Quantitative structural analysis of fractures using digital outcrop models

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The use of digital outcrop models (DOMs) in geosciences has been increasingly common since the beginning of the 2000s due to the technological advances in the positional and image-quality field equipment, data collection, and processing with practicality, agility, and high accuracy even in inaccessible sites. DOMs incorporate all the visual elements that geoscientists analyze in the outcrops as 3D models with a spatial resolution of a few millimeters per pixel and positional accuracy of less than 2 cm. The great advantage of DOMs is their daily availability for visual inspection and interpretation in the office, complementing the data analysis performed in the field. Therefore, the continuous development of high accuracy and dense image-based and point cloud models has been crucial for quantitative approaches using digital models. Another challenge in this process involves the development of tools and methodologies for interpretation of DOMs, especially analysis and interpretation of linear and planar features such as lineations, paleocurrents, joints, faults, and deformation bands. This study aims to systematize the manual and semi-automatic methods of plane extraction using tools (e.g., Compass and Facets) available in the open-source software such as the CloudCompare, and statistically analyze the structural measurements from the extracted data. In this work, we analyzed two 3D integrated ground-UAV photogrammetric models reconstructed with the Structure from Motion (SfM) technique. The study areas are part of the Araripe Basin basement, located in Northeastern Brazil, and represent two case studies involving joints and faults associated with the damage zone of the boundary fault. Initial results obtained by the automatic planes measured with the Facets plugin show distinct fracturing patterns. This is mainly due to the difference of the rock rheology and competence. In the metasedimentary outcrop, we identified 731 planes in phyllites, reduced to 459 real planes after noise remotion and visual inspection during interpretation. In this case, the data accuracy is 62% for plane recognition. The preferential orientation is N40-90E and N40-80W, with high dip angles, and subordinately N45E and N10W with low dip angles. In the metatonalite, 347 planes were recognized, but only 38 of them showed to be real planes, totaling accuracy of 10.9%. The planes validated as real indicate a preferential orientation of N10-15W with high angles of dip. Both outcrops used the same processing routine and configuration. The
difference observed in the number of planes automatically recognized in each outcrop is a consequence of the relationship between the plane orientation and outcrop orientation, spatial resolution of the model, and the degree of weathering. Besides that, positional accuracy and visual quality are crucial for accurate quantitative interpretation of structural features using digital outcrop models, as well as a well-defined data processing routine and careful inspection of the results by an expert. The data obtained from this methodological approach will contribute to quantitative approaches in structural geology based on robust datasets.