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Study of the Optimal Exploitation and Reinjection in the Dongying Geothermal Reservoir in Tianjin Binhai Area, China

Lei Haiyan and Zhu Jialing

Tianjin Geothermal Research & Training Centre, Tianjin University, Tianjin 300072, China

Leihy1216@yahoo.com

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ABSTRACT

A physical and mathematical model of the Dongying geothermal reservoir in Tianjin Binhai Area, China was set up to study the effects on the pressure and temperature distributions of the porous geothermal reservoir under different exploitation-reinjection patterns using AQUA3D. The results indicate that reinjection is an effective way to slow down the pressure drop and prolong reservoir life, as well as to make an effective use of the geothermal resources. What was learned could be used for guiding the development of the geothermal resources in Tianjin Binhai Area.

1. INTRODUCTION

Tianjin Binhai Area is located in the north of China plain, in Shandong Peninsula and the intersection of Liaodong Peninsula. Tianjin Binhai Area has rich natural resources, such as petroleum, natural gas, crude salt, topography, marine etc. Tianjin Binhai Area has the planning area of 2270 km^2 including three functional areas: the Tianjin Port, development zones and bonded all; and 3 Administrative Region: Tangu District, Hangu District, City latter part. Fig.1 gives the map of Tianjin Binhai Area.

Although geothermal development has a long history in Tianjin city zone, China (Wang, 2000), and reinjection has also been carried on step by step due to pressure declining of the reservoir, geothermal energy in the Dongying reservoir in Fig.1. Tianjin Binhai Area has almost not been exploited yet until now. In order to make an efficient development of the limited geothermal resources, it is necessary to study the heat transfer, heat flow distribution and regional temperature in the Dongying reservoir, as well as to predict the pressure and temperature distribution under different exploitation patterns so as to optimize the geothermal development.

Figure1: Location of Tianjin Binhai Area

2. GEOLOGICAL AND MATHEMATICAL MODEL IN THE DONGYING RESERVOIR IN TIANJIN BINHAI AREA

2.1 Geological Model of the Porous Reservoir

The top of the Dongying porous reservoir is composed mostly of sandstone and in stratified distribution with loose structure, high porosity and low density, the average porosity is 25.54 %. The total area of the Dongying reservoir is about 889.72 km^2, with bottom depth of 1650-2630 m and average thickness of 100-830 m.

2.2 Mathematical Model of the Porous Reservoir

2.2.1 Initial conditions

Initial conditions include initial pressure and temperature distributions. Right now there is only one geothermal production well (Tan 20-2) and around 39 oil wells in Tianjin Binhai Area. The initial pressure and temperature distributions in the Dongying reservoir are available according to the data supplied by Petroleum Department.

2.2.2 Boundary conditions

According to the hydrology and geology analysis, the west part of Dongying reservoir was absent, which was set to impervious boundaries, north area was set to supplement boundary, east area is near to the sea, and south is saline, which are all set to discharge boundary.

2.2.3 Determination of reservoir parameters

In numerical model of the Dongying geothermal field, a triangle grid system covers an area of 889.72 $km^{2.}$ Permeability coefficient of 5×10-9 m/s, porosity of 25%, density of 2000 kg/m^3, specific heat of 1209 J/kg.℃, storage coefficient of 7.6×10-4 m-1 were given to the rock according to the local hydrology and geology characters (Enrique and Toshiaki, 2000). Because the vertical permeability data is not available, 1/10 of the horizontal one was given according to some experimental data (Zhu and Wang, 2006), which may cause in tiny error to the simulation results.

