

Analysis of long-term CO₂ emission reduction scenario and the role of CCS

*Yasuhide Nakagami¹, Keigo Akimoto¹

1. Research institute of innovative technology for the earth

As significant CO₂ emission reduction is required on the long-term at international level, this presentation will introduce various assessments based on RITE models on the following topics:

- The global CO₂ emission pathways for achieving the 2°C and 1.5°C target
- The marginal abatement costs for CO₂ emission reductions
- The evaluations of Nationally Determined Contributions (NDCs) under the Paris Agreement
- The role of CCS

Keywords: CO₂, Climate Change, Model Analysis, Environment, CCS

Automatic optimization for well placement for large-scale geologic CO₂ storage

*MIYAGI ATSUHIRO¹, HAJIME YAMAMOTO¹, Ziqiu Xue²

1. Taisei Corporation , 2. Research Institute of Innovative Technology for the Earth

Carbon dioxides capture and storage (CCS) is a viable technique for reducing amount of CO₂ emitted to the atmosphere by injecting captured CO₂ into underground reservoirs. When we consider a large scale CCS with more than 1Mt/y injection rate, the injection has to be processed efficiently and safely keeping reservoir pressure at an allowable level. One of the promising solutions is to employ pressure relief wells to reduce reservoir pressure by producing formation water. However, a huge number of reservoir simulations would be required to determine an optimum placement of the relief wells such as the number of wells and location. Therefore, automatic and efficient optimization methods that can reduce number of reservoir simulations and obtain beneficial solution will be essential. In this study, we developed a tool for efficient and automatic optimization by combining a commercial general-purpose optimizer HEEDS with a multiphase fluid flow simulator TOUGH2/TOUGHREACT. Users can select a variety of optimizers and will be benefited from massively parallel computation that can largely reduce computational time of each simulation. The tool was applied to well placement problems on reservoir models having homogeneous and heterogeneous permeability. The performance of a couple of optimizers (i.e. generic algorithm, particle swarm optimization, simulated annealing) were investigated and demonstrated through the applications

Keywords: Carbon dioxide capture and storage, Optimisation, Reservoir Simulation, TOUGH2

Numerical simulation study on mitigation of the pressure build-up in the geological formation during injection of CO₂

*Claudia Fujita¹, Yusuke Hiratsuka¹, Hajime Yamamoto¹, Takahiro Nakajima², Ziqiu Xue²

1. Taisei Corporation, 2. Research Institute of Innovative Technology for the Earth Kyoto

The injection of supercritical CO₂ into the deep underground increases the pore pressure in the geologic formation, first locally around the injection point, later spreads radially throughout the capture formation. The range of pressure increase depends on the injection rate, injectivity and reservoir volume. The increase of pressure in the reservoir may cause several problems, including fault reactivation, changes in the groundwater flow direction, changes in hydrogeological conditions and changes in the neighboring pressure regimes.

We investigated how effective pressure build-up can be reduced by applying pre-injection formation water (brine) production as proposed by Buscheck et al. in 2014 (dual-mode wells), or production of brine in parallel to CO₂ injection. Numerical simulations were conducted, using the TOUGH2/ECO2N code, developed at the Lawrence Berkeley National Laboratory (LBNL).

We employed a simple reservoir model based on available data of the large-scale CCS demonstration project at the Tomakomai area in Hokkaido, Japan. The efficiency and influence of two reservoir volumes, and a hypothetical placed production well, on pressure build-up in the storage formation were tested. Two models with different volumes, and an injection rate of 1 Mt/yr were applied and three cases were simulated for each model. The first case only considered injection of CO₂ for 100 years without previous production. The second case examined the dual-mode well, which included previous production for 5 years prior CO₂ injection for 100 years. The last (third) case considered production of brine while injection of CO₂ by using a separate installed production well. Judging from the results, the following conclusion can be drawn: 1) The dual-mode well with short duration of water production (5 years) was not so effective to maintain the reservoir pressure in the large reservoir volume considered here. The method would be better suited for smaller reservoir, otherwise a very long-term production would be necessary. 2) Water production in parallel with injection was very effective in order to maintain the reservoir pressure and to avoid harmful effects on the overlying seal layers and other hydrogeological conditions. The methods can be applied to make CCS technology much more sufficient through increasing the effective capacity of injectable CO₂. It may also lead to more opportunities related to site selection. However, it has to be emphasized, that the effectiveness of the production strategies investigated here may highly depend on site conditions. Therefore, the results obtained in this study should be regarded as a preliminary evaluation for the Tomakomai site specifications. Further investigations would be necessary, when more data become available through the site investigation and even operations.

