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The Reinjection Research of Dongli Lake Bedrock Reservoir in Binhai New Area, Tianjin

Chuanxia Ruan, Baocheng Sun, Jian Shen, Xinzhi Gao, Rongguang Liu

Tianjin Geothermal Exploration and Developent Designing Institute, Tianjin, China

rchx12@sohu.com

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ABSTRACT

Wumishan reservoir has rich fissures with high water yield property and good water quality, and is the major development and utilization thermal reservoir in Dongli Lake Area, Tianjin. Currently, this area has 11 Wumishan geothermal wells, the static water level is about 110m, and the deepest water level reaches about 129m. For the large-scale development, the static water level showed the trend of dropping year by year, which the annual drop was 3m/a. In order to prevent dropping the water level, the area used the processed lake water to a centralized reinjection test during the high water period to construct the centralized reinjection system. Reinjection test was conducted to confirm the thermal reservoir parameters, which the geothermal well max reinjection volume was $152m^3/h$. We adopted TOUGH2.0 simulation software in order to forecast the reservoir pressure and temperature under the reinjection condition. The results showed that the groundwater reinjection can prevent dropping the rate of pressure without obvious influences on the temperature.

1. INTRODUCTION

The scope area in this study is Dongli Lake, Tianjin Binhai New Area, and the area is 67.84 km^2 (Figure 1). This study area has several reservoirs with advantages in geothermal resources and is the first “Chinese Hometown of Warm Spring” in China. Geothermal resource provides clean energy for space heating, bath demands of local residents, and planting and breeding industries. The study area exists rich geothermal resources, and geothermal resources have become the backbone energy for local area because of high degree development and utilization and high independence on the geothermal resources. There are rich groundwater resources with high supply amount during high water period. Therefore, it has advantages of natural conditions to promote surface water centralized reinjection test in local area.

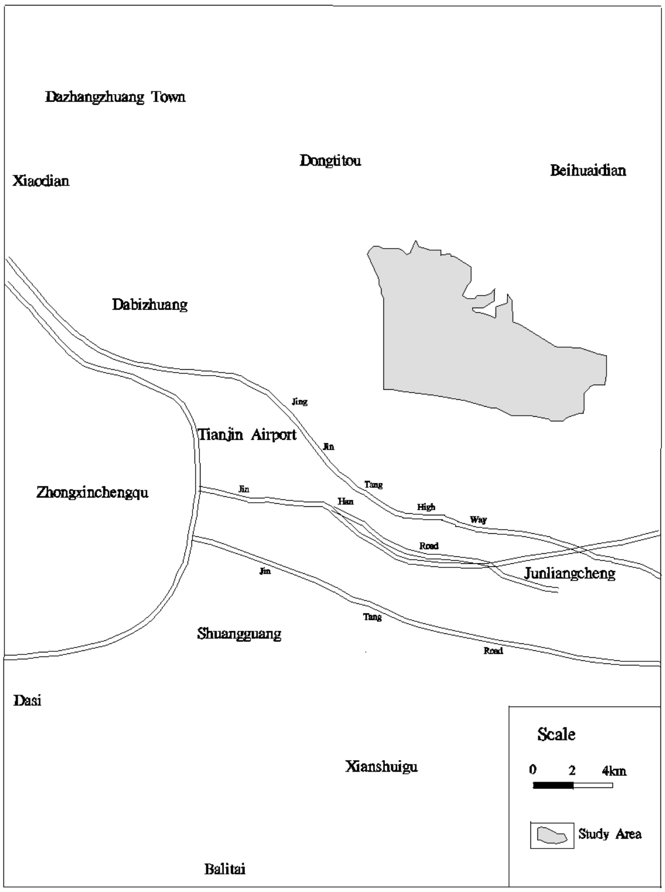

Figure 1: The scope area in this study.

2. GEOTHERMAL GEOLOGICAL CONDITIONS

2.1 Structure characteristics

The study area is located at the northeast side of the Shanlingzi Geothermal Field, and the structural location settles at the west side of the Panzhuang uplift at the IV grade structure unit in Cangxian uplift, which is III grade structure unit. Panzhuang uplift is the strip area in plane which shows the NE direction spread to the northwest and southeast of the Tianjin fault and Cangdong fault zone and Wuqing depression and Beitang depression to the south of Shuangyao uplift with the boundary at Haihe fault. The internal bedrock surface of Panzhuang uplift is high in the south and low in the north with uplift in part, it doesn’t have Neogene System Guantao Formation, Paleogene System and Mesozoic, Cainozoic underburden Cainozoic - Neoproterozoic Erathem. The depth of bedrock top layer is1200-1900m (Figure 2).

