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Simulation study of the in-situ formation deformation behavior of a shallow formation in the Southern Kanto Natural gas field, Chiba Prefecture, Japan

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Abstract. In 2010, eight companies which are exploiting natural gas and brine water in the Southern Kanto natural gas field, Chiba prefecture, Japan constructed an in-situ formation deformation monitoring well with a depth of approximately 80 m, and in-situ formation deformation was measured on a trial basis.

After this field test, by conducting the simulation study, we verified whether the deformation behavior at the monitoring well was perfectly elastic or not. In addition, we compared in-situ rock properties like Young's modulus and Poisson's ratio which were estimated by the simulation study with those determined from a triaxial compression test.

1 Introduction

In the Kanto region of Japan, a large amount of natural gas is widely dissolved in brine water. This natural gas field is known as "the Southern Kanto natural gas field" (Fig. 1). In particular, the Kujukuri plain of Chiba Prefecture has not only reserves of natural gas dissolved in brine water but a high concentration of iodine in brine water. These resources have been produced commercially for about 80 years in this area.

In the Kujukuri plain, land subsidence has been observed since the late 1960s. Recently, land subsidence has reduced in almost all areas, but land subsidence of more than 10 mm per annum has been observed in some places. So the eight companies exploiting natural gas in this area are making efforts to address environmental problems through the Environment Committee of the Japan Natural Gas Association Keiyo Natural Gas Association (hereinafter referred to as the Environment Committee).

2 In-situ formation deformation monitoring well

The Kazusa Group formation contains the natural gas deposits and consists of alternate layers of unconsolidated sandstone and mudstone. The thickness of the stratum is from several decimeters to several meters.

For measuring the in-situ formation deformaiton of each stratum, the eight natural gas companies constructed a monitoring well with a depth of approximately 80 m in 2010. This well is open to formation from 30 to 80 m and installed with settlement gauges, rods, optical fiber etc. By measuring displacement of settlement gauges, this well can measure the in-situ formation deformation of each stratum within a part of Kazusa Group continuously. In addition, water level was measured in this well.

At a distance of 10 m from the monitoring well, a production well was installed. This production well was screened from 45 to 59 m. Permeability of sandstone was estimated 2000 md from a pumping test and vertival permeability of mudstone was estimated 0.02 md from a core test. However, we did not use these values in the model because we could not match the measured drawdown and the simulated draw-

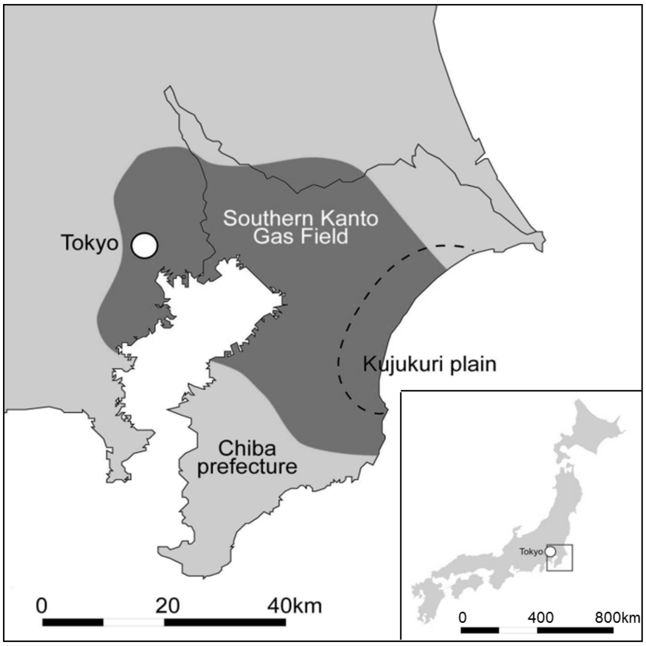

Figure 1. The Southern Kanto gas field.

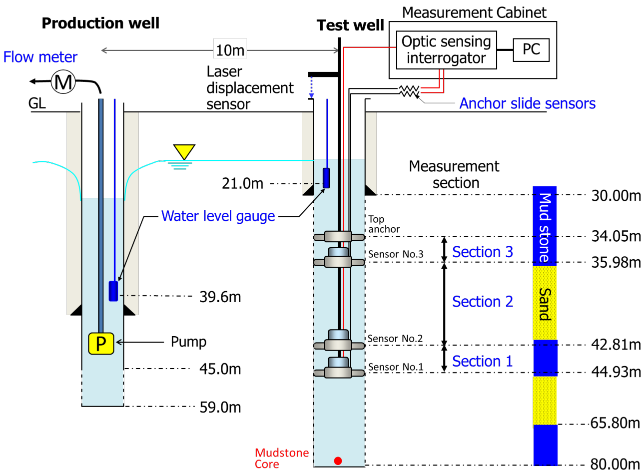

Figure 2. Formation deformation monitoring system (revised Murai et al., 2013).

down. Groundwater was pumped from 10 November 2010 to 16 December 2010 while vertical deformation of the formation was monitored. Figure 2 shows formation deformation monitoring system. Figure 3 shows the pump flow rate and bottom hole pressure at 55 m of each well.

