In-situ Volume Change Monitoring for Deep Underlay Strata with Fiber Optical Technology

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Abstract

The Southern Kanto gas field, the largest field of natural gas dissolved in groundwater in Japan, is located in the Chiba Prefecture, eastern part of Japanese main island. In this gas field, 8 companies produce $460*10^6$ m^3/y of natural gas. In addition, the iodine is extracted from the brine. Iodine is industrially useful and essential for the human body. About 30% of world production is produced in this area in recent years.

On the other hand, land subsidence due to the gas-brine extraction from the strata has become a big issue to b solved since 1965. Natural gas and iodine producers in this area have made "The Land Subsidence Prevention Agreement" with the local government and have made an effort to prevent and minimize the land subsidence. Although the pumped up brine is inferred as the main cause of the subsidence from the early time, the geological mechanism of the subsidence, which includes the quantitative relationship between the volume change and extracted gas-brine's volume, has yet well known. As the measurement of the actual volume change of each stratum has become an important technological issue to reveal the mechanism, a new monitoring system has been developed jointly by them to identify the volume change of the target stratum.

Key words: Volume Change Monitoring, Deep Underlay Strata, Stratified Observation, Optical Fibers; Southern Kanto Natural Gas Field, Brine.

1. Introduction

"The Southern Kanto gas field", the largest field of natural gas dissolved in groundwater in Japan, is located in Chiba Prefecture, eastern part of Japanese Main Island. In this gas field, eight companies produce $460*10^6$m3/year of natural gas. In addition, the iodine extracted from the brine is industrially used, about 30% of world production is produced in this area in recent years.

On the other hand, land subsidence has become a big concern due to the gas-brine extraction from the strata since 1965. Natural gas and iodine producers in this area have made "The Land Subsidence Prevention Agreement" with the local government and have made an effort to prevent and minimize the land subsidence. These eight producers organized "Environment Committee of the Japan Natural Gas Association Keiyo Natural Gas Association (hereinafter the Environment Committee) " to address environmental concerns including land subsidence.

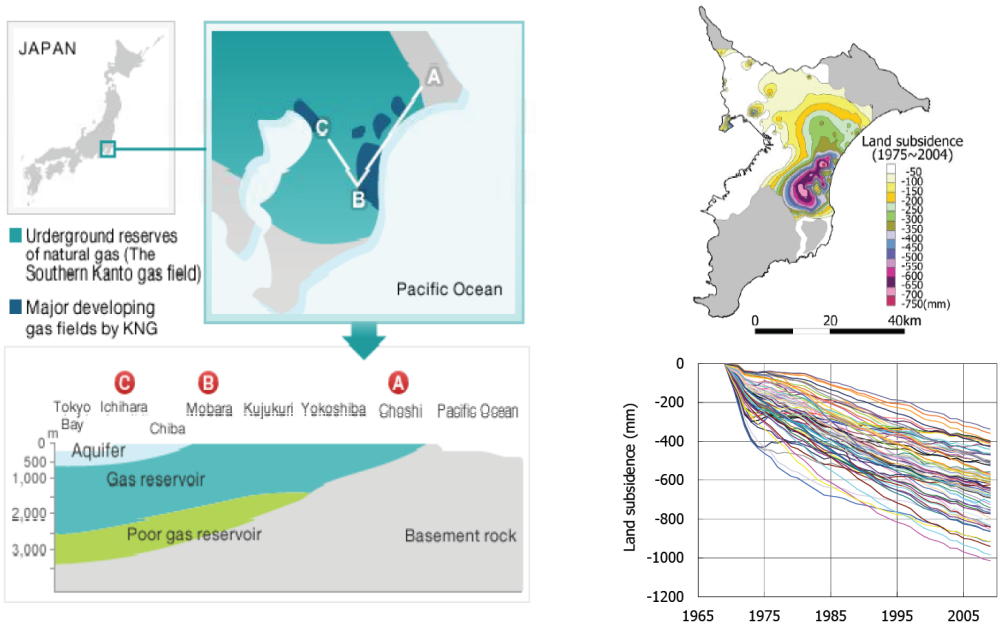

Fig. 1 Southern Kanto Gas Field in Japan

Although the pumped up brine accompanied with the gas extraction is inferred as the main cause of the subsidence since early stage, the geological mechanism of the subsidence, especially the quantitative relationship between the volume change and extracted gas-brine's volume, has yet well known.

