known, on the other hand much remains to be done for the chronological characterization of single depositional events. In particular, interesting new insights are expected from a better characterization of late-glacial deposits and slope gravitational phenomena.

Finally, it should be pointed out that Quaternary deposits are not only interesting from a stratigraphic point of view, but they also play an important role in slope instability, settlements and land management policies. In the next future, we underline the need for improved understanding and investigations on the ongoing changes of the paraglacial environments, which are widespread in the mountain ranges of the UNESCO Dolomites and subject to rapid modifications in response to climatic changes.

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