Geophysical Research Abstracts
Vol. 14, EGU2012-11483, 2012
EGU General Assembly 2012

CO_2 sequestration in deep coal seams: experimental characterization of the fundamental underlying mechanisms

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The process of injecting and storing carbon dioxide (CO_2) into suitable deep geological formations, such as saline aquifers, (depleted) oil or gas reservoirs, and unmineable coal seams, is referred to as CO_2 sequestration. In little more than a decade, this technology has emerged as one of the most important options for reducing CO_2 emissions. Among the different options, unmineable coal seams are not as broadly distributed as saline aquifers or oil/gas reservoirs, but their peculiarity resides in the proven capacity of retaining significant amount of gas (mainly methane, CH4) for a very long time. Additionally, the injection of CO_2 into the coal reservoir would enhance the recovery of this natural gas, a source of energy that will most likely play a key role in the power sector over the next 20 years from now. This process is called Enhanced Coal Bed Methane (ECBM) recovery and, as for enhanced oil recovery, it allows in principle offsetting the costs associated to the storage operation.

A study was undertaken aimed at the experimental characterization of the fundamental mechanisms that take place during the process of injection and storage in coal reservoirs, namely adsorption and swelling (Pini et al 2010), and of their effects on the coal's permeability (Pini et al. 2009), the property that plays a dominant role in controlling fluid transport in a porous rock. An apparatus has been built that allows measuring the permeability of rock cores under typical reservoir conditions (high pressure and temperature) by the so-called transient step method. For this study, a coal core from the Sulcis coal mine in Sardinia (Italy) has been used. In the experiments, an inert gas (helium) was used to investigate the effects of the effective pressure on the permeability of the coal sample, whereas two adsorbing gases (CO_2 and N2) to quantify those of adsorption and swelling. The experiments have been interpreted by a one-dimensional model that describes the fluid transport trough the coal core, thus including mass balances accounting for gas flow, gas sorption and swelling, and mechanical constitutive equations for the description of porosity and permeability changes during injection.

The combination of the experimental data with the model predictions allow to successfully relate the dynamics of gas flow to parameters such as the effective pressure on the sample, sorption capacity and swelling, and to estimate important parameters, such as the mass transfer coefficient describing gas diffusion into the porous matrix of the coal. In particular, an increase in permeability is observed with decreasing effective pressure on the sample and, when an adsorbing gas is injected, a reduction in permeability caused by swelling, with CO_2 having a much stronger effect as compared to N2. This last observation represents the starting point to the investigation of attractive options aimed at optimizing the ECBM operation, such as the use of CO_2/N2 mixtures (flue gas) as a way of keeping the permeability in the reservoir sufficiently high.

Acknowledgment
Luigi Burlini was at the heart of this co-operation, and made it possible a synergy between engineers and geologists that has been extremely fruitful. With this contribution we would like to acknowledge Luigi's humanity and scientific visions and to remember a friend.

References

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