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Automated fracture segmentation and characterization in X-ray computed tomographic images with Python

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Abstract

Open fractures can affect petrophysical properties of their host rock masses, as well as fluid transport and storage, so characterization of them is important to many industries. Mineralized fractures are of particular interest to mining companies because they commonly host valuable minerals. Generally, structural data about fractures are acquired by geologists making manual measurements on rock cores. This methodology is expensive, time-consuming and subjective. Instead, we are working to automatically detect and characterize fractures in cores in an objective and time-saving way using X-ray computed tomography (CT) - a fast, nondestructive imaging technique, from which three-dimensional information can be obtained. Raw CT data are typically inverted to 2-D image stacks that are then compiled to create 3-D datasets. The latter comprise voxels (3-D pixels) that have unique values related to the attenuation of the X-rays within the materials that make up the cores at that location. CT attenuation is primarily a function of atomic number of the material the x-rays pass through at that location, so these 3-D images typically show the arrangement of different minerals within the core.

We have developed algorithms, implemented as a Python script, that analyse CT image stacks of core samples and detect widths and orientations of fractures and veins within them. This script also estimates the fracture intensity variation along the z-axis by measuring P22 for each 2-D image, as described by Dershowitz and Herda (1992). P22 is defined as the total fracture trace length divided by the trace plane area. Other profiles of critical parameters (such as average fracture width, orientation, etc.) could also be extracted. We have carried out both of these analyses on filled and open fractures in rock cores from the active Alpine Fault Zone in New Zealand, and from gold-bearing basalts that host now inactive fault zones in the Yilgarn Craton, Western Australia.

The same cores have also been scanned using a HyLogger, which can quantify mineralogy by measuring reflectance spectra of visible and infrared light scattered from the core surface across different wavelength ranges. Variations in these spectra are linked to mineralogical variations, allowing estimation of the type and quantity of the minerals present along a scanned surface.

We are comparing fracture intensity profiles to the HyLogger-derived mineralogy using spectral methods such as the fast Fourier transform, power spectral density, joint recurrence plots, and multifractal analysis employing wavelet transforms. These analyses may demonstrate if systematic relationships exist between these datasets, which would indicate that mineralogical variation is related to alteration by fluids that permeated in these fractures.