Experimental Study on CO_2 Injection Into HDR Geothermal Reservoir

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ABSTRACT

The purpose of this research is to study sequestering CO_2 in solid carbonate minerals. CO_2 dissolved in water was injected into an open hole interval of a 1,100 m depth well which was drilled into a Hot Dry Rock (HDR) geothermal reservoir. The bottom hole temperature was measured around 230 °C. Ca concentration of the water sampled at 1,030 m depth increased in a few hours after CO_2 dissolved water injection. Calcite precipitation on calcite crystals set in CO_2 dissolved water at 850 m in the well was observed within a few hours.

INTRODUCTION

In Japan there are many active volcanic areas. There is a possibility that CO_2 injected into high temperature rock reacts faster than normal temperature rock allowing CO_2 to be sequestered in the formation as solid carbonate minerals such as calcite as shown in Figure 1 (Ueda et al., 2005). We conducted some field experiments to study CO_2 sequestration in solid minerals by injecting CO_2 dissolved in water into high temperature a borehole drilled into granitic rocks.

EXPERIMENT PROCEDURE AND RESULTS

The test site is located at Ogachi, northern Japan. At Ogachi there are three 1,000 m class wells (OGC-1, 2, 3) which were drilled into granodiorite. These wells were drilled for basic experiments for Hot Dry Rock geothermal energy development (Kaieda et al., 2005). The temperature of the wells at 1,000 m depth was measured at around 230 °C. OGC-2 was used for this research. OGC-2 was completed with casing from the ground surface to a depth of 700 m and below 700 m to the bottom of the well of 1,100 m was left uncased (open-hole).

Chemical reaction of CO_2 dissolved in water with rock

For the first experiment, neutralised river water was injected into OGC-2 following which water was recovered from the 1,030 m level of OGC-2 using a water sampler. Six samples per day were taken for 12 days. The results of chemical components analysis of the sampled water are shown in the upper part of Figure 2. Ca concentration in the sampled water does not change very much. In the second experiment, 1 wt % CO_2 dissolved in river water was injected into OGC-2 and again water at 1,030 m depth in OGC-2 was sampled, 4 times for 12 days. The chemical components results were shown in the lower left part of Figure 2. In this Figure, we can see that Ca

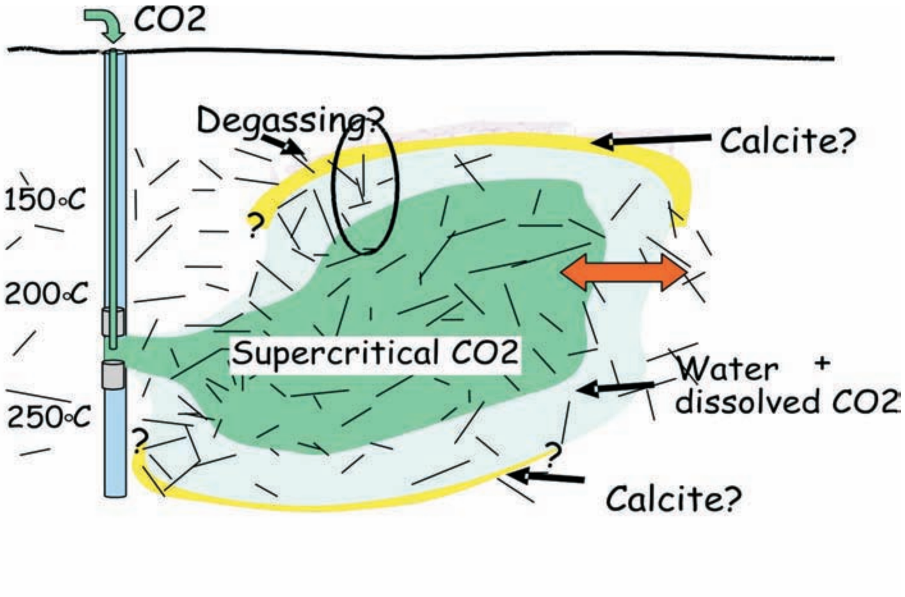

Figure 1. Concept of CO_2 injection into geothermal reservoir.

concentration of the sampled water increased up to 21 mg/kg at 16 hours after CO_2 dissolved water injection was stopped. Then Ca concentration decreased to original level. In the third experiment, 3 wt % CO_2 dissolved in river water was injected, whereafter water at 1,030 m depth in OGC-2 was sampled 6 times for 8 days. The chemical components results are shown in the lower right part of Figure 2. In this figure we can see Ca concentration of the sampled water from OGC-2 increased to 85.2 mg/kg in one hour and decreased to the original level for some days.

