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The Sustainable Development and Utilization of Geothermal Resources in Tianjin, China

Wang Kun[1], Li Chunhua[1], Lei Haiyan[2],

[1]Bureau of City Planning and Land Resources,Tianjin, 300070

[2]Geothermal Research and Training Center, Tianjin University, 300070

Kun1302@sina.com

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ABSTRACT

The Tianjin geothermal field is a typical low-temperature system, which is located in the middle-lower reaches of the Haihe River System on the North China plain. The reservoir in bed rock is the main developing aquifer.The mainly feeding chan-nels are the karst conduits in weathering carbonate rock of Proterozoic and Lower Paleozoic. It is an extensive zone with the temperature of 76-100 ℃ .The production rate of the whole field reached nearly 24Mm^3 in 2003. A numerical model for this geothermal field is set up, using the Tough2 program. The characteristics of the reservoir are calibrated and matching the measured and calculated water level from 48 production wells over the past 20 years. Based on this, predictions of the reservoir response to the planned production and reinjection rates were made up to the year 2013. The flow model indicates that the draw-down water level can be reduced to 150m in prediction period.

1. INTRODUCTION

Tianjin is one of the biggest cities in China, which is located at the Bay of Bohai, the northeast of Huabei Plane. Its total area is 11,000km^2. It is the important traffic hinge and is about 120km southeast of Beijing(Fig.1).

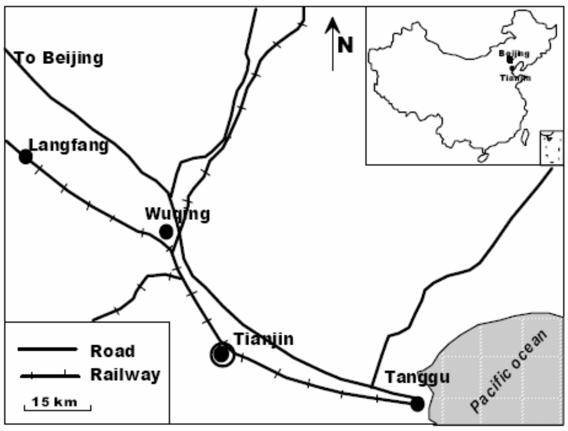

Fig. 1: Location of Tianjin

The Tianjin geothermal field is a typical sedimentary basin low-temperature system, which are common in eastern and northeastern China.

Since Holocene epoch, the regional sea level ascends. Several times transgressions supply the salty materials for the wedge-shaped salty water mass, which is thin in west and thick in east in the Quaternary aquifer. The rising of the regional base level of erosion hindered the horizontal movement of geothermal water. The upright heat flow is obstructed by the huge thick Quaternary stratum and water mass. The sealing state is in favor of the heat-up of geothermal water. Although the sealed water moves slowly, it has quite fast velocity in decompression zone.

The geothermal water mainly located in the range of Cangxian uplift. They are “fractured karst geothermal water in bedrock”, accumulated in medium Pro-terozoic Jixiannian Wumishan (Pt_2W), lower Paleozoic Cambrian (PzH) and Ordovician (PzO) reservoir; and “porous geothermal water in clastic rock” exists in Tertiary and Quaternary. The cold underground water deposits in the fissure of the basement in front of the Yanshan Mountain and the shallow porous/fracture aquifer (500-800m depth) in Tertiary and Quaternary. As the isotope analysis, geothermal water geothermal water come from the precipitation seepage in latest glacial period of upper Pleistocene (10000-21000B.P.), and sealed up to the present since Holocene. It is a closed deep circular system.

The fractured geothermal water in bedrock has the near ^{14}C value (15-4.5 pmc), bigger than the value of porous water(7.6-4.5 pmc). So the bedrock geothermal water is younger than porous water. After the denudation of long geological period, the bedrock has a huge weathering shell and well-developed fracture and dissolved cavity. Meanwhile there is a large outcrop area in the north and west mountains, so it is semi-closed reservoir. In the other hand, the reservoirs in Tertiary and Quaternary system have a good closed condition. Hereby, the deep circular geothermal system can be divided into:

(1)semi-open and semi-closed bedrock subsystem, where the karst geothermal water exists;

(2)closed clastic rock subsystem, where the porous geothermal water exists.

The geothermal utilization history can be traced back to 1930s. There are at least 220 geothermal well in Tianjin. In 1979 the first geothermal well in bedrock was drilled. Until now more than 70 geothermal well have been drilled in basement reservoir.

2. RESERVOIR CHARACTERISTICS

2.1 Geology

The investigation area is located at the north part of Cangxian uplift, which is mainly on the north of Shuangyao uplift. On the whole, the center part is upheaved with the low-lying part in east and west part. The anticline structure is the main regional trend. The mainly fractures are Tianjin Fracture in the west, Cangdong fracrure and Baitangkou fracture in the east, in the middle is Haihe and Chenglinzhuang fracture. Several sub-fracture go with them.

