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Semi-automatic mapping of fault rocks on a Digital Outcrop Model, Gole Larghe Fault Zone (Southern Alps, Italy)

Alice Vho and Andrea Bistacchi

Department of Earth and Environmental Sciences, Università degli Studi di Milano Bicocca, Piazza della Scienza, 4, 20126 Milano

A quantitative analysis of fault-rock distribution is of paramount importance for studies of fault zone architecture, fault and earthquake mechanics, and fluid circulation along faults at depth. Here we present a semi-automatic workflow for fault-rock mapping on a Digital Outcrop Model (DOM). This workflow has been developed on a real case of study: the strike-slip Gole Larghe Fault Zone (GLFZ). It consists of a fault zone exhumed from ca. 10 km depth, hosted in granitoid rocks of Adamello batholith (Italian Southern Alps). Individual seismogenic slip surfaces generally show green cataclasites (cemented by the precipitation of epidote and K-feldspar from hydrothermal fluids) and more or less well preserved pseudotachylytes (black when well preserved, greenish to white when altered).

First of all, a digital model for the outcrop is reconstructed with photogrammetric techniques, using a large number of high resolution digital photographs, processed with VisualSFM software. By using high resolution photographs the DOM can have a much higher resolution than with LIDAR surveys, up to 0.2 mm/pixel.

Then, image processing is performed to map the fault-rock distribution with the ImageJ-Fiji package. Green cataclasites and epidote/K-feldspar veins can be quite easily separated from the host rock (tonalite) using spectral analysis. Particularly, band ratio and principal component analysis have been tested successfully.

The mapping of black pseudotachylyte veins is more tricky because the differences between the pseudotachylyte and biotite spectral signature are not appreciable. For this reason we have tested different morphological processing tools aimed at identifying (and subtracting) the tiny biotite grains. We propose a solution based on binary images involving a combination of size and circularity thresholds. Comparing the results with manually segmented images, we noticed that major problems occur only when pseudotachylyte veins are very thin and discontinuous.

After having tested and refined the image analysis processing for some typical images, we have recorded a macro with ImageJ-Fiji allowing to process all the images for a given DOM.

As a result, the three different types of rocks can be semi-automatically mapped on large DOMs using a simple and efficient procedure. This allows to develop quantitative analyses of fault rock distribution and thickness, fault trace roughness/curvature and length, fault zone architecture, and alteration halos due to hydrothermal fluid-rock interaction. To improve our workflow, additional or different morphological operators could be integrated in our procedure to yield a better resolution on small and thin pseudotachylyte veins (e.g. perimeter/area ratio).