Geophysical Research Abstracts
Vol. 19, EGU2017-6741, 2017
EGU General Assembly 2017

Some open issues in the analysis of the storage and migration properties of fractured carbonate reservoirs

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Underground CO_2 storage in depleted hydrocarbon reservoirs may become a common practice in the future to lower the concentration of greenhouse gases in the atmosphere. Results from the first experiments conducted in carbonate rocks, for instance the Lacq integrated CCS Pilot site, SW France, are quite exciting. All monitored parameters, such as the CO_2 concentration at well sites, well pressures, cap rock integrity and environmental indicators show the long-term integrity of this type of geological reservoirs. Other positive news arise from the OXY-CFB-300 Compostilla Project, NW Spain, where most of the injected CO_2 dissolved into the formation brines, suggesting the long-term security of this method. However, in both cases, the CO_2- rich fluids partially dissolved the carbonate minerals during their migration through the fractured reservoir, modifying the overall pore volume and pressure regimes. These results support the growing need for a better understanding of the mechanical behavior of carbonate rocks over geological time of scales. In fact, it is well known that carbonates exhibit a variety of deformation mechanisms depending upon many intrinsic factors such as composition, texture, connected pore volume, and nature of the primary heterogeneities.

Commonly, tight carbonates are prone to opening-mode and/or pressure solution deformation. The interplay between these two mechanisms likely affects the petrophysical properties of the fault damage zones, which form potential sites for CO_2 storage due to their high values of both connected porosity and permeability. On the contrary, cataclastic deformation produces fault rocks that often form localized fluid barriers for cross-fault fluid flow. Nowadays, questions on the conditions of sealing/leakage of carbonate fault rocks are still open. In particular, the relative role played by bulk crushing, chipping, cementation, and pressure solution on connected porosity of carbonate fault rocks during structural evolution and diagenesis is not determined yet. Differently, porous rocks are mainly affected by deformation banding. The latter process involves the collapse of primary porosity within narrow bands, which often localize into well-developed clusters. Currently, researchers focus on the assessment of the 3D pore geometry of the shear bands, which may act as possible sites for residual C02 trapping.

The fault-bounded rock volumes are mainly crosscut by background fractures. These diffuse fractures are often compartmentalized into discrete mechanical units, which are bounded by primary heterogeneities such as bed interfaces and transgressive erosional surfaces. Moreover, bed-parallel pressure solution seams, structural elements that commonly form in limestone rocks during burial diagenesis, can also act as mechanical interfaces during growth of background fractures. However, early embrittlement of carbonates was also documented, suggesting to further investigate their diagenetic evolution to determine the conditions at which the latter phenomenon takes place. Results could shed new lights into the storage properties and, hence, the amount of CO_2 that can be securely stored within significant volumes of fractured carbonates in the underground.