Keywords: Carbon Capture and Storage, pressure build-up, production of formation water

An automatic seismic event identification method by sequential discounting autoregressive (SDAR) change point detecting

*Luchen Wang¹, Ziqiu Xue¹

1. RITE Research Institute of Innovative Technology for the Earth

In recent years, more and more reservoir evaluation studies, including CO₂ sequestration, hydraulic fracturing and fracture mapping, focus on seismicity monitoring. The primary task for monitoring is the identification of seismic events in a long-term sustained time series record. Unfortunately, the time-varying characteristics of SNR (signal to noise ratio) and seismic event waveforms increase the difficulty in the automatic detection of seismic events. First, The uneven data energy distribution due to uneven data energy distribution influences the outlier identification of the targeted event, especially for weak energy earthquakes. Second, different seismic events contain different waveform properties. A fixed detecting model is inappropriate for long-term observation. Events in close propinquity of a time series also lead to a complex automatic detecting model.

The STA/LTA (short term averaging / long term averaging) method is a widely used seismic first arrival identification algorithm. This method is simple and suitable for real-time processing. It contains 2 steps: 1. set a short time window included in a long time window and calculate the time window signal amplitude (or energy) average, respectively. 2. slide the windows in the time series and calculate the two average ratios. The outlier of the ratio refers to the appearance of a seismic event. The STA/LTA method can be employed for real-time processing. However, for low SNR or related signal noise situation, STA/LTA detecting effect will be impaired. Besides, for long-term series, it is difficult to estimate an appropriate time window size for the ratio calculation. Considering seismic observed record as a stochastic time series, AR (autoregressive) process can be applied for seismic event detecting. For the event phase arrival, AR method assumes that the segments before and after the event phase is stationary as different AR models. The change point between these two models refers to the seismic event on time series. Since the AR method avoids the amplitude or energy calculation, it produces better results for low SNR signals. However, AR method needs the signal stationarity assumption, so it is not suitable for time-varying long-term records.

In this work, an improved AR method for automatic seismic event detecting is applied. This algorithm, called SDAR (sequential discounting AR learning), is widely used to represent a statistical behavior of a time series. There are 2 advantages of SDAR: 1. Real-time estimation. When new data appears in the record, the SDAR model parameters can be updated. 2. Discounting property. Comparing with AR method, the SDAR introduces the discounting parameter to decrease the statistic value on future data. Therefore, the SDAR method can handle the unstable time-varying long-term series. Comparing SDAR and STA/LTA method, the Tomakomai OBC observation test shows that SDAR can increase the seismic event detecting rate.

Keywords: seismic event detecting, SDAR, change point

Acoustic sonar detectability of gas bubbles from seafloor for environmental monitoring at offshore CO₂ storage sites

*Takamichi Nakamura¹, Makoto Nishimura¹, Keisuke Uchimoto¹

1. CO₂ Storage Research Group, Research Institute of Innovative Technology for the Earth

Geological CO₂ storage is proposed in sedimentary formations. Because storage sites are selected deliberately to minimize the risk of leakage, CO₂ is assumed to be stable in the reservoirs. CO₂ leakages from geological storage systems are unlikely, but still possible. At offshore CO₂ storage site, CO₂ could leak out from the seafloor into the seawater. CO₂ leakage may lead to significant effects on the local environment. From the public and stakeholders, concerns about the risk of in situ leakage and ecological impacts are emerging. Therefore, it is the most important verification for geological CO₂ storage project that there is no detectable leakage or migration of CO₂ by environmental monitoring. Appropriate environmental monitoring methods and public communications are lead to secure social license and also needed to progress of safety geological CO₂ storage project. Further, in Japan, operators of offshore CCS are required to plan monitoring programs, as stated in the Act for the Prevention of Marine Pollution and Maritime Disasters. In the monitoring plan, an operator has to be able to determine the location and extent of any CO₂ leakage. Consequently, it is necessary to develop detection methods of CO₂ leakage in the sea.