2.2 Geochemistry

In general, the fluid chemistry type changes from simple to complex with the increasement of the TDS value in geothermal water from the north to the south in Tianjin Goethermal fields.

Compared the changes of the mineralization degree in medium Proterozoic Jixiannian Wumishan from 1997 to 1998(Fig.2.), the values in the geothermal water of every geothermal well increased at large. The figure shows that, the TDS increment is rather bigger in the cracked zone along the Cangdong–Baitangkou Fracture. It means this area is an active deep circulation pathway. In recent years, the original hydrodynamic field was destroyed by the rapidly increasing of the production in Pt_2W reservoir. The speedy geothermal water circulation made the recharge flow moved towards the production center along the deep and huge fracture zone, especially from the south to central production area.

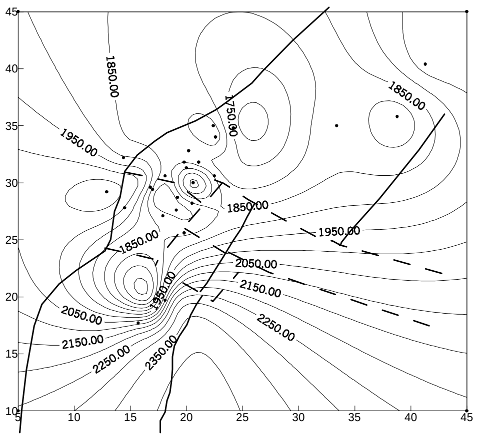

Figure 2. The TDS contours in medium Proterozoic Jixiannian Wumishan group from 1997(above) to 1998

From the water chemical analysis of the geothermal water in Pt2W, the cracked zone along the Cangdong-Baitangkou fracture is the main passage of the bed rock geothermal water, which is identical with the geological condition.

Meanwhile, the temperarue logging data indicates that the reservoir temperature along the fracture zone is higher than the other area.

2.3 Geothermal reservoir

2.3.1 Ordovician reservoir

Ordovician karst cranny reservoir is distributed like a stripe from northeast to southwest direction along the east side of Tianjin faults. The depth of its top is 1000-2000m and gradually deepened from southeast to northwest, with the range of 450-750m thick. The reservoir temperature is about 60-70□. The average porosity is between 3.5%-6%.

At present, there are 7 production wells (including 3 reinjection well) in it. The annual production rate is about 1,220,000m^3. The water level drawdown is slowly, lower than 2m/year.

2.3.2 Cambrian reservoir

This reservoir distributes unevenly. The top depth is about 2000-3400m, with 10-100m thick. Its porosity is higher to 6%-8%. The reservoir temperature is about 90□, the flowrate is between 100-200m^3/h.

Until now, there are 5 geothermal well used for space heating. In city area the first well was drilled in 1993, the original water level is+13.46m. The static water level is –12.57m in Nov.1998. the drawdown is 4-5m/year.

2.2.3 Jixianian Wumishan group reservoir

The Jixianian Wumishan group reservoir dispreads widely in Tianjin. The reservoir top depth is 988-3000m or so. In 3-5 km width along the Baitangkou faults, it is shallow burying area, which contacts the Tertiary reservoir. The porosity reaches 5%-7%. The flow rate is 100-200m^3/h, but near the fracture it almost reaches 380m^3/h. the wellhead temperature is 79-95□. Its top depth is deepened towards west direction. The porosity is 4%-7%. The karst fracture developed in this reservoir and formed strong storage ability. It is the main productive reservoir in Tianjin area. Along the Baitabgkou faults, there is a water-abundant zone with the unit flowrate of 6-12m^3/h/m.

Figure 3 is the history curve of the water level draw down and production rate around city urban area from 1992----2002. Since 1997, the annual water level draw down goes beyond 3m. Till 2002, it goes up to nearly 10m in 2002. This suggest that the recharge to Wumishan group reservoir has been reduced very quickly. Reinjection will be a necessary way to keep the sustainable development of geothermal resources in Tianjin.