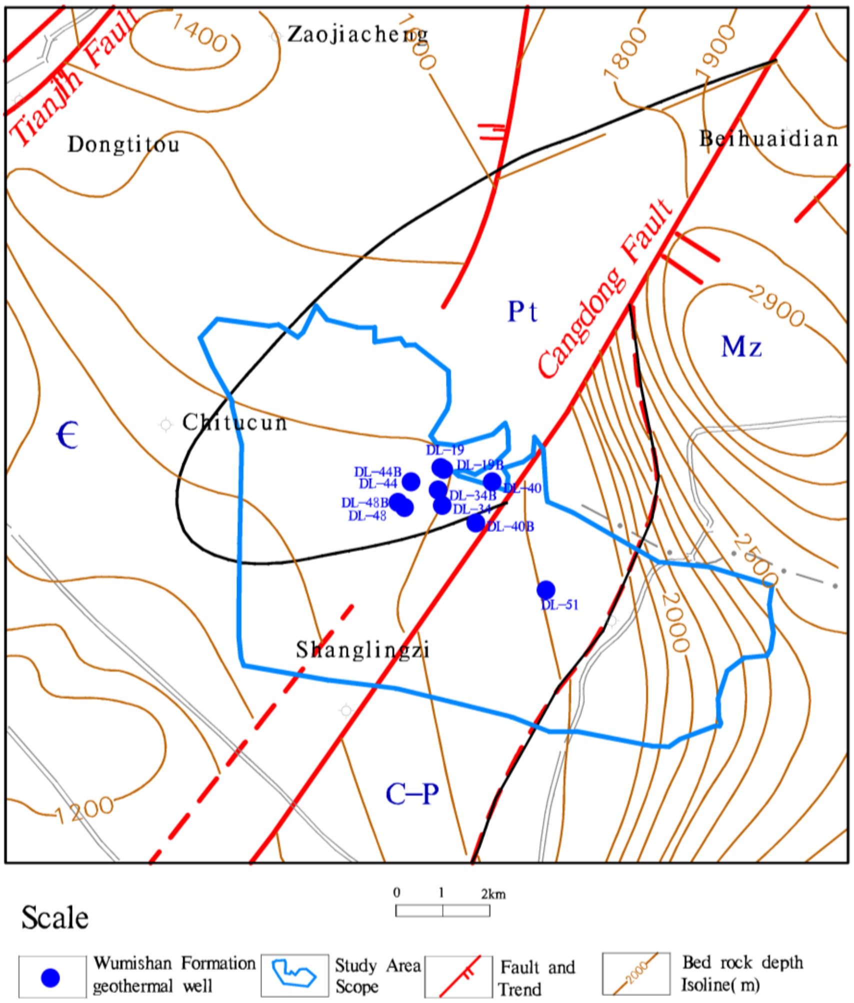

Figure 2: Bedrock geology map of study area.

2.2 Temperature field characteristics

The horizontal temperature distribution has direct relation with the aigneous activity, geological structure characteristics and hydrology geological conditions. The geothermal gradient along the fault structural zone and bedrock uplift area are relatively high. The geothermal anomaly area of geothermal gradient equivalent line trap is mainly controlled by the NNE direction Cangdong fault zone, and the main body direction spreads along the NNE direction. The geothermal gradient gradually drops from the fault zone to both sides, which drops from 5.0 °C/100 m to 3.0 °C/100 m. In the north part of the work area near Jiacheng, the geothermal gradient reaches 5.0 °C /100 m (Figure 3).

