Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

HRE29-01 Room:103 Time:May 22 09:00-09:15

Quick mechanochemical reaction of CO2 and silicate rocks

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CO2 is found to be adsorbed quickly on mafic minerals by mechanochemical reaction. Various rocks and minerals are examined for their reactivity with CO2. The silicates are crushed gently in a big ball mill with mixed gas of 10% CO2 and 90% N2. Residual gas is monitored by a gas-chromatograph. The 80% of CO2 in the mill is found to react in 8 hours with olivine and peridotite. The quick reaction of CO2 and fresh surface of peridotite is also expected in natural environments.

<ref.> Tanaka, T. and Mimura, K. (2013) Quick mechanochemical reaction of silicate rocks and CO2. A possible candidate for 14C dating. In Summaries of Researches using AMS at Nagoya University XXIV. It will be published in March 2013 also will be opened in CiNii after 2014.

Keywords: carbon dioxide, CO2 sequestration, mechanochemical reaction, silicate rocks

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HRE29-02 Room:103 Time:May 22 09:15-09:30

Migration and carbonate mineralization by past CO2-rich fluid in the Izumi Group, southern Osaka: A natural analogue on

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The stability of storage system recently attracts attentions with an increasing importance of CO2 geological storage (CGS) as a counter-measure to the global warming. Physical and sedimentary-petrological properties of seal layer are particularly important in relatively short time span. A good seal layer composed of thick, poorly permeable mudstone lacking any fractures, however, is difficult to expect in Japan as it lies on an active island arc. Nevertheless, it can be expected for moving reservoir fluid to dissolve into intact formation water during its lateral and upward migration, thereby trapped through a mechanism called solubility trapping. In fractured bedrock, the flowing CO2-rich fluid in fractures is further expected to precipitate carbonates, which finally closes the fractures and recovers mechanical strength of the bedrock. These processes, however, cannot be investigated in an actual demonstration site, even though the follow-up study in the Iwanohara demonstration site strongly suggests chemical changes of reservoir fluid toward the conditions promoting mineral precipitation.

Carbonate minerals considered to be stable under the geochemical conditions of CGS are widespread in the foothills of Izumi Mountains, southern Osaka, SW Japan. The area is a good example of carbonate mineralization from CO2-rich fluid and can be a natural analogue on the geochemical processes associated with the migration of CGS reservoir fluid. This study reports the differences on the development of carbonate-bearing alteration veins in relation to the geological properties of seal layers.

Keywords: carbonate vein, dawsonite, self-sealing, seal layer, reservoir fluid, CO2 geological storage

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HRE29-03 Room:103 Time:May 22 09:30-09:45

Distributed fiber optic temperature and strain sensing in a cement specimen

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[1]RITE

Injection of CO2 induces the increasing of pore pressure in a reservoir, leading to the uplift of ground level around an injection well. Cracks might appear in the ground if geological layers deform largely. This decreases the reliability of safety sequestration of CO2. Therefore, it is important to evaluate the stability of the geological layers by monitoring the amount of the deformation.

The stability evaluation requires the monitoring of the deformation of whole geological layers form reservoir to ground level. Displacement meters buried in the ground can measure the deformation of geological layers. However, displacement meters are not suitable to successive monitoring due to inadequate numbers of the meters that are buried in the ground. We have therefore researched fiber optic sensing technology that is used in oil and gas development field to apply it to CCS field. Fiber optic sensing technology was initially used as a temperature sensor to monitor the distribution of temperature in a well over several kilometers. The technology has now been used to measure even the deformation of casing pipes. Monitoring of the deformation of casing pipes measures the strain of the pipes. If the strain of geological layers can be measured successfully, we can monitor the stability of the layers.

Fiber optic sensing technology is divided into two categories in terms of the alignment of sensors: point sensor system and distributed sensor system. Point sensor system is the most popular in fiber optic sensing technology that has high sensitivity and accuracy in data acquisition at measurement points printed on optical fibers. Fiber Bragg Grating (FBG) sensor system is a typical one. Some studies on measurements of the deformation of the ground have adopted this system. However, the point sensor system has fewer number of measuring points compared to the distributed sensor system because optical power losses at every measuring point in this system. Optical fiber itself works as sensors without any processes in the distributed sensor system, and thus the number of measuring point is infinite (the number of measuring point depends on a measuring equipment). In recent years, the maximum resolution of temperature and strain has been reached to 0.0096 deg C and 0.078 me respectively due to the improvement of measuring equipments. The resolutions are almost as high as those of FBG. Therefore, the distributed sensor system is coming to the front as a new monitoring method compensating for the defects of the point sensor system such as expensiveness relating to printing sensors and the limitation of the number of measuring point.

Our previous laboratory experiments revealed that the distributed sensor system successfully measures the strain of rocks as accurate as strain gauge during compressive and dilatational process. Fiber optic cables will be installed in cement slurry along a casing pipe if they are put into practical use. Therefore, the cables should have enough strength against cementing, and should be sensitive to measure strain. An existing fiber optic cable for the use in wells is made to measure temperature change. Three layers of stainless steel wire enforce one optical fiber which is set at the center of the cable. Therefore, this cable may fail to measure strain of geological layers due to the protection structure.

Laboratory experiments were conducted to assess the validity of strain measurement using the existing fiber optic cable mimicking the installation along a well. The results show that the cable measures strain during the change of confining pressure. We report the details of the results obtained from the experiments.

Keywords: optical fiber, distributed sensor, temperature and strain measurement

Japan Geoscience Union Meeting 2013
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HRE29-04 Room:103 Time:May 22 09:45-10:00

Microseismic monitoring at the commercial-scale CO_2 geological storage site, Cranfield, U.S. (Part 2)

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Microseismic events induced by CO_2 geological storage have been discussed. These induced events are assumed to be unfelt with negative magnitudes by concerning case studies at the CO_2 injection sites around the world. For ensuring the safety and obtaining public acceptance, microseismic monitoring is necessary for operating CCS project, especially for countries with high seismicity such as Japan.