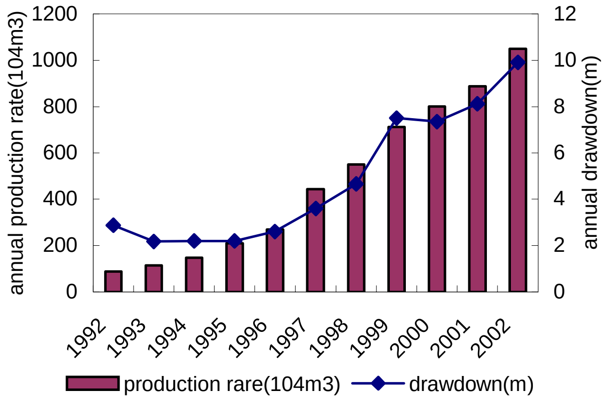

Figure 3 the history curve of the water level draw down and production rate in medium Proterozoic Jixiannian Wumishan group reservoir around city urban area from 1992----2002

3. PREDICTION OF THE DEVELOPMENT POTENTIAL

According to the geological condition, the software pack Tough2 was adopted to simulate the bedrock reservoir.

Because the Jixiannian Wumishan group is the main production reservoir in bedrock, the production potential of the Jixiannian Wumishan group reservoir in future 10 years are predicted which is based on these datas,.

The past 20 years production history was simulated. Till now, there are 58 production wells and 10 reinjection wells in Jixiannian system.

At first, the following situation is assumed, all geothermal well will keep the average production rate (80-120m^3□h in winter) of 2002 in future 5 years. In the summer, the production rate is about 5-10% of that in the winter space heating time. All present reinjection wells are put into the use with reinjection rate of 50-100m^3/h. The total annual production rate will be 1.3716 × $10^7 m^3$ (deducting the reinjection rate 1.7×$10^6 m^3$). Till 2014, the deepest water level will be –193m.

The simulation results shows that if the reinjection rate will increases 150%, the deepest water level will be recovered to –138m in 2013. Figure 4 is the calculated water level contours in September 2013. The reinjection will be an effective way to maintain the reservoir pressure.

The reinjected water will extract more thermal energy from the rock matrix when geothermal wells are shut down in summer, resulting in slower cooling rates. However, the result is highly uncertain because the flow channel dimensions are unknown. So a tracer test must be conducted to study the flow paths between injection and production wells, and estimate the possible cooling resulting from the injection.

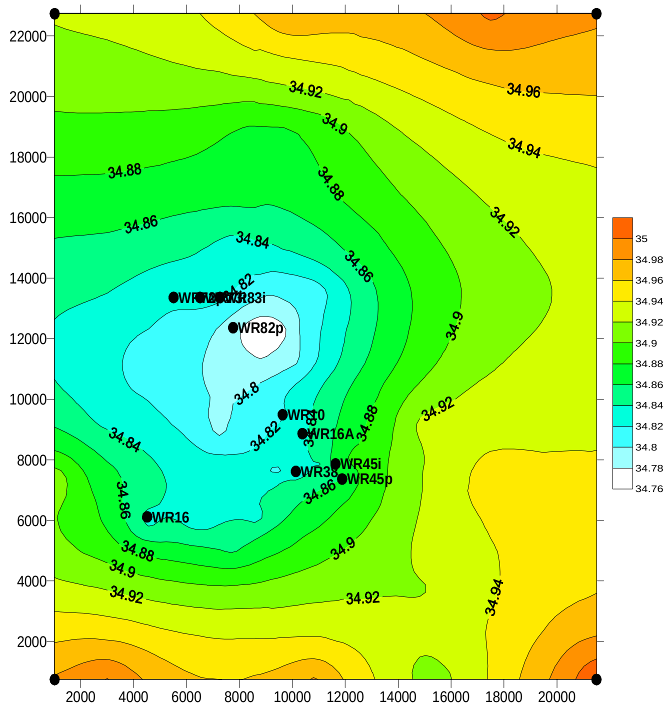

Figure 4. Calculated water level contours of the Jixianian Wumishan group reservoir in Sept.2013

4. CONCLUSIONS

To sum up, the geothermal hydrothermal water system in bedrock would be summarized as: semi-open and semi-close bedrock subsystem, where the karst geo-thermal water exists with the ^{14}C age of 4□20 ka(BP).

The origin of geothermal water is the precipitation in upper Pleistocene (10000-21000BP.). The main phase of Yumu glacial period (23□11 ka, BP.) is the active interaction phase to form the geothermal water. Since Holocene epoch, the regional sea level ascends. The geothermal water comes into a closed heat-up period. The main recharge channels are weathering karst system in bedrock and northeast regional fracture system.

The large-scale collective development of geothermal water caused the remove of the balance interface between geothermal water and cold underground water or geothermal water and seawater. A new balance will be carried out. The geostatic pressure may drive the geothermal water in Jizhong and Huanghua depression to replenish the geothermal water in Cangxian uplift.

If all geothermal well of Jixianian Wumishan group will keep the average present production rate (1.4 × $10^7 m^3$/year) in future 5 years, the deepest water level will be –123m.

During the long term utilization of the field, reinjection will enable to an increase in the production without causing too much draw-down. A new project about the reinjection technology has being conducted.

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