Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

HRE28-P01 Room:Convention Hall Time:May 25 18:15-19:30

Carbonate reaction experiments in hot springs as a natural analogue field of CO2 geological sequestration

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Carbon dioxide geological sequestration (CGS) into aquifer formations involves various geochemical processes starting from dissolution of injected CO_2 in underground waters. Among such processes, the reaction of carbonates is most important from both perspectives of storage potentials and leakage risks. However, there have remained many uncertainties on its kinetics under conditions of CGS. On this subject, we applied the approach to measure reaction rates in a condition cloth to CGS. The approach has two important concepts. First, we focus on carbonated or bicarbonated springs as a reaction field because they are exactly regarded as a natural analogue of CGS. Another point is that seed crystals are introduced into spring waters artificially, thereby allowing us to get highly reliable reaction rates in a short time.

The experiment was performed at the Utoro hot spring in Hokkaido, Japan. In this site, the spring water from a well was stored once in a tank, and then it was flew down through a pipe 50 meters long. The CO_2 is degassed during the drainage, which causes the degree of supersaturation with respect to carbonates to be progressively higher downstream. We set the tank interior, and the middle and lower end of a pipe, as observation points. For each point, cleaved samples of major carbonate species, calcite and aragonite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), and magnesite ($MgCO_3$), were dipped into the water over a period up to 24 hours. Then, the sample was taken out one by one at predetermined time. Present experiments included additional reactions adding respectively the CO_2 gas and magnesium chloride to the spring water within a tank, along with reactions in the untouched spring water.

Reaction rate was estimated from measurements of the height level difference between original and reacted surfaces by using a phase-shift interferometer and a laser microscope. The result showed that the reaction rates of carbonates change sensitively to the change of the water composition. Specifically, the calcite reaction rate in nature was much lower than that calculated from the empirical equation, which was compiled based on laboratory experiments. This is possibly because the current equation includes no inhibitor effect of dissolved ions (mainly magnesium ions) and uses unrealistic function form with respect to the saturation-state dependency. We also found that although dolomite generally indicated the highest degree of supersaturation, its growth rate was significantly lower than that of calcite and aragonite. This suggests that judging the possibility of any carbonate precipitation only from its degree of supersaturation would mislead a prediction of long-term behavior of injected CO_2.

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Keywords: CO2 geological sequestration, natural analogue, carbonate, reaction rate, mineral trapping, hot spring

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current trends and challenges in monitoring of injected CO2 in saline aquifer storage

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A major challenge in geological sequestration is to map the movement of CO2 in the subsurface and to demonstrate that the CO2 is safely contained within the reservoir. When CO2 is injected into an aquifer, the existing formation water in pore spaces of the reservoir rock will be partially displaced by the CO2. This process will change the compressibility and density of the reservoir rock. These changes will in turn affect propagation characteristics of seismic waves. Recent research shows that seismic methods are among the most promising monitoring methods. Time-lapse 2D/3D seismic survey has been widely used in CO2-EOR fields, particular in North America. Achievements in CO2-EOR strongly suggest effectiveness of seismic survey in monitoring CO2 migration in an aquifer. Other technologies such as well-based monitoring (VSP, logging, crosswell seismic and EM tomography) are also useful in monitoring the injected CO2 around the wells with high resolution compared to seismic survey.

Several key questions need to be answered when CO2 geological storage is to be undertaken worldwide. How should CO2 be stored underground? Can trapping be assumed in saline formations and can CO2 be retained for long periods safely in the subsurface? This presentation will give a review on CO2 monitoring carrying out at the injection sites particular in North America and also provide information on what kind of technology works well and what did not work. Pilot and demonstration CO2 injection projects provide unique data to develop economically viable, environmentally effective options for reducing carbon emissions in the near future.

Keywords: carbon dioxide, saline aquifer, well logging, seismic survey, trap mechanism, monitoring

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Prediction of changes in geophysical observables associated with CO2 migration through vertical faults

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To appraise the utility of geophysical measurements in detecting potential CO2 migration through vertical faults, we carried out numerical simulations based on a hypothetical aquifer model and calculate changes in geophysical observables caused by changing underground conditions as computed by the reservoir simulation.

Considering that frequent repetition of reflection surveys, especially 3D surveys, seems to be unrealistic due to its high cost, continuous gravity measurements using superconducting gravimeters are quite promising for lowering monitoring costs by complementing standard time-lapse reflection surveys.

Useful geophysical techniques depend on characteristics of each injection site. We need further studies of various techniques including surface deformation, self-potential and electromagnetic measurements suitable for injection sites under various geological conditions.

Acknowledgement: This research is funded and supported by Ministry of Economy, Trade and Industry (METI).

Keywords: reservoir simulation, geophysical monitoring, potential risk, CO2 geological storage

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Risk Assessment of Microbial Associated CO2 Geological Storage and CH4 Production

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Among in-situ microbes within depleted oil-gas reservoir, there are special species those produce much more methane gas in CO2 rich environment than in CO2 poor environment. CO2 acts as a catalyst in the reaction. If we maintain preferable conditions for methanogenesis archaea during geological CCS, we will be able to abate greenhouse gas emission and produce natural gas as one of natural energy resources at the same time.

