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The Countermeasures Research about the Sustainable Development of the Geothermal Energy in Tianjin, China

Kun Wang

Tianjin Bureau of Land, Resources and Real Estate Management

84 Qufu Road, Heping Distric, Tianjin 300042, CHINA

E-mail : wangkungeo@163.com

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ABSTRACT

The geothermal resources in Tianjin are classified as typical low-medium geothermal resources in a sedimentary basin. As clean energy, the geothermal resource is widely used for space heating, potable water, agriculture etc. This paper gives a brief introduction to geothermal resources, the exploration and development in Tianjin. The main contents of the Plan for Geothermal Development and Utilization in Tianjin are reviewed from the point of view of sustainable development, integrated use, reinjection etc. The related encouraging policies of the application of reinjection and integrated technologies and some examples are amply discussed here. Based on the continuous geothermal monitoring for many years, a new evaluation on the geothermal resources in the plain area of Tianjin will be finished in 2015. The optimized plans are put forward for future geothermal developments.

1. INTRODUCTION

Tianjin, located in the Bay of Bohai and northeast of Huabei Plane, is one of the biggest cities in China. Its total area is 11,000 km^2. It is an important transport hub and is about 120 km southeast of Beijing (Figure.1). The geothermal fields in Tianjin are typical sedimentary basin low-temperature systems, which are common in eastern and northeastern China.

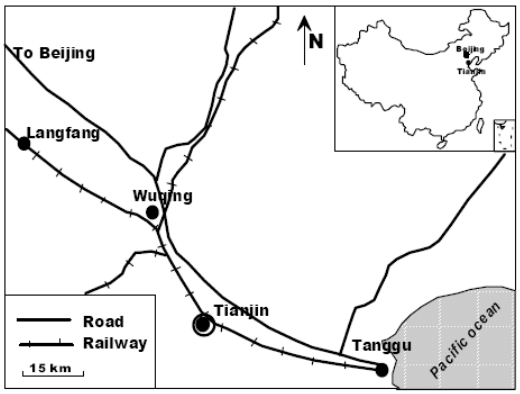

Figure 1: Location of Tianjin

The geothermal utilization history can be traced back to 1930s. There are at least 450 geothermal wells in Tianjin. Since the first geothermal well in bedrock was drilled in 1979, the geothermal resources have been widely used in Tianjin for space heating, tapping water, agriculture etc. By 2013, there are more than 300 geothermal stations of space heating during winters in Tianjin, with a total heating area of 1953×10^4 m^2. The annual production rate is 3706×10^4 m^3. Figure 2 show the proportion of the geothermal utilization in Tianjin.

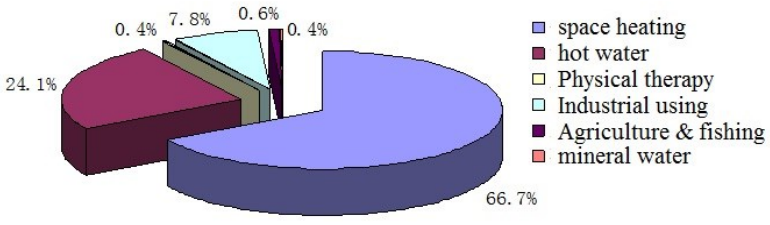

Figure 2: Proportion of the geothermal utilization in Tianjin

2. RESERVOIR CHARACTERISTICS

The main geothermal area is located in the north part of Cangxian uplift (Figure 3), which is mainly in the north of Shuangyao uplift in Tianjin. On the whole, the center part is upheaved with the low-lying parts in east and west. 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-fractures go with them（Tianjin Bureau of Geology, 1992）.