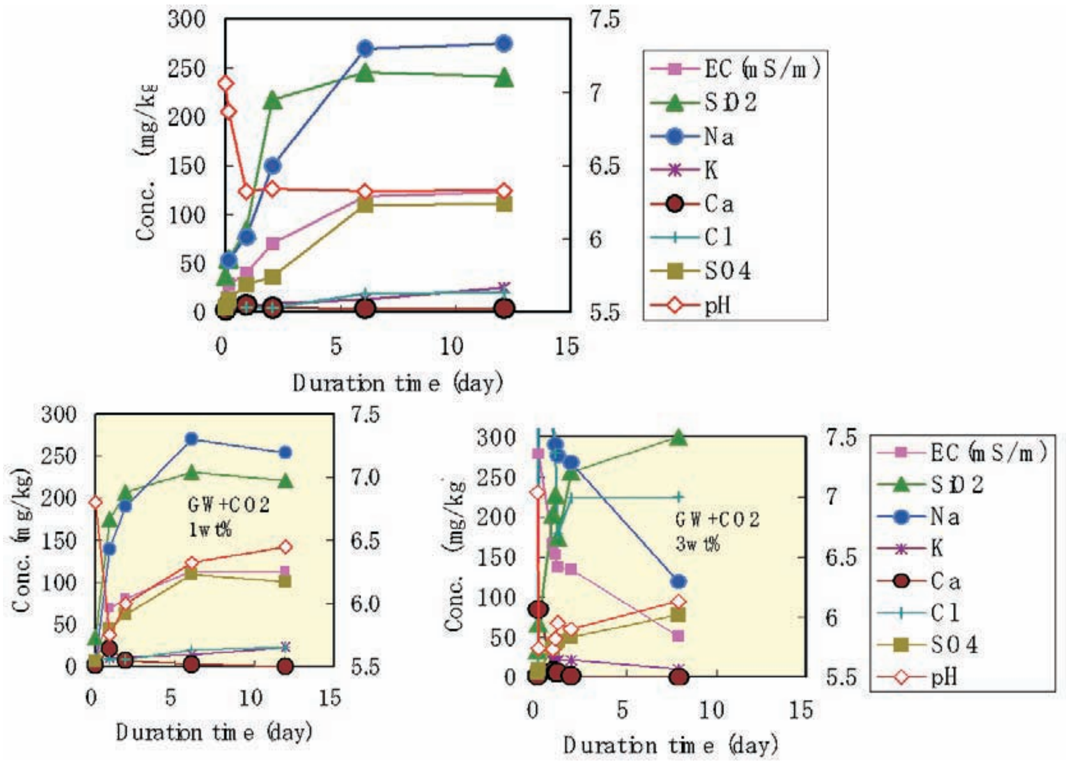

Figure 2. Chemical components concentration after CO_2-charged water injection.