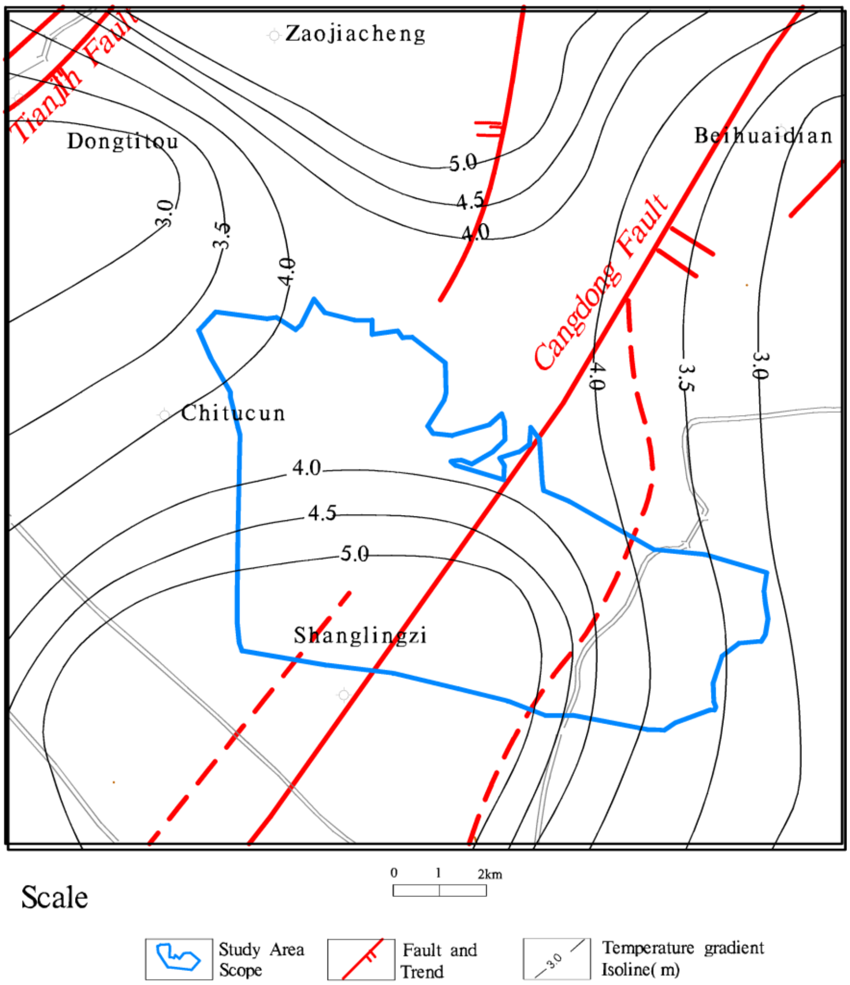

Figure 3: Cap formation average geothermal gradient near the study area.

2.3 Chemical field characteristics

The water quality types of Wumishan formation thermal reservoir in this study area are mainly $HCO_3 \cdot Cl \cdot SO_4$-Na and $HCO_3 \cdot Cl$-Na, the mineralization degree is 1600-2200mg/L, the mineralization degree of the geothermal well near the Cangdong fault zone doesn't have serious difference. The farther to Cangdong fault zone, the higher the mineralization degree of geothermal well. The pH value of the geothermal fluid 7.1-8.3 is the light-strong corrosive geothermal fluid.

Table 1: Thermal Reservoir Characteristics in the Study Area.

Reservoir	Top depth(m)	Thickness	Single well rate(m^3/h)	Temperature(°C)	Total dissoloved solids (mg/l)
Nm	280-320	950	30-100	45-75	700-2000
Ng	1420-1530	360-440	50-80	65-75	1600-1800
O	1674-2630	22-419	85	96-99	1600-2800
∈	1550-2470	80-300	80-120	75-96	1700
Jxw	1600-2000	500-600	80-120	96-102	1600-2200

3. GEOTHERMAL RESOURCES DEVELOPMENT AND UTILIZATION SITUATION

The geothermal exploited well in this study area has centralized distribution, currently, the work area has 18 geothermal wells, including one Wumishan Formation geothermal well, five exploited wells, and six reinjection wells. In 2012, the total pumping rate was 140.7×10^4 m^3, and total reinjection rate was 119.9×10^4 m^3. Since the Jixian County Wumishan Formation thermal reservoir is the targeted layer for the major exploitation and reinjection in the local area and even the Shanlingzi geothermal field, the reinjection well is also Wumishan Formation thermal reservoir geothermal well. Therefore, the followings are the analysis on its thermal reservoir current status of exploitation. In recent years, the Wumishan Formation thermal reservoir still water level buried depth shows the trend of dropping year by year, according to the 2012 dynamic monitoring documents, this area Wumishan Formation still water level buried depth is about 110m, the annual drop is 3m/a. Figure 4 is the Wumishan Formation geothermal well still water level buried depth information in the work area. It is known from the drawing that the annual drop of some wells has exceeded 3m. The water level showed an obvious drop. The max water level buried depth has reached about 129m.

