Development of Geological CO_2 Storage Technology

By Murai Shigeo

1. Measures to Combat Global Warming

Since an agreement on global warming was reached in 1996 in the form of the Kyoto Protocol, anti-global warming measures have become a worldwide challenge. In May this year, the Intergovernmental Panel on Climate Change (IPCC) issued its fourth assessment report, suggesting short- to medium-term measures that should be adopted by 2030, and longer-term measures that could be applied from 2031. The report noted that if efforts are made in the next 20 to 30 years to reduce emissions of greenhouse gases (mainly carbon dioxide, hereafter referred to as CO_2), a rise in the Earth's average temperature could be prevented and the effects of climate change could be mitigated.

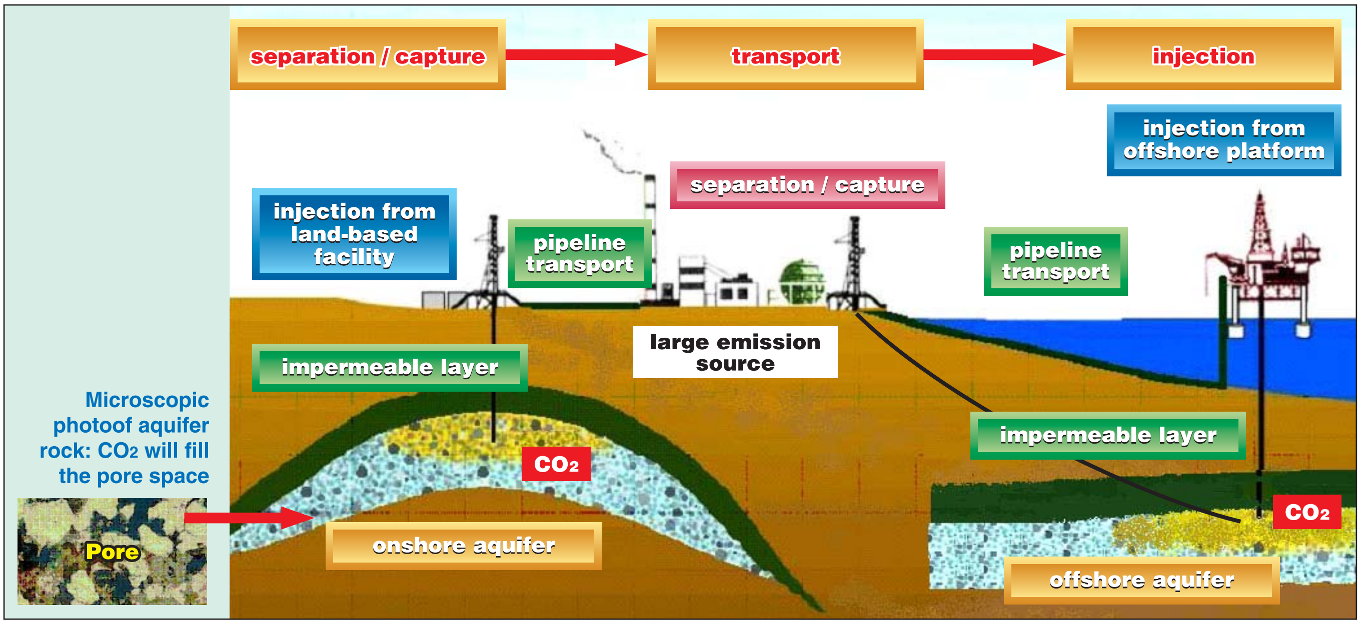
Meanwhile, the G-8 Summit in Heilingendamm, Germany, in June paved the way for efforts to be made to halve CO_2 emissions by 2050, in effect confirming the need for a framework to achieve this objective. Shortly before the G-8 Summit, Japanese Prime Minister Abe Shinzo announced an "Invitation to Cool Earth 50" initiative, outlining proposals for Japan's anti-global warming measures. In this article, I would like to discuss the CCS (CO_2 Capture and Storage) technology, which is considered effective in reducing CO_2, explaining in particular how geological CO_2 storage technology is being developed in Japan.

2. Hopes High on CCS Technology

Scientists around the world compiled their findings in a special IPCC report, "CO_2 Capture and Storage," in 2005. It assessed the validity of CCS technology in curbing global warming by collecting scientific expertise on various issues, including technologies for the capture, geological storage and ocean sequestration of CO_2 and their economic efficiency. Meanwhile, international frameworks to promote CCS technology are being set up in the form of the IEA Greenhouse Gas R&D Program, the Carbon Sequestration Leadership Forum, etc.