For offshore environmental monitoring, acoustic methods were expected that could direct detection of CO₂ bubbles in the seawater. It was described that effectiveness of acoustic methods for seafloor and water column monitoring in IEAGHG special report (IEAGHG, 2012). In practice, it was used in seafloor survey of several offshore geological CO₂ storage projects. For example, in Sleipner, side scan sonar (SSS) and multibeam echo sounder systems (MBES) were used for seafloor observations on storage site (www.eco2-project.eu). In QICS project (Blackford et al., 2014) that CO₂ controlled release experiment from shallow seafloor, clearly images of both gas plume within the water column and pockmarks on the seafloor obtained using MBES (Cevatoglu et al., 2015). Furthermore, gas flux quantification using hydrophone, passive acoustic method was shown (Bergès et al., 2015). However, there were no data about flow rates of released CO₂ and MBES image data was used as check the location of releasing point. Detectability of acoustic methods was unclear.

This paper focuses specifically on the detectability of active acoustic method. Controlled compressed air release experiments were carried out in shallow inner bay at the depth of 5 to 6 m. Observations using active acoustic instruments such as multibeam sonar (MBS) and SSS were deployed to assess its detectability for gas bubbles stream. Analysis of the image acquired by active acoustic instruments led to the following conclusions:

- Images of MBS data could detect gas bubbles stream. The survey using MBS have the potential to be effective method for localization of leakage point in narrow area.
- Images of SSS data could detect gas bubbles stream. Images of SSS data showed high detectability of gas bubbles stream The survey using SSS have the potential to be effective method for detection of CO₂ leakage and localization of leakage point.
- Image processing and analyzing of SSS data, the quantification data of gas bubbles stream were obtained. Flow rates from any image data could estimate within order of magnitude, with relative high quantification accuracy.
- The survey using SSS have the potential to be effective method for not only leakage detection but also leakage scale grasp. The broad seafloor survey using active acoustic instruments such as SSS is crucial point of efficient leakage detection and localization.