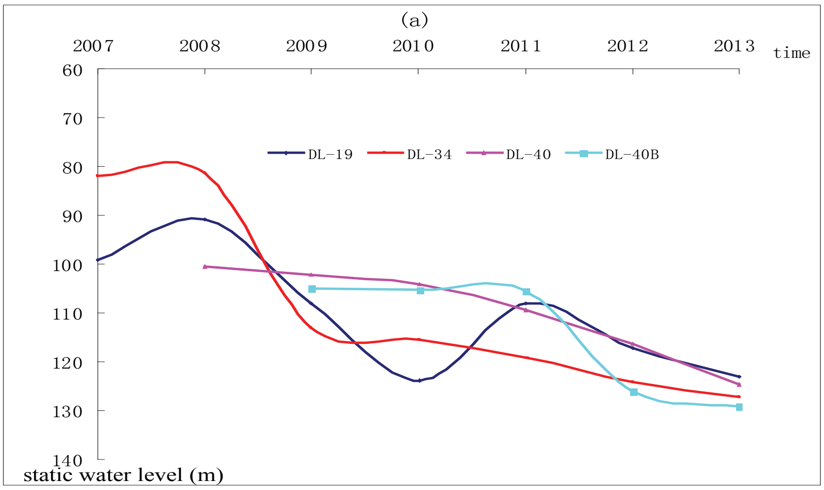

Figure 4: Wumishan formation geothermal well static water level buried depth change trend in the study area (20 °C fluid surface).

4. REINJECTION WELL CONSTRUCTION AND TEST

4.1 Reinjection well construction

This study area constructed one reinjection well (H-1). The targeted layer was Wumishan Formation thermal reservoir. The well depth was 2495m. The targeted layer was 671m.

4.2 Reinjection test

Before reinjection test, the still water level buried depth of H-1 well was measured, which was 112.14m. The corresponding fluid temperature is 25 °C (Table 2).

Table 2: Reinjection test record.

Test items	stable reinjection volume (m^3/h)	reinjection water temperature (°C)	stable dynamic water level (m)	stable duration (h)
Stage 1	60	21.5	107.6	19
Stage 2	80	20.6	96.6	30
Stage 3	100	19.8	77.6	100
Stage 4	120	19.2	48.9	120
Stage 5	140	14	20	60

4.3 Reservoir parameters

It was assumed that the current thermal reservoir fluid was stable. The value of ΔH was set to 112.94m according to the P-ΔH relation graph (Figure 5). The absorption rate was 0.015m^3/d·m^2, which means when the dynamic water level is 0 m. When the geothermal water was used for reinjection, the max theoretic reinjection volume of H-1 geothermal well was 146m^3/h. On the other hand, when the surface water was used for reinjection, the max theoretic reinjection volume of H-1 geothermal well was 152m^3/h.

5. INFULUENCE OF REINJECTION TO RESERVOIR

5.1 Geothermal geological model

According to the geothermal geological conditions in the work area, a geothermal geologic model can be generalized with heat source (heat production layer), thermal reservoir, cap formation, heat transfer direction, heat control, heat accumulation structure (Figure 6).

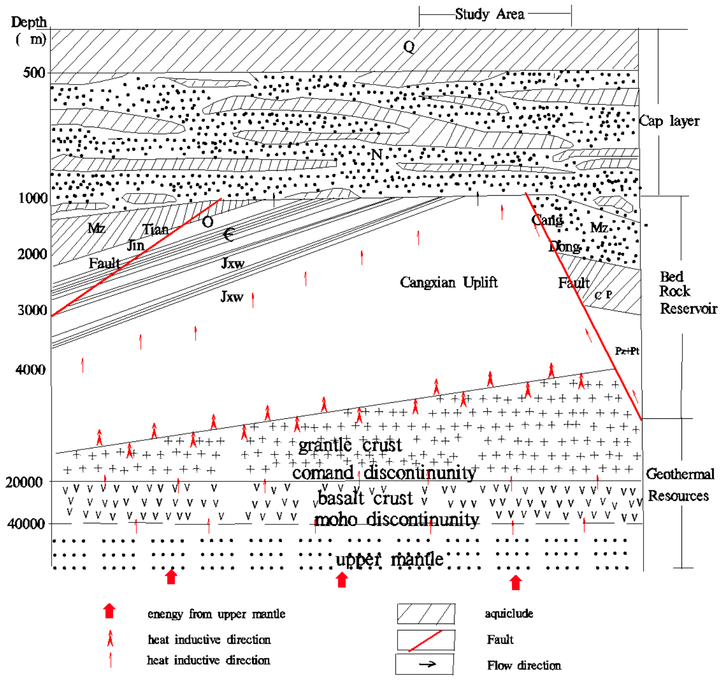

Figure 6: The geothermal geological model of study area.

