Fluid mobility in fractured carbonates from geological analogues of reservoir: implications for the underground CO_2 sequestration

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Faults and fractures have a crucial role in the control of permeability, in fact, they can act as a preferential corridor or barriers for fluid flow in fractured carbonates (groundwater, hydrothermal fluids, CO_2). For this reason, the characterization of their structure, including the parameters of the associated fracture network (length, trend, density, spacing, intensity, connectivity, orientation) is fundamental. Since the distribution of faults and fractures in the subsurface is largely unknown due to their sub-seismic size and well/core data give only local information, large outcrop analogue studies are the only method to investigate small scale structures.

For this PhD project, I propose to study selected outcrops of fractured carbonates to increase the knowledge about faults, fractures and fluid flow properties, which have strong implications for the geological storage of CO_2. The first part of the project will consist in gathering information to produce a review of the current state of the art regarding the control of fractures and faults on the permeability of carbonates and models on the mobility of fluids within them. Once this review has been carried out, it will be possible to proceed with the identification of outcrops in order to allow the evaluation and characterization of fractures and faults, through both a purely structural and geotechnical survey, and recovery of samples to carry out various analyses in the laboratory and obtaining a series of data such as, for example, permeability. Finally, the results obtained from the study of the outcrops can be used to identify the various factors that potentially affect the fluids flow and, therefore, characterize any reservoirs in more detail.

The study will be conducted at multiple scales integrating the following methods:

- Identification of various outcrops of fractured carbonate rocks suitable for investigating the factors, identified from the preliminary literature survey, that control the fluid flow;
- Geological mapping and review of the regional geology to define the ambient conditions during fault activity and the large-scale geometry of faults;
- Structural field survey: measurements of slicklines and steps on fault surfaces, veins and stylolites for the reconstruction of paleostress and paleostrain;
- Geotechnical field survey: use of scan-line and scan area methods to collect the parameters of fractures like height, length, aperture, spacing and orientation, for a first analysis of the fracture network;
- Use of photogrammetric techniques to obtain a Virtual Outcrop Model (VOM) collecting georeferenced photos with a drone (if possible, otherwise with a camera) and processing them with software like Agisoft Metashape;
- Digitize faults and fractures by exporting the VOM to specific software such as Move (Midland Valley) or Petrel (Schlumberger) to get a 3D model of the fracture network;
- Microstructural analysis of fault rock samples;
- Petrophysical characterization of the wall rock and of the fault rocks (porosity, density, permeability);
- Geochemical analyses on the carbonate cements to trace the extent of fluid circulation and unravel long-term fluid-rock interactions (stable isotopes, 87Sr/86Sr, trace elements).

The combination of fieldwork and high-resolution VOM allow collection and analysis of an amount of data on a scale usually difficult to characterize with only field works and allow the characterization of the fracture network and the variability of permeability with much greater confidence. The ultimate objective of this PhD project, therefore, is to produce, through the studies on the outcropping analogues, conceptual and quantitative models about the effects of faults and fractures on the fluid flow which can be used for potential buried reservoirs for CO_2 sequestration.