Land subsidence is generally monitored by leveling and sometimes by a GPS survey or synthetic aperture radar using artificial satellites. However, all such methods are intended to monitor relative changes at the ground surface, and not to measure actual volume change of underlay strata. The observation of stratified land subsidence in this study was focused on identifying vertical volume change, i.e. expansion and shrinkage, in a specific underground section (Fig. 2).

As the measurement of the actual volume change of each deep underlay strata has become an important technological issue, a new monitoring system has been developed jointly by the producers to reveal the mechanism of subsidence in the target stratum.

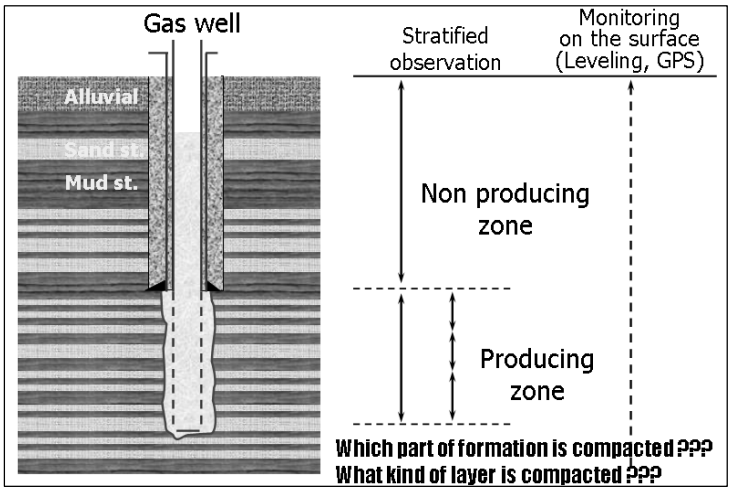

Fig. 2 Concept of stratified land subsidence observation

The monitoring sites were selected from the regions having an annual subsidence rate of 10

mm/year or more, based on the annual survey report of local governments. The monitoring sections were decided in light of the rock types and properties of formations. In this area, the natural gas dissolved in water is collected by pumping up brine from the formations underlying several hundred meters to 2,000 m deep. The gas reservoir is a marine stratum that was accumulated since 2.4 million years ago until 450,000 years ago, resulting to form alternative layers of sandstone and mudstone which have tens of cm to 2 m in thickness.

2. Measuring method

The newly developed monitoring system basically consists of the settlement gauges (including displacement gauges and anchors) and the rods used in deformation transmission. As a new attempt, we introduced optical fibers and transmission lines as displacement gauges. The use of optical fiber technology has a possibility to measure a tiny deformation in deep underlay stratum with high accuracy in real time.

In the measurement principle of the monitoring system, settlement gauges are fixed at the boundary of the target sections at several depths in the observation well. Between the sensors are measured sections. Each settlement gauge is connected with rod. The rod is directly connected to an optical fiber sensor which is mounted inside the lower settlement gauge. Settlement gauges have an anchor mechanism that is able to fix the gauge directly in an open hole. Whenever deformation occurs in one of these sections, the section's rod will be pulled toward lower settlement gauge. Consequently, optical fiber sensor will measure the pulled length of the rod as deformation (Fig. 3).

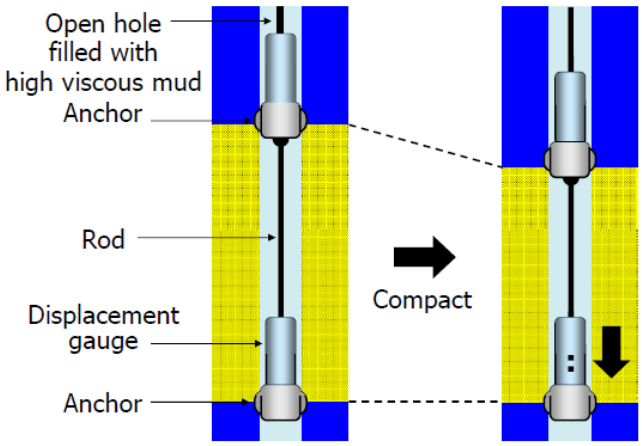

Fig. 3 The measurement principle of the new monitoring system

The monitoring system made it possible to measure each section of deformation by the volume changes in deep underlay strata in real time and continuously.

