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DEEP BASEMENT RESERVOIR IN TIANJIN GEOTHERMAL FIELD

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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 $13Mm^3$ in 1999. A numerical model for this geothermal field is set up, using the Aqua3D 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 2009. The flow model indicates that the draw-down water level can be reduced to 150m in prediction period.

1. INSTRUCTION

Tianjin is one of the biggest city 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.

The Tianjin geothermal field is a typical sedimentary basin low-temperature system, which are common in eastern and northeastern China (Wang et al., 1995).

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 Proterozoic 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(Fig.1.). It is a closed deep circular system.

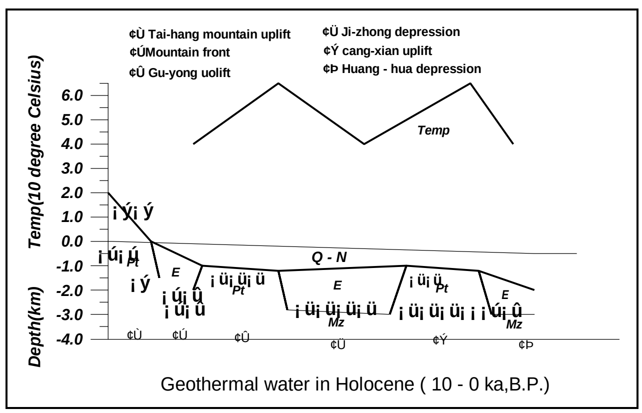

Figure.1. Geothermal water in Holecene(10-0 ka B.P.)

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 200 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. The reservoir evaluations about porous reservoir in sand stone have been finished. But detailed reservoir engineering study about the deep reservoir in bedrock has been carried out till 2000.

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.

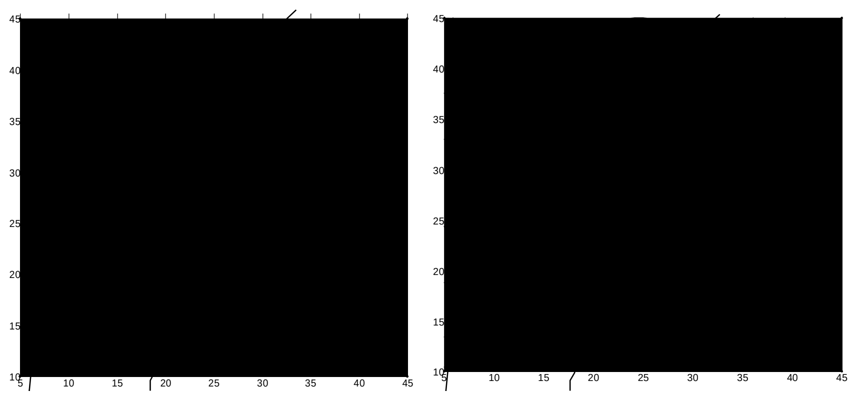

Figure. 2. The TDS contours in medium Proterozoic Jixiannian Wumishan group from 1997(left) to 1998

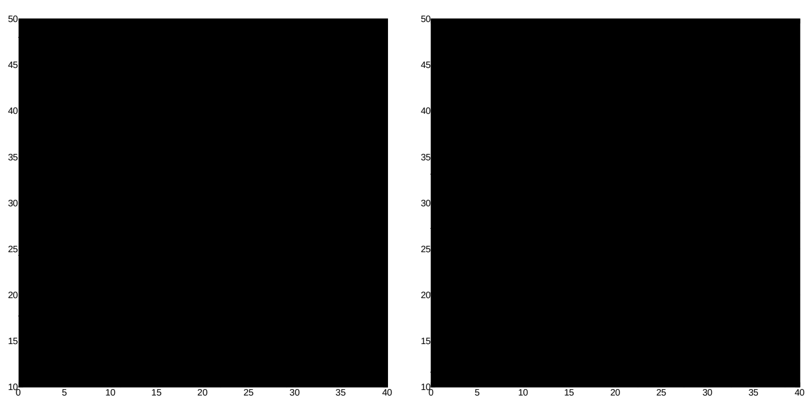

Figure 3. The water level contours in medium Proterozoic Jixiannian Wumishan group from 1998(left) to 1999

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.

Till 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+13.46? . 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.

Fig. 3 is the water level contours in Sept. 1998 and 1999. The water level draw down goes up from 5-7m in 1998 to 7-8m in 1999.