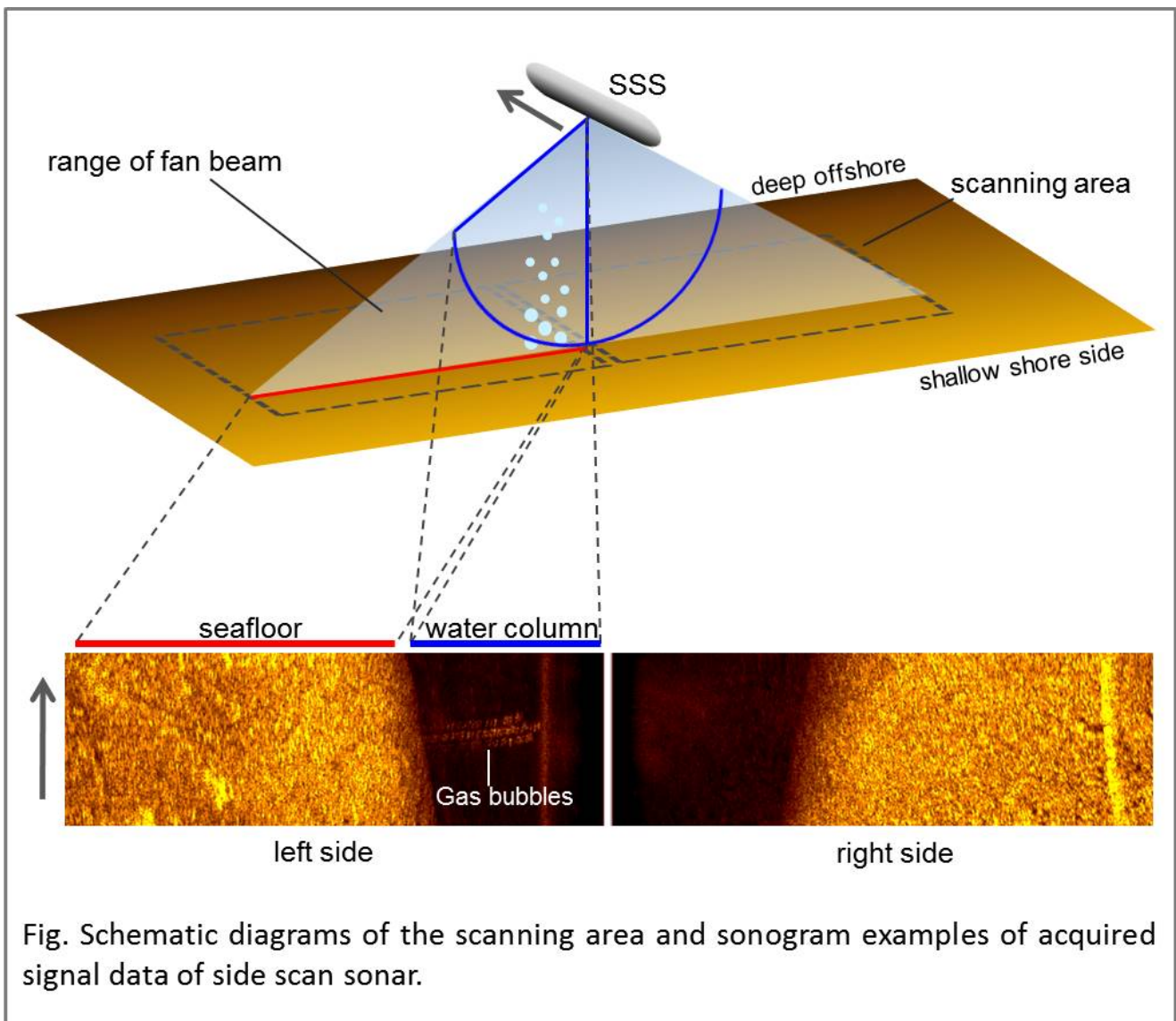
Bergès, B.J.P., Leighton, T.G., White P.R. (2015) Passive acoustic quantification of gas fluxes during controlled gas release experiments. *Int. J. Greenh. Gas Cont.* 38, 64-79.

Blackford, J., Stahl, H., Bull, J.M., et al. (2014) Detection and impacts of leakage from sub-seafloor deep geological carbon dioxide storage. *Nat. Clim. Chang.* 4, 1011–1016.

Cevatoglu, M., Bull, J.M., et al. (2015) Gas migration pathways, controlling mechanisms and changes in sediment acoustic properties observed in a controlled sub-seabed CO₂ release experiment. *Int. J. Greenh. Gas Cont.* 38, 26-43.

IEAGHG. (2012) Quantification Techniques for CO₂ Leakage. Report. 2012/02.

Keywords: offshore environmental monitoring, offshore CO₂ geological storage, acoustic sonar, leakage detection



Scientific response to successive changes of next Earth and human society and CO₂ capture system

*Yasunori Miura¹

1. Visiting (Yamaguchi University, Foreign University (AIC))

Any sustainable future oriented idea on active Earth is indispensable for the active human society from the mini Earth type system where we would like to report briefly on the future of human society located in planet Earth as follows.