3. Preliminary test

In order to check a reliability of this system and the challenges for installation phase, the preliminarily test was carried out. The prototype system was installed in the shallow observation well at approximately 80m deep, and the actual formation compaction was measured. The water well was drilled at the 10m away from the observation well, and the formation was artificially compacted by pumping groundwater from the water well. As a result of the preliminary test, the monitoring system was confirmed to work without problem even in the field.

The formation was compacted/extended with the groundwater level fallen/risen according to the

flow rate change(Fig. 4).

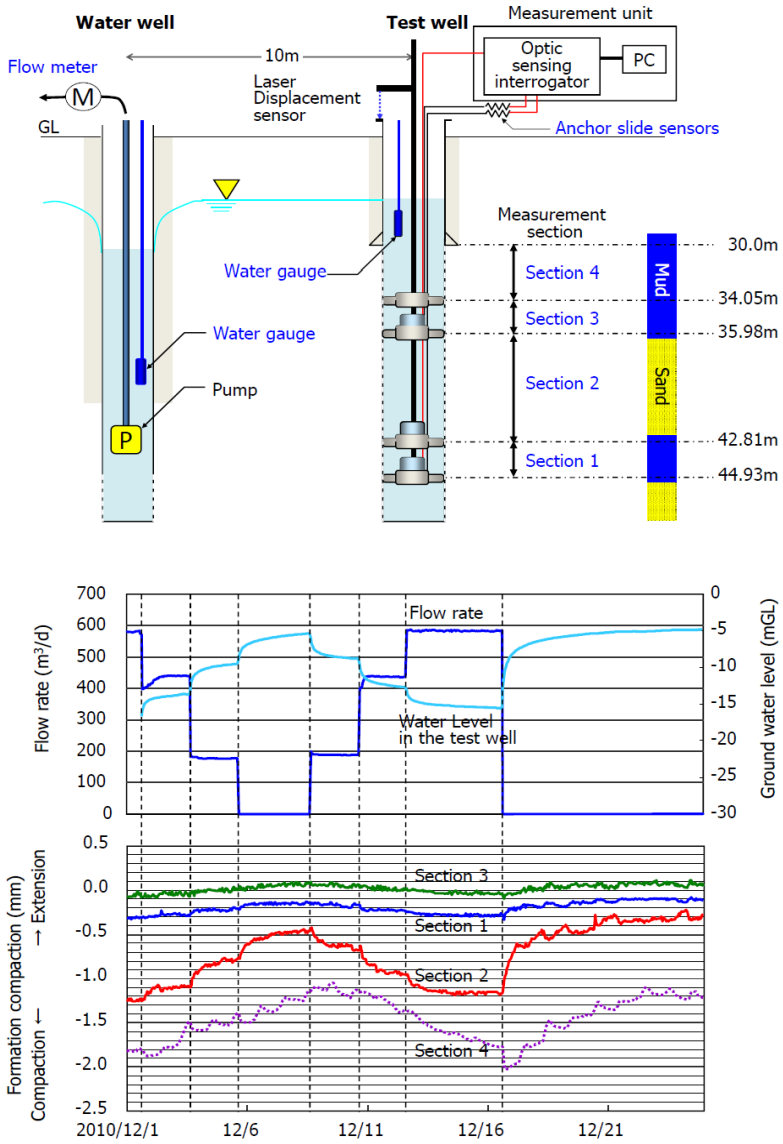

Fig. 4 The data of the preliminary test

4. Monitoring volume change of gas reservior

The monitoring system was was installed in the deep observation well at about 800m deep in July 2012.

Now we have been measuring the volume change of each stratum in the natural gas reservoir and gaining the field data shown in Fig. 5.

