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Technical Report

History Matching of Gas Production Performance in Nishikanbara Water-dissolved Gas Field

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In Nishikanbara Gas Field of Niigata prefecture, Japan, water-dissolved gas has been produced since the 1950s. To establish an optimum development plan, numerical reservoir simulation models were constructed for the first time in this field using a black oil reservoir simulation software. For validating the model, history-matching of production gas water ratio (GWR) and reservoir pressure was carried out treating the absolute permeability of reservoir rocks and initial distribution of solution GWR as matching parameters. After several trial and errors, the models were successfully validated through the history-matching with actual data.

1. Introduction

In the Nishikanbara gas field of Niigata prefecture, Japan, water-dissolved gas, whose major component is methane, has been produced since the 1950s. Because the water-dissolved gas is dissolved in the groundwater, large amount of the water needs to be pumped up for gas production. As a result of producing groundwater, significant land subsidence was induced at the early stage of production in this area. To prevent the land subsidence, all produced water has been re-injected to the reservoir since October, 1973 and no land subsidence has been observed since then. On the other hand, production gas water ratio steeply dropped in some wells due to the mixing of original groundwater with the re-injected water.

Various approaches have been proposed for the development of water-dissolved gas field. Marsden (1993) reported the development of water-dissolved gas around the world[1)]. Akibayashi, Karube and Hara (1986) estimated the transmissibility in the water-dissolved gas field[2)]. Nishida and Aoki (1980) simulated the subsidence behavior in water-dissolved gas field[3)]. However, water-dissolved gas fields are not commonly known on a global scale and its simulation method have not been established yet though it is important to create an optimum development plan.

This study aims to develop numerical reservoir simulation models that reproduce the gas production performance from the water-dissolved gas reservoirs by using a black oil reservoir simulation software.

2. Geology

The Nishikanbara water-dissolved gas field is located in the western part of Niigata city of Niigata prefecture, Japan. (Fig. 1, Fig. 2) The number of production and injection wells is 130 and about 33 million sm^3 of methane gas has been produced from the gas field per year. In this study, numerical models were developed for the main reservoirs, G4, G5 and G6 in this field.

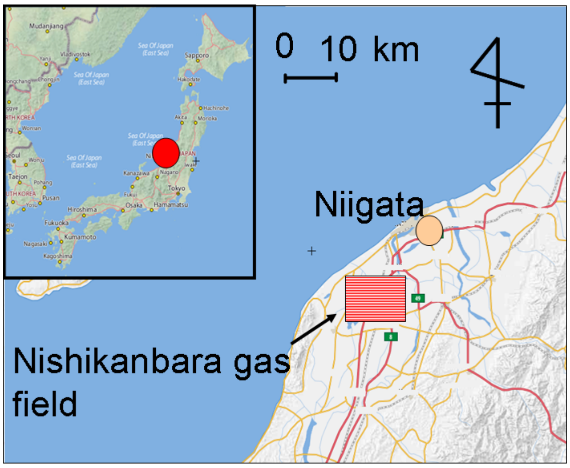

Fig. 1 The location of Nishikanbara area.

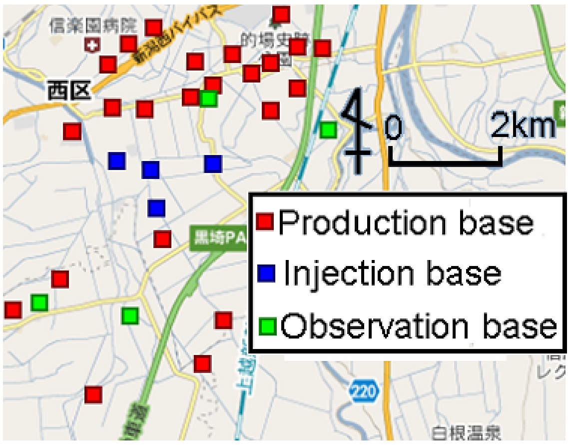

Fig. 2 The locations of the bases.

The Nishikanbara gas field is located in the southeastern part of a synclinal structure. From south to north, the top depth of the reservoirs gradually becomes deeper in the production area. Fig. 3 shows the top depth of the reservoir G4. The trend of the structure of each reservoir is similar to that of the reservoir G4.