1. Descriptive present research on the later stages of the Earth have been overlooked to be studied precisely carbon dioxides change during resource burning.
2. Carbon dioxides gas capture immediately after burning before cool atmosphere because of difficult collection at global distribution.
3. The sources of action of the inorganic planet Earth and the organic matter are different with formation conditions.
4. Earth atmosphere ocean water and solid rocks show different activities with remnants of changed signature.
5. Our Earth and human society show different system in duplicated circulated system. Earth's natural resources with CO₂ gas formation should be applied to circulated processes developed in human society.
6. Material changes of our Earth are reconfirmed as evidence of its activity by remained rocks reacting with atmospheric gases and seawater solutions. Author has been confirmed and reported the remained traces of the three states changes naturally and artificially by the recent high technical observation method.

In short in the case of using active Earth resource substances in our human society any effective scientific and technical developments of recycling of disposal waste is definitely indispensable for future human energy by using the Earth resources with carbon dioxides gas waste.

We would like to present scientific ideas and proposals at the meeting. This is main essence of our Earth and human society with related scientific and technical development of continuous reformation process of active Earth resources where we should apply to human life society by duplicated process of Earth and life systems.

Keywords: Carbon dioxides capture system, Earth system, Human life system

Evaluation of shale volume using a combination of the gamma-ray logs and core analysis in terms of sedimentology and geochemistry: a case study of the Nagaoka site, Japan

*Takuma Ito¹, Atsushi Ohbuchi², Takahiro Nakajima¹, Ziqiu Xue¹

1. Research Institute of Innovative Technology for the Earth, 2. Rigaku Corporation

Evaluation of spatial distribution of shales is important for selecting of reservoir rocks suitable for geological storage of CO₂. Shale volume from well logs is useful as deterministic data for evaluation of spatial distribution of shales in the strata. Gamma-ray log can be used to evaluate shale volume in the reservoir. Gamma-ray logging is a method of measuring naturally occurring gamma radiation from ²³⁸U, ²³²Th, and ⁴⁰K in the strata. Mudstone generally has higher total GR value than sandstone. However, it is difficult to evaluate reliable shale volume if the mineralogical composition significantly changes during deposition of the strata. This means that understanding the minerals which have an effect on the total GR value is essential for evaluation of shale volume, but few studies have focused on that. Herein we present the results of reservoir characterization in terms of sedimentology and geochemistry, and comparison among core analysis and gamma-ray logging as a case study of the Nagaoka geological storage site, Japan. Furthermore, we show the importance of sedimentological interpretations of the strata for reliable evaluation of shale volume.

In the Nagaoka project, total of about 10,000 tons of CO₂ was injected into the saline aquifer, which situates about 1,000m depth below the Niigata Plain. The target saline aquifer is correlated to the early Pleistocene Haizume formation. During the project, one injection well (IW-1) and three observation wells (OB-2, -3 and -4) were drilled. Sediment core of the target reservoir rock was taken from the IW-1.

Standard GR logging was carried out at all the wells, and spectral gamma-ray logging, which can measure ²³⁸U, ²³²Th, and ⁴⁰K contents, was performed at all observation wells.

We carried out the interpretation of depositional environments, measurements of major and minor elements by XRF analysis, and identification of minerals by XRD analysis in the target strata. The target reservoir comprises two depositional sequences characterized by fining-upward to coarsening-upward succession that developed on the erosional contact. According to core description, the deposits can be interpreted as prodelta to deltafront deposits. Total GR value has high sensitivity to depositional environments. Profile of total GR value is basically consistent with that of mud content (<1/16mm), and this suggests that main source of total GR value is mainly attributed to minerals in mud fraction. Comparison between total GR value and spectral GR logging shows that distribution range of K content against total GR value show low contrast between prodelta and deltafront deposits, and this trend suggests that K content is not carrier of radioactivity. On the other hand, distribution range of U and Th contents against total GR value show basically high contrast between two deposits and have positive correlation. This result indicates U and Th-bearing minerals are main carrier of radioactivity. Comparison between total GR value and major and minor elements shows that minerals including MgO, TiO₂, Th, and Zr are likely to be main source of total GR value. The XRD analysis using samples of mud fraction shows that those minerals can be attributed to zircon grains, smectite and chlorite, because it is known that these minerals contain or adsorb the Th and/or U ions.

