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Microtomography experiment for rock texture analysis: 3D shape orientation distribution function of crystals and vesicles in volcanic products

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Preferred orientation in rocks is strongly related to the their physical properties; as an example, rock mechanical properties are strongly influenced by crystal alignment, and anisotropy in rock permeability can be influenced by pore shape and alignment.
To obtain quantitative information about the preferred orientation of crystals the most widespread methods are Electron Back-Scattering Diffraction (EBSD) and X-ray (or neutron) diffraction texture analysis. Both methods require the components of interest to have a crystal structure. The preferred orientation of pores is usually studied on thin sections, extracting 3D information from 2D data by means of stereological methods.
A preferred orientation study using microtomography data can overcome some of the problems encountered with the above techniques. We developed a method, included in the Pore3D package available at the Elettra Synchrotron Light Laboratory in Trieste (Italy), to perform texture analysis and applied it to volcanic rock samples measured by X-ray computed microtomography (using both synchrotron and conventional x-ray sources). To obtain information about the objects' preferred orientation we fit their shape with ellipsoids to estimate the orientation of their axes. All the ellipsoids can then provide an Orientation Distribution Function (ODF). We obtain a 3D Shape Preferred Orientation (SPO) in contrast to the Crystallography Preferred Orientation (CPO) obtainable with diffraction methods. We can then plot pole figures of the directions of interest for our components (e.g. crystals and vesicles elongation axes). Moreover, additional textural parameters can be easily calculated, such as the Texture Factor (F2), mean orientation of selected axes, percentage of objects with an axis oriented within a given solid angle, etc.
In the present work we analyzed volcanic scoria samples from Campi Flegrei, Stromboli and Etna (Italy). These samples are interesting since they contain both crystals and vesicles displaying anisotropy. Preferred orientation of these components provides precious information about the evolution of the magma that created these rocks.
We usually found a good correlation between the direction of the long axis of the crystals and the vesicles' elongation direction, with moderate texture strength.
The correlation of vesicles with respect to crystals preferred orientation is impossible to obtain with EBSD and diffraction texture analysis, and thin section stereological analysis cannot give true 3D information.
Our approach provides significant advantages: in a single measurement it is possible to get enough information to obtain a good description of the material structure, with a focus on texture. Another advantage of our method is that it can provide both "texture by number" and "texture by volume". The results of the latter could be compared with those obtained by diffraction, when shape and crystallographic directions are clearly correlated. Moreover, each object is labeled with its volume and aspect ratio, so pole figures of the same objects, but divided into classes are possible: e.g. we plotted pole figures of vesicles above and below a given volume value to see if different generations show different orientations and/or texture strength.
In conclusion, the proposed method provides a viable way to perform texture analysis for the characterization of the structure of rocks yielding some very useful complementary data with respect to most conventional methods used in texture analysis. This approach is extremely promising for the analysis of complex volcanic rocks.