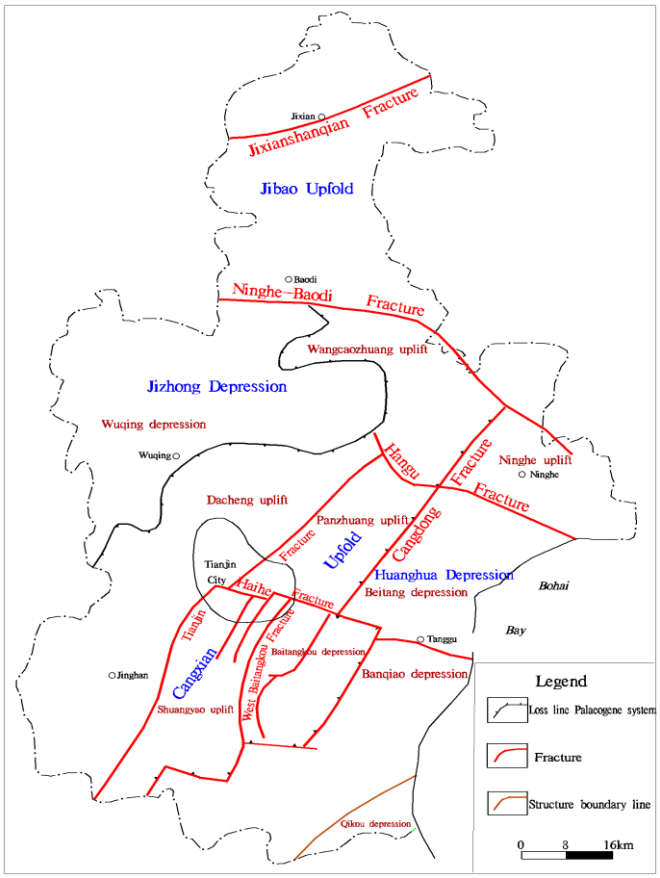

Figure 3: the Sketch of the Geological Tectonic in Tianjin

Since Holocene epoch, the regional sea level has ascended. 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 rise 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 high velocity in decompression zone.

The geothermal water is 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" existed in Tertiary and Quaternary. The cold underground water deposited in the fissure of the basement in front of the Yanshan Mountain and in the shallow porous/fracture aquifer (500-800 m deep) in Tertiary and Quaternary. According to the isotope analysis, geothermal water geothermal water came from the precipitation seepage in latest glacial period of upper Pleistocene (10000-21000 B.P.) (Wang Kun, 2001), and sealed up to its present since Holocene. It is a closed deep circular system.

TABLE 3: The Hydro-geological Characteristics of Main Geothermal Reservoirs in Tianjin

Reservoir	Distibution	Depth (m)	Lithology	flowrate (m3/h)	Temp. (°C)	Hydro-chemistry	TDS (mg/L)
Nm group in late Tertiary	Widely spread in Southern plain	500-1200	Sandston, silty sandstone	40-60	40-60	HCO_3-Na HCO_3·Cl-Na HCO_3·Cl·SO_4-Na	850-1800
Ng group in late Tertiary	Tanggu,Dagang, Wuqing District	1200-2400	Sanstone with gravel	80-120	65-87	Wuqing: CO_3-Na	1000-1400
						Tanggu:Cl·HCO_3-Na	1500-1800
						Dagang: Cl-Na	1500-2000
Ordovician	Urban area and the surrounding Disricts	950-1900	limestone	＞100	55-76	SO_4·Cl-Na·Ca	4000-6000
Cambrian	Local part	1300-1800	limestone	＞100	68-95	Cl·HCO_3-Na Cl·SO_4-Na	1700-1800
Jixianian in Middle Proterozoic	Widely spread on Cangxian Upfold	910-3190	Sandstone dolomite	＞100	74-103	North: HCO_3·SO_4-Na South: Cl·SO_4-Na	1000-2100

The fractured geothermal water in bedrock has the near ^{14}C value (15-4.5 pmc) bigger than the one of porous water (7.6-4.5 pmc) (Wang Kun, 2001). So the bedrock geothermal water is younger than porous water. After the denudation of long geological period, the bedrock has a huge weathering shell, a well-developed fracture, and dissolved cavities. Meanwhile, there is a large outcrop area in the north and west mountains, so it is a semi-closed reservoir. On 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 (Wang Kun, 2005):

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

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

Table 3 lists of the hydro-geological characteristics of the main geothermal reservoirs in Tianjin (Song D., Wang K., Xu P. et al., 2007).

The Jixianian reservoir of the Middle Proterozoic is widespread in Tianjin. The depth of its upper boundary is 988-3000 m or so. Over a 3-5 km width along the Baitangkou faults, the porosity reaches 5-7%. The flow rate is 100-200 m3/h, and near the fracture it reaches almost 380m^3/h. The upper boundary of the reservoir is at a progressively greater depth towards west. The karst fracture is well developed in this reservoir and has formed strong storage ability. It is a main productive reservoir in Tianjin. Along the Baitangkou faults, there is a water-abundant zone with a unit flow rate of 6-12m^3/h/m.

3. THE ANALYSIS OF GEOTHERMAL DEVELOPMENT IN TIANJIN

3.1 The status of geothermal utilization

Compared with fossil fuels, geothermal energy has the benefits of lower running cost and friendly environmental influence. By the end of 2013, there were 298 production wells and 122 reinjection wells in Tianjin. The total production rate was $3706\times10^4m^3$ with a reinjection rate of $1553\times10^4m^3$.

Geothermal energy is used for space heating in residential and public buildings in Tianjin. It not only saves on investment and operation cost, but also brings on evident environmental benefits. According to incomplete statistics, the extent of geothermal space heating corresponds to replacing 320,000 tons of standard coal, reducing the discharge of coal dust by 2300 tons, sulphur dioxide by 9875 tons, nitrogen dioxide by 2963 tons, and carbon monoxide by 254,400 m^3.