3 Purposes of simulation study

We verified formation deformation behavior measured at the in-situ formation deformation monitoring well with a simulator. Purposes of this study are as follows:

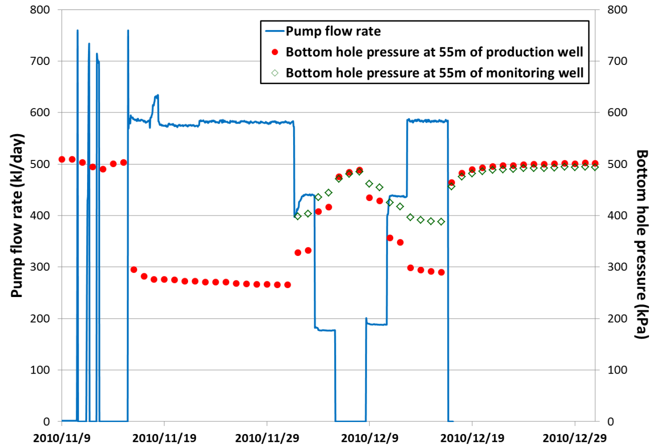

Figure 3. Pump flow rate and bottom hole pressure of each well.

- To confirm whether formation deformation behavior measured at the monitoring well can be explained by elasitc deformation simulated with a perfectly elastic model.
- To determine whether deformation properties estimated from the simulation and properties measured by a core test are consistent.

4 Settings of simulation model

Formation deformation behavior can be simulated with STARS provided by Computer Modelling Group Ltd. (CMG). STARS is a 3-D oil simulator using FDM in flow analysis and FEM in stress-strain analysis. Flow-deformation analysis is coupled. And it can simulate elastic deformation and elasto-plasticity deformation.

One production well and one monitoring well are located at the center of the simulation model (Fig. 4). The distance between two wells is about 10 m. In addition, the aquifer system in Kazusa Group is simulated as confined flow in this model. Figure 5 shows the grid setting for z axis. This model has 9 layers. Water is produced only from the aquifer represented by layer 9 in the model. The intervals of in-situ deformation monitoring are represented by layer 3 ∼ layer 7 in the model. Table 1 gives settings for this simulation. Young's modulus and Poisson's ratio are history matching parameters.

5 Results of simulation study

Figure 6 shows measured and simulated drawdown of each well. Figure 7 shows the measured and simulated vertical deformation of each layer. Red circles highlight mechanical errors in measurements. In-situ deformation behavior measured at the monitoring well was reasonably simulated using a perfectly elastic model. However, Young's modulus values

Table 1. Simulation settings.

Number of wells	Production well Monitoring well	1 1	
Model size	X Y Z	10 000 m 10 000 m 65.8 m	
Porosity	Mudstone Sandstone	0.45 0.40	From core test at this well Estimate from other wells
Permeability	Mudstone Sandstone	10 md 1700 md	From history matching From history matching

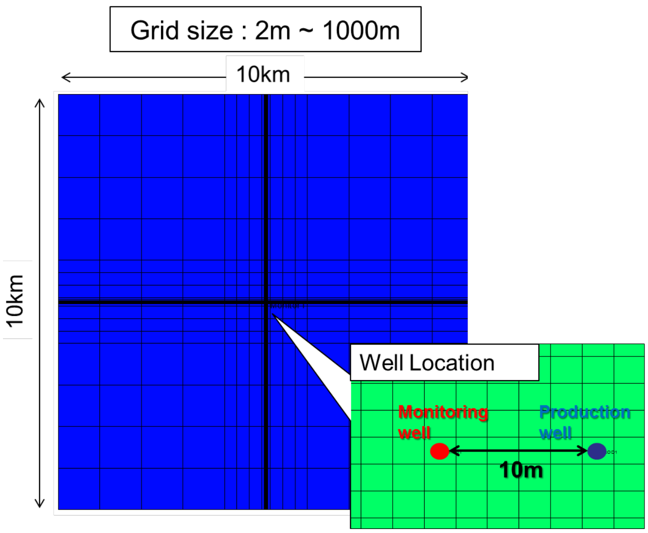

Figure 4. Model gridding (x-y plane).

