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Progress of Geothermal Reinjection in Bedrock Reservoirs in Tianjin

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ABSTRACT

Since the early 1990s, geothermal reinjection research in bedrock reservoirs has been started in Tianjin, Various geothermal reinjection tests have been carried out. And from 1999, reinjection has come into force by government requirement. Reinjection wells have been drilled progressively in urban and suburban areas of Tianjin. In 2008, 5.86 million m^3, 41.3% of the exploited bedrock geothermal fluid was reinjected. The reservoir pressure had been showing a declining trend that has mitigated since reinjection started. In addition, geothermal reinjection saves exploitation cost, and has gained obvious environmental benefits.

1. INTRODUCTION

Tianjin geothermal field is a typical low-medium geothermal resource in a sedimentary-fault basin, it exhibits clear characteristics, a few of these are listed below.

1.1 Surface Geothermal Characteristic

There are 10 geothermal anomaly areas in Tianjin determined by temperature gradients of 3.5ºC/100m. In table 1 (at the end of this paper) the temperature gradients of the cap rocks are shown.

1.2 Vertical Geothermal Characteristic

There are two kinds of geothermal reservoirs in Tianjin: The porous Cenozoic sandstone reservoirs and Proterozoic limestone reservoirs. The porous Cenozoic sandstone reservoirs include Nm group Ng group in the tertiary. The limestone reservoirs include Ordovician, Cambrian, jixianian in Middle Proterozoic.

1.3 Geothermal Field Reserves

Through 30 years of geothermal exploration work at Tianjin until the end of 2007, eight geothermal fields have been explored, and reservoir reserves have been determined. Wang Lanzhuang, shanlingzi, binhai area, wuqing, wanjiamatou, panzhuang and lutai, ninghe and hangu, jinghai. recoverable amount of geothermal fluid is 58.541Mm^3/yr in explored area (the porous Cenozoic sandstone reservoirs is 36.2 Mm^3/a, the limestone reservoirs is 22.3 Mm^3/yr).We estimate geothermal fluid recoverable amount in blank area by experience is about 18.6 Mm^3/yr. So the total recoverable amount is 77.1 Mm^3/yr .

2. GEOTHERMAL UTILIZATION IN TIANJIN

2.1 Geothermal Utilization

Geothermal exploration started in the 1930s, and came into large scale development in the late 1970s. By the end of 2007, there were 255 production wells in production in Tianjin., the total production rate was 24,500,000 m^3, of which 169 wells are in the porous Cenozoic sandstone reservoirs well and the rate was 11,000,000 m^3 , 86 wells are in the limestone reservoirs well and the rate was 24,500,000 m^3. Table 2 shows detailed information.