As stated earlier, stratigraphic profiles of GR logging show two depositional sequences at all wells. The scatter diagrams of radioactive elements by spectral GR logging against total GR value shows similar trend basically in two depositional sequences, implying that no significant changes of mineralogical composition during deposition. However, maximum of total GR value is significantly different between two

sequences. The result indicates that the endmembers of total GR value for evaluating shale volume by gamma-ray logging should be selected in each depositional sequence. Detailed studies in terms of sedimentology are essential for reliable evaluation of shale volume.

Keywords: Nagaoka site, Sedimentology, Geochemistry, Natural gamma-ray logging, Spectral gamma-ray logging, Shale volume

Reservoir heterogeneity based on sediment sorting associated with GR and permeability in turbidity sandstone sequence, Kitaura Formation, Akita, Japan

*Shun Chiyonobu¹

1. Faculty of International Resource Sciences, Akita University

Outcrop and core data from the interbedded with turbidity sandstone and siltstone, Kitaura Formation of Akita basin show that realistic reservoir characterization can be based on stratigraphic architecture. This deposit represents turbidity sandstone reservoirs that developed from cyclic turbidity currents within hemipelagic basin. Kitaura Formation outcrop are good analogs to CO₂ reservoir characterization and modeling in off Akita area. Analysis and modeling of the turbidity sandstone based on outcrop measurements provide detection and identification of ranging data for sandstone reservoir characterization.

Ourcrops displays of differential weathering, coloration, cementation, and seepage reflect stratigraphic and sedimentary control of fluid flow within the turbidity sandstone. The first step of this study is observations of sedimentary facies that characterized by sedimentary structures, grain-size distribution, thickness of sandstone and siltstone, and cyclicity and lateral variations of sandstones. Measurements of permeability using a field permeameter and conventional soil analysis (e.g. Talsma and Hallam, 1980) yield some of magnitude range of values between distinct populations as follows; a part, b part, and c part of Bouma sequence and low density current deposit composed very fine sandstones. These differences within turbidity sandstones depend on grain size distribution, which indicate sediment sorting. The lateral variations of the sorting of a sandstone layer reveal that various values of reservoir property depend on depositional mechanisms. Natural gamma ray (GR) measured for ratio between clay and sand contents in sandstone layers can regards as a physical property of reservoir heterogeneity. Recognition of physical levels of reservoir heterogeneity can be identified GR and permeability within turbidity sandstone layer even though factor and distribution of physical properties are sampling scale dependent. Outcrop analogs for flow within turbidity sandstones can be generated spatial distribution of reservoir heterogeneity based on sedimentary systems.

Keywords: Reservoir heterogeneity, turbidity sandstone, sediment sorting

Impact of the injection speed on CO₂ saturation and pore pressure

*Keigo Kitamura¹, Hiroyuki Honda², Shinnosuke Takaki², Mitsunori Imasato², Yasuhiro Mitani³

1. International Institute for Carbon-Neutral Energy Research, Kyushu University, 2. Graduate School of Faculty of Engineering, Kyushu University, 3. Faculty of Engineering, Kyushu University

