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The Geothermal and its Utilization in Liangxiang Geothermal Field, Beijing, China

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ABSTRACT

Liangxiang geothermal field, about 30km SW of the urban area of Beijing, is rich in low-temperature geothermal energy. Geologically, the area of Liangxiang is in the same graben as the urban geothermal field in Beijing. Geothermal water was first tapped in 1959 in the area, but its utilization only started in late 1970s. More than 20 geothermal wells, which are a few hundred meters to about 3000m deep, have been drilled for production since then. The temperature of the geothermal fluid is 40-72ºC, and the annual production is about 100Mm^3/yr from an area of 68 km^2 in the geothermal field at present. The geothermal water, which is of low mineral content and is believed to have good effects on curing certain diseases, is used mainly for various direct purposes. The well with the highest temperature is in Nangong (north-eastern part of the geothermal field), and the geothermal water is used in a cascaded manner there, including space heating, domestic hot water, fish-farming, greenhouse, swimming pools. In the meantime, a world geothermal natural museum (including a hall for geothermal exhibition) has been planned and most parts of the facilities have been constructed. The industrialized geothermal development is bringing great economic and environment effects.

1. INTRODUCTION

Liangxiang town has abundant low-middle temperature geothermal resources. It is one of the biggest geothermal field explored in Beijing, China. In the 1950s, 30ºC underground warm water was found in Haotian town nearby. During the 1960s and 1970s, several geothermal wells were drilled, and temperature was about 40ºC at a depth less than 1000 meters. In the middle to late 1990s, another geothermal well was drilled about 1500 meters deep and temperature was up to 54.6ºC. This broke the record of 50ºC. All of these showed that geothermal resources in Liangxiang area has very wide sustainable utility value. Up to now there are 20 wells, locating in Liangxiang town government and Guangyang City. The depths are 800-1500 meters and the temperatures are 36-60ºC. Nangong geothermal well has been drilled successfully, located in the north of Liangxiang geothermal field, the depth was 3100 meters and temperature was 67ºC. This is another important evidence for abundant geothermal resources. The foundation of the world geothermal museum in Nangong demonstrates typical engineering in China.

2. GEOTHERMAL GEOLOGICAL FEATURES

2.1 Basic structural frame

Liangxiang town is located in the transition area between Tuoli-Fengtai depression (the fifth structure unit) and Liuli river depression (the sixth structure unit) in the Beijing graben (Rank III structure unit), north China (Rank II structure unit) between Chinese and northern Korea platform (Rank I structure unit). Beijing laminated depression distributes from southwest to northeast. The northern borderline is Huangzhuang-Gaoliying fault, the southern borderline is Nanyuan-Tongxian fault. Taking the Liangxiang uplift as a borderline, the north is Tuoli-Fengtai laminated depression, the south is Liuli river laminated depression. The Yongding river fault divides the Tuoli-Fengtai laminated depression into east and west parts. The geothermal field is located in the western Liangxiang uplift.