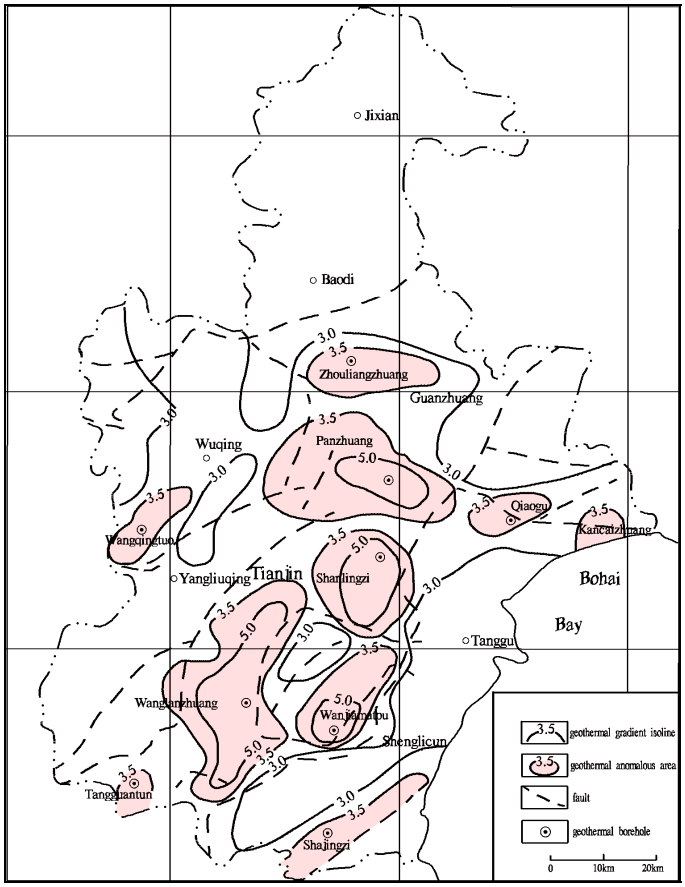

Figure 1: The location of geothermal anomaly areas in Tianjin

Table 2: Geothermal Utilization conduction of wells in different reservoirs

Reservoir		Production wells	Total production (per year)
Late tertiary	Nm	72	4,040,000
	Ng	95	6,900,000
Dongying		2	60,000
Limestone	Ordovician	10	830,000
	Cambrian	5	3,700,000
	Jixianian	70	12,100,000
	Changcheng	1	200,000
Total		255	245,000,000

2.2 Geothermal Utilization Patterns and Dimensions

The exploration and development of geothermal resources have played an important role in many aspects of Tianjin's economical development, such as attracting investment, improving environmental quality and standard of living.

From 2001 to 2008, the total production was increasing gradually. In 2008, the total geothermal production was $2604\times10^4\ m^3$, and geothermal resources were being used for space heating, domestic hot water, springs, green house, fish farming therapy, potable water and recreational tourism (Fig. 2). Space heating has a substantially bigger share, the total heating area is $12Mm^2$ or about 10% of the whole Tianjin heating area. Now Tianjin is the biggest city in geothermal resource heating in China

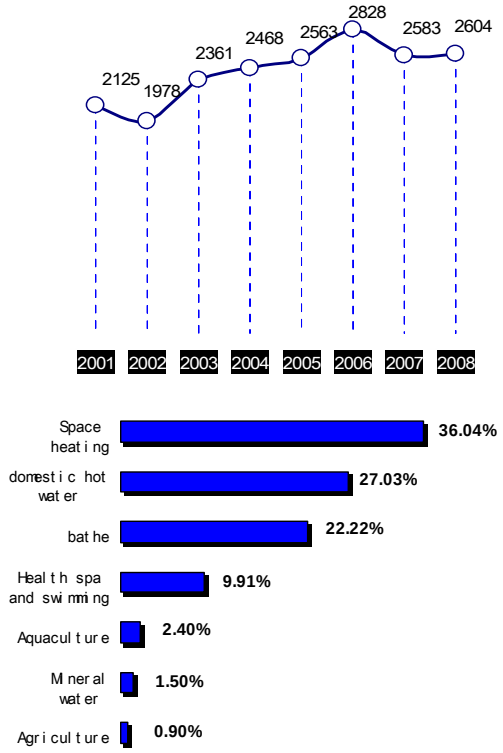

Figure 2: Geothermal production and Utilization patterns in Tianjin

3. THE REINJECTION STATUS IN TIANJIN

3.1 Overview of Reinjection

In 2008 there was a total of 53 reinjection well in Tianjin, the number in the limestone and late tertiary is 43 and 10 respectively. The reinjection wells are located in Wumishan formation, Ordovican system, and Guantao formation. The reinjection well of Wumishan is largest, more than 55% in all the reinjection well in Tianjin. Wumishan formation is the primary reinjection formation.

The geothermal well in the Minghuazhen and Wumishan formations are distributed in the urban and suburban districts. The geothermal wells with hot water from the Guantao formation are distributed in the Dagang, TangGu and WuQing districts. All the districts are mainly mining areas of geothermal, so reinjection is very important for sustainable geothermal use.

The number of reinjection wells is increasing annually, but the speed of increment is still slow, only 13% of total the number of wells (Figs. 3, 4). New techniques for sustainable use have been applied for several years and the hot water production has decreased in recent years, while reinjection appears to have increased.