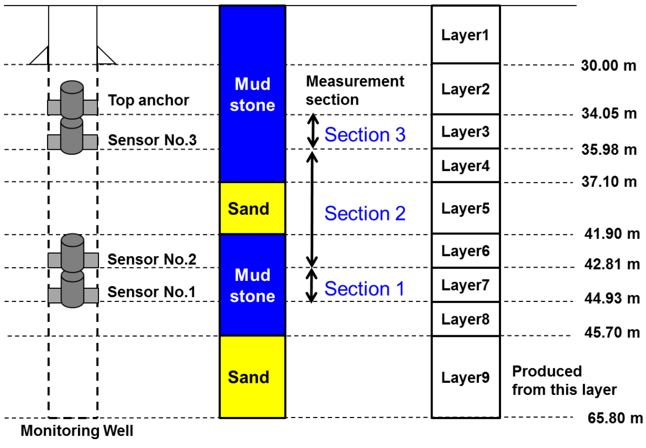

Figure 5. Model gridding (z axis).

estimated from the simulation were smaller than that determined from a triaxial compression test. On the other hand, estimated values of Poisson's ratios were fairly consistent with

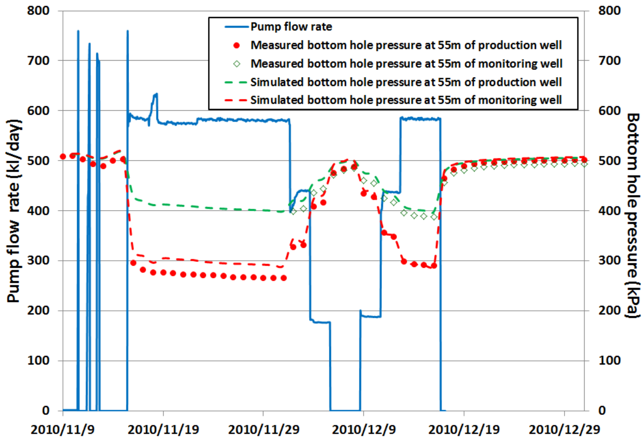

Figure 6. Simulated and measured drawdown.

the value determined from the core test. Because the in-situ drainage condition is strongly affected by the stress-strain response. The differences between the simulated response and the measured response from the core test are attributed to differences in drainage conditions.

Previous core tests show Young's modulus of sandstones and mudstones are equivalent. But the core test in this study was done on a core sampled from mudstone because the sandstones in the shallow formation were too fragile. Therefore, Young's modulus of sandstones and mudstones were assumed to be equivalent in this simulation model. In order to more accurately simulate the in-situ deformation behavior, given that one of either the Young's modulus or Poisson's ratio parameters are equivalent for sandstone and mudstone, then values of the other parameter should be different for sandstones and mudstones.

Measurements of these parameters (Young's modulus and Poisson's ratio) are needed for both sandstones and mudstones.

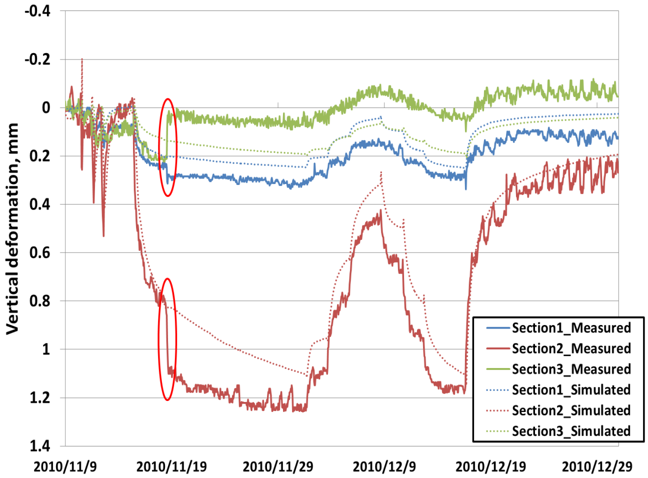

Figure 7. Simulated and measured vertical deformation.

6 Conclusions

- In-situ deformation behavior measured at the monitoring well was simulated reasonably well using a perfectly elastic model.
- Simulated Young's modulus values were assumed to be equivalent for sandstones and mudstones, and the estimated values from the simulation was smaller than that determined from a core test. Poisson's ratios estimated from the simulation were fairly consistent with that determined from a core test.
- It is possible that Poisson's ratio of sandstones and mudstones is different. Core tests for measuring static Poisson's ratios of sandstones and mudstones are required. Some core tests are planned in 2015 to validate these results.

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