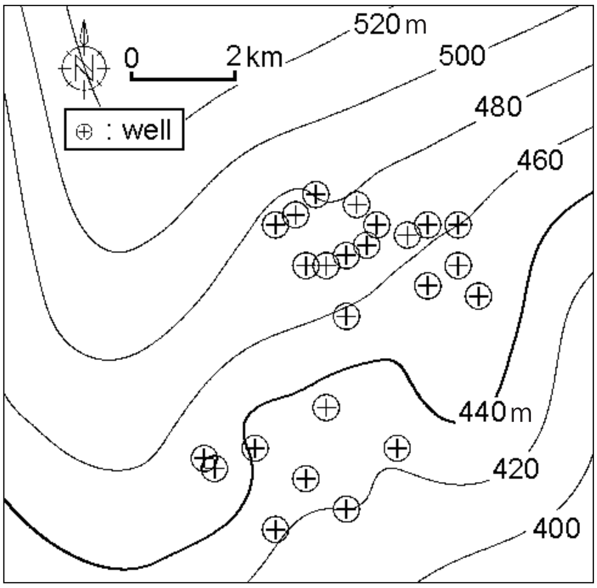

Fig. 3 The top depth of the reservoir G4.

Table 1 Parameters of each reservoir

Name		Lithology	Depth(m)	Thickness (m)	Permeability (darcy)
G4	G4(b)	coarse sand	420-510	30-35	15-20
	G4(c)	coase sand, gravel	485-580	25-30	20-25
	G4-1	coase sand, gravel	555-640	20-25	10-15
G5		coase sand, gravel	640-840	80-120	15-20
G6		gravel	855-1025	60-70	20-25

The parameters of each reservoir are shown in the Table 1. The reservoirs lie at the depth from 400 m to over 1000 m. These reservoirs are consisted of coarse sand or gravel, whose permeability ranges 10-30 darcy and the porosity is averaged as 28 %. G4 is separated into G4(b), G4(c) and G4-1 by mud layers. Similarly, the reservoir G5 is divided into G5 and G5-1 and there is an impermeable layer between them. Furthermore, the extent of this impermeable layer is not clarified yet. G5-1 and the reservoir G6 disappear at the north part of the production area.

Since the reservoir pressure is higher than the saturation pressure, a gas cap is not formed in these reservoirs. The value of the initial solution gas water ratio (SGWR) ranges from 1.0 SCM/SCM to 1.7 SCM/SCM. From south to north, initial SGWR gradually increases as the top depth of the reservoirs become deeper. As the production of natural gas continued, the SGWR gradually dropped due to the mixing the groundwater with the re-injected water in some part of production area.

3. Numerical Modeling

Numerical models were developed for the reservoir G4, G5 and G6 respectively using a black oil reservoir simulation software, ECLIPSE100 ver.2008.2 (Schlumberger co., Ltd). Since the dissolution of methane gas into water can not be modeled in this simulation software, the water was regarded as oil and the properties of groundwater were given to the oil.

For the first stage of model development, the reservoirs were discretized to numerous cells. The size of one cell in the production area was decided as 200 m × 200 m for G4 and G6 and as 150 m × 150 m for G5. This production area was configured as 8.4 km × 15 km in the model of G4, 9 km × 13.5 km in G5 and 9 km × 11 km in G6. As approaching the outer boundary, the size of cells is increased to shorten the computation time. Finally the size of each model was decided as 58.8 km × 65.4 km in the model of G4, as 85.2 km × 89.7 km in G5 and as 59.2 km × 61.4 km in G6 (Fig. 4). The grid of vertical direction was configured for each model individually. Each reservoir in G4 is divided into two layers and the impermeable layers between the reservoirs are regarded as one layer (Fig. 5). Though there are a lot of multiple completed wells among G4(b), G4(c) and G4-1, the ratio of the production rates from individual reservoir has not been measured. Hence, the product of permeability and thickness (k-h) of G4(b), G4(c) and G4-1 were used to allocate the production rate to each reservoir.

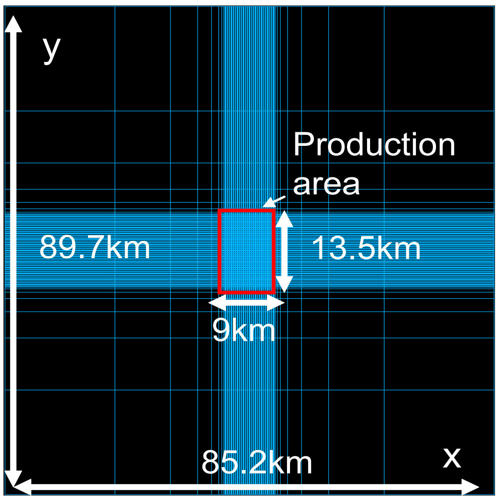

Fig. 4 The grid of the numerical model of the reservoir G5.

