Geomechanical agenda for the CO_2 geological sequestration: from the experience of petroleum industry

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1. Introduction

From the view of safety and effectiveness of CO_2 geological sequestration, long and short term behavior of injected CO_2 in the underground formations is an important issue. In the oil industry, we have studied the behavior of formation fluid for the exploration, reservoir evaluation and management, and production optimization. For purposes of well stimulation and enhanced oil recovery (EOR), artificial creation of fractures as a fluid path and formation pressure control are performed. During such operations, the industry has experienced various troubles. Here, we introduce some fluid-solid coupling phenomena in which the fluid influences the stability of the formations, and causes the change of fluid behavior.

2. Fluid motion and formation stability

More than 10MPa pressure variation is often caused by the hydrocarbon production and fluid injection. Such pressure change can cause irreversible deformation and failure in formation rocks. Some examples are presented as follows:

(1) Reservoir compaction and CO_2 storage capacity

Surface subsidences due to oil/gas production are reported in many oil fields. On the other hand, such surface phenomena is not observed in some huge oil field even after several decades of oil production. The reason of such locality is that the phenomena is highly dependent on the rock type and its consolidation natures. In such oil reservoirs, porosity and permeability have been reduced during the oil production, then the storage capacity of the CO_2 is changed. Furthermore, the mechanical properties such as elasticity and strength are also changed.

(2) Fault and fracture reactivation

It is well known that pressure increase and drop of effective stress due to fluid injection can cause the shear failure of the fractures and faults. Such fault motion by the artificial pressure change is called as the fault reactivation. Because the pressure change causes the total horizontal stress, fault reactivation is caused even by the pressure decrease under normal fault type stress regime. When the fault motion is observed by seismic wave, it is called as an induced earthquake. Such reactivation mechanism creates new paths of CO_2, and can cause the leakage.

(3) Tensile failure of the formation due to high gas column

The density of CO_2 is lower than water in both gas and super critical conditions, then the vertical pressure gradient is also lower than the ground water. Then the pressure of the top of gas column can exceed the formation stresses, and cause the tensile (hydraulic) fracturing. Such failure can lead the severe CO_2 leakage. Then the well location and injection schedule should be designed to maintain the height of the gas column.

3. Conclusion

In the previous section, some examples are introduced for compression, shear, and tensile failure mechanisms of the formation rock due to pore pressure change. In order to consider such events, the following three items should be studied:

(1) Stress and initial formation pressure of storage formation and cap rock should be investigated.
(2) As characters of the formation rock, consolidation, fracture/fault distribution, fracture network and permeability should be known.
(3) Precise and time series study of vertical pressure profile using the saturation/concentration distribution of CO_2 are necessary.

It is important to integrate the information of geophysical survey, core analysis, logging, and monitoring for establishing the comprehensive geomechanical models in the stages of survey, injection and post injection monitoring. Especially, since the drilling is an only one chance to touch the formation rock itself, the intensive studies are expected to develop the technologies such as the a constant pressure core sampler to recover formation samples, stress measurement using hydraulic fracturing, well logging technology, and sonic, resistivity, permeability tomography techniques.