RITE performs a long-term microseismic monitoring at the commercial-scale CO_2 injection site in the U.S. to evaluate the relation between CO_2 injection and microseismicities collaborating with Lawrence Berkeley National laboratory (LBNL) and Bureau of Economic Geology, University of Texas at Austin (BEG). Obtained knowledge will be utilized to develop microseismic monitoring system for the planning CCS pilot project held in Japan.

Microseismic monitoring is conducted at the Cranfield oilfield, Mississippi. This site is the CO_2-EOR field, a million tons of CO_2 is injected into the Cretaceous sandstone reservoir at the depth of 3,100m every year. A total of 4 million tons of CO_2 have been injected since 2007. RITE composed a microseismic monitoring array at the site deploying 6-3component of seismometers at the depth of 100m in a 3km radius. Monitoring started on December 15th 2011. For the initial data for a month, no microseismic events induced by CO_2 injection have identified [Takagishi et al, (2012, JpGU)].

In this presentation, we will show preliminary results by analyzing the microseismic data recorded for more than a year. We confirmed that monitoring system was working normally, but no CO_2 injection induced microseismic events have been detected for now. The recorded data were classified into background noise, artificial noise, lighting strikes, and teleseismic natural earthquake events. The results were concordant with those obtained by visual judgments. We will also discuss the event detection ability (Magnitudes and Epicentral distances) for the monitoring system at the site using the recorded teleseismic natural earthquake events.

Acknowledgements: This study was funded by Ministry of Economy, Trade and Industry (METI) as a part of the ”Safety evaluation technology development projects carbon dioxide capture and storage”.

Keywords: CO_2 geological storage, microseismic monitoring

Japan Geoscience Union Meeting 2013
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HRE29-05 Room:103 Time:May 22 10:00-10:15

A relationship between Vp/Vs and lithology in the reservoir at the Nagaoka site

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Seismic methods have been widely used for explorations of CCS sites and monitoring of CO_2 behavior. In this method P-wave data are primarily used. S-wave velocity has independent properties from P-wave velocity, such as S-wave is insensitive to the existence of fluid in the pore of rock. The ratio of these velocities has been utilized to evaluate lithology of formations and gas saturation in the rocks (e.g. Brie et al. 1995). This paper reports a relationship between Vp/Vs data and rock properties at the reservoir of Nagaoka site in Japan.

Nagaoka is the first Japanese pilot-scale CO_2 injection site. A thin permeable zone at the depth of 1100m was selected for the reservoir. For the sonic logging, a low frequency dipole sonic tool has been used at Nagaoka to observe P- and S-wave velocities. Data for the uncased hole logging were used to analyze Vp/Vs, since the Vs data of the cased hole logging had difficulty to separate true S-wave from flexural waves through the casing. Therefore Vp/Vs data in this paper showed results before the CO_2 injection.

Cross plot between porosity and Vp/Vs in the reservoir showed that the scattered data can be categorized into two parts; Vp/Vs were almost constant but porosity changed, and Vp/Vs were dispersive but porosity remained constant. This tendency cannot be seen in the cross plot between porosity and Vp, therefore Vp/Vs might has better response for the lithological evaluations. These differences in the Vp/Vs distributions are consistent with the Fullbore Formation MicroImager logging results, and the distribution in Vp/Vs had dependency on shale volume. The relationship between Vp/Vs and rock properties will be interpreted. Note that the difference in Vp/Vs distribution can be seen in the reservoir with the thickness of 10m. These Vp/Vs distribution might be a feature in Japanese formations, where rock properties change within complex alternate layers.

Keywords: CO2 geological storage, Nagaoka, Vp/Vs, Well logging

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HRE29-06 Room:103 Time:May 22 10:15-10:30

A three-dimensional static reservoir model of the Nagaoka CCS Site and to simulate a carbon dioxide plume migration

Shun Chiyonobu[1*], NAKAJIMA, Takahiro[1], XUE, Zique[1]

[1]RITE

Authors constructed a three-dimensional static reservoir model of the Nagaoka CCS Pilot Site and to simulate a carbon dioxide (CO2) plum migration for 10,000 t injected. The scope of work included incorporating all available geological and geophysical data (well logs, seismic, core, and cuttings data, as well as previously observed depositional and structural trends) to create a geological model of formations from the Haitsume sandstone near the Minami Nagaoka Natural Gas Field, Niigata, Japan. The injection well is to be located in the immediate vicinity of Nagaoka city, Niigata. The boundaries of the static reservoir model span a geographical area of approximately two square km around the Iwanohara base of INPEX.

Several phases static and dynamic modeling were conducted, each with successively greater geoscience data support. Static model was constructed a reservoir from the Zone2 to Zone5 bottoms included 3D seismic data for Stratigraphic control as well as well log petrophysical data. Petrophysical properties in the Zone2 and Zone5 were supported by data from 4 wells and attributed data from 3D seismic. Simulation modeling explored the impact of stochastic uncertainty in static model properties on injection performance using the Nagaoka data (Sato et al., 2011). Petrophysical properties (porosity and permieability) were computed from well logs of Injection Well-1 (IW-1), Observation Well (OB-2), OB-3, and OB-4, 3D seismic data, and core analyses. The amount of well log based petrophysical property control diminishes with depth. Petrophysical property were interpolated throughout the static model using seismic attribution, stochastic method, and upscaled into the simulation grids.

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HRE29-07 Room:103 Time:May 22 10:30-10:45

Time-lapse simulation for the Ketzin (Germany) CCS site assuming a single seismic ACROSS and multi-seismic receivers

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ime-lapse-studies of the physical state of the injection zones or fractured zones is a key component in the CCS, CO2-EOR and shale-gas development. Monitoring systems using the seismic-ACROSS can be one of the most suitable methods for these purposes. We have made simulations assuming a single ACROSS source and a multi-seismometer- array installed at the Ketzin pilot site for CO2 storage in Germany. At Ketzin, CO2 has been injected since July, 2008. About 62 ktons of super-critical CO2 have been injected to date at about 630-650 m depth, and injection will continue into 2013. To monitor how the injected CO2 behaves after injection is extremely important for studying the long term behavior of a storage site. The objectives of this study are to find the most suitable locations for an ACROSS-source and receivers at the Ketzin site given infrastructure constraints. Preliminary results using the velocity-density structure site model shows that a rectangular injection zone 200 m wide and 10 m thick at 665 m depth is well imaged. This result encourages us to plan for using an ACROSS-source for time-lapse-studies to monitor the migration of injected CO2 at Ketzin, even after injection has finished.