It is an essential issue to understand the behavior of injecting CO₂ in reservoirs. Injected CO₂ forms two-phase flow with brine and arises CO₂ saturation (SCO₂) and pore fluid pressure (Pp). The estimation of SCO₂ in the reservoir is one of important task in CCS projects. Fluid pressure (Pp) is also important to estimate the integrity of CO₂ reservoir and overlying cap rocks. Generally, elastic waves are used to monitor the changes of SCO₂. Previous experimental and theoretical studies indicated that SCO₂ and Pp are controlled by the fluid velocity of invaded phase. In this study, we conducted the CO₂ injection test for Berea sandstone ($\Phi=18.1\%$) under deep CO₂ reservoir conditions. We try to estimate the changes of SCO₂ and Pp with changing CO₂ injection rate (FR) from 10 to 5000 ml/min for Berea sandstone. P-wave velocities (Vp) are also measured during CO₂ injection test and used to investigate the relationships between SCO₂ and Vp and Pp. We set 3 Vp-measurement channels (ch.1, ch.2 and ch.3) to monitor the CO₂ behavior. The result shows step-wise SCO₂ changes with increasing FR from 9 to 25% in low-FR condition (10-500 ml/min). Vp also shows step wise change from ch.1 to ch.3. Ch.1 indicates that Vp-reduction stops around 4% at 10ml/min condition. However, ch.3 changes slightly from 4% at 10 ml/min to 5% at 100 ml/min. On the other hand, differential Pp (DP) dose not shows obvious changes from 10 to 30kPa. Over 1000 ml/min, SCO₂ increases from 35 to 47 %. Vp show slight reductions and Vp-reductions reach constant values as 8%, 6% and 8%, respectively at 5000 ml/min. Then, DP shows rapid increasing from 50 to 500 kPa. It suggests a drastic change of CO₂ behavior with injection rate. CO₂ flows gently and enlarges SCO₂ up to 25 % under low FR conditions without arisen DP (<500 ml/min). Over 1000 ml/min, CO₂-flow causes rapid increment of SCO₂ and DP. These results clearly indicate that SCO₂ and DP are strongly controlled by CO₂ injection rate.

Keywords: CO₂ saturation, differential pressure, injection speed, two-phase flow

Numerical Study on the Effects of Change of Contact Angle on Sealing Capacity

*Yuki Kano^{1,2}, Tsuneo Ishido^{1,2}, Masao Sorai^{1,2}

1. AIST, Geological Survey of Japan, 2. Geological Carbon Dioxide Storage Technology RA

For geological storage of CO₂ in Japan, general aquifer storage site often have geological characteristics favorable for geochemical reactions. When pH-lowered pore water due to CO₂ dissolution causes geochemical reactions in such formations, some kind of mineral may envelop the surface of rock, change the wettability (contact angle), and result in change of the capillary pressure. In this study, we will present the results of the numerical analysis of the effects of change of contact angle on seal capacity and the long-term behavior of injected CO₂.

We constructed a two-dimensional radial model with 20 km width and 0.5 km depth for the simulation. Subsurface conditions of 31 °C and 9.0 MPa are assumed for the top boundary. Reservoir is located at 1,000 m depth with 100-m or 200-m thickness. A 100-m thick seal layer overlies it. Basement underlies the reservoir, and second aquifer overlies the seal layer. CO₂ is injected into the reservoir at a rate of 1 Mt/year. The injection interval is 50 years. We conducted numerical simulations on the long-term behavior of CO₂ for the injection period and 450 years of shut-in. Simulations are carried out using the "STAR" reservoir simulation code with the "SQSCO2" equation of state.

Reservoir and seal layer have vertical/horizontal permeabilities of 10/100 mD and 0.1/1 mD, respectively. Models of relative permeability for water and CO₂ were assumed to be common to all formations. They are represented by functions of van Genuchten type and Corey type, respectively. Irreducible water saturation and residual CO₂ saturation are 0.2 and 0.05, respectively. Hysteresis model is adopted for the relative permeability. Capillary pressure was represented by van Genuchten type, and the threshold pressure (P_{th}) was given as the capillary pressure at the residual CO₂ saturation. P_{th} of reservoir is set to be 0.1 MPa, and that of seal layer is 0.5 MPa or 1.0 MPa. In this study, the initial contact angle of water-CO₂-rock system is assumed to be water-wet 0°. We assume the contact angle θ changes at some point, to be 15°, 30°, 60°, and 75°. According to the change of contact angle, threshold pressure P_{th} will change following Laplace' s equation: $P_{th} = 4 \sigma \cos \theta / d$, being proportional to $\cos \theta$ at all CO₂ saturation. Interfacial tension σ and throat diameter d remain unchanged in this study. For case study, P_{th} is i) unchanged all over simulated time, changed at ii) 25 years, iii) 50 years, and iv) 100 years later from the start of the injection.

