

50 Years of Geothermal Development in Beijing, China

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ABSTRACT

Although historical books showed some records of existence of hot spring in Foyukou of Beijing 1,500 years ago, geothermal development started only in the past 50 year. Preliminary geothermal investigation and exploration were carried out in Xiaotangshan hot spring area in 1950s, in order to ensure the construction of local sanatorium. Then there was an attempt to find new geothermal area in 1960s, but was not successful. From the beginning of 1970s, geothermal exploration started in Beijing Urban area accompanying geological and geophysical survey. One year later, artesian geothermal water flowed out from the first group of wells within 1,000 m of depth. Geothermal was utilized in bathing, health care, space heating, greenhouse and fish farming. In 1980s, several new geothermal fields were found relying on analogue geological setting. At that time, reinjection and corrosion tests were carried out. And the management of geothermal resources was also started. In 1990s, along with the restructuring the economy from socialist planned economy to market economy, individual investors emphasized geothermal development in tourism and health aspects. It set off a new upsurge of geothermal development. In the beginning of 21st century, on one hand, some new models in newest design, comprehensive utilization and cascade use have appeared under market competition. On the other hand, total exploitation of geothermal water has been kept stable, but total energy utilization has significantly increased.

1. INTRODUCTION

There were 3 hot springs in Beijing. The Foyukou hot spring in Yanqing County has longest history. It was recorded in the book 'Classics of Water with Notes', which is a famous book printed in the 5th century A.D. in China. This spring is situated in mountain area close to the northwest boundary of Beijing. Unfortunately, the local inconvenient traffic made its difficult to utilize. Thus, it is still artesian. The other 2 springs are located at piedmont plain. One is in hot-spring village of Haidian District, and had dried up in 1950s. The other in Xiaotangshan had historical record dated 700 years ago. It dried up in 1970s.

Preliminary geothermal investigation and exploration were carried out in Xiaotangshan in 1950s. However, geothermal development as energy resource had started from the beginning of 1970s. The world's petroleum crisis initiated an upsurge of developing the new energy in all the countries of the world. Thus, at that time, Beijing started to explore geothermal in Urban Area. Accompanying geological and geophysical survey, exploration wells were drilled to 1,000 m of depth. Artesian geothermal water flowed out in 1971. Geothermal water was started comprehensive use in bathing and health care, space heating, greenhouse planting, aquaculture feeding, and industrial use e.g. air-conditioning, dyeing and washing in textile workshops. In the middle of 1970s, Xiaotangshan

hot spring faced a crisis of drying up. Geothermal workers extended exploration there under local user's requirement. Consequently, production well exploitation replaced previous extraction from hot spring. It enlarged the area of the geothermal field and concerned geothermal utilization.

In 1980s based on summing up experience and relying on the same geological setting, geothermal workers extended exploration and successfully found new geothermal fields in Liangxiang, Tianzhu, Lisui and Shuangqiao etc. areas. Success continued in 1990s in Yanqing, Shahe and Houshayu geothermal fields. At that period, along with the restructuring the economy from planned economy to market economy, national investment in geothermal exploration had decreased significantly. Adapting to the demand of market economy, individual developers invested in geothermal for the purpose of earning money. This new upsurge of commercial geothermal development, with main goal aimed at tourism and health care development, set off. Real estate of 'Hot Spring Entering Home' had also become a hot issue.

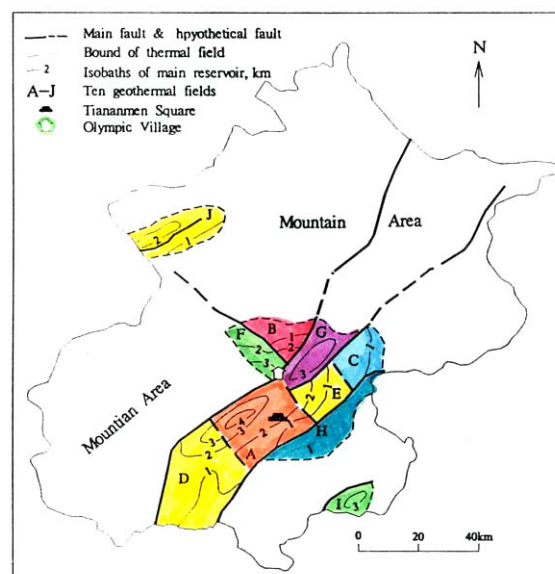


Figure 1: Geothermal fields extending in Beijing Plain A-Beijing Urban; B-Xiaotangshan; C-Lisui; D-Liangxiang; E-Tianzhu; F-Shahe; G-Houshayu; H-Shuangqiao; I-Fengheying; J-Yanqing

Since the beginning of the 21st century, large-scale commercial geothermal development ascended a new step showing enterprise-like operation in comprehensive utilization and cascade use. Such industrialized development has formed the main part of local economy. It is called 'Hot Spring Economy'. It brought great growth of local economy.

2. EXPLORING HOT SPRING AND ATTEMPTING NEW DISCOVERING

Hot spring bathing is traditional top grade enjoyment in China. Many famous hot springs were usually occupied by ancient emperors. In the 7th century, the Emperor of Tang Dynasty, Xuanzong, always bestowed his highest-ranking imperial concubine Yang to bath in Huaqing Hot Spring in suburban Lintong of Xi'an City, the capital of the Dynasty at that time. The Xiaotangshan Hot Spring in Beijing was the bathing place where the Emperor of Ming Dynasty Wuzong brought his maids of honor to bath. In Qing Dynasty, the Emperor Kangxi constructed a temporary dwelling palace and decorated the hot spring pools. Then the Empress Dowager Cixi constructed a private hot spring bathing palace. Later on, one of warlords occupied the hot spring. After liberation the people's government constructed a hot spring sanatorium. It was served to the public as a welfare institution. In order to ensure the hot spring water supply for the sanatorium, preliminary geothermal investigation and exploration were carried out under supervising of Russian experts in 1956-1958. This is a representative geothermal exploration at the early period of the new China. It covered geological mapping, geophysical survey, hydro-chemical investigation and exploration drilling. The initial hot spring appeared in 0.3 km² of area. In order to examine the extent of resources, 26 exploration drill-holes were laid out within the area of about 10 km². It drilled the total of 4271.17 m with a maximum depth of 433.03 m. Due to limited technical level at that time, although artesian flow with the maximum temperature of 54.5°C was discovered, it finally trapped an area where higher than 37°C had only 0.6 km².

Later on, geologists intended to find new geothermal area in Beijing in 1960s. Passing through groundwater temperature measurement, some anomaly areas with higher temperature were found. Two exploration wells were drilled in Wali area in 1966-1967. Unfortunately, one well that was drilled to 657.8 m of depth, got a temperature of 26°C. Even a 10 m shallow well had 22°C. Somebody proposed a further drilling in another anomaly area. However, it was not implemented.

At the same time, oil reconnaissance drilled 3 exploration wells in Fengheyang area close