Keywords: Time lapse, CCS, ACROSS, monitoring, seismic waves, timerevesal method

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HRE29-08 Room:103 Time:May 22 11:00-11:15

X-ray CT visualization of CO2 microbubbles migration in Berea sandstone

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Laboratory core flooding experiment was run to investigate supercritical CO_2 migration in brine saturated sandstone. The sample was cylindrical Berea sandstone measuring 35mm in diameter and 70mm in length. A grooved disc and a special porous filter were set to the sample ends. Superciritical CO_2 was injected into the sample under same pressure and temperature conditions. X-CT system was used to visualize migrations of CO_2 injected from different filters. When injecting CO_2 from the special porous filter the CO_2 was microbubble and through the grooved disc the CO_2 was normal bubble. CO_2 saturation estimated from CT values and the CO_2 distribution clearly showed advantages of microbubble CO_2 injection and the experimental results suggest the usefulness of microbubble CO_2 injection in both saline aquifer storage and enhanced oil recovery.

Keywords: microbubble CO2, Berea sandstone, X-ray CT, Visualization, enhanced oil recovery, saline aquifer storage

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HRE29-09 Room:103 Time:May 22 11:15-11:30

Development of stable geological storage technique by CO2 nano-sizing

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Introduction

Geological storage is considered as an important key technology to mitigate CO_2 emissions into the atmosphere. However, the risk of CO_2 leakage from storage reservoirs remains a crucial problem. The injected CO_2 migrates upward because of the buoyancy effect, and caprock structures are therefore necessary to prevent CO_2 leakage.

Injected CO_2 generally forms a continuous plume in aquifers, and larger buoyancy effects are caused by the larger continuous phase of CO_2. To develop a stable geological storage technique, this study proposes a novel method that uses nanosized CO_2 droplets in a porous structure to allow stable geological storage. The buoyancy effect can be reduced by changing the CO_2 from a continuous phase to nanosized droplets before injection. In this study, experimental and study was performed to examine the stability of nanosized CO_2 droplets in the aquifer.

Experimental apparatus

The experimental study focused on the nanosizing process, the size distribution of the CO_2 droplets, and their behaviour in porous media. Figure 2 shows the experimental apparatus. The CO_2 nanosizing process was observed using a closed circulation channel that consisted of a static mixer, a circulation pump, and an observation section. The circuit pressure was controlled to give 6 to 9 MPa. The temperature was set approximately 20 to 40 degree Celsius. The volume ratio of CO_2 to water was set to 1:2, and a surfactant was added to assist with the micronization of the CO_2. The concentration of surfactant was kept as low as possible to reduce the storage costs.

The size distribution and time evolution of the nanosized CO_2 droplets were observed through windows made of sapphire glass. The droplet size distribution of the CO_2, and its time evolution, were measured using dynamic light scattering (DLS).

The nanosized CO_2 droplets and water were slowly aspirated using a syringe pump, and were injected into water-saturated porous media. The porous media was a packed silica sand bed (with grain diameters of 125 to 250 micrometer) in a stainless steel tube. The behaviour of the nanosized CO_2 in the porous media was investigated using X-ray computed tomography (CT).

Results and discussion

As the result, nanosized CO_2 droplets were successfully generated and observed through observation windows made of sapphire glass placed in the channel. The average diameter of the CO_2 droplets was initially 40 to 70 nm. The average diameter increased with time. It is considered that the change in the diameter distribution was caused by the coalescence and Ostwald ripening of the CO_2 droplets.

The nanosized CO_2 was injected into the porous media and it was observed by using X-ray CT. Reconstructed three-dimensional CT images were obtained with spatial resolution 20 micrometre (i.e. pore-scale structure can be observed). The CT images cannot resolve the shape of nanosized CO_2 droplets itself right after injection. After a day, micro-scale CO_2 droplets emerged in the pores because of coalescence of nanosized CO_2 droplets; however, the number of pore-scale CO_2 droplets and their positions remained unchanged during an observation period of a few days. It is considered that any increase in the CO_2 droplet diameter was prevented in the porous media by capillary force, and the droplets were finally trapped in the pore-throat structure. The experimental results suggested the high potential of the nanosized CO_2 droplets for stable geological storage.

Keywords: CO2 geological sequestration, Micronization, Nano-sizing, X-ray CT

Japan Geoscience Union Meeting 2013
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HRE29-10 Room:103 Time:May 22 11:30-11:45

Geological Surveys for CCS Demonstration in Kitakyusyu, Western Japan.

Shuji Ajima[1*], Shiro Ohkawa[1], Akio Hara[2], Motonori Higashinaka[2], Shogo Shirahama[3], Mio Shimoyama[4], Tomoyuki Tanaka[1], Junichi Takio[1], Masanori Abe[1]

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Evaluation study of site screening for CCS large-scale demonstration in Japan was performed by Japan CCS Co., Ltd. (JCCS) in 2008 by a subsidy from the Ministry of Economy, Trade and Industry of Japan (METI). In this study, the Kitakyushu site, western Japan, was selected from 115 candidate sites as one of the three most potential candidate sites for the CCS demonstration. The Kitakyushu is the only candidate site in the western Japan while the others are located in the eastern Japan. The Kitakyushu is also the unique site where Paleogene formations are considered as a target of CO2 storage. Therefore, storage capacity of CO2 in Japan will be expected to increase if enough performance of reservoirs and seal formations can be confirmed by the investigation and demonstration of the Kitakyushu site. Verification of the storage performance of the Kitakyushu site will contribute to evaluate the storage capacity of the Paleogene formations at the other sites where similar formations are distributed.