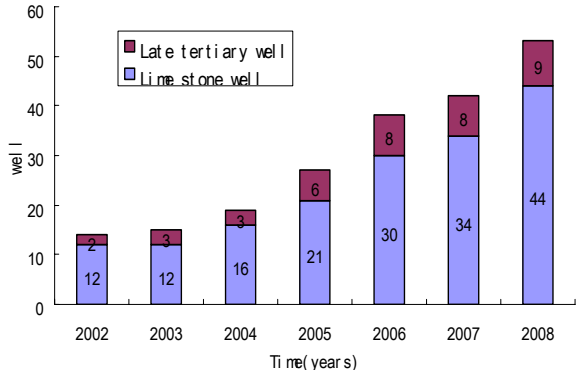

Figure 3: The constituent of rejection wells in Tianjin

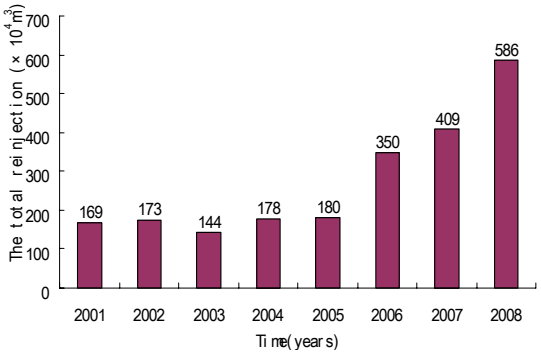

Figure 4: The total reinjection in Tianjin

3.2 Reinjection Effects

The geothermal reinjection wells are mainly located in the Wumishang formation of the Jixian, Ordovician system and the Guantao formation of the Tertiary system, But the reinjection in the Guantao formation does not seem to be efficient. Geothermal reinjection is most effective in the Ordovician system with reinjection rates of 100% but most reinjection in the late tertiary does not seem to be efficient and the reinjection rate is mostly below 50%. Based on the statistics data of 2008, the reinjection rate is $586\times10^4\ m^3/yr$, the reinjection is accounts for 22.5%. and the reinjection of limestone reservoir is accounts for 41.3%, but the reinjection in the Tertiary system is not good, only 1.92% on account of blockage.

3.3 Reservoir Pressure and Temperature after Reinjection

3.3.1 Reservoir Pressure after Reinjection

Reinjection is the efficient method to control water level drawdown based on the monitoring data. X-14 and HX-25 are production wells HX-25B is a reinjection well, a reinjection test proved that HX-25B have water rate that relates with that of HX-14, Fig.5 is a curve showing declining annual rate. Reinjection can contribute to control the tendency for water level to decrease (Figure 5).

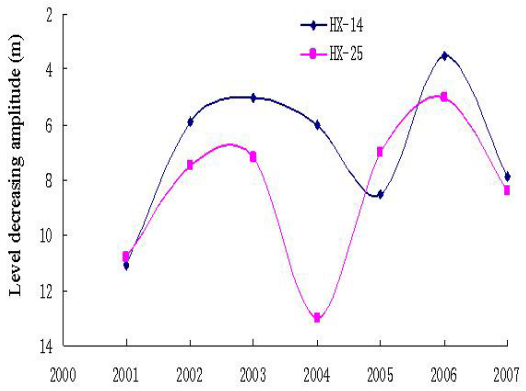

Figure 5: Level decreasing amplitude duration curve in HX-14,HX-25

3.3.2 Reservoir Temperature after Reinjection

We compare the temperature in the same time in different geothermal wells, results show that the water temperature is in the stability state. (Table3)

Table 3: The change of temperature in Tianjin geothermal wells

Well	Temperature (℃)			
	Jan,2005	Jan,2006	Jan,2007	Jan,2008
HD-12	83	82	84	83.6
HD-14	83	85	86.8	86.7
HD-16	86	88	87.7	87.1
HX-25	91	93	91	90.4
HX-14	92	92	90	90

Temperature logging from the geothermal wells, which are off reinjection for several yeas, can provide, not only information on temperature conditions of the geothermal reservoir, but also the effects of reinjection fluid upon the geothermal reservoir.

We also compare the temperature at different time in the same geothermal well. HX-25B is a reinjection well which was recharged for 14 years from 1995. In recent years, we did logging in this well many times (figure 6). In 2008, the total reinjection reached 140,000 m^3 in that heating season.

Thus, reinjection has no influence on the geothermal reservoir temperature in the short term. On the other hand, reinjection is an important method to realize the sustainable development of the geothermal resources.