We named the technological concept as 'Microbial associated Geological CCS'. In Microbial associated Geological CCS, CO2 will be injected from a well for two purposes: to abate greenhouse gas emission and to cultivate methanogenic geo-microbes. CH4 gas will be produced later using other wells. The procedure is similar to the Enhanced Oil/Gas Recovery (EOR/EGR) operation, but in Microbial associated Geological CCS, the target is production of methane out of depleted oil/gas reservoir during CO2 abatement.

When we consider feasibility of Microbial associated Geological CCS technology concept, the most essential information is CH4 produce potential. To estimate production rate, we set a developed a basic geological model of Microbial associated Geological CCS process on CHEM-TOUGH simulator, and implemented microbial activities and CCS process into it. For mineralogical composition of rock matrix and formation water in depleted reservoir, we applied measured value in Nagaoka and Yabase. We assumed a fluid flow model; residual oil is a part of matrix and it will not move; fluid will flow in the rest, 0.1 real pore space. Then we obtained preliminary results of CH4 production and other masses' distributions (2).

We analyzed accident statistics of ground surface industrial facilities and oil/gas wells especially accidental leakage of CO2 and methane leak. We estimated distribution of accident probabilities and accidental leak volume for 105 ton/year CO2 injection. These accidental leak scenarios were offered for environmental impact studies. As regard with risks of produced methane gas, it will vary on the quantities of the production from the well. Timescale of biological methanogenesis is different from that of CO2 injection rate. To assist basic site evaluation and help understanding of Microbial associated Geological CCS technology concept, we are preparing a prototype of Bio-CCS site evaluation system.

Keywords: CCS, microbial, peripheral risk, methan production, environmental impact

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Current Status of CCS in the World

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CCS is a promising technology to mitigate the global warming. The low-carbon technology, according to an analysis by the International Energy Agency (IEA), is required to contribute to 14% of the global CO2 emissions reduction by 2050 necessary to achieve the internationally-agreed goal of limiting the rise of the average global temperature to 2 degree C. There have been more than 10 commercial-scale CCS projects, including the world first CCS project in the power sector that became operational in Canada in autumn 2014, and there have also been around 10 projects under construction. The progress of CCS deployment is, however, far behind the anticipated trajectory. This is mainly because there is lack of business case. This is underpinned by a fact that most of the projects under operation and construction are in combination with enhanced oil recovery (EOR) by using anthropogenic CO2, which contributes to making them feasible commercially. The situation draws wider attention to policies and regulations to incentivize or mandate CCS implementation. Such policies and regulations have been in place mainly for fossil fuel power plants in, for example, the USA, Canada and the UK. This presentation is to summarize the current status of large-scale CCS projects and CCS incentive/ mandatory policies and regulations.

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Stress dependency of permeability through a single fracture in Neogene-Quaternary siltstone

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In case that mudstone seal layers for carbon dioxide geological storage have some fractures, carbon dioxide can leak at the fractures. Therefore, it is important to reveal condition which fracture of mudstone becomes a flow channel.

Uehara et al. [1] indicated that, when an effective pressure is increased, a fracture in mudstone was closed and it cannot function as a under a certain effective pressure, which is related to yield conditions of the intact rock. However, in the case of carbon dioxide geological storage, it is necessary to pay attention to a process of decompression of effective pressure, because carbon dioxide is injected and pore pressure is increased. It is not clear how the fracture permeability develops at this process of decompression under the depth for Neogene-Quaternary mudstone, which is one of the potential candidates of seal layers for carbon dioxide geological storage in Japan.

The purpose of this study is to make clear how fracture permeability in mudstone changes at an effective pressure-decompression process, and how the features depend on depth and yield condition of the rock. This study conducted water permeability tests with two siltstones from the Kazusa Group, the Ohara Formation siltstone (OHR3) and the Kiwada Formation siltstone (KWD2), which be different from the yield condition. A single fracture was made in these cylinder rock specimens by using a vice. Permeability for each specimen was measured under several compression-and-decompression cycles of effective pressure with increasing the maximum effective pressure (2∼21 MPa). These experiments were carried out three times for OHR3 and two times for KWD2.

All results of experiments had two characteristic effective pressure cycles; a cycle at which differences in permeability between process of compression and decompression become clear, and a cycle at which the permeability becomes almost the same as the permeability of the intact rock. This study calls the former cycle as ”the fracture yield starting cycle”, and the later as ”the fracture closed cycle”. The maximum effective pressure of the fracture closed cycles are 5∼9 MPa for OHR3 and 17∼21 MPa for KWD2, and the maximum effective pressure of the fracture yield starting cycles are 5 MPa for OHR3, and as well as 3∼9 MPa for KWD2. The fracture closed cycles almost equal the yield conditions of the intact rocks, which corresponds with the previous study [1]. While, the fracture yield starting cycles tend to appear lower pressure conditions than the yield conditions of the intact rocks. This is possibly because of the degree of matching between the opposite surfaces of the fracture. The stress on contact area at the fracture is larger than the effective stress applied on the specimen. In summary, the fracture closed conditions depend on the yield condition of rock, while the fracture yield starting conditions depend also on fracture condition.

