Analysis of Rock Fracture Patterns by Persistent Homology

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Structures of fractures and faults dominate fluid flow in rocks, while physical and/or chemical processes of fluid affect fracture formation. Thus, their interactions and the relationship between fractures and fluid flow are of importance in geoscientific research and geological development. This study aims to quantify topological patterns of fracture distributions and their flow properties. Persistent homology is a method of topological data analysis, which measures features of connected components of a topological space and encodes multi-scale topological features in the persistence diagrams. First, we generated synthetic regular patterns of fractures and evaluated features of their persistence diagrams. Fracture properties, such as fracture aperture and grain size, were characterized and quantified in their persistent diagrams. An example of fracture characterization using persistent homology is shown. Photos of mesh textures of serpentine were analyzed, as well as simulation results from a distinct element method (DEM) consisting of complex fracture network. Although their textures have complex distributions, quantity of topological features were evaluated on their persistent diagrams. Finding similar feature of their persistent diagrams would help to compare between actual rocks and simulation results and to understand how the serpentine were formed within the oceanic lithosphere. Persistent homology is expected to evaluate images that humans judged sensibly or that humans were not able to recognize their regularity.

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