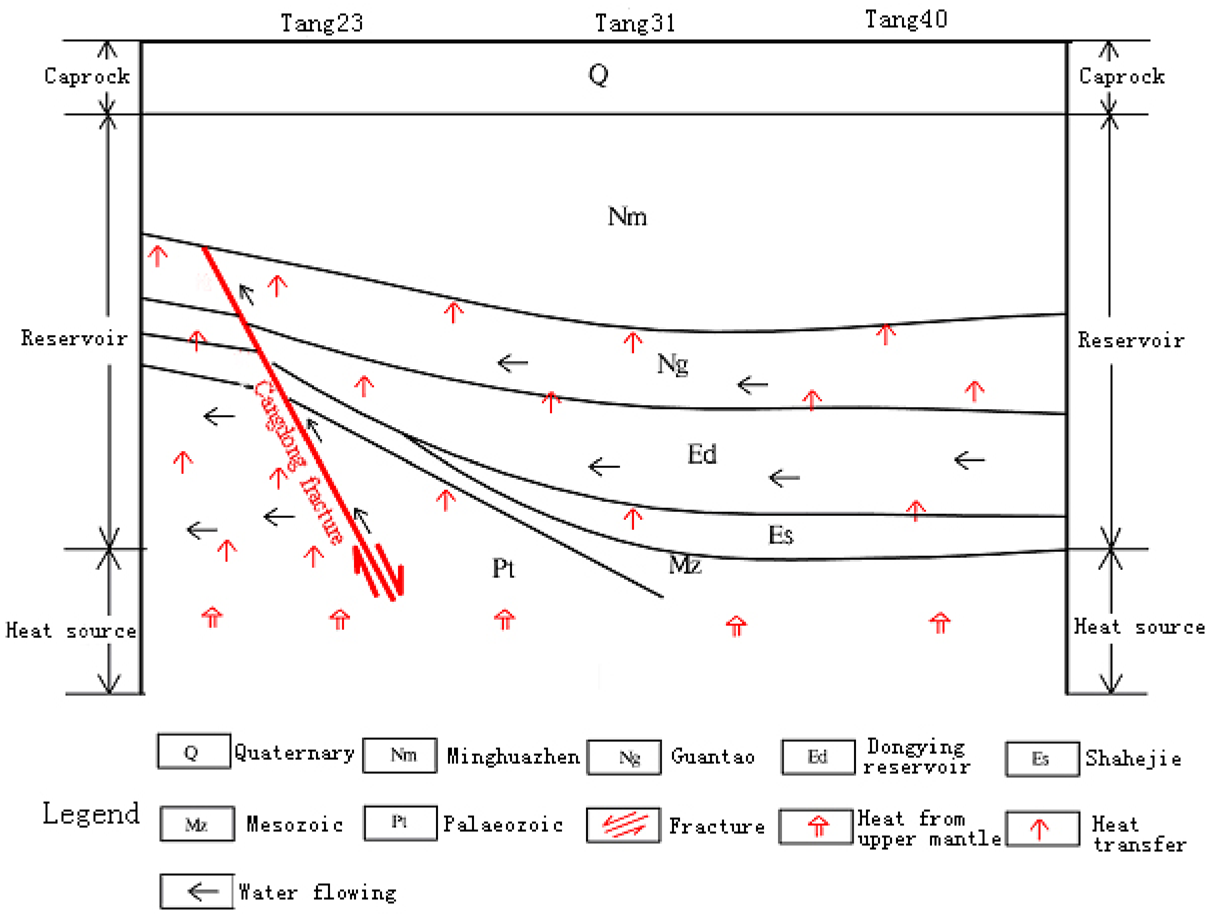

Figure2: Geological model of the Dongying reservoir

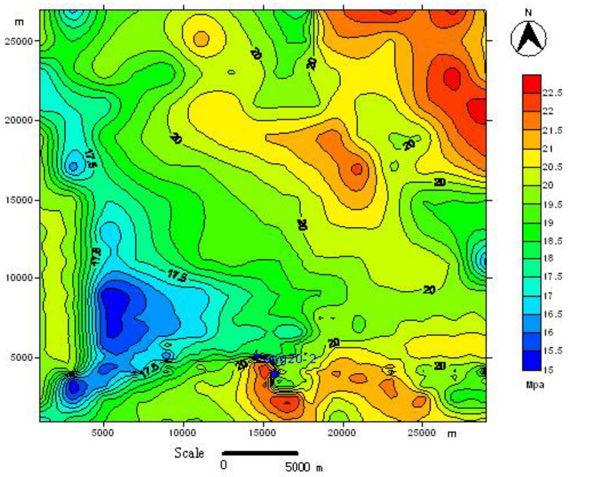

Figure 3: Pressure distributions in the Dongying reservoir at 1900 m in depth

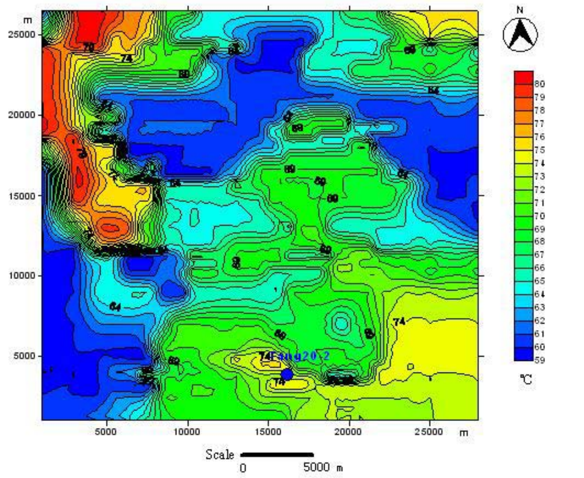

Figure 4: Temperature distributions in the Dongying reservoir at 1900 m in depth

2.2.4 Meshwork and time step

AQUA3D was used here for modeling the pressure and temperature distributions in the Dongying reservoir, 2-D triangle mesh was made based on reservoir formation, geological and drilling information (Fig.5), the well location was set on the triangle node (Kiryukhin and Yampolsky, 2004) and time step was set to one day.