3.4 Reinjection in Sandstone Reservoir

Through years of research, the reinjection problems of carbonate rocks reservoir have basically been solved. But the injection problems of the sandstone reservoir still exist, mainly with regards to the low reinjection rate and short duration. The production from the geothermal sandstone reservoir exceeds 50% of the total production of the city. Thus, it is important to resolve the reinjection problems for the sustainable development and utilization of geothermal resources in Tianjin. In recent years, we have chosen the Neogene Guantao formation geothermal sandstone reservoir for reinjection testing in the Wuqing, Dongli and Dagang Districts, and we have studied reinjection well drilling technology, reinjection plugging problems and ground reinjection systems.

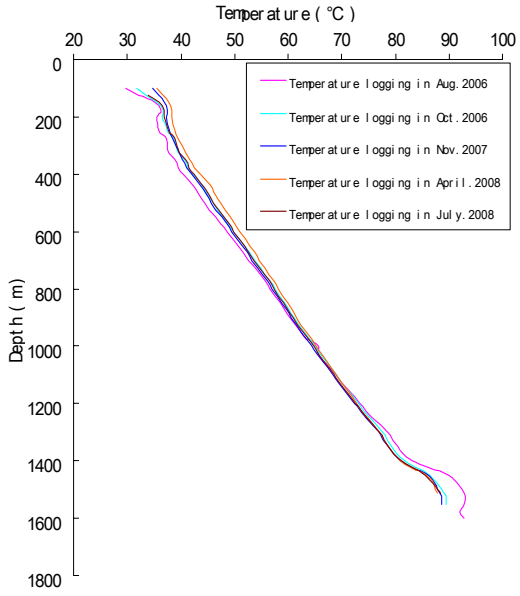

Figure 6: Temperature logging curves of reinjection well HX-25B

4. PROBLEMS

4.1 Reinjection Rate is Lower

Although through years of work and study, reinjection technology, especially the bedrock reinjection technology problems are solved in recent years, and the government management department also increased geothermal resources sustainable development, but the total amount is very low. The main reason is the problems left by history, early development was wasteful in exploitation and single production. There was little reinjection.

4.2 Problems are Difficult to Solve in Reinjection in Sandstone Reservoir

Through the study of reinjection well-drilling technology and the ground reinjection system, the problems of physical and chemical reinjection plugging have been resolved, but decreasing reinjection rates remain a problem.

4.3 Reinjection Rate is Lower

Since 2006 the geothermal management department has done a lot of work in resource integration for improving reinjection in order to maintain the sustainable development of geothermal resources. This is relating to different companies, so it is difficult to coordinate the interests of all the companies. Geothermal well integration is hard to implement

4.4 Reinjection Policies Should be Further Improved

Reinjection work requires a lot of money and manpower to establish reinjection system to achieving geothermal resources integration. Howerer, how to distribute the benefit? This is a problem, so policy should be further improved.

5. CONLUSIONS

Reinjection is an efficient method to control water level drawdown. The rates of resources development and reinjection have risen in the majority of the geothermal reservoirs. Because of space limitations, geological condition, etc., it is difficult to increase the number of reinjection wells. However, reinjection wells are needed to create a sustainable environment.

6. REFERENCES

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Table1 : Geothermal anomaly area

Geothermal anomalies	Structural type	Distribution	Area (km^2)	Geothermal gradient (°C/100m)
Wang Lanzhuang	Shuangyao uplift	central and south of urban district and north of West Area	534	8.0
Shanlingzi	Da\xiaodongzhuang uplift	Northeast of urban district and Dongli district	315	8.3
Wanjia Matou	Xiaohanzhuang uplife	Jinnan and west of Dagang district	235	8.8
Panzhuang	Panzhuang uplift	West of Ninghe district	610	6.9
Zhouliangzhuan	Wangcaozhuang uplift	Southesat of Baodi district	180	5.5
Qiaogu	tectonic zone	North of Hangu district	90	5.5
Wangqingtuo	dacheng uplife	Southeast of Wuqing	114	5.0
Shajingzi	beidagang uplife	Southeast of Dagang district	190	4.5
Tangguantun	tectonic zone	South of Jinghai district	40	7.6
Kancaizhuang	tectonic zone	East of Hangu district	20	5.5
total	-	-	2328	-