Simulated results showed that i) for unchanged case, part of CO₂ intrudes into the seal layer during the injection period, however, it almost stops in shut-in period. ii) CO₂ remains with in the reservoir and seal layer, and do not reach the second aquifer after 450 years later from the stop of the injection in the all cases of this study. Low permeability of the seal layer and residual gas trapping are presumed to contribute it. iii) When capillary pressure is lowered due to change of contact angle, CO₂ intrusion into the seal layer continues during shut-in period in some cases. iv) This effects are pronounced especially in the cases where the initial capillary pressure is low, and/or buoyancy is large due to thick reservoir. These results indicate that change of contact angle due to geochemical reaction can affect long-term seal capacity at CO₂ storage site.

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Keywords: Geological storage of CO₂, contact angle, capillary pressure, numerical simulation

Micro-bubble Injection Enhanced dissolution during CO₂ Sequestration in saline

*LANLAN JIANG¹, Ziqiu Xue¹, Hyuck Park¹, Tamotsu Kiyama¹

1. Research Institute of Innovative Technology for the Earth

CO₂ micro-bubble injection is available for storing CO₂ in aquifers with non-anticline (monotonic) structure in a low-cost concept. In this study, the dynamic displacement and dissolution during CO₂ flushing was investigated by using medical X-ray CT scanner. CO₂ was injected into brine saturated sandstone with 0.05 mL/min under reservoir condition (10MPa/40°C). Two sets experiments with micro-bubble and normal bubble CO₂ were conducted to quantify compare the enhanced dissolution efficiency. Larger interfacial area between CO₂ and brine during the injection enhanced the mass transfer and delayed CO₂ breakthrough. The breakthrough time for micro bubble was nearly 120 min corresponding to 180 min for normal bubble under the same injection rate. By image analysis, the high sweep efficiency during micro-bubbles injection was obtained. Micro-bubble CO₂ preferred to trap into tiny pores since the small size bubble and micro-bubbles injection accelerated gas trapping because of the fully dissolution. CO₂ micro-bubble sequestration is also a novel technology to store CO₂ from the small- to middle-scale emission sources by enhanced dissolution and effective use of pore space suggested by our experimental results.

Keywords: micro bubble, CO₂ saturation, high sweep efficiency, dissolution

Study of advanced CO₂ dissolution technology for improvement of CO₂ storage efficiency

*Ryo Ueda¹, Masanori Nakano¹, Ziqiu Xue²

1. Japan Petroleum Exploration Co., Ltd., 2. Research Institute of Innovative Technology for the Earth

Reducing cost of CO₂ injection and storage is important challenge for applying to commercialization. Establishing the advanced CO₂ dissolution technology which controls the reservoir pressure during CO₂ injection is very important to inject and store CO₂ in reservoir efficiently and we focused the technology of CO₂ injection as the microbubble (MB). In this study, we proceeded the unraveling the efficiency of increase of CO₂ storage and the mechanism by MB-CO₂ from experiment and flow simulation.

MB is formed by CO₂ passed through the porous filter. In past study, it was seen that CO₂ saturation which is ratio of CO₂ volume divided by pore volume increase by MB-CO₂ injection more than normal injection and now it is the key point to applying this technology to field scale to study for the behavior and the efficiency of MB in the well and the reservoir and the mechanism of them.

As one of the studies, we targeted the “Effective area of MB-CO₂” and estimated the relation between the effective area of MB-CO₂ and CO₂ storage by conducting core flooding test with the long berea sand core (length : 30cm). Core flooding test was conducted at the reservoir condition (40°C, 10MPa) at which it is supercritical CO₂ and CO₂ saturation was increased 7.4% and CO₂ Storage is also increased 30.4% in core by MB-CO₂ injection as relative increase against normal injection. It was considered that these results show the effect of advance of CO₂ dissolution to water by MB-CO₂ injection technology. In addition, the behavior, which breakthrough time of CO₂ in MB-CO₂ injection was later than that in normal injection, was observed.

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