Reference: [1] Uehara, S., Simamoto, T., Matsumoto, T., et al. (2011), Journal of MMIJ, Vol.127, 139-144.

Keywords: Fracture Permeability, Neogene Siltstone, Laboratory Permeability Test, Stress Dependency

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X-ray CT visualization technology for CO2-EOR laboratory test

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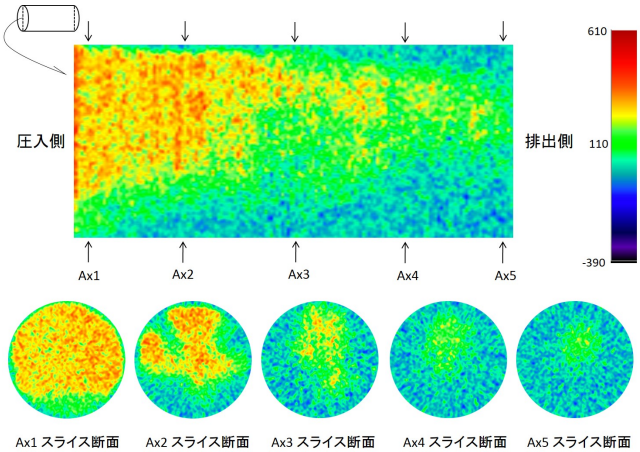
X-ray CT visualization technique has come to be actively utilized in the field of earth science not only medical and industrial fields. With this technique, it is possible to monitor the fluid movement of the internal structure and confirmed in a pore of the rock samples in a nondestructive manner. In particular, it is possible to quantitatively evaluate the physical properties such as porosity and fluid saturation in the rock sample by analyzing the X-ray CT data. Such techniques are also used in research related to oil development.

There are three main categories of EOR (Enhanced Oil Recovery); thermal recovery, gas injection and chemical injection. In particular, CO_2-EOR, one of the gas injection method is a technique which has attracted attention of many new markets among EOR technology.

We developed an experimental system in which the CO_2-EOR laboratory tests and X-ray CT visualization can be performed simultaneously using a rock sample. The experimental system is intended to quantitatively evaluate whether there is an effect on CO_2-EOR for the rock sample. Berea sandstone (diameter: 35mm, length: 80mm) were used for this experiment. The experiment was carried out under conditions that simulate the temperature and pressure of the underground; confining pressure 12MPa, pore water pressure 10MPa and temperature 40 ℃. Injection of the fluid was controlled by a high-precision syringe pump. In addition, specially designed high-pressure vessel to X-ray transparent was utilized for X-ray CT visualization. Porosity of the rock sample determined by X-ray CT image was about 20.21%, which is consistent with the porosity obtained in the previous test by the saturated immersion method. The sample has been saturated with KI aqueous solution, and then mixed with oil (KI-Oil mixed state; oil saturation rate 58.50%). The CO_2-EOR test was carried out until the CO_2 injection reaches 2PV (pore volume), finally, about 66.10% of the oil recovery rate was confirmed. Figure 1 shows a CT image when the CO_2 injection amount reaches the 0.25PV.

In this study, the CO_2-EOR laboratory test of porous sandstone and X-ray CT visualization were carried out to obtain the porosity, fluid saturation and oil recovery rate. We report the experiment method and results in detail. This study is expected to contribute to the development of CO_2 injection methods for efficiency improvement of CO_2-EOR (for example, micro-bubble CO_2-EOR).

Keywords: X-ray CT, CO2-EOR, visualization, image analysis, quantitative assessment



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Gravity monitoring at the Farnsworth CO2-EOR site, TX (2)

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We have been making continuous measurement using a superconducting gravimeter (SG) iGrav15 at the Farnsworth field, TX, for the purpose of studying the effects of CO2 injection at an enhanced oil recovery site. In 2014 CO2 injection has started near the observation site. Determining the drift rate of SG is very important to distinguish real gravity changes from time-varying instrumental drift. Usually annual or semi-annual parallel measurements with an absolute gravimeter (AG) are made for determining the drift rate of SG. The best method is parallel SG and SG measurements located in close proximity. In July the second SG, iGrav17, was deployed by the iGrav15 and parallel measurement has been made for five months. Then iGrav17 was re-installed at the new site, which is about 600 m from the base station. Followings were observed: (1) the parallel SG and SG measurements located in close proximity was very effective not only for determining time-varying instrumental drift but also studying noise components, (2) regarding the instrumental drift a small gap was observed at the re-install, however, the drift rate was converged to the former value in ten days.

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Keywords: gravity monitoring, superconducting gravimeter, CO2 storage