Combining with the Wumishan thermal reservoir rock characteristic, the fluid characteristic, the structure property, and the stratum in the work area, the numerical model of the work area with TOUGH2.0 software was generated to analyze the initial condition and boundary condition of the model, to differentiate the parameters of Wumishan thermal reservoir, and then to identify the model. By using the monitoring data of the lake water reinjection, the influence of the lake water reinjection on reservoir temperature and dynamic field were simulated. The simulated results were compared with the actual monitoring data, and then the distributions of dynamic field and temperature field in the work area were predicted under the reinjection condition at a certain mode with confirmed time condition.

Currently, Wumishan Formation thermal reservoir is the major exploitation and reinjection targeted layer in the study area. The targeted layer of two reinjection wells for this project work is also Wumishan Formation thermal reservoir. In order to simulate migration and exploitation dynamic of this thermal reservoir geothermal fluid, we formed the complete zone with the numerical model scope as the fault boundary of the geothermal field, the work area is the key area. extends to Hangu fault in the north, natural flow boundary in the south, Tianjin fault in the west, Cangdong fault zone in the east, and the total area is about 347 km^2 (Figure 7).

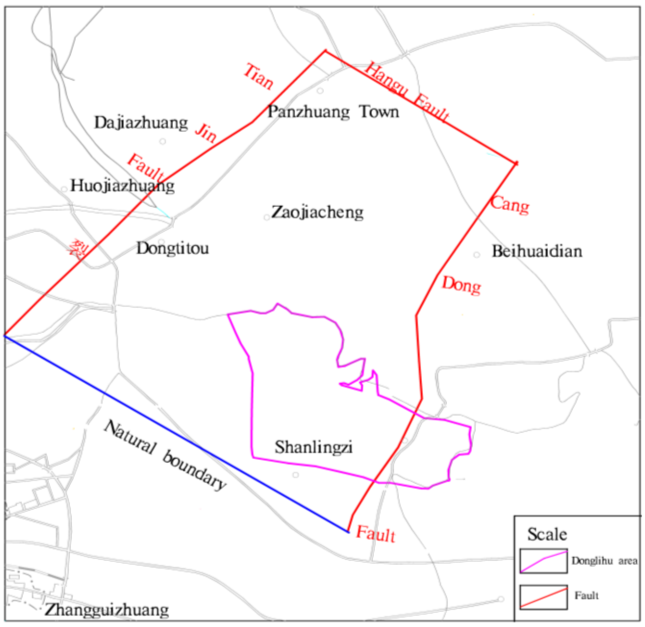

Figure 7: the Scope of the Study Area.

5.2 Reinjection influence on pressure field

According to the above mathematical model, we forecasted the dynamic field of the study area, shown in Figure 8. The lake water reinjection test was conducted for 35 days from September 27th to October 31st, 2013, and the total reinjectiond surface water reached 66,000m^3. The reinjection test was divided into 5 teams: reinjection volumes are 60m^3/h, 80m^3/h, 100m^3/h, 120m^3/h and 140m^3/h. When the max reinjection volume was 140 m^3/h, the stable dynamic water level was about 20m, and the water level of recovery value is about 93.6m. The reinjection test information is shown in Table 3.

Table 3: Lake water reinjection test information.

Height of Fall	Water Volume (m^3/h)	Dynamic Water Level (m)	Duration (h)	Water Temperature (°C)	Still Water Level (m)
1st Height of Fall	60	107.6	21	21.5	113.58 (20℃fluid level)
2nd Height of Fall	80	96.6	49	20.6	
3rd Height of Fall	100	77.6	142	19.8	
4th Height of Fall	120	48.9	229	19.2	
5th Height of Fall	140	20	81	14	

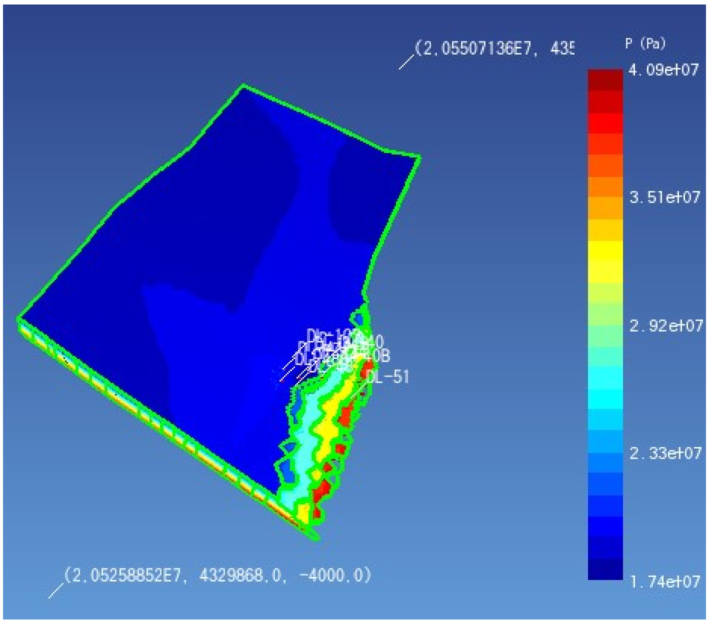

Figure 8: Study area dynamic field before lake water reinjection.