The Kitakyushu site does not have enough information of deep subsurface geology. Therefore, as a first phase, a series of basic surveys, consisting of a gravity survey, drilling of a survey well, and a 2D seismic survey were carried out for a geological evaluation of the site. Gravity analyses with supplemental gravity measurements were carried out in 2009 and 2011. Drilling (Kitakyushu CCS-1: 1180 m), 2D seismic survey around the well and VSP (Vertical Seismic Profiling) using the well bore were carried out in 2010. Sedimentary facies analysis and integrated geological analysis using all the acquired information through the surveys were carried out in 2011. A shape of the sedimentary basin and a general geological structure were delineated clearer than ever before by the gravity survey. The survey well was drilled into the basement rock lying below 1000 m for the first time in this area. Stratigraphy was confirmed by this drilling. Structural data including strike and dip around the well was obtained by the VSP and the 2D seismic survey. Moreover, initial conceptual geological model was constructed by integrating these various geological data.

Invaluable subsurface geological data for the site evaluation were obtained by these surveys. These data were mainly obtained in a limited area onshore in Kitakyushu city. However, the Paleogene reservoirs are estimated to be distributed widely under the sea. Geological data from the wide offshore area is required for a regional evaluation. In 2012, as one of the surveys for the evaluation, a preliminary 2D seismic survey was carried out at the coastal and the shallow marine area of Shimonoseki city.

This paper summarizes a part of the result of ”CCS Demonstration Project in Japan” which was commissioned by METI to JCCS.

Keywords: CO2 geological storage, CCS pilot-scale demonstration, Paleogene

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HRE29-11 Room:103 Time:May 22 11:45-12:00

Geological Conceptual Model Based on Integrated Analysis Using Some Geological data obtained in the Kitakyusyu Site.

Akio Hara[1*], Miyuki Nonaka[1], Shuji Ajima[2], Shiro Ohkawa[2], Tomoyuki Tanaka[2], Motonori Higashinaka[1], Junichi Takio[2]

[1]JGI, Inc., [2]Japan CCS Co., Ltd.

The Kitakyushu site, western Japan, is one of the most promising CCS demonstration candidate sites. The Kitakyushu is also the unique site where Paleogene formations are considered as a target of CO_2 storage. A series of basic surveys, consisting of a gravity survey, drilling of a survey well, and a 2D seismic survey were carried out by Japan CCS Co., Ltd. (JCCS) for a geological evaluation of the site. Observation of the core samples, analyses of the log data for a survey well "Kitakyusyu CCS-1(TD=1180m)", and a field survey of surface geology were also carried out for a facies analysis. Some geological information to estimate facies environments around the well was extracted by the analysis. This study was performed to construct a preliminary geological conceptual model based on the geological information, sedimentary environments and distribution patterns of the Paleogene sedimentary rocks in the site.

It was presumed from the observation of the boring cores that the Tenraiji and Kamiitozu members which are members of the Ideyama formation and are overlying the basement rock (Cretaceous granites), are likely to be consisted of terrigenous sedimentary rocks accumulated in the channel and inter-channel environments.

The sandstones in the Tenraiji and Kamiitozu members were classified into two categories, i.e., channel-fill sandstone (often contains conglomerates) and sandstone derived from overflow sediments which are interbedded in mudstones by the geophysical properties obtained from the well logs.

Seismic data acquired near the well were interpreted to infer depositional environments in this area. Strong waves seen in the seismic sections are interpreted as the reflections from the geological formation corresponding to the Tenraiji member, suggesting that these strong waves can be reflected from the conglomerates interbedded at the base of channel-fill sandstones. Mapping of these reflections shows an elongated shape in the NE-SW direction. The major axis of the elongated structure may indicate the axis of channels deposits.

Gravity data also indicate the shape of sedimentary basin that is half-graben elongated in the north to south direction. The half-graben basin is accompanied with steep slope at the east wall whereas gentle slope to the west.

To deepen the regional geological concept, a surface geological survey was supplementarily carried out on the islands in Hibiki-nada Bay which is thought to be located on the western slope of the basin. The result of the geological survey suggests that geological structure in this area shows a gentle anticline plunging into the N-S direction which is consistent to the shape of the sedimentary basin deduced from the gravity data.

The sedimentary environments of the Tenraiji and Kamiitozu members can be concluded that the terrigenous channel and inter-channel sediments deposited at the beginning of formation of the half-graben which is elongated in the north to south direction by these various geological analyses.

Based on the integrated analysis using various geological data, a preliminary geological conceptual model which is expected to contribute to future reservoir evaluation has been successfully established in this site.

This study was performed as a part of "CCS Demonstration Project in Japan" which was commissioned by the Ministry of Economy, Trade and Industry of Japan (METI) to JCCS.

Keywords: carbon dioxide capture and storage (CCS), Sedimentary facies analysis, Geological conceptual model

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HRE29-12 Room:103 Time:May 22 12:00-12:15

A CO2 injection-experiment with subseafloor coal measures under in-situ pressure and temperature condition

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The release of one-carbon compounds (i.e., CO_2 and CH_4) into the atmosphere due to human activities has been recognized as a major factor causing dramatic climatic change on the Earth. In recent years, the increasing concentrations of greenhouse gases are expected to cause warmer surface temperatures at an accelerating rate and subsequent alternation of ecosystems and biogeochemical cycles. Consequently, a variety of CO_2 disposal options are discussed, including CO_2 Capture and Storage (CCS) followed by injection of CO_2 into deep subseafloor hydrocarbon reservoirs such as coal formations. However, geophysical and geochemical behaviors of high concentration of CO_2 within subseafloor environments, as well as ecological consequence and biogeochemical carbon cycle, remain largely unknown. In this study, we performed a CO_2 injection-experiment using subseafloor bituminous coal samples (Kushiro Coal Mine, Co. Ltd.) under high pressure and temperature condition.