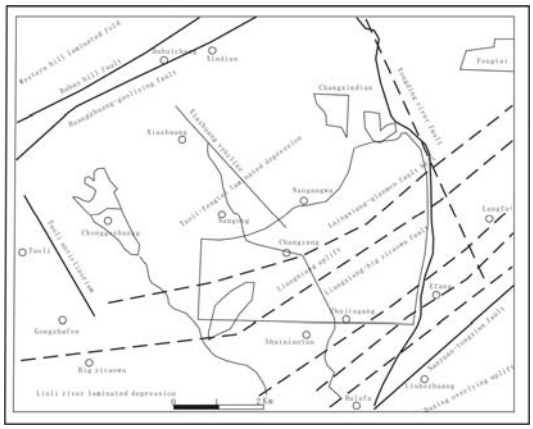

Figure 1: Location map of Liangxiang area

2.2 The gravity field features

Beijing graben shows very clearly in the Bouger gravity contour map, the north western and south eastern areas have a relative intensive belt. The gravity value is a little high beyond the thick belt and shows that the two sides of depression are in relative uplift areas. According to the geological structure, the north western side is western hill laminated depression, the south eastern side is Daxing laminated depression, forming the structural frame of two uplifts and one depression in the Beijing area. Tuoli-Fengtai laminated depression, Liangxiang uplift and Liuli River laminated depression are parts of the depression in Beijing area (Figure 2). The sequence structure of Liangxiang area is simple. From new to old, the stratigraphy is Quaternary Cenozoic era, Tertiary, Mesozoic era Cretaceous system, and Proterozoic group, only in Tuoli-Fengtai laminated depression the westernnorth granite can be found along the Babao hill fault.

Liangxiang is a gravity high and forms a -28mg contour trap gravity anomaly area. On its northern part, -45mg contour trap gravity formed two different gravity negative anomaly areas, this represents the sedimentary center of the Tuoli-Fengtai depression. From the Liangxiang gravity high area to the north, the gravity value gradually decreased. It shows the base rock's burial depth increased to the north,

"Liangxiang gravity high area" distributed from the east to the west in Liangxiang town and its western part. On the southwestern side, there is a –36mg anomaly area, that is "southern Liyuan gravity low value area", relative to the "Liangxiang gravity high area", form an obvious gravity increasing value belt.

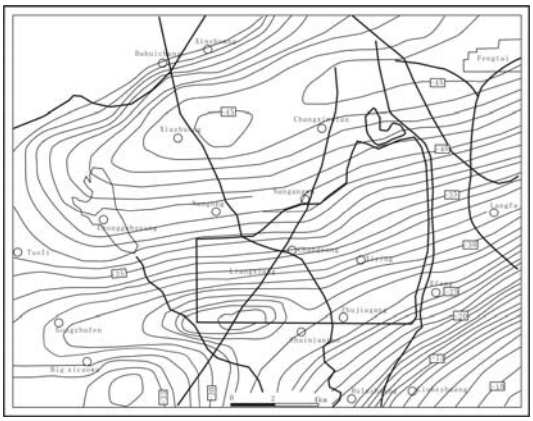

Figure 2: Bouger gravity contour map of Liangxiang area

2.3 The hot reservoir cap rock and temperature features

The geothermal resources in Beijing are a low temperature sedimentary basin (lower than 90ºC), mainly increasing temperature by geothermal gradient. The temperature increases when the bury depth increases (Bin Dezhi et al., 2002). The distribution of geothermal reservoirs is also like this, supplying the condition for local concentration and exploration of geothermal resources.

The geothermal reservoir is in the Wumishan group, and local area is in the Gaoyuzhuang group and Tieling group. Taking geothermal reservoir exploration as an objective, from the bottom to the top, the cap rock is Quaternary system, Tertiary, Cretaceous system stratigraphy. The stratum of Quaternary system is thick. The Tertiary stratum distributes on the eastern margin. The stratum of Cretaceous is distributed all over the whole area, mainly consisting of thick sand, mudstone and gravel stone and is very thick.

From the analysis of measurements in 1982, in the geothermal area of Liangxiang around 70 meters, the temperature is over 15ºC. Influenced by the geological structure, faults developed well, and formed the structural frame of relative uplift on the Liangxiang uplift. The sedimentary layer is very thick, can resist heat, and retain warmth. The temperature of the thermal reservoir is relatively high, but on the uplift, because the cap rock is very thin, the temperature is relatively low. According to the statistics of 20 geothermal wells around 1200 meters deep the temperature is not more than 40ºC, but beside the uplift the heating burial depth is 1200 meters and the temperature is up to 60ºC. This shows the importance of the cap rock in the process of forming geothermal resources.