It is shown from the pressure test data and simulated result that 1 month after reinjection, the thermal reservoir pressure increased lightly. It suggests that the centralized reinjection can prevent dropping reservoir pressure effectively and ensure the sustainable development and utilization of geothermal resources, particularly in the centralized exploitation area with rich surface water. The surface water centralized reinjection mode may be adopted for maintaining the thermal reservoir pressure.

We simulated the influence of lake water reinjection on thermal reservoir dynamic field in the future with this numerical model. The reinjection mode included heating season and non-heating season. The heating season reinjection volume was 30×10^4 m^3/a. The average heating season was 120 days. The reinjection water temperature was 20 °C. For non-heating season, reinjection volume was 40×10^4 m^3/a. The average high water period was 120 days. The reinjection water temperature was 20 °C. Other geothermal wells were kept the original exploitation and reinjection condition. The features of dynamic field of the study area after 1 year and 5 years under the condition without lake water reinjection and with lake water reinjection were predicted (Figure 9 and Figure 10).

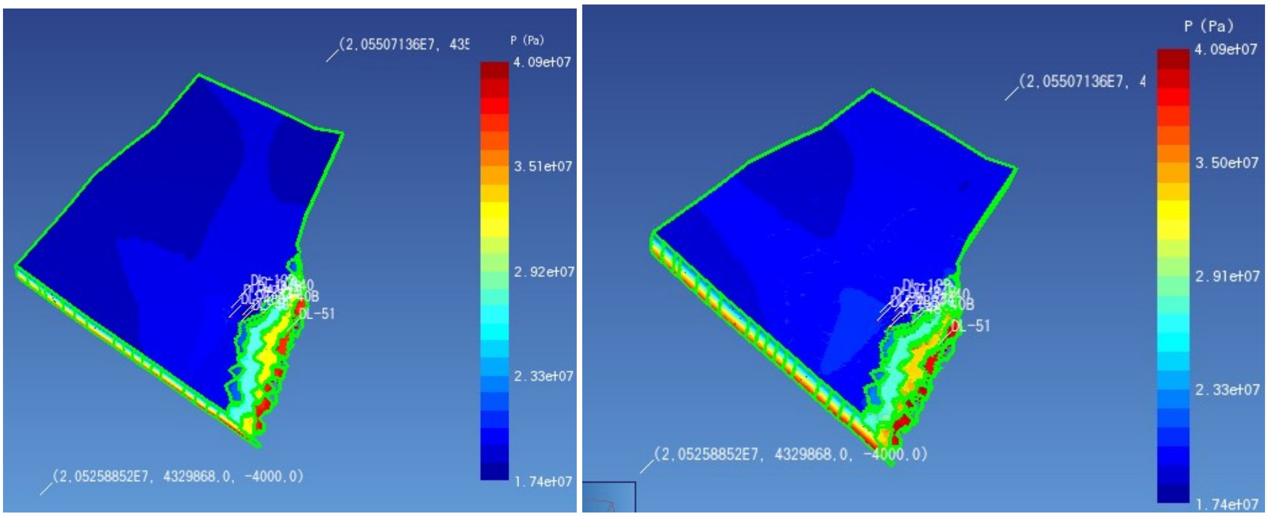

Figure 9: Dynamic field of the study area one year (Left) and five year (Right) after geothermal fluid reinjection.