3. SIMULATION OF PRODUCTION HISTORY

According to the geological condition, the software pack AQUA3Dwin was adopted to simulated the bedrock reservoir.

The first geothermal well in bedrock reservoir was drilled in Oct. 1979. So the past 20 years production history was simulated. Till now, there are 7 production well in Odovician System reservoir, including 1 reinjection wells; only 5 production well in Cambrian system, and 48 production wells and 10 reinjection wells in Jixianian system.

Figure 4 is the calculated water level contours of the reservoir in Jixianian system in Sept.1999, which is quite fit the actual production state on the whole. As most pf the production wells centralized in the city area, a large superficial drawdown center region has been formed. Meanwhile, the southwest area near the BTK fracture is going to be a new production center. It caused the funnel of city area moved towards the east and cut down the recharge flow from the east. So the water level decline faster than before.

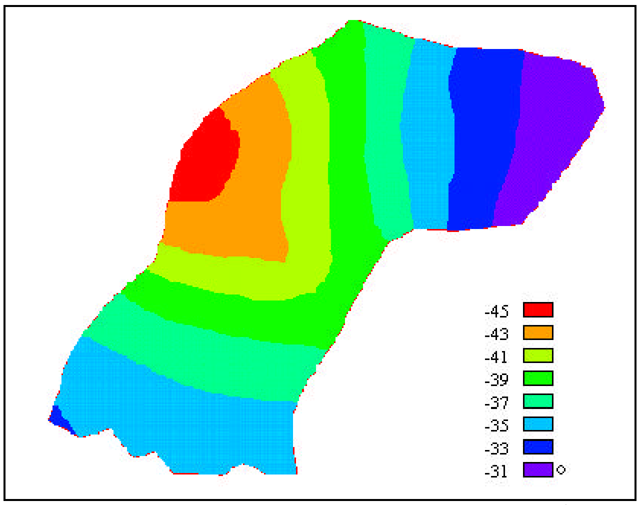

Figure 4. The calculated water level contours of the Jixianian Wumishan group reservoir in Sept.1999

Along with the geothermal production, the hydro-geothermal system and its recharge condition changed. Since 1990s, the production rates increase rapidly, especially in recent years. The large scale production break the original water equilibrium phase. Through the simulation, it was found that the gradually enlarge of the drawdown funnel caused the movement of the underground watershed. The recharge flow from the south increased more than the north. And the vertical flowing along the fracture (accelerate) prick up. This is coordinate with the chemical and isotope analysis.

The best simulated parameters are as follow:

The permeability ($\times 10^{-5}$,m/s):	0.1-2.0
Specific storage coefficient(10^{-7},m^{-1}):	0.7-9.0
Porosity:	3.5%
Anisotropy angle:	60 °
Dispersivity:	10
Molecular diffusion ($\times 10^{-6}$,m^2/s):	1.0

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

4. PREDICTION

At first, the following situation is assumed, all geothermal well will keep the average production rate (80-120m^3/ h in winter) of 1998 and 1999 in future 10 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 $1.1916 \times 10^7 m^3$ (deducting the reinjection rate $1.2 \times 10^6 m^3$). Till 2009, the deepest water level will be –113m. Figure 5 is the calculated water level contours in September 2009.

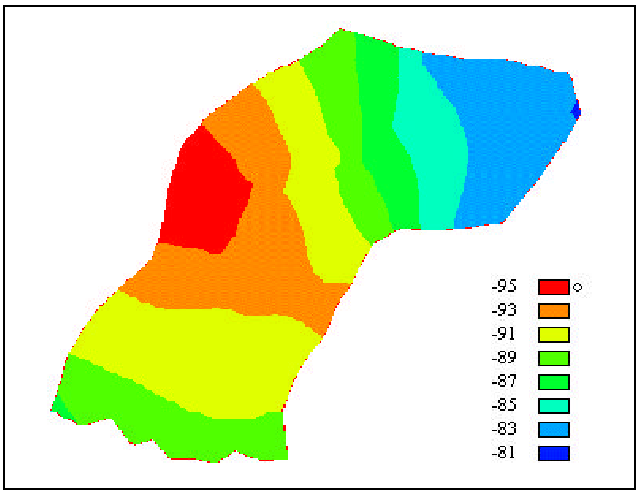

Figure 5. Calculated water level contours of the Jixianian Wumishan group reservoir in Sept.2009

5. CONCLUSION

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 will keep the average present production rate($1.1916 \times 10^7 m^3$/year) in future 10 years, the deepest water level will be –113m.

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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