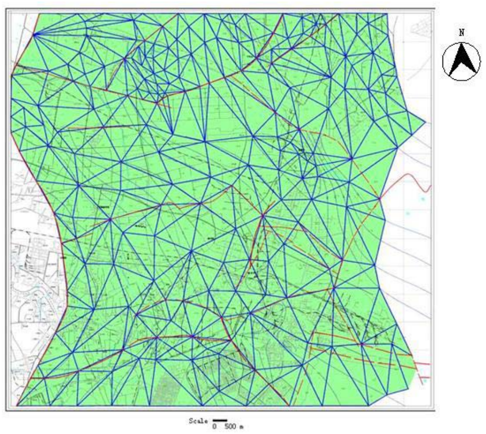

Figure 5: Meshwork in the Dongying reservoir

3. POTENTIAL PREDICTION AND OPTIMIZATION OF GEOTHERMAL EXPLOITATION AND REINJECTION

3.1 The Influence of Production & Reinjection on Pressure Distribution in the Dongying Reservoir

3.1.1 Case 1 (one production well Tang 20-2)

Mass flow of Tang 20-2 well is 60 m^3/h during heating period in the next 5 years and only 5-10 % of the mass flow for tap water during non-heating period. The initial static water level is -20.5 m based on pumping test.

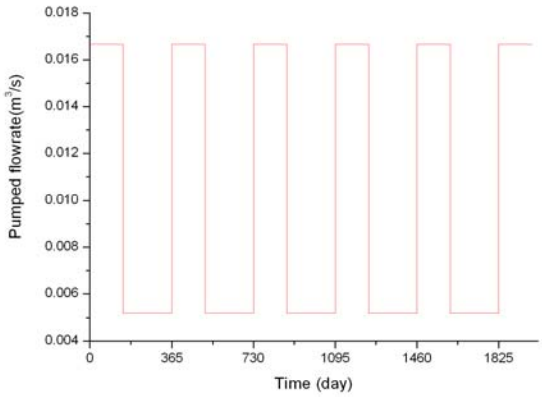

Figure 6: Annual pumping-up data of Tang 20-2 well

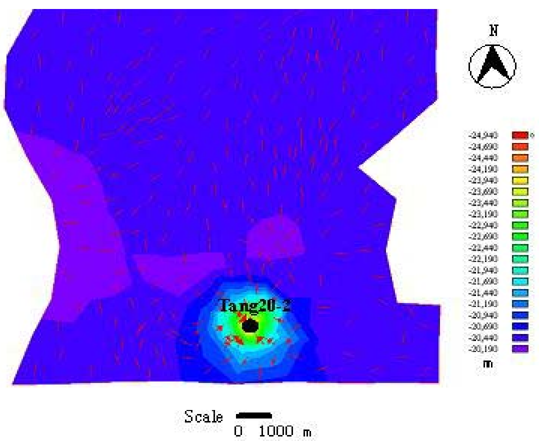

Figure 7: Case 1: Water level predication in the Dongying reservoir in the 5th year

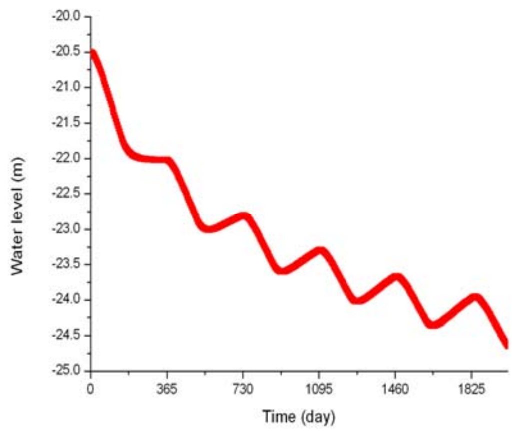

Figure 8: Case 1: Water level drawdown prediction in Tang 20-2 well

It can be seen from Fig.7 and Fig.8 that water level of Tang 20-2 well will decrease from -20.5 m to -25 m after 5 years if there is only one production well in the geothermal zone, and annual average water level drawdown is 1.1 m. Fig.8 shows that for the single production well system, radius of water level drawdown area due to reservoir pressure decrease extends continuously with the time elapsed.