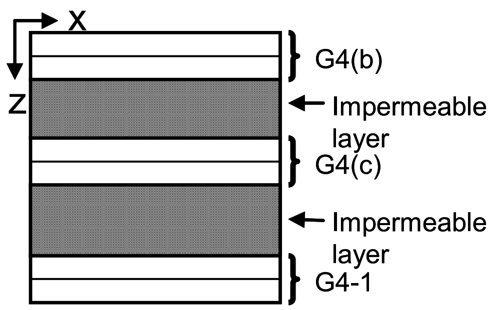

Fig. 5 The separation of depth direction in G4.

Reservoir G5 is separated into 10 layers of same thickness. Top four layers are regarded as G5 and the fifth layer from the top was regarded as impermeable layer. Bottom five layers are regarded as G5-1 (Fig. 6). Reservoir G6 is separated into 5 equal parts.

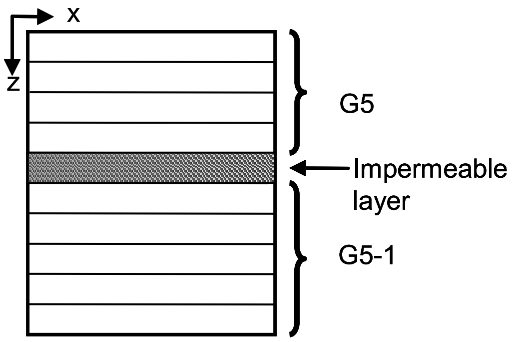

Fig. 6 The separation of depth direction in G5.

After defining the gird systems, the petrophysical properties obtained from the field were input to the models[4]. Then, production and injection history of each well were input to caluclate the production performance. The calculation was continued until the calculated production GWR and reservoir pressure at each well matched the observed ones. The absolute permeability of the rocks and initial distribution of solution GWR were mainly adjusted for history matching. In addition, the porosity of outermost grids was also adjusted because the water-dissolved gas reservoirs have large lateral extent but the models have limited extent.

4. Result

4.1. Reservoir G4

Fig. 7 and Fig. 8 show the results of history matching of reservoir pressure and production GWR in a well. The decrease and recovery of the reservoir pressure is reproduced well as shown Fig. 7. The decreasing production GWR is also reproduced in other wells. A example is shown in Fig. 8. Since there are a lot of multiple completion wells in the reservoir G4, it is important to reflect not only the thickness but also the permeability of the reservoir for allocating the production rate. In this study, horizontal permeability values, were 23 darcy, 22 darcy and 8 darcy for G4(b), G4(c) and G4-1 respectively. The vertical permeability was assumed as 20 % of horizontal permeability. The ratios of the thickness of the reservoirs to whole thickness of G4 are 17.0 %, 15.5 % and 19.0 % for G4(b), G4(c) and G4-1 respectively.

4.2. Reservoir G5

The reservoir G5 is divided into G5 and G5-1. G5 is the upper part of the layer and G5-1 is the lower part of the layer. Because it is not obvious whether there is a connection between the two layers, the numerical model was initially configured without connection between the two layers. However, the numerical simulation model could not be reproduced with reasonable accuracy.

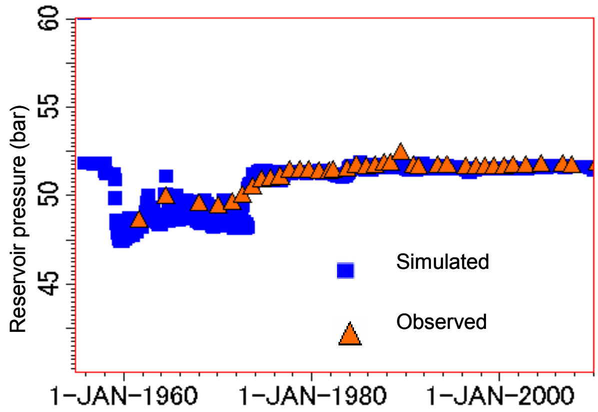

Fig. 7 The result of history matching of reservoir pressure in a well (Reservoir G4).

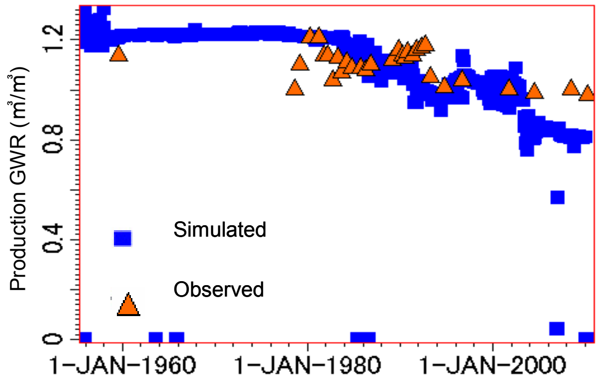

Fig. 8 The result of history matching of production GWR in a well (Reservoir G4).

