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# Characterization of rock samples by a high-resolution multi-technique non-invasive approach

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This paper describes a high resolution multi-technique non invasive approach in which three different techniques (photogrammetric, terrestrial laser scanner and acoustic tomography) are integrated with petrographic data for a detailed characterization of rock samples. To study stone materials both outcropping and in depth, with appropriately prepared samples one can make as many measurements as necessary with different techniques. Moreover, some characterization analyses are destructive and there is a limit on the number of samples that can be sacrificed. The samples need to be carefully selected to ensure they are representative of the rock types under study and significant in different fields (e.g. analysis of the degradation of stone building materials, analysis of aquifer, study of natural reservoirs). As a result, analysis made by the above non invasive techniques integrated with petrographical data on the same materials becomes an indispensable source of data. For the characterization of non-invasive rock samples we started a computation of high resolution 3D models of two samples of a different nature, a comenditic pyroclastic rock and a Pietra Forte carbonate rock, using the terrestrial laser scanning (TLS) methodology and digital photogrammetry. Data were collected using a Leica HDS6200 TLS and a Nikon D-300 digital Reflex camera with the necessary conditions of the highest resolution modality, small incidence angles and a high dynamic range (HDR) in the case of digital images. The resulting clouds and images were processed by specific software using a multi-step procedure which starts with the data input and filtering with elimination of defective points, manual data editing, automatic filtering, raw and fine registration with an iterative closest point (ICP) algorithm in a bundle adjustment modality and successive aggregation of all clouds in high resolution 3D models. Finally, the resulting radiometric information available, such as reflectivity maps, high resolution (HR) photogrammetry textured models and patterns of geometrical residuals, were interpreted in order to locate and underline materials anomalies and differences in composition together with a comparison of reflectance and natural colour anomalies with the roughness of surface materials. Starting with the accurate 3D reconstruction from previous techniques, an acoustic tomography on each rock sample was carefully planned and carried out. Travel time of longitudinal elastic waves were measured along a large number of measurement paths between stations located on the perimeter of the investigated samples. Each measurement point was alternatively used as transmitter and receiver. Inversion techniques were used to obtain a map of the distribution of the longitudinal wave velocity across the sections, thanks to specific software exploiting appropriate reconstruction algorithms. Ultrasonic tomography proved an effective tool in detecting internal defects and heterogeneity of the samples, and led to their fine characterization in terms of elastic-mechanical properties. Finally, the integration of the above three geophysical non invasive techniques with petrographical data represents a powerful method for the definition of the heterogeneity of the rocks at a different scale and for calibrating in situ measurements.

Key words: Terrestrial laser scanner, photogrammetric technique, 3D ultrasonic tomography, stone samples.