3.1.2 Case 2 (group production wells)

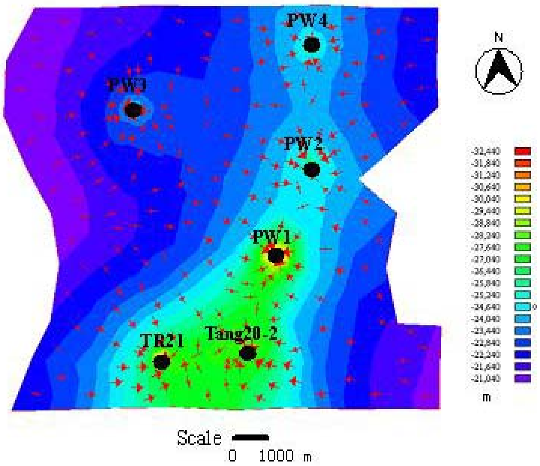

Figure 9: Case 2: Water level predication in the Dongying reservoir in the 5th year

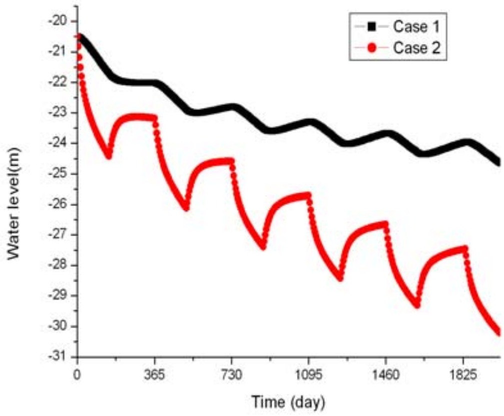

Figure 10: Comparison of water level drawdown of Tang 20-2 well between Case 1 and 2

In order to predict the dynamic exploitation in the DONGYING reservoir, 5 additional production wells were added based on Case 1, Mass flow of each well is around 60 m^3/h and initial static water level is -20.5 m. Temperature and pressure declines after 5 years in the Dongying reservoir were analyzed and predicted.

Fig.9 and Fig.10 show the water level declines to -32.4 m around PW1 after 5 years and annual average water level drawdown is 2.4 m when 6 production wells are operating in the geothermal zone. It is obvious that water level decreases significantly when more production wells added.

Based on Case 2, 6 corresponding reinjection wells were added, thus 6 doublets are constituted in Case 3. The ratio of volumetric flow between reinjection and production were set to 0.5:1 and 0.7:1 respectively and 20□ geothermal backwater was re-injected. Pressure and temperature distributions after 5 years were analyzed.

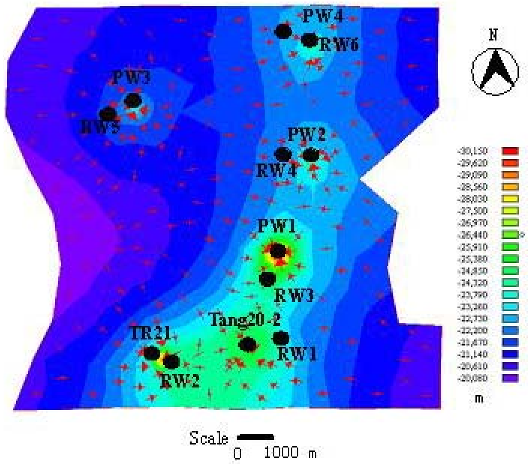

Figure 11: Case 3: Water level prediction in the Dongying reservoir in the 5th year (50% reinjection)

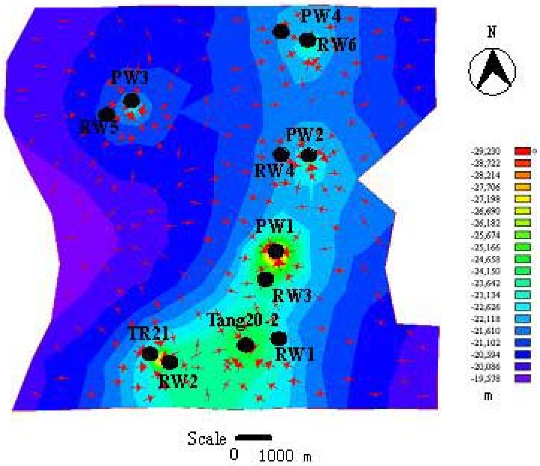

Figure 12: Case 3: Water level prediction in the Dongying reservoir in the 5th year (70% reinjection)

The calculation result in Case 3 shows that water level decreasing becomes slower compared to that of Case 2. Until 5 years later, the water level around PW1 will change from -32.44 m (Case 2) to -30.15 m (Case 3) with 30 m^3/h reinjection volumetric flow and rise to -29.23 m as reinjection volumetric flow increase to 42 m^3/h.

