Trapping mechanisms in field scale observed by time-lapse well logging at the Nagaoka site

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This paper discusses CO_2 trapping in field scale observed at the Nagaoka pilot-scale injection site. IPCC (2005) illustrated the contributions of various trapping mechanisms over time, and pointed out the importance of capillary and solubility trapping at the early stage of geological CO_2 storage. Capillary trapping is caused by interfacial forces at the pore of rock and prevents migration of CO_2 bubble. Solubility trapping means that gaseous CO_2 dissolves into formation water. After the report of IPCC, many laboratory experiments related to these trapping mechanisms have been conducted. Meanwhile, field observations were limited. In this paper, we study trapping mechanisms observed at the Nagaoka site.

Nagaoka project was undertaken in order to verify an ability of CO_2 injection into Japanese formation. The target reservoir is consists of a limb of anticline structure and have 15 degree dipping. About 10 k-tones of CO_2 were injected into a thin permeable zone from July 2003 to January 2005. Time-lapse well loggings have been carried out for more than 12 years, and the number of monitoring logging is 44 times so far. CO_2 breakthrough was detected at a down-dip well (OB-2) located 40m away from the injection well, and at a up-dip well (OB-4) located 60m from the injection point. From the neutron logging data, CO_2 saturation in super-critical phase was evaluated, and from the induction logging the existence of super-critical and dissolved CO_2 is deduced. At OB-2, CO_2 saturation peaked at 63% around 22 months after the start of injection, decreased gradually, and stabilized at around 20%. At OB-4, CO_2 saturation peaked at 69% around 15 months and remained relatively high value (40%).

We considered that the maximum saturation at each depth was corresponding to the initial saturation of drainage process and the latest observation could be assumed as the residual state. The relationship between the initial and residual saturation is called IR curve and represents the fundamental flow properties in drainage process. The results at OB-2 showed that most of the data can be explained by single Land’s model. Exception came from relatively silty layer, which means pore distribution is different from other layers. At OB-4, IR relationship was scattered and indicated that the latest state is far from the residual condition. The difference between down- and up-dip direction is thought to exhibit migration effects in the reservoir.

Concerning the dissolved CO_2, the thickness of the low resistivity anomaly became larger. This showed that the solubility trapping was progressing. The rate of thickening was the same order as the dissipation of bicarbonate ion. This was consistent with the expectation from the linear instability theory for density convection of CO_2 dissolved water.

These results showed capillary and solubility trapping mechanisms in the field scale observation. The drainage process in field scale could be explained by Land’s model as laboratory experiments, and the fitted model was depend on rock type. Solubility trapping in several mD formations was confirmed that dissipation process was dominant during the first decade of CO_2 storage. These results could be used for simulation tasks to build a better flow model.

Keywords: CO2 geological storage, multiphase flow, residual trapping, solubility trapping, Land model, Nagaoka site