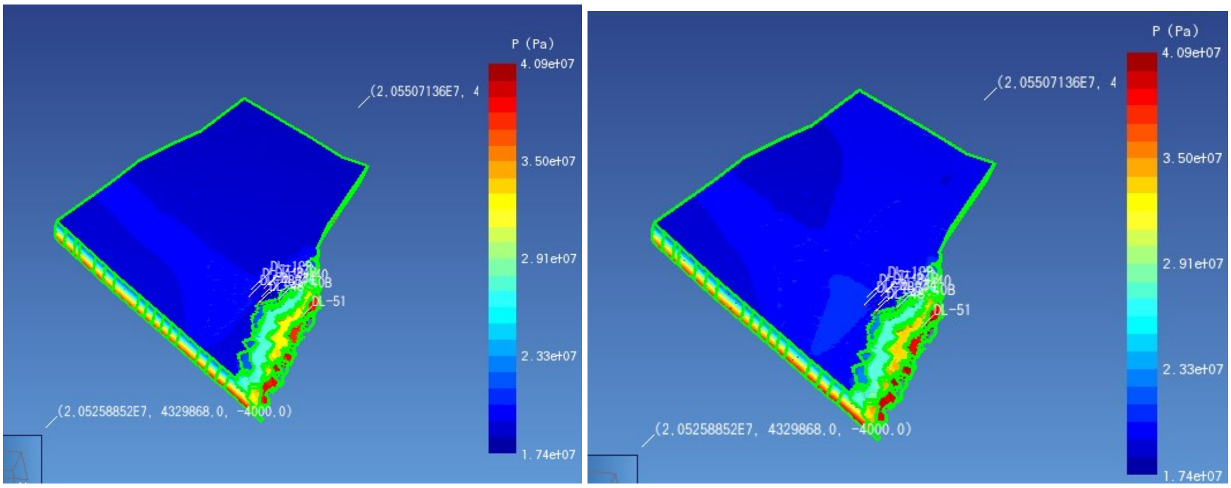

Figure 10: Dynamic field of the study area one year (Left) and five year (Right) after reinjection of lake water and geothermal fluid.

It is shown in Figure 9 and Figure 10 that after increasing the lake water reinjection, compared with the single geothermal fluid reinjection, the pressure of DL-48B well Wumishan Formation thermal reservoir may increase from 20.65MPa to 20.70MPa afer 5 years, which means that the drop is prevented by 0.01MPa every year. It is shown that the reinjection can prevent dropping of pressure. If the reinjection is carried out persistently, it can promote sustainable development of the geothermal resources.

5.2 Reinjection influence on temperature field

Figures 11 and 12 show the temperature distribution in the study area before the lake water is injected. Figures 13 and 14 show the temperature field distribution after the lake water is injected. According to the simulated results, after lake water reinjection, the temperature in the bedrock section had the trend of temperature drop, which was 0 - 0.58 °C. The major reason was that the temperature test was undertaken instantly after reinjection, and the reinjection fluid doesn't have complete time for heat exchange. It is possible after a certain period that the reinjection fluid temperature in the bedrock may reach the thermal reservoir balance state, and recovers to the same state as before reinjection. Therefore, it requires forecasting the temperature change after reinjection fluid has entered into the thermal reservoir.

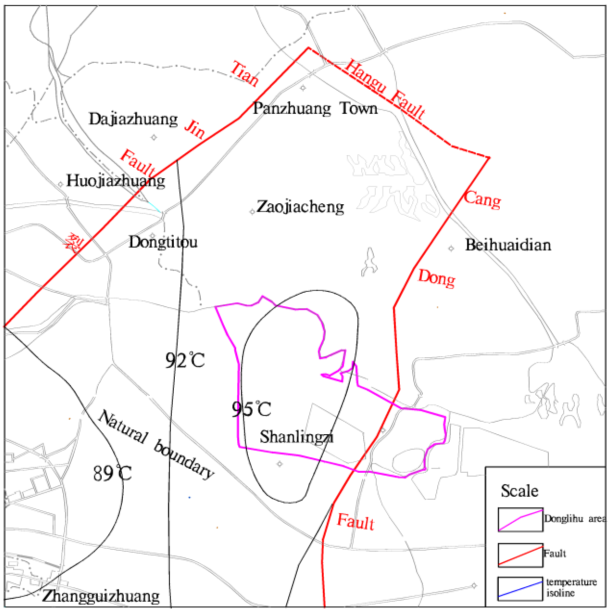

Figure 12: Study area stale flow temperature.

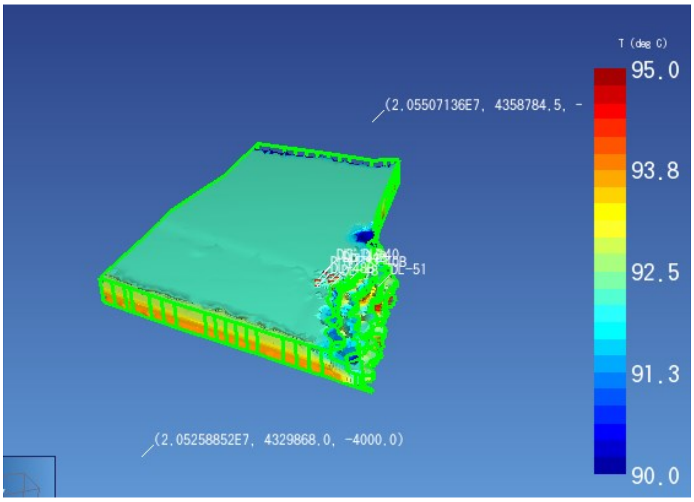

Figure 32: Study area temperature field before lake water reinjection.