Japan is cooperating in these activities and at the same time promoting its own studies and looking for ways to apply CCS technology. In May 2006, the Ministry of Economy, Trade and Industry (METI) unveiled a "CCS 2020" initiative, demonstrating the government's leadership in research and development by pursuing development of geological CO_2 storage technology at home and utilizing it in Clean Development Mechanism (CDM) projects abroad. What is envisaged here in terms of practical application of CCS technology is to separate and capture CO_2 at large emission sources and store the CO_2 thus collected underground in

Chart 1 Schemes of CO_2 capture & its geological storage



Source : RITE

Photo: RITE

Pilot site for CO_2 geological storage in Japan (Nagaoka city)

either onshore or offshore aquifers *(Chart 1)*. The technology involves injecting CO_2 gas 1,000 meters underground, putting it into a supercritical condition (in a middle state between liquid and gas), and pushing it into the pores of a sandstone layer. In the long term, CO_2 dissolves in the water in the sandstone bed and is mineralized through chemical reaction with the sandstone.

3. Field Tests

3-1. CO_2 Storage Test

Full-fledged development of geological CO_2 storage technology began in Japan in 2000 when field tests were held in Nagaoka, Niigata Prefecture, to inject CO_2 underground. The METI-funded project was conducted by the Research Institute of Innovative Technology for the Earth (RITE). Japan has distinctive and complex geological formations and the test was aimed to confirm the possibility of underground storage under such conditions. The test was held at the Iwanohara base, about 8 km from the center of Nagaoka city. This area was chosen for CO_2 storage for the following three reasons: natural gas had been extracted around 4,000 meters underground in the past, plenty of information was available on its geology, and local residents showed understanding of the project. During the test, CO_2 was injected 1,100 meters underground into an aquifer about 60 meters thick, pushing away saline water in the aquifer. Above this layer is a pelitic rock layer some 140 meters thick that serves as a cap, and the geological formation prevents the CO_2 from moving toward the ground surface.

3-2. CO_2 Injection Test

Facilities as seen in the *photo* were used in conducting the CO_2 injection test. Used was commercially supplied liquefied CO_2, which was transported by tanker. The CO_2 was compressed with three pumps, turned into gas with a heater, and sent underground from an injection well. *(Chart 2* on the next page*)* A total of 10,400 tons of CO_2 were injected from July 2003 to January 2005. During the first half of the period, the injection rate was 20 tons a day, and was doubled to 40 tons in the latter half. The injection process was brought to a halt three times - twice for a planned break, and once when the facilities stopped working due to an earthquake. Nonetheless, all of the CO_2 was safely injected according to schedule. The magnitude-6.8 Chuetsu earthquake in Niigata occurred at a point around 20 km from the location of the field test, but apart from the halt in the aboveground facilities caused by a blackout, no major abnormally was found, and operations were resumed once safety was confirmed.

