Progress for Ontology of Fractures and Faults

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Abstract

This extended abstract report some progress in developing an ontology of fractures and faults.

Introduction

Fractures and faults are the most ubiquitous structures in the upper crust. Fractures refer to a group of structures with displacement mainly perpendicular to their discontinuity, while faults have displacement primarily parallel to their discontinuity. Fractures and faults are related to many societal and industrial problems including oil and gas exploration and production, CO\(_2\) sequestration, and waste isolation. However, many of these fractures, faults, or components of faults can not be well-characterized, if detectable at all, by current technologies. Therefore, it is essential to understand the formation mechanisms of fractures and faults, so to characterize them in field analogues and to establish their geometrical, statistical, and petrophysical properties, and to assess their impact on fluid flow in the subsurface. To facilitate a sound education and communication among the highly diverse community interested in fractures and faults, we developed an ontology on these topics.

Preliminary Result

We chose the Web Ontology Language description logic (OWL-DL) as our ontology format. All class names in our ontology are in singular form. If a class name contains more multiple words, the first letter in each word is capitalized and no space runs in between. Typographical Italic font style is used for class names throughout this abstract.

The core of the ontology is divided into four major classes, \textit{GeologicalStructure}, \textit{DeformationMechanism}, \textit{Property/Factor}, and \textit{Relationship} among the first three categories. Roughly speaking, geological structures are formed by some deformation mechanisms controlled by many factors; they have some properties directly correlated to the formation mechanisms; their presences change some petrophysical properties of the host rocks and effect subsequent fluid flow and deformation (Figure 1). Beyond the core categories, there are some annexational categories, like Measurement Techniques which include how certain property, like spacing and extension or shortening, can be measured.

![Figure 1. Diagram showing the relationship between three core classes of the Ontology.](image)

The first three core classes in our ontology have corresponding classes in the SWEET ontology. The \textit{GeologicalStructure} class can be mapped as subclass of \textit{Feature} class in DOLCE; or to the \textit{Strain} class in SWEET, which has subclass \textit{Fault}, \textit{Fold}, and \textit{Fracture}. The \textit{DeformationMechanism} class can be loosely mapped to the \textit{GeologicalProcess} and the \textit{PhysicalProcess} classes of SWEET. Some overlapping classes include \textit{TectonicProcess}, \textit{MechanicalProcess}, and \textit{Motion}. Each subclass of \textit{Formation}, including initiation and individual propagation and growth may be analogous to the \textit{Event} referred by some other authors. The \textit{Property} class in our ontology can be mapped to the \textit{Property} class of the SWEET ontology. They have a few overlap, such as \textit{Pattern}, \textit{Roughness} and \textit{Force}.

The \textit{GeologicalStructure} class comprises the fundamental structures observed in the upper crust, including mainly joints and veins, pressure solution seams, deformation bands, and faults. The further classification of this class proceeds based on common associations such as...
structure component, zone, set, multiple sets, domain, and assemblage. From there on, structures are further categorized based on geometrical characterization.

The DeformationMechanisms class has subclasses of Macro- and Micro-Mechanisms, involved in the formation of geological structures. Macro-Deformation Mechanisms are then branches into four major subclasses, jointing, pressure solution and cleavage, strain localization and faulting. Jointing is characterized by opening displacement discontinuity, pressure solution produces closing displacement discontinuity, and faulting is associated with shear displacement discontinuity. Strain localization can produce a whole range of displacement discontinuity, with end members of volumetric dilation, volumetric compaction, and shear. Shear strain localization is also a kind of faulting. Micro-mechanisms, on the over hand, refer to the deformation mechanisms working on grain or crystal scale, such as grain translation, grain crushing, dissolution, diffusion, and precipitation. In addition, the stages of progressive development for macro mechanisms, such as initiation and growth, are organized in the Formation class.

The PropertyFactor class covers concepts about stresses and the nature of rocks or structures. There are six major subclasses of PropertyFactor: Geometry, SurfaceMorphology/SurfaceRoughness, MaterialProperty, MechanicalProperty, PetrophysicalProperty (flow properties), and Loading. Lithology is a space holder for the rock classification ontology.

The hierarchy under the Relationship class has three major branches: factors effecting deformation mechanisms, factors effecting geometrical pattern/distribution/scaling, and fluid flow properties affected by geological structures. The further classification of the Relationship class is largely based on deformation mechanisms. One example of Relationship is the factors effecting joint spacing. Joints form commonly in rocks with strong matrix support, usually in zones or sets. The spacing of the zone or set is an important geometrical parameter and is affected by many factors, like the layer thickness in layered rock, the subcritical index of the rock, the evolution of the jointing process, and the cooling rate for thermal joints.

**Preliminary Conclusion**

Our ontology is process-based emphasizing formation mechanisms of geological structures (i.e., fractures and faults), their geometric, mechanical, and petrophysical properties and their interrelationships. We believe that this ontology will be helpful where related knowledge is required, especially in inferring the type of structures, their geometry and formation mechanism.