The reaction experiment was performed using a newly developed flow-through geobio-reactor system at the Kochi Institute for Core Sample research, Japan Agency for Marine-Earth Science and Technology (JAMSTEC). The reaction column was prepared from the coal chips (from 1 to 3 cm in diameter) and powdered sandstone, which were packed in a heat-shrinkable tube under anaerobic condition. Anaerobic artificial seawater (ASW) and CO_2 were continuously supplemented into the column for 56 days under the following condition: flow rate of ASW; 0.002 ml/min, flow rate of CO_2; 0.00001 ml/min, pore pressure; 40 MPa, confined pressure; 41 MPa, temperature: 40 degrees C. After the reaction, XRD analysis showed no or very little changes on mineral assemblages of the sandstone, whereas minor carbonate generation was observed by SEM-EDS analysis. The sandstone contained ~10^4 microbial cells/cm^3 after experiments, which was similar to the biomass prior to the experiment. Molecular analysis of the extracted 16S rRNA genes revealed the predominance of spore-forming bacteria (e.g., Lysinibacillus and Bacillus) in the coal samples, which members were also found in the reaction column after the CO_2-injetion experiment. During the reactor operation, we observed increase of dissolved CH_4 concentration up to 186 micro M, whereas total dissolved inorganic carbon in the medium passed through the column decreases compared to the injected amount (e.g., total dissolved inorganic carbon in the medium: 125.6 mM, the injected total dissolved inorganic carbon: 138.38 mM at 56 days). Based on the carbon isotopic composition of DIC, it is most likely that no or very little microbial methanogenesis occurred and the absorbed CH_4 was released from the coal samples during the CO_2-injection experiment.

Keywords: Bio-CCS, Coal, CO2

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Risk Assessment Study for Bio-CCS

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We have started a new R&D project titled ”Energy resources creation by geo-microbes and CCS”. It aims to cultivate methanogenic geo-microbes in CCS conditions and produce methane gas effectively and safely. To meet these needs, we are evaluating risks around new Bio-CCS technology. Our consideration involves risk scenarios about Bio-CCS in geological strata, marine environment, surface facilities, ambient air and injection sites. To cover risk scenarios in these areas, we are carrying out a sub-project with five sub-themes. Four sub-themes out of five are researches for identifying risk scenarios: A) Underground strata and injection well, B) Ambient air, C) Surface facilities and D) Seabed. We are developing risk assessment tool,named GERAS-CO2GS (Geo-environmental Risk Assessment System,CO2 Geological Storage Risk Assessment System. We are going to combine identified risk scenarios into GERAS-CO2GS accordingly. It is expected that Development of GERAS-CO2GS will contribute to risk assessment and management for not only Bio-CCS but also individual injection sites, and facilitate understanding of risks among legislators and concerned peoples around injection site.

Keywords: CO2 geological storage, risk assessment, CO2 migration, the surface of the earth, impact analysis, Bio-CCS

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HRE29-P01 Room:Convention Hall Time:May 22 18:15-19:30

Coupled fluid flow and geomechanical modeling in geological CO2 storage: Application to Matsushiro phenomena

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The mechanical responses of CO2 reservoir and the caprock around the storage region become crucial for Japanese geological CO2 storage (GCS) after the M9.0 East Japan earthquake on March 11, 2011. The CCS Research Committee, METI (Ministry of Economy, Trade and Industry), recommended to screen out areas having a large-scale faults in the process of selection of storage site for 105t-scale demonstration (2009). Although the site for the planned demonstration adequately selected, we do not exclude fully at present the possibility of GCS reservoir failure and/or leakage of stored CO2 from GCS site(s) elsewhere in Japan caused by geomechanical motions.

The examples of such phenomena are the re-activation of pre-existing faults, induced seismicity, reservoir failure and unintended uplift and so on, some of which are observed in an actual demonstration site (Mathieson et al., 2009; Vasco et al., 2010; Onuma et al., 2011).

The unintended phenomena listed above are essentially connected with stress filed changes due to the increase in pore pressure, around the area of GCS, which is inevitable as GCS injects pressurized CO2 into an underground reservoir. The rise in pore pressure reduces an effective confining stress to modify the conditions toward the critical failure line of Mohr-Coulomb law. The change in pore pressure is most probably cause micro-scale (or, pore-scale) deformations within the rocks, which will give rise to the changes in rock permeability. The permeability change probably cause a change in fluid flow underground in the next step, which will promote further rock deformation and then change in fluid flow. The sequence of process can be analyzed by a coupled analysis using fluid flows simulator for rock media and that calculating the geomechanial process under the changing pore pressures. The TOUGH-FLAC code is a good and working example of this coupled simulator, being applied to follow the CO2 motion within faulted and tectonically active formations (Rudqvist et al., 2007, 2008) .

We consider that the coupled simulation of fluid flow and geomechanics, exemplified by TOUGH-FLAC simulation collaborating with LBNL, is the most important tool in developing the scheme to assess the fluid-mechanical conditions around the underground storage regions of CO2.

As not enough data such as rock deformation related to fluid flow is available from GCS site for evaluation of TOUGH-FLAC code applicability to Japanese geological condition, we investigate the Matsushiro field, Nagano, central Japan is selected for our natural analogue study. The Matsushiro field is famous for the earthquake swarm associated with the CO2-rich fluid upwelling during the period of 1965-1967. The Matsushiro phenomena was previously studied by using TOUGH-FLAC (Cappa et al., 2009), however, the geological model was simplified very much, so it is afraid that the possibly important geological features can be missed.

In this study, we modified their model based on the various filed and laboratory data and re-constructed the geological model with three layered strata according to P-wave velocity profile.

TOUGH-FLAC simulation has been conducted using updated geological model. The simulation results indicated the ground uplift due to fluid injection and the maginitude of the ground uplift is reasonably agree with actual observation in Matushiro field during the swarm.

Keywords: Coupled fuild flow geomechanical modelling, Geomechanics, Geological CO2 storage, Natural analogue, Matushiro phenomena

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HRE29-P02 Room:Convention Hall Time:May 22 18:15-19:30