According to the incomplete geothermal well, it shows the deeper the hot burial depth, the higher the temperature is. From Figure 2, as the hot reservoir increases 100 meter in depth, the geothermal temperature rises 1.5ºC. The geothermal rate is 2.5ºC/100 meter on the Liangxiang uplift. On average, the geothermal gradient in the geothermal reservoir is 1.4ºC/100m□while some drilled wells have seen up to 2.0ºC/100m (Figure 3).

The geothermal feature is close to the geological frame in Liangxiang area. It shows: the heat reservoir burial depth is thin, the temperature is low, the heat reservoir burial depth is deeper, the temperature is higher. The general trend is from Liangxiang government to the north-east, the temperature increases fast, the main reason is because the cap rock is thick and far away from the western part the cold supply area.

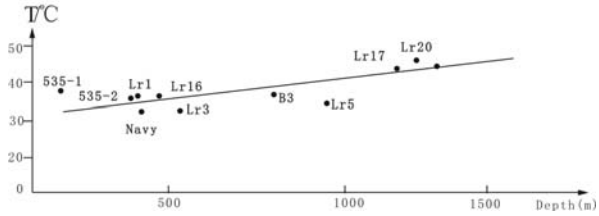

Figure 3: Relation between geothermal well temperature and heat reservoir bury depth in Liangxiang area

2.4 The geothermal fluid chemistry features

Dissolved material concentrations in the geothermal water of Liangxiang area are low, between 237-287mg/l, with only a few up to 360 mg/l. The type of dissolved material is mainly $HCO_3.SO_4$-Ca.Na and $HCO_3.SO_4$-Na.Ca. Water chemistry type of some wells is $HCO_3.SO_4$-Ca.Na.Mg. The pH value is between 7.18-7.88, with extreme values of 6.81 and 8.05. Acid-base is neutral. The mineralization is between 0.472-0.633 mg/l and belongs to fresh water.

3. GEOTHERMAL RESOURCES EXPLORATION SITUATION

The area of geothermal resource distribution in Liangxiang is about 388 km^2, and the resource evaluated area is 68 km^2. The geothermal resource is 1602.54×10^{10}kJ. According to the standard of geothermal plan GB11615-89, the reservoir is calculated with ranks D+C. The area of rank D is 42.5km^2□the productivity is 240×10^4 m^3/yr□amount of heat is 61.7×10^{10}KJ/yr. The area of rank C is 20.5 km^2□and the productivity is 130×10^4 m^3/yr□amount of heat is 26.32×10^{10}KJ/yr. The productivity of rank C+D combined is 370×10^4 m^3/yr□amount of heat is 88×10^{10}KJ/yr.

Until the end of 2000, there were 11 geothermal wells in Liangxiang area. The total region of geothermal exploration was 77.29×10^4 m^3. Here we introduce a concept about productivity to predict the abundancy of geothermal resources. From the statistics of 17 wells, we can calculate the productivity. The yearly productivity is 844.06×10^4 m^3, but the total hot water produced is 77.29×10^4 m^3, only accounting for about 9% of productive ability, the production accounts for only 0.25‰ of the total geothermal resources. This means Liangxiang geothermal field bears very abundant geothermal resources and has big exploration space and utility range. Now well are being drilled around Liangxiang government and Changyang town. So we suggest developing other geothermal fields, especially west and south east of Liangxiang town, which according to geological features may reach higher geothermal resources.

4. UTILITY SITUATION

4.1 Geothermal space heating

The geothermal resources in Liangxiang provide very precious clean energy, used mainly for bathing, entertainment and exercising. Preserving and growing these uses, the efficient development of geothermal energy can

lead to fast development of travel, construction, and agriculture. The geothermal water up 50ºC can be used in supplying warmth and can solve consumer's problems.

4.2 Warm spring entertainment and bathing

Warm spring entertainment and bathing can promote the development of traveling and construction. From old times until now, traveling scenes are always seen in warm springs. Warm spring swimming pools meet the need of people's entertainment and can increase the service quality of hotels and can get good efficiency.