We simulated the influence of lake water reinjection on temperature in the future with this numerical model. The reinjection mode includes heating season and non-heating season. In the heating season, the total reinjection volume was 30×10^4 m^3. The reinjection fluid temperature was 20 °C. For non-heating season, the total reinjection volume was $40\times10^4 m^3$. The reinjection water temperature was 20 °C. Other geothermal wells were kept the original exploitation and reinjection conditions. We forecasted the temperature of the study area under this reinjection condition 1 year and 5 years after reinjection (Figures 13 and 14). According to the data analysis of a single well, the temperature drop of H-1 was 0.01 °C after one year, while the temperature drop was 0.05 after 5 years.

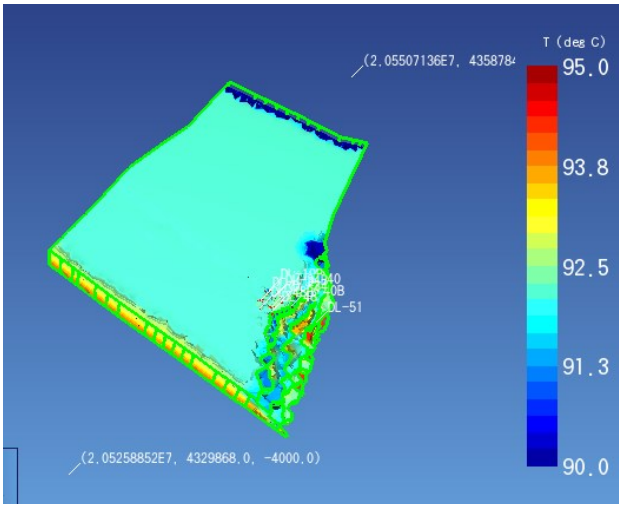

Figure 43: Temperature field in the study area after lake water and geothermal fluid reinjection after 5 years.

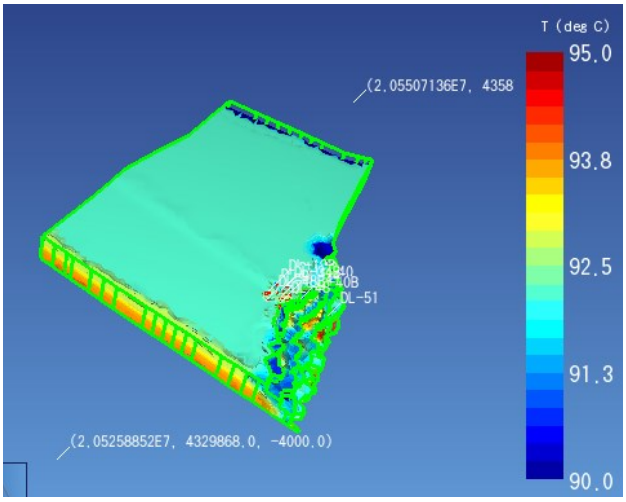

Figure 54: Temperature field in the study area after lake water and geothermal fluid reinjection after 1 year.

Therefore, according to the above forecasting, during the high water period, we can adapt the surface water to the reinjection in the local area. Wumishan Formation thermal reservoir effectively prevents dropping the pressure caused by large-scale development of geothermal resources. Additionally, the low temperature fluid doesn't have obvious influence on the reservoir temperature, therefore, the surface water reinjection won't cause adverse impact on the geothermal resources development and utilization in the local area.

6. CONCLUSION

According to the geothermal geological conditions in the study area, we excavated one Wumishan Formation geothermal reinjection well (H-1) promoted a reinjection test for this geothermal well, and confirmed that the max reinjection volume of this geothermal well was 140m^3/h.

On the basis of scientific geologic model, we adopted TOUGH2.0 simulation software in order to forecast the reservoir pressure and temperature under the reinjection condition. The results showed that within 5 years, the surface water reinjection can prevent dropping the rate of pressure by 1m/a. The results did not have an obvious influence on the temperature. The temperature drop at H-1 well was 0.01 °C after 1 year, while the temperature drop was about 0.05 °C after 5 years .

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