



Geomorphological mapping as a tool to characterize and manage quarry dump deposits: the case study of Carrara marble basins

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The peculiar landscape of Carrara (Apuan Alps) is well renowned all over the world for the many naturalistic and anthropic landforms which are strictly related to quarrying activity. The valuable white Apuan marble was exploited since the first millennium BC predating the Roman period and was chosen by many artists, as Michelangelo, for their masterpieces. The pluri-millennial quarrying activity left a high density of quarries (among the highest in the world), determining a unique landscape dominated by anthropic landforms including the huge quarry dump deposits, locally called "*ravaneti*".

Waste materials from marble quarrying of Carrara basin retain typical textural characteristics closely linked to the different techniques adopted over time for marble extraction. Therefore, quarry dumps represent a key access for reconstructing the evolution of the Apuan marble exploitation. For this reason, ancient *ravaneti* assume an inestimable value within the historical and cultural heritage of Italy.

In this highly dynamic context, the shape of quarry dump deposits is frequently modified because of their continuous addition and re-exploitation, also due to the necessity of preventing slope processes inducing instability (i.e. debris flows). In fact, during the last decades widespread debris flows frequently affected the area representing serious hazardous events for quarrying activity, infrastructures as well as urban centres.

Here we present the "*Geomorphological Map of Ravaneti of Carrara Marble Basins*", developed applying a detailed landscape analysis, updated to 2017, using remote sensing data and field surveys in key sites. All the data were managed in GIS environment and collected into a properly created geomorphological database of the Apuan Alps. The map shows the spatial distribution of quarry dumps according to their geomorphological and sedimentological characteristics.

We identified and quantified the number and the extent of areas affected by natural processes, as debris flows, landslides and running water erosional landforms. Quarry dump deposits were distinguished on the basis of the size of the debris, the weathering of the clasts surface and different vegetal cover degree. The presence and abundance of fine matrix in quarry dump deposits play a relevant role in favouring their stability and in regulating their reservoir effect during intense precipitation events. The geomorphological characterization represents a relevant

tool for the monitoring and management of *ravaneti* suggesting both potentially removable and potentially worthy of geo-conservation quarry dumps on the bases of i) their historical heritage, ii) their role in slope instabilities, and iii) their role in preventing hazardous flooding events, being this sector among the rainiest regions of Europe.

Considering that *ravaneti* are highly hazardous being widely affected by debris flows, the updated geomorphological data will be relevant for evaluating most susceptible areas and for developing risk assessment models.