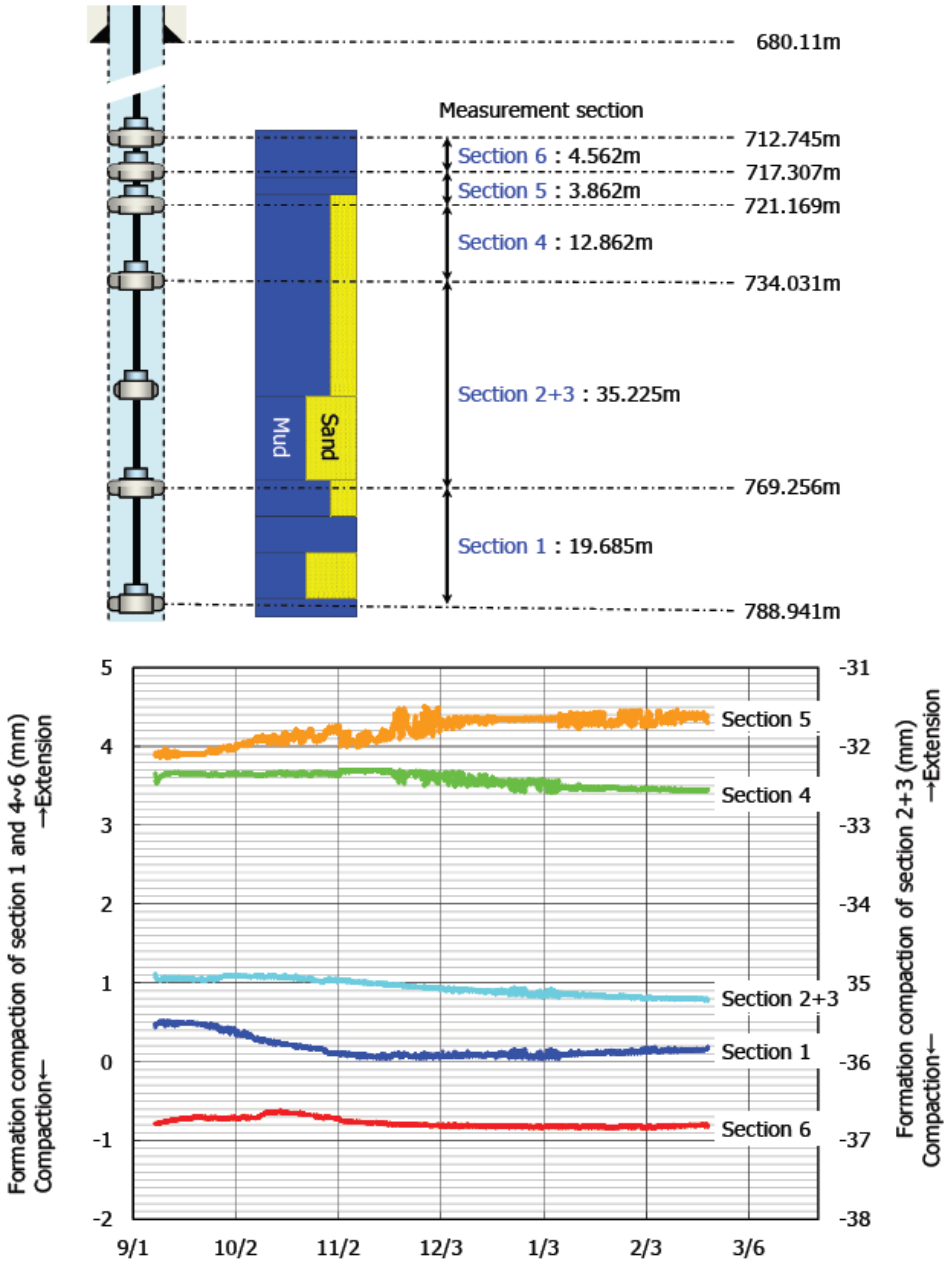

Fig. 5 The monitoring data of the 6 strata in the natural gas reservoir

5. Conclusions

(1)The new monitoring system have been developed which measures the volume change of each stratum below deep ground continually by using “Optical Fiber Technology”.

(2)In order to verify the reliability of this system and identify the challenges during installation phase, the preliminary test was carried out. The prototype system was installed at 80 m below the ground and the volume change of the strata was measured. The test result showed that the monitoring system could be applied in the field without any difficulties during installation and could measure volume change of the stratum, precisely.

(3)Full scale test with 800m deep well have been conducted, and the system was installed to monitor the 6 strata in the natural gas reservoir in July 2012.

(4)Continuous monitoring at this well has been conducted since September 2012.

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