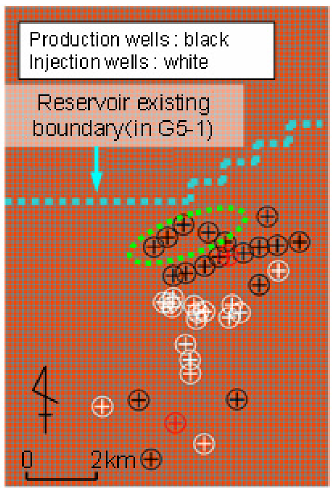

Fig. 9 The map of the production area (Reservoir G5).

The disagreement in the model was found in the production GWR near the reservoir boundary (Fig. 9). Because sand was produced from the reservoir to some of the injection wells through the open intervals, the lower part of the injection wells were plugged by sand. Because of this sand trouble, groundwater is mainly injected into the layer G5. If there is a connection between G5 and

G5-1, the groundwater of the G5 could have invaded to the G5-1. Therefore, it is important to estimate where the connection exists. Because the production GWR steeply dropped in the wells near the reservoir boundary, it was infered that the connection between G5 and G5-1 exists near the reservoir boundary.

After some trial and errors of history matching, the shape and the width of connection was decided as shown in Fig. 10 and Fig. 11. In southern part of the production area, upper four layers were regarded as G5, and lower five layers were regarded as G5-1. However, only the upper five layers of G5 exist in the northern part.

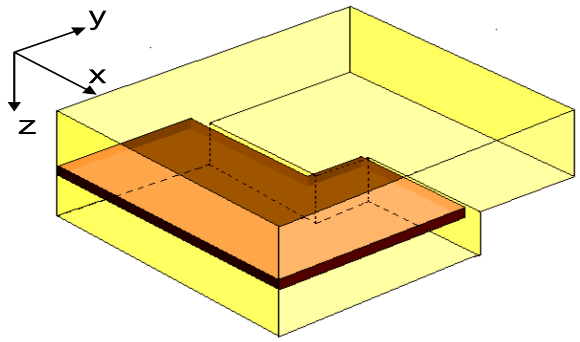

Fig. 10 Conceptual model of G5 which has a connection.

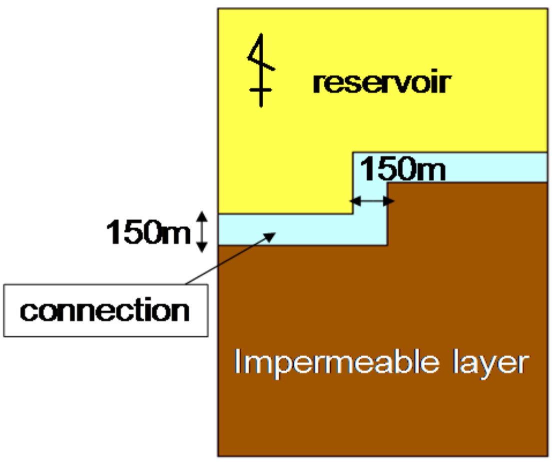

Fig. 11 Plain view of the conceptual model of G5.

Fig. 12 shows the result of history matching of production GWR in a well, one without connection (CASE1) and the other with connection (CASE2). In CASE1, production GWR did not drop in the 1990 though the ovserved data showed a decrease. On the other hand, produced GWR showed good matching in CASE2.

This results show that there would be a connection between G5 and G5-1 in the northern part of prodcution area. Because the injected water moved into G5-1 through the connection, the groundwater of G5-1 has been gradually diluted by the groundwater of G5. Since the reservoir pressure was also matched, the numerical simuration model is considered to have reasonable accuracy (Fig. 13).

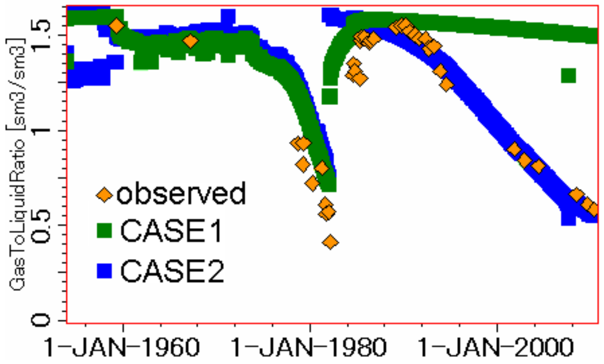

Fig. 12 The result of history matching of production GWR (Reservoir G5).