Moreover, an "indoor warm spring" is a hot spot of construction development. According to the statistics, for a property with "warm spring going to the house", the price per square meter can increase 10%□but can enjoy the natural warm spring indoors. Warm spring can attract many buying house consumers, and businessmen can get much profit from it.

4.3 Medical treatment and health work

Because of bearing many kinds of microscale elements, geothermal water is not only clean energy, but also has much medical efficacy. The content of metasilicate (bisilicate) and fluorine can go up to the concentration of medical treatment value in geothermal water of Liangxiang area.

4.4 Planting and breeding

Geothermal warm planting is a mark of modern agriculture. It uses the geothermal as hot resource to plant many kinds of plants in warm rooms, mainly vegetables, flowers and trees. According to statistics, only in Xiaotangshan, productivity value of warm house planting was 24 thousand yuan per mu. Breeding use of geothermal water to protect fish in winter, protecting the mature fish, fish living in winter, and hatching little fish, also can breeding soft-shelled turtle, and can shorten the growing period, going to the market in advance, enhancing the economy efficiency.

4.5 Productivity drinking water

Through analysis of water quality, the content of Fu in hot mineral water of Liangxiang geothermal field exceeds the standard of drinking water, can produce the drinking water (if decrease the content of Fu to 1.0mg/l). As is well known, water resources are very scarce in Beijing city, so the low Fu geothermal water as drinking water can replace groundwater sources.

4.6 The world geothermal museum

Nangong world geothermal museum uses the geothermal resources very well, in nearly all aspects. The facility has a warm spring, fish breeding, geothermal warm room, planting, warm spring swimming pool, and warm spring hotel. In temperature, the water starts from 72ºC with initial temperature 48ºC of supply, and the final water temperature is lower than 30ºC. The utility projects include supplying warmth, taking bath, warm room, aquatic production, entertainment. These complex utilities use every kind of potential of geothermal resources, and represent productivity development.

5. ENVIRONMENT EFFICIENCY ANALYSIS

According to the productivity now, the area can produce hot water volume of 844×10^4 m^3, convert to heat quantity 36.55×10^{10}K cal/yr (152.918×10^{10}Kj/yr)□which is equivalent to heat released by 5.22×10^4t of coal or 3.65×10^4t of petroleum.

According to explored capacity of hot water 60×10^4 m^3/yr, converts to heat quantity 2.6×10^{10}K cal/yr (10.88×10^{10}Kj/yr)□which is equivalent to heat released by 3710t/yr of coal□or 2600t/yr of petroleum, or 216×10^4 m^3/yr of liquefied gas.

Moreover, using any kind of fossil fuel will cause certain pollution, according to some material, the release of SO_2 60kg, CO and CO_2 26.4kg, NO_2 5.6kg, and dust 10 kg.

If burning crude coal to provide the heat supplied in 1999, the required fuel is 5197t per year. But burning this amount of coal will release 500 t CO_2 S CO, 5 t dust, and have 800 t. If burning natural gas, need air 2000 m^3□and will produce 2600×10^4 m^3 CO_2 CO poisonous gases.

From these observations, exploring and using geothermal energy can cause some pollution, but relative to other energies the impact caused by geothermal energy is less, and decreases the influence to the environment.

6. CONCLUSION AND SUGGESTION

Liangxiang has abundant geothermal resources which have a certain exploration utility. How to use these precious resources is very important. The first step is that we should protect them so that we can explore them reasonably and in an orderly manner. Efficient exploration and utility of the geothermal resource will do well to improve the environment. Used for bathing, entertainment and exercising, etc. with the development of travel facilities and construction, can promote utility and exploration.

Geothermal resources are distributed over a wide area and have more exploration and utility potential. Based on the good use of geothermal resources in Liangxiang, we should not only adopt scientific and suitable exploration, but also preserve this precious resource.

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