China has a traditional hot spring culture, which makes geothermal resources one of the unique opportunities for recreation projects. In recent years, real estates and tourism have developed rapidly in Tianjin. The exploration and development of geothermal resources attract more and more investments in hot spring vacation resort projects. Some large scale construction projects are under construction.

FIGURE 4: Geothermal Utilization in Tianjin

For example, the Zhouliangzhuang geothermal field is located in Baodi District, where there was mainly deserted salty land before. There were only few farms and one village there. As a result of the geothermal exploration, the first geothermal well was drilled in 2002 with a natural flow rate of 380 m^3/h. The wellhead temperature is 103°C, the artesian pressure is 4 Mpa. Now, a new town called Zhujiang Hot Spring Town has come into being there. The total investment will be more than $140 millions.

The governments of China and Singapore signed the agreement for the Sino-Singapore Eco-City project. The Sino-Singapore Eco City is located between the Tanggu and Hangu Districts of Tianjin's Binhai New District. It is the second cooperation project after the Suzhou Industry Garden between China and Singapore, occupying a land area of 32 km^2. The highest investment is estimated to be $4300 million. Once completed, there will be 300,000 residents living and working in energy-efficient buildings in Eco City. Besides preservation and restoration of natural ecology, green consumption and low carbon emissions, it is social cohesion that tops

the list of features for the eco-city. The geothermal exploration and planning have been finished and some geothermal projects have been used for space heating and hot spring entertainment.

3.2 Monitoring of Geothermal reservoir

Every year, the geothermal resources administrative department funds the geothermal monitoring, according to the related provisions of the management and the use of mineral resources. Based on the status of geothermal utilization and the monitoring data from the previous year the fieldwork, such as monitoring, investigation, maintenance and the update of the monitoring facilities, geophysical logging and geochemistry of geothermal fluid are chosen. After analyzing the water quality, interpretation of temperature and pressure logging, the annual report of geothermal monitoring is compiled. Figure 5 shows the contour of water levels of Jxw reservoir in Proterozoic, 2012 (Tian, G., Song, M., et al., 2013).

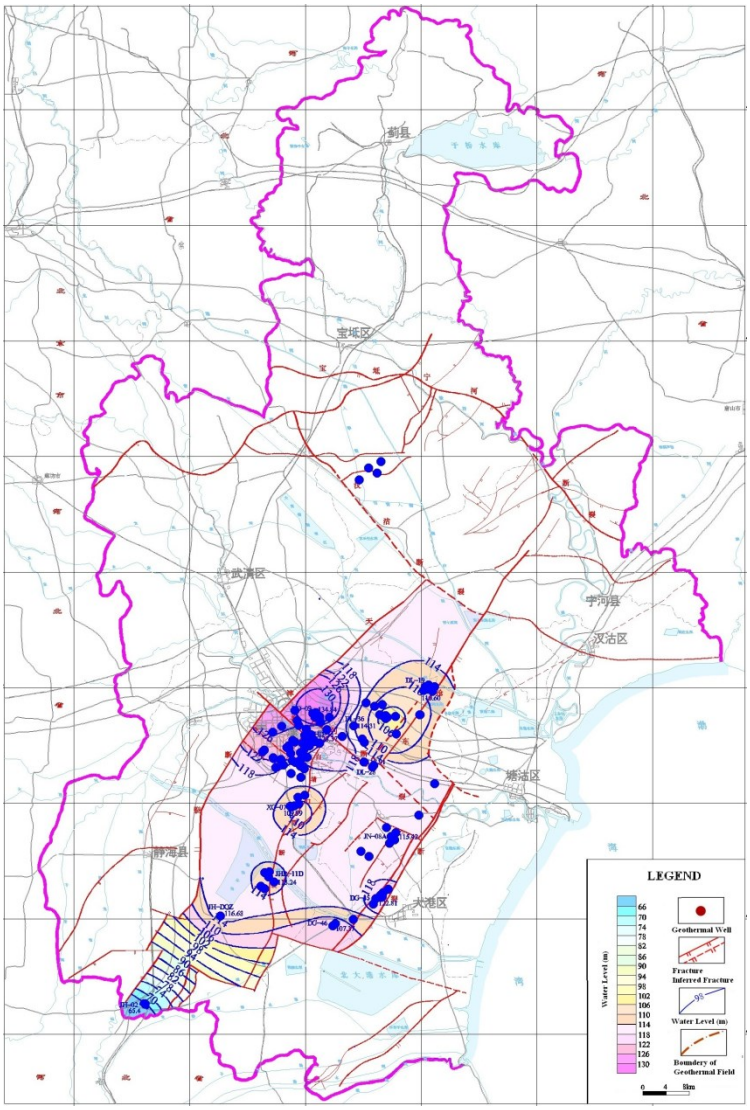

FIGURE 5: Contour of Water levels of Jxw reservoir in Proterozoic, 2012

For example, Jixianian Wumishan group reservoirs spreadwidely in Tianjin. The reservoir top depth is 988-3000 m 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 flow rate of 6-12m^3/h/m.Since 1997, the annual water level draw down goes beyond 3m. Till 2012, it goes up to 10m. This suggests 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.