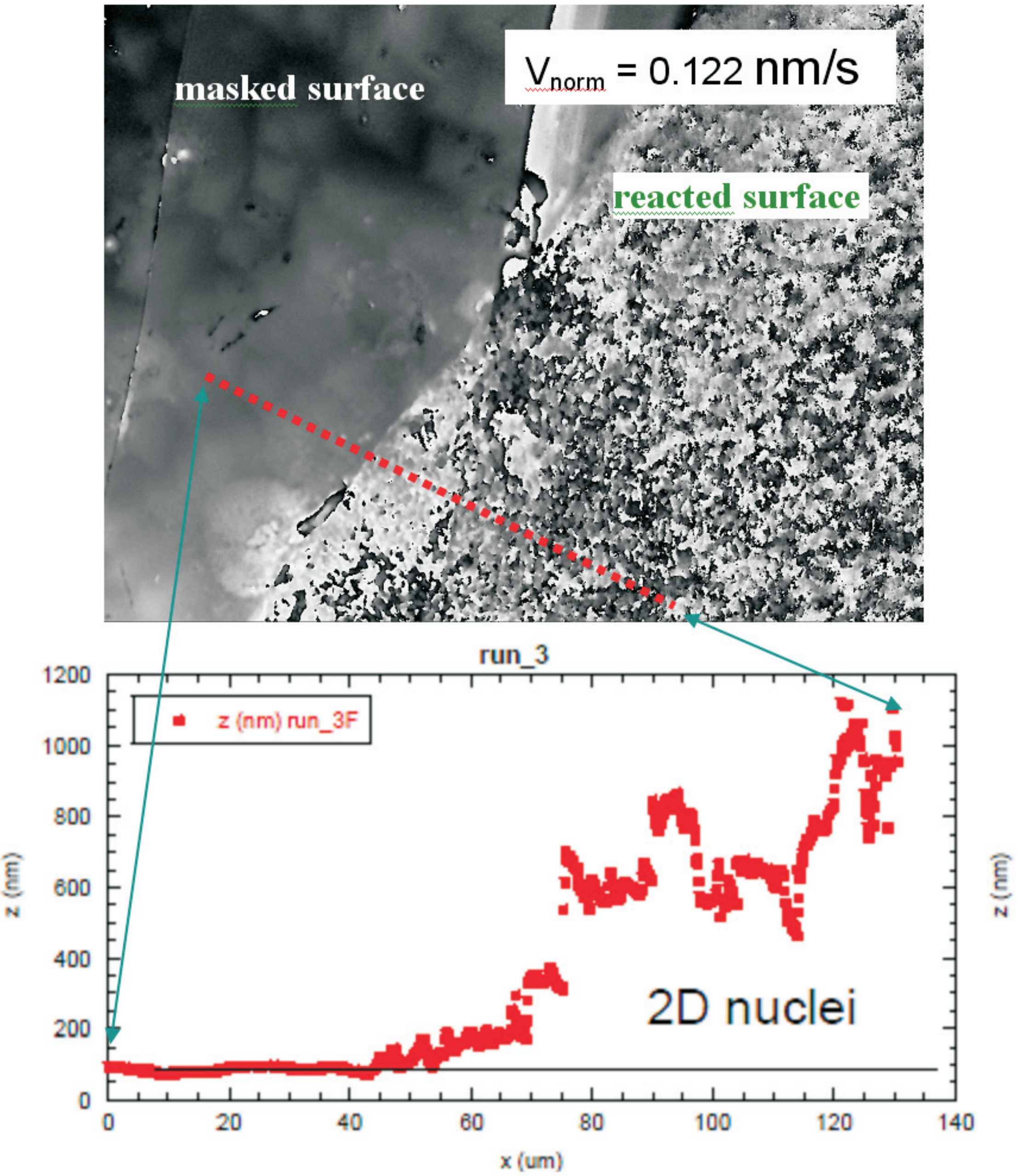

Figure 3. $CaCO_3$ precipitation in CO_2 dissolved water.

From these results, we considered that the reaction of CO_2 dissolved river water with rock is very fast. Ca concentration after injection of CO_2 dissolved in river water increased in a few hours. The ratio of the concentration increasing depends on dissolved CO_2 percent. After increasing Ca concentration, the concentration decreased to the original level for some days. The Ca concentration decrease may be caused by water flow in and/or out between OGC-2 and surrounding rock, or by precipitation as $CaCO_3$. We considered that Ca was supplied from Ca-feldspar in granodiorite.

Calcite precipitation in water with dissolved CO_2 at high temperature

In the previous experiment, we confirmed that Ca concentration increased by injecting CO_2 containing water into high temperature granitic rock. In this experiment we intended to study the possibility for CO_2 sequestration as calcite. Calcite crystals partially covered with Au film was held in a sonde. The sonde was put into OGC-2 to a depth of 850 m where CO_2 containing water was injected. The sonde was recovered after one hour and the calcite crystal surface was observed by a phase shift interferometer.

Figure 3 shows an example of a picture of the calcite crystal surface by a stereo microscope (upper picture) and roughness of the crystal surface along the red dashed line observed by the phase shift interferometer (lower figure). The masked surface means the area covered with Au film. In this masked area, no change occurred, but other area shown as reacted area calcite crystal grew to a maximum height of about 1,100 nm. From the results we can calculate the calcite precipitation rate of order of 0.1 nm/s. This means calcite precipitate crystals of 0.1 mm in 12 days.

CONCLUSION

CO_2 dissolved in water was injected into an open hole interval between 700 m to 1,100 m depths of OGC-2 at Ogachi which was drilled into a Hot Dry Rock (HDR) geothermal reservoir. The bottom hole temperature was measured around 230 °C. Ca concentration of the water sampled at 1,030 m depth increased in a few hours after CO_2 dissolved water injection then decreased in a few days. For the Ca increase it was considered that Ca was supplied from Ca-feldspar in granodiorite. Calcite precipitation on calcite crystals was observed for CO_2 dissolved in water at 850 m in the well, within a few hours.

ACKNOWLEDGEMENTS

This research has been conducted as a collaboration work between the Central Research Institute of Electric Power Industry and Research Institute of Innovative Technology for the Earth in the Research & Development Program "Development of innovative technology for the CO_2 fixation by GEOREACTOR" under the fund from Ministry of Economy, Trade & Industry of Japan. The authors are grateful to Professor Victor Rudolph for his comments and suggestions which have improved this abstract.

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