The potential of Vp and Vs monitoring for MVA program of offshore CCS project

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For the safe operation of CCS, we are required to monitor the CO_2 behavior and to accurately account for the storage volume of CO_2 in deep reservoirs. It is well-known that the P-wave velocity measurements (Vp) can be used for monitoring the CO_2 behavior in deep reservoirs. However, it is difficult to accurately estimate the storage volume of CO_2 by only using Vp. Takahashi (2000) indicated the potential of S-wave velocity for monitoring of fluid behavior and accounting for the storage volume of natural gas in deep reservoirs. S-wave monitoring can be achieved by deploying a permenent ocean bottom cable(OBC) system at the off-shore CCS sites. In our own study, we conducted a simultaneous measurement of Vp and Vs of porous sandstone by injecting various types of fluids under set in-situ pressure and temperature conditions. For this study, we use the Tako sandstone, which is an early Miocene marine sandstone, mainly composed of quartz and plagioclase. Tako sandstone has near 10mDarcy of permeability and almost 24% porosity. The sample was cut into a column shape (5cm in diameter and 10cm in length), and polished on both ends (1PV=47 ml). In this study, we tried to estimate CO_2 saturation, and to monitor the CO_2 behavior in porous sandstone by measuring Vp and Vs. First, we injected near 1.3PV water into the vacuumed specimen (Water injection). After this process, over 2.2PV CO_2 is injected into the water saturated specimen (Drainage). Finally, CO_2-saturated water over 2.3 PV is re-injected into the CO_2-injected specimen (Imbibition). We illustrated the Vp-Vs relationships of all the processes. This Vp-Vs relationship diagram clearly illustrates the obvious differences between water injection and drainage. On the other hand, drainage and imbibition show the similar tendency of Vp-Vs change with injecting CO_2 and CO_2-saturated water. These changes indicate the changes of CO_2 saturation during drainage and imbibition stage. This result suggests the potential to estimate CO_2 saturation by using the Vp-Vs relationship. Additionally, Vp does not recover to pre-drainage levels after end of imbibition process. This Vp difference is considered to be the effect of residual trapped CO_2. This result also indicates the potential of monitoring the residual trapped CO_2 from seismic wave velocities.

Keywords: P-wave velocity, S-wave velocity, Porous sandstone, CO_2 saturation, MVA

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HRE29-P03 Room:Convention Hall Time:May 22 18:15-19:30

Acoustic characteristics of formation water when injecting scCO2 microbubbles

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The effectiveness of CO_2 microbubble method for geological sequestration was investigated. For the comparison of the conventional method and CO_2 microbubble method, the CO_2 behavior in Berea sandstone saturated by the KCl solution was monitored by measuring ultrasonic compressional velocity (Vp) in both method.

However, in the injection of CO_2, there were two factors of the change of Vp. One is CO_2 dissolution into pore water and another is replacement of CO_2 and pore water. To separate the factor of the change of Vp, Vp of saline water was measured when injecting CO_2 microbubbles into saline water. The change of Vp effected by CO_2 dissolution was less than 1 %. Therefore, in first experiment. the change of Vp in the injection of CO_2 was effected by the CO_2 replacement of pore water more than the CO_2 dissolution. And the change of Vp in Berea sandstone showed the slow CO_2 migration in CO_2 microbubble method. This is because dissolution of amount of CO_2 microbubbles increased.

This result shows microbubble method could increase the reservoir potential for CO_2, which also showed by X-ray CT scan results.

Keywords: microbubble, carbon capture and storage, P-wave velocity

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Monitoring the Strain of Tako sandstone injected with CO2 using Optical Fiber Sensing

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CO2 capture and geological storage (CCS) is a significant technology to reduce CO2 emissions. Surface deformations around CO2 injection wells at In Salah, Algeria were analyzed by InSAR data. For the safety of CCS, it is required to ascertain the relationship between pore pressure buildup by CO2 injection and rock deformation in the depth direction. Traditional strain gauges can measure rock deformations only at installation points. However, optical fiber sensing enables us to obtain the rock deformation distribution over 20 km. In this study, we conducted the laboratory experiment to confirm that the optical fiber sensing can measure the strain of rocks.

In the experiment, we measured strain changes during injection of CO2 into water-saturated Tako sandstone. The rock sample was cylindrical and had a fine part and a coarse part. The strain changes were measured using an optical fiber and strain gauges. Strains measured by the optical fiber sensing accorded with strains of strain gauges. Strains at the coarse part were greater than strains at the fine part. The optical fiber sensing could measure physical properties of different layers. Such results suggest the possibility of monitoring the rock deformation distribution in the depth direction using the optical fiber sensing at CO2 geological sequestration sites.

Keywords: CO2 geological sequestration, porous sandstone, optical fiber sensing, strain

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Strain analysis in Rock samples using Neutron diffraction at J-PARC/BL19 ”TAKUMI”

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A high-intensity proton accelerator facility named J-PARC (Japan Proton Accelerator Research Complex) has been constructed at Tokai in JAPAN. Various neutron experiments using high intensity pulsed neutron beam are being performed at J-PARC. The Engineering Materials Diffractometer ”TAKUMI” was constructed at BL19 in J-PARC, which is dedicated to investigate the stress-strain state using neutron diffraction technique. In order to develop neutron diffraction technique applicable to rock samples, strain measurements in rock sample have been performed at TAKUMI. As results, in spite of the long neutron path length (ca. 40 mm) and small sample gauge volume (2 x 2 x 2 mm), sufficient neutron diffraction patterns could be obtained. In addition, as results of in situ strain measurements under uniaxial compression loading, discrepancy was found in strain values obtained by strain gauge and neutron diffraction. It was suggested that macroscopic strain value of rock sample included intragranular strain and intergranular slip.

In order to utilize underground environment, e.g. CCS, accurate estimate of crustal stress is indispensable. Borehole core sample might have residual strain corresponding to crustal stress the core sample was taken. Neutron diffraction measurements of borehole core sample have been performed, and we have attempted to analyze residual strain in borehole core sample.

A borehole core sample is a tuff, which was taken by drilling in underground rock mass (depth: 589m) at Mie in 2009. Variations of the P-wave velocity exhibited orthotropic anisotropy. Lattice plane spacing of quartz grain and that of feldspar grain varied with measurement position. It was speculated that quartz grains contain tensile strain, on the other; feldspar grain contains compression strain. Residual strain in borehole core might become helpful to estimate states of the crustal stress where the core was taken. Therefore, it is expected that strain measurements using neutron diffraction serve to understanding of stress state in underground environment.