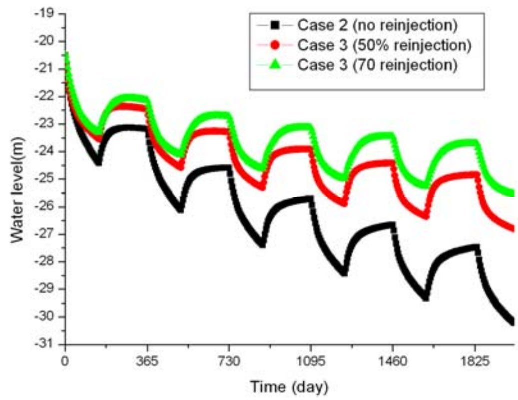

Figure 13: Case 3: Comparison of water level decline of Tang20-2 well between Case 1 and 2

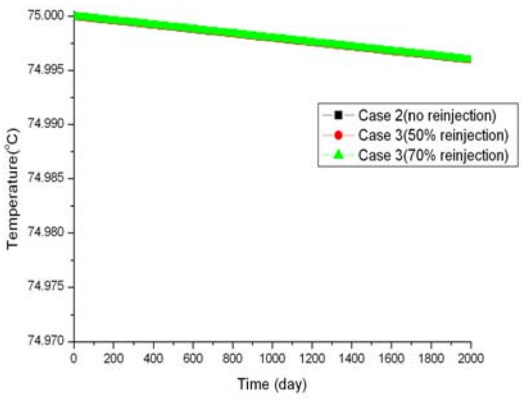

Figure 14: Temperature distribution prediction in the DONGYING reservoir under Case 2 and 3

3.2 The Influence of Production & Reinjection on Temperature Distribution in the Dongying Reservoir

Isotherms are the basic information to determine the initial temperature distribution of the Dongying reservoir. The average temperature of every node can be obtained by superposing meshwork and isotherms.

Initial temperature distribution of the Dongying reservoir in 2006 was given according to the water temperature in the wellhead and bottom of Tang 20-2 well (Fig.4). In order to study the influence of continuous exploitation on reservoir temperature distribution, it is assumed that only one production well is available in the Dongying reservoir in the next 5 years, thus reservoir temperature distribution was analyzed based on Fig.4.

The temperature distributions in the Dongying reservoir under three different cases are similar by simulation (see Fig.14). It can be concluded that the geothermal exploitation-reinjection system affects reservoir pressure distribution obviously but the influence on the temperature distribution effect on the latter can be neglected during 5 years.

4. CONCLUSIONS

Simple production well system will result significant reservoir pressure decline. In the Dongying reservoir of Tianjin Binhai Area, the annual water level drawdown are 1.1 m in Case 1 and 2.4 m in Case 2, the annual water level drawdown are 1.9 m with 50% reinjection and 1.7 m with 70% reinjection in Case 3, which indicate that geothermal exploitation-reinjection systems are more benign for geothermal resources. Geothermal reinjection could slow down the water level declines, prolong reservoir life and utilize geothermal resources effectively. The results can be used for guiding the geothermal development for the management department.

REFERENCE

Wang Kun: Reservoir evaluation for the Wuqing geothermal field, Tianjin, China, *Proceedings of World Geothermal Congress*, Japan (2000).

Enrique A. Porras and Toshiaki Tangaka, Numerical modeling of the Momotombo geothermal system, Nicaragua. *Geothermics,* 36, (2000), 304-329.

Zhu Jialing, Wang Kun and Lei Haiyan: The study on optimal exploitation scenario of reinjection abound periphery of geothermal zone, *ACTA Energiae Solars Sinica*, 27, (2006), 794-799.

Alexey V. Kiryukhin, Vladimir A. Yampolsky: Modeling study of the Pauzhetsky geothermal field, Kamchatka, Russia. *Geothermics*, 33, (2004), 421-442.