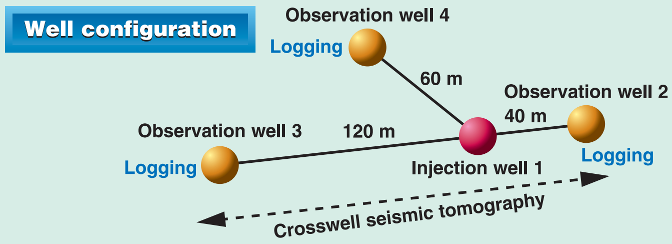
3-3. CO_2 Monitoring

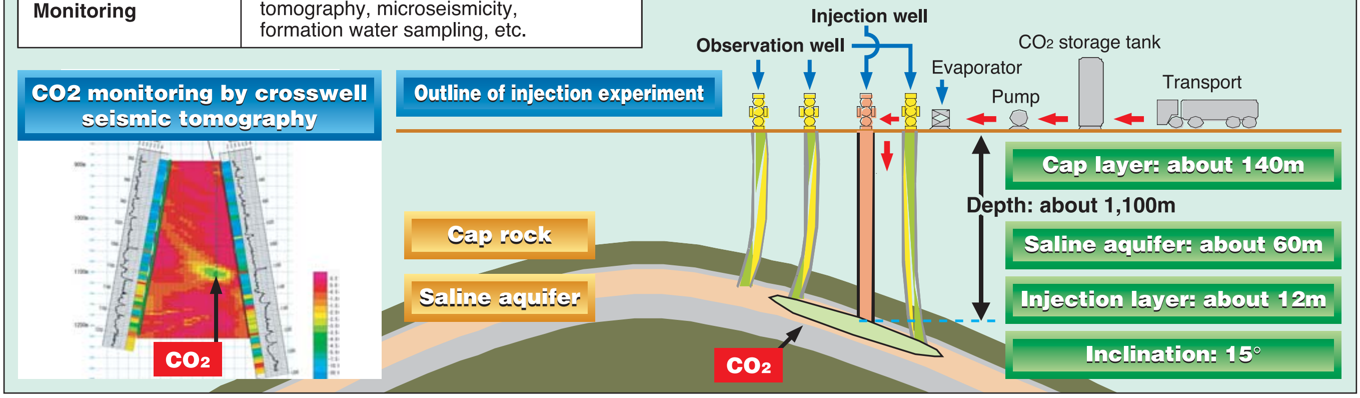
In the monitoring test, emphasis was placed on the technology to predict underground CO_2 behavior and confirm the possibility of long-term CO_2 storage. Three monitoring wells were dug around the injection well to monitor the CO_2 and predict long-term CO_2 movements through simulation. Various methods were employed for this monitoring process, including geophysical loggings, cross-hole seismic tomography, sampling of fluids from the aquifer, and observation of microseismicity. In the geological loggings where sound waves were used for observation, it was confirmed that CO_2 had respectively reached the observation wells located 40 meters and 60 meters from the injection well when 3,000 tons and 5,000 tons of CO_2 were injected. In observations using cross-hole seismic tomography, we were able to clarify through visualization how the CO_2 was spreading between the two observation wells sandwiching the injection well. It was the first time in the world that this kind of observation had been successfully made, and we were able to show that this method would be useful in predicting the behavior of CO_2. In the sampling of the aquifer water, we were able to scientifically confirm, again for the first time in the world, that the CO_2 injected underground had dissolved into the saline water. We also obtained results suggesting the likelihood that the injected CO_2 would chemically react to the rock and become mineralized and fixed in place. Using these data and simulation technology (GEM-GHG) to predict CO_2 behavior, we came up with calculation results showing that 1,000 years after being injected underground, CO_2 would stay in almost the same place, and there would be little possibility of it spreading in a wider area.

Chart 2 Pilot test for CO_2 geological storage in Japan (Nagaoka city)

Pilot test overview

CO_2 injection period	Jul. 2003 to Jan. 2005
CO_2 injected amount	About 10,400 t-CO_2
CO_2 injection rate	20 to 40 t-CO_2/day
CO_2 source	Purchased commercial CO_2
Monitoring	Well logging, crosswell seismic tomography, microseismicity, formation water sampling, etc.





Source : RITE

4. Challenges in Application of CCS Technology

To help mitigate global warming by applying geological CO_2 storage technology to large-scale CO_2 emission sources, it is vital to lower the total cost for separating and capturing CO_2, and transporting and storing it underground. Since the cost of separating and capturing CO_2 makes up 70% of the total cost, countries around the world are making active research into this part of the procedure. Japan is also furthering studies on various methods for CO_2 separation and capture that would most suit the characteristics of emission sources. The KS liquid, which Mitsubishi Heavy Industries Ltd. and Kansai Electric Power Co. have jointly developed to capture and absorb CO_2, has gained worldwide attention. Also drawing attention is RITE's ongoing Cost-Saving CO_2 Capture System (COCS) project to develop technology utilizing waste heat to regenerate the absorbent.

According to boring results and other data, we can estimate with a high degree of certainty there is currently storage potential for around 5.2 billion tons of CO_2 in Japan. With future studies, Japan's total CO_2 storage potential is likely to reach about 150 billion tons. The challenge we face now is to enhance the accuracy of estimating storage potential by conducting boring research focused on geological CO_2 storage. Since approximately 80% of the storage potential includes sea areas, another challenge for Japan is to develop technology to store CO_2 in sub-seabed geological formations. We are currently engaged in engineering studies on assumed model storage sites with the aim of looking in a comprehensive way into such aspects of CCS technology as emission sources, capture methods, transport methods, storage layers and injection methods.

5. Recent Trends

In other countries, there have recently been moves for geological CO_2 storage on a scale of 1 million tons a year, such as Norway's Sleipner project, Canada's Weyburn project, and Algeria's In Salah project. However, there is still a lot to be done with regard to geological storage projects for emissions from facilities such as thermal power plants and steelworks. While technological advances are being made in Japan for lower CO_2 emissions, we are seeking to help cut CO_2 emissions still further by the implementation of CCS technology. METI is currently holding CCS technology study meetings to work out new policies on the basis of a road map for developing geological CO_2 storage, sequestration and capture technologies. Meanwhile, the Environment Ministry's bill revising the seawater pollution prevention law in line with the effectuation of a protocol for the London Convention was enacted into law in May, setting a legal framework for geological CO_2 storage. Japan is cooperating internationally in forums such as the Kyoto Protocol, the United Nations Framework Convention on Climate Change (UNFCCC), the Carbon Sequestration Leadership Forum (CSLF), and the Asia-Pacific Partnership on Clean Development and Climate (APP). In the future, Japan is scheduled to participate in the United States' FutureGen project to develop technology for zero-emission power generation based on coal gasification. JS

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