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3D image analysis of a volcanic deposit

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During the last decades, X-ray micro CT has become a well established technique for non-destructive testing in a wide variety of research fields. Using a series of X-ray transmission images of the sample at different projection angles, a stack of 2D cross-sections is reconstructed, resulting in a 3D volume representing the X-ray attenuation coefficients of the sample. Since the attenuation coefficient of a material depends on its density and atomic number, this volume provides valuable information about the internal structure and composition of the sample.

Although much qualitative information can be derived directly from this 3D volume, researchers usually require more quantitative results to be able to provide a full characterization of the sample under investigation. This type of information needs to be retrieved using specialized image processing software. For most samples, it is imperative that this processing is performed on the 3D volume as a whole, since a sequence of 2D cross sections usually forms an inadequate approximation of the actual structure.

The complete processing of a volume consists of three sequential steps. First, the volume is segmented into a set of objects. What these objects represent depends on what property of the sample needs to be analysed. The objects can be for instance concavities, dense inclusions or the matrix of the sample. When dealing with noisy data, it might be necessary to filter the data before applying the segmentation. The second step is the separation of connected objects into a set of smaller objects. This is necessary when objects appear to be connected because of the limited resolution and contrast of the scan. Separation can also be useful when the sample contains a network structure and one wants to study the individual cells of the network. The third and last step consists of the actual analysis of the various objects to derive the different parameters of interest. While some parameters require extensive calculations, others can be obtained easily.

The different parameters which can be obtained are related to the size, shape and orientation of the objects. Additionally, the connectivity of a network can be analysed by comparing the set of objects before and after separation.

The size of each object can be characterized by its volume, equivalent diameter and the diameter of the maximum inscribed sphere. The surface can be determined by extracting a polygonal mesh from the volume data. Calculation of Feret's diameter reveals information about the objects elongation. Additionally, the moments of inertia can be calculated to obtain the axes of an equivalent ellipsoid. This data can be used to determine the main axis and therefore the orientation of the object within the sample.

Feret's diameter and the equivalent ellipsoid are representative for the basic shape of the object. Additionally, using a routine that fills concave regions, the convex hull of an object can be retrieved to quantify the convexity. Different ratios can be defined, which compare the surface area with the volume of the object (sphericity) or the volume of the convex hull. These ratios and the convexity characterize the objects roughness and shape.

The described parameters are used to characterize volcanic deposits found in the area west of Lac Pavin (lake in Auvergne, France). The samples are taken from the most recent 'red scoria' layer, which is believed to be the result of the latest eruption in Western-Europe. There is however, ambiguity on the origin of the layer in terms of age and placement. The aim is to fingerprint this layer in such a way that the various eruptions in the area can be distinguished from one another. Measurements of the vesicle density, volume and connectivity of the investigated deposits provide information about the intensity of the eruption. Additionally, vesicle geometry can be related to the magmatic permeability, which is essential to the dynamics of the eruption.