Mathematic modelling is an important tool to study the changes in geothermal reservoirs. Based on fieldworks, analysis in lab and geophysical logging, combining the historical changes of geothermal reservoir, the pressure, temperatures and the chemistry can be simulated and predicted by numerical modelling in an annual report. Every short-term development potential of geothermal reservoirs has been predicted. Suggestions on geothermal development and management are put forward in the report.

4. FUTURE PLANNING AND COUNTERMEASURES

4.1 Scientifically positioning the geothermal energy in city development

The development of the renewable energy has been scientifically positioned in different future periods: as complement energy before 2010, as replacement energy before 2020, as primary energy before 2030 and as dominant energy before 2050.

Geothermal resources have been formed under the special geological, tectonic and hydro-geological conditions. The resources are limited because of the deep embedding, long recharge term and lower renewability. So the ever-growing demands for geothermal resources can not simply rely on increasing the geothermal productions.

So it is necessary to scientifically positioning the geothermal energy in city development of Tianjin. The geothermal energy is much more suitable to be one of the complement secondary energy currently in municipal space heating, instead of being the primary energy. For the future, geothermal projects should be taken into account to prior develop on the space heating projects with better economic and social benefits.

4.2 Sufficiently developing the advantages of geothermal energy as mineral and heat resources

As clean and renewable energy with special mineral contents and medical advantage, geothermal resources have been used for a long history in China. There are bright prospects for geothermal utilization on tourism, physical therapy or spa.

In future, we should make full use of geothermal resources with its unique thermal and mineral advantage. It will be focused on the geothermal development of high value-added applications and good economic benefits, such as tourism and spa projects. Combined with the city development plan, some hot spring tourism projects will be developed according to the detailed characteristics of geothermal water in some geothermal fields. For the geothermal resources in bedrock reservoir, the projects will change the single mode of winter space heating to the comprehensive and cascade utilization of diversified optimal model. The reinjection is difficult for the geothermal resources in Neogene sandstone reservoir, which is mainly distributed in the Binhai New District. Exploitation and utilization of geothermal resources should be well designed, in order to maximize the geothermal projects with high added value and encourage the investment and economic development in Binhai New District.

4.3 Accelerating the geothermal exploration in the northern mountain area

The northern foothills area of Tianjin used to be an area with no development and utilization of geothermal resources. Recently, two geothermal exploration holes were drilled successfully in Jixian County, with the wellhead water temperature up to 48 ℃. This has started a new path for geothermal exploration in the mountains to the north. The low temperature geothermal resources are explored and rich in the northern mountains. In the vast southern plain of Baodi-Ninghe fault, the distribution of shallow crustal heat flow is primarily controlled by concave and convex geological tectonic pattern, with the higher ground temperature gradient generally. So the development of the geothermal resources between 25 ~ 40 ℃, which is buried shallowly and exploited easily, has the great potential in future.

4.4 Enhancing the geothermal resources prospecting and evaluation of potential

Since the state government reduced the geothermal exploration investment in 90s of last century, the exploration and development of geothermal resources mainly follow the market demand and business operation mode. The lack of new geothermal exploration technology results in that geothermal exploration research cannot meet the demand of development. So far, only 4 geothermal fields are exploited and proved among 10 geothermal anomaly areas and 3 geothermal fields are discovered in the geothermal normal area. Especially in the coastal area, the proved reserves cannot meet the requirement of development and open in Binhai New District. It is urgent to speed up the exploration of deep geothermal resources. Meanwhile according to the requirements of geothermal resources exploration, the regular evaluation of the geothermal field should be carried out aiming at its potential of the large-scale development. Through improving the accuracy of geothermal resources exploration, exploration risk can be reduced and the strategic objectives of sustainable development of geothermal resources can be achieved.

5. CONCLUSION

To sum up, the development and utilization of geothermal resources in Tianjin feature large scale, multiple purposes, wide scope, and good benefits. But the geothermal technology still has uneven and big individual difference. The large-scale collective development of geothermal water in Tianjin causes the rapidly drawdown of reservoirs. It makes the removal of the balanced 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.

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

The scientific management and planning will be continuously strengthened in future. The strict examination and approval of geothermal wells of high standard will ensure the rational distribution of resources and balanced development. The research on new technology on resource-saving, reinjection, cascade utilization will be promoted by more and more geothermal projects, in order to saving resources, optimizing the geothermal utilization pattern, and prolonging geothermal field's life.

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