Keywords: Neutron diffraction, strain measurement

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Continuous gravity measurement with an iGrav superconducting gravimeter for CO2 sequestration

Mituhiko Sugihara[1*], Kazunari Nawa[1], Yuji Nishi[1], Tsuneo Ishido[1], Masao Komazawa[1], Nobukazu Soma[1]

[1]AIST

We have started gravity monitoring at the Farnsworth test site in Texas along with US's project of Southwest Regional Partnership. We have been making three kinds of gravimetric baseline measurements: continuous gravity measurements at the gravity hut with an iGrav superconducting gravimeter (SG), co-located absolute gravity measurements at the gravity hut, and relative gravity measurements around the gravity hut with portable gravimeters. The SG is distinguished from other gravimeters by superior precision, better than 1 nm/s2 and by the ability to record gravity continuously over periods of months and longer. The SG meter is a type of relative gravimeter, therefore, it is necessary to monitor temporal changes of its scale factor and the zero level of its output signals. We have made the first co-located measurements with the FG5/217 absolute gravimeter for a week (08/01/2013-15/01/2013) to determine the scale factor of the SG meter. We decomposed the continuous gravity data using the program BAYTAP-G into tidal effects and irregularities such as drift, occasional steps and disturbances caused by external mass displacements (CO2 sequestration, oil and/or gas production, atmospheric, hydrological, and tectonic processes). This research is funded and supported by Ministry of Economy, Trade and Industry (METI).

Keywords: CO2 sequestration, gravity monitoring, superconducting gravimeter, Farnsworth

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Gravity Survey in Farnsworth, Texas

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A gravity survey was carried out January in 2013 in order to understand a shallow and whole underground structure. The measurement points were arranged at every 300m interval along the road and the number of measurement points became 141 points. The characteristic Bouguer anomalies are that the gravity high anomalies corresponding to anticline structure extend from NW to SE.This research is funded and supported by Ministry of Economy, Trade and Industry (METI).

Keywords: Texas, Fansworth, Gravity anomaly, CO2 sequestration

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Threshold pressure measurement by several methods on sedimentary rock in Japan

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We conducted laboratory tests to investigate threshold pressure in CO_2/water system. First technique is mercury intrusion test (MIT). Second technique is threshold pressure measurement with N_2 using step by step method. Third technique is threshold pressure measurement with supercritical CO_2 using step by step method. These techniques are commonly used but have both advantages and disadvantages. MIT is less time consuming but we cannot control the direction of injecting fluid. Test apparatus for threshold pressure measurement with N_2 is much simpler than that using supercritical CO_2. However, we have to estimate actual threshold pressure in CO_2 storage condition by converting threshold pressure in N_2/water system using interfacial tensions and contact angles. Threshold pressure measurement with supercritical CO_2 is most reliable.

Rock cores used in this study were derived from outcrop of The Yourou-valley, located in Chiba prefecture in Japan. This outcrop belongs to Kiwada formation of the Kazusa formation group which is thought to be formed in Plio-Pleistocene. Porosity of sample is 45%, natural density is 1.89g/cm^3, water content is 31%.

In MIT, we used two methods to calculate threshold pressure. By first method, we drew the tangent line with minimum grade against the curve relating saturation and capillary pressure. The tangent line is spread to the vertical line which expresses mercury saturation is zero and this intercept means the threshold pressure. By second method, threshold pressure is determined by the pressure at 10% mercury saturation1). Threshold pressure evaluated from former method is 4.08MPa and 4.87MPa is obtained by second method. Using the contact angles and interfacial tensions, we can convert threshold pressure in Hg/Air system to that in CO_2/water system. Estimated threshold pressures in CO_2/water system are 0.32MPa in first method and 0.38MPa in second method.

Threshold pressure measurement with N_2 was also conducted. Room temperature was kept approximately 21 deg c. By N_2 injection, pore water in a rock core was pushed out from a specimen but water production ceased according to the passage of time. Injection pressure was increased step-wisely when water production stopped. This procedure was repeated until continuous water flow was observed. In this test, continuous water flow was observed after injection pressure reached to 1.71MPa. We evaluated threshold pressure in N_2/water system is 1.66MPa which is average pressure of final pressure step and former pressure step (1.60MPa). Estimated threshold pressure in CO_2/water system is 0.66MPa.

Threshold pressure measurement with supercritical CO_2 was conducted under the temperature of 40 deg C. Pore water pressure of 10MP was applied to ensure that CO_2 was in supercritical state during the test. After injection pressure reached to 1.10MPa, continuous water flow occurred. Threshold pressure in CO_2/water system is evaluated 1.04MPa.

Threshold pressure estimated by MIT was lowest. Threshold pressure obtained from direct measurement with supercritical CO2 was highest value which is 1.6 times higher than that of N_2. Possible reasons for these test results are listed below;

1. Change of the structure of rock by drying procedure might affect the result of mercury intrusion test.
2. Difference of flow direction between mercury intrusion test and other techniques may have an influence on the value of threshold pressure.
3. Uncertainty of contact angles and interfacial tensions of displacing fluids is also a possible factor which leads different test result.

We gratefully acknowledge special support received from New Energy and Industrial Technology Development Organization(NEDO). Part of this study was performed under Innovative zero-emission integrated coal gasification combined cycle project.

1) Tim T. Schowalter. Mechanics of Secondary Hydrocarbon Mitigation and Entrapment. AAPG Bulletin, 1979, 63, 723-60

Keywords: Threshold Pressure, Supercritical CO2, Sedimentary Rock

Japan Geoscience Union Meeting 2013
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Permeability of fault and grain size distribution -Evaluation for the permeability of methane-hydrate bearing layers-

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Permeability of sediments is important factors for production of natural gas from natural gas hydrate bearing layers. Methane-hydrate is regarded as one of the potential resources of natural gas. As results of coring and logging, the existence of a large amount of methane-hydrate are estimated in the Nankai Trough, offshore central Japan, where has a lot of faults. For the purpose of a rational evaluation of permeability of methane-hydrate layers, it is important to understand properties of fault zone because of different condition from other layers due to large displacement shear. In this study, we investigated the permeability of a specimen formed artificial fault in ring-shear test. Moreover, under high and low normal stresses the difference in grain size distribution of shear zone and other zones were discussed. This study is financially supported by METI and Research Consortium for Methane Hydrate Resources in Japan (the MH21 Research Consortium).

Keywords: Fault, Permeability, Grain size distribution

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Examination of the possibility of gel trapping using artificial-mineral Sumecton

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Smecton SA which is is a synthetic inorganic polymer with a saponite structure became hard gel by ion conbination when it is mixed with water at the acid condition.
If the character of Smecton SA could be applied to CCS,the safety of CCS may improve by it.
Therefore, we verified in the experiment of reacting Smecton SA and water, carbon dioxide.

Keywords: Smecton, Smectite, CCS, gel

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Global underground gas winery absorbing air CO2 and reproducing methane gas reservoirs : underground carbon recycling

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A new counter-geoengineering scheme: leak-free air-CCS under hydrate sealing is proposed here to slash the artificially increased atmospheric CO2 level directly. The naturally most secure and extensive storages for CO2 are the deep aquifers in cold regions and beneath ocean floors. The high-pressure experiments suggest the precipitation of CO2-hydrate occurs in CO2-saturated aquifers at the pressures higher than about 3MPa. Huge volumes of secure CO2-storages under the CO2-hydrate autogenous sealing are expected in deep aquifers in the sub-permafrost regions throughout the world. Virtually limitless secure CO2-storages under the CO2-hydrate autogenous sealing are possible in worldwide marine sediments and oceanic basalts under sea floors deeper than about 300m. The conventional carbon capture and sequestration (CCS) scheme is not viable in the remote areas due to the large infrastructure investment and energy loss for long-distance transportation of huge amount of CO2. However, the air-CCS may be viable while CO2 is extracted directly from the atmosphere instead of the flue gas of fossil fuels. As the atmospheric CO2 concentration is very thin (about 390ppm), the excess energy is required to extract the CO2 from the atmosphere. CO2 is selectively injected into deep aquifers by the air microbubbles sequestration with the pre-concentration by micro-porous membranes. The unused natural energy (wind, solar, geothermal and natural gas) is used for the recovery of CO2 from the atmosphere and for the underground injection of CO2-rich gas. Energy penalty of air-CCS can be compensated by use of unused natural energy in the remote regions.

Carbon dioxide injection under gas-hydrate-filled layers or under permafrost layers may realize the greenhouse gas mitigation and recovery of unused natural gas. Autogenous sealing of carbon dioxide in deep and cool aquifers assures virtually complete and practically unlimited subsurface containment of carbon dioxide. Chemoautotrophs fix carbon dioxide in deep aquifers even in the absence of sunlight. Thermophile methanogens can convert the carbon dioxide into methane in anoxic aquifers. Biogenic restoration of subsurface hydrocarbon deposits is possible in CO2-injected aquifers probably after some ten of years. Microbiological recycling of carbon dioxide in aquifers brings the renewable hydrocarbon gas energy resources into reality.

Keywords: carbon recycling, CCS, hydrate, methanogen, renewable energy, natural energy

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New Formation Model of Carbon-Bearing Materials Produced Greenhouse Gases on Earth-Type Planets

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Fundamental problem on the atmosphere of greenhouse gases with carbon has not solved completely mainly due to simple and local discussion on activity in the atmosphere (and ocean) of the planet Earth (Miura, 2008). This is mainly because basic problems of carbon-bearing carbon dioxides are not solved on the origins, reservoirs and existences in air of planet Earth. Thus estimation and calculation of interior carbon contents on underground carbon changes have not taken into account sufficiently on the dynamic carbon circulation (especially coal etc.) due to unknown lost and old process. On the present wide-area JpGU Society, the Earth (planetary) sciences have main characteristics of visual developments with accurate and detailed descriptions relatively in short-time period. On the other hand, it is considered exceedingly to be academic black-box with unknown knowledge of long active Earth planet with repeated formation and extinction processes strongly (Miura, 2012). However, it should unravel the academic black box with long unknown history to develop fundamentally appropriate ideas to human society for the air pollution and green house problem (Miura, 2013).

Supply of carbon and hydrogen to the Earth is considered to be transported from the Asteroids, Comet and planetary debris finally to the well-formed Earth (Miura, 2000), so that origin of main hydrogen-bearing air and water are explained by quenching by asteroid collisions, with subsidiary flows by carbon-bearing phases. Previous outline of primordial carbon-dioxides airs in the Earth-type planets (Mars and Venus) have been existed on primordial Earth surface, where main carbon-bearing air on primordial Earth has been changed and formed wide carbonate minerals deposits in the ocean-sea finally (Miura, 2010). The problem of the previous model is difficult to explain formation of wide ocean-water system on Earth-type planets without carbonates deposits remained as main gas processes of normal smaller impacts on the planetary surfaces. New breakthrough reverse model of underground carbon coals produced greenhouse-gas in planet Earth is proposed based on carbon dioxides airs on the Venus and Mars originally by other surface material data.

The surface on the moon and Mars reveal voids-rich grains to penetrate gaseous fluids to the interior by many impact processes to form carbon-rich resources (Miura, 2012). Carbon dioxides in the interior of primordial Venus and Mars are lifted by volcano-like process by the pulled tidal forces during the rotations from the Sun etc., and form stable carbon dioxides air (even in high temperature) than hydrogen-bearing water (Miura, 2011). The primordial ocean waters of Earth-type planets are based on the present water-planet Earth which is considered to be generated by huge planetary impact with much water contents with less carbon dioxides in the interior of large planets collided.

From the present model of multi-steps (i.e. impact-penetration to store light elements and the lift-up to the surface), the interior carbon and coal etc. are considered to be concentrated to large resources eventually for natural energy to generate artificially industrial greenhouse gas finally.

Three types of carbon origins and cyclic processes with time periods on our Earth reported at the JpGU-2012 meeting are long-range natural resources, short-range life, and industrial wastes (Miura, 2012), The former two main carbon processes cannot change on Earth by artificial short-time period as main untouchable carbon cycles. However it is expected strongly by applied global carbon process model (Miura, 2008-2013) that the main point of the third carbon gas process generated by industrial carbon gas as artificial wastes should be applied to dynamic stable changes of states by global planet Earth (Miura 2013)

Keywords: Carbon dioxides gas, Greenhouse warming, Carbon-bearing materials, Earth-type planets, Multy-steps formation model, Primordial air-planets