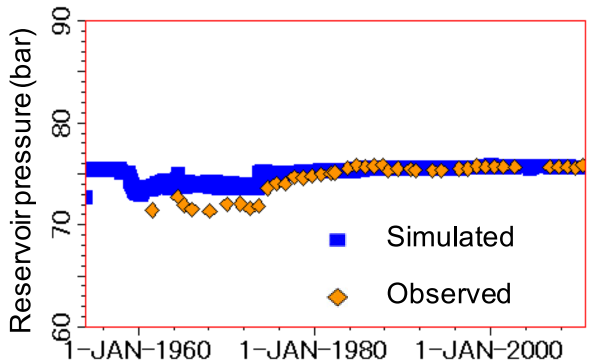

Fig. 13 The result of calculation of reservoir pressure (Reservoir G5).

4.3. Reservoir G6

In the history matching, the production GWR dropped too fast in some wells. This problem occured because the production and injection depth changed due to the sand production in each well. A field survey showed that almost all of injection wells were partly plugged by sand. In particular, some injection wells were plugged more than 30 % of the open intervals. To reproduce this trend, the layer 3 was defined as an impermeable layer.

The results of history matching in a well were shown in Fig. 14 and Fig. 15. The SGWR in the lower part of the reservoir showed no decrease because the upper part of the reservoir was selected as the injected zone due to the sand trouble. In the process of production, the groundwater in upper and lower zone was mixed and the production GWR was kept about 0.5 SCM/SCM from the 1980 as shown in Fig. 15.

Because both reservoir pressure and production GWR matched well for G6, the validity of the G6 model was confirmed.

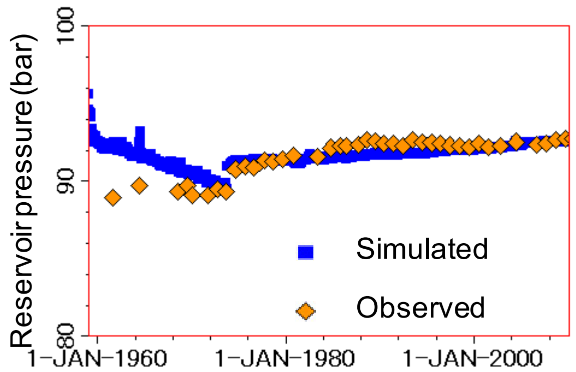

Fig. 14 The result of history matching of reservoir pressure in a well (Reservoir G6).

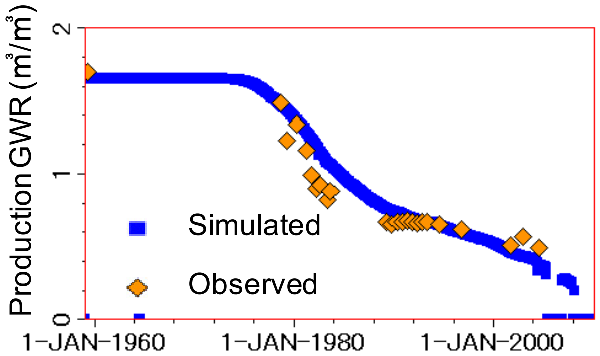

Fig. 15 The result of history matching of production GWR in a well (Reservoir G6).

5. Conclusion

Using a black oil reservoir simulation soft, ECLIPSE100, numerical simulation models were developed for the main reservoirs, G4, G5 and G6 in Nishikanbara water-dissolved gas field, Niigata, Japan. For developing these simulation models, petrophysical properties and geological information were input to the models. To obtain good matching results, absolute permeability of the rocks, initial distribution of solution GWR and the porosity of outermost grids were treated as the matching parameters.

In the history matching, the trend of decreasing solution GWR and the change of reservoir pressure were reproduced with good accuracy. Through the history matching, it is estimated that there is a connection between the layers G5 and G5-1, and also there is an impermeable barrier between the upper and lower zone of G6.

References

1) S. Marsden, in *the Future of Energy Gases, U.S. Geological Survey Professional Paper 1570*, ed. by D. G. Howell, United States Government Printing Office, Whashington, p. 383 (1993).
2) S. Akibayashi, K. Karube and J. Hara, *Journal of the Japanese Association for Petroleum Technology*, **51**(3), 42 (1986).
3) T. Nishida and K. Aoki, *Journal of the Mining Institute of Japan*, **97**(1115), 13 (1981).
4) Japan Natural Gas Association, *Handbook of Water-Dissolved Gas (Suiyousei tennengasu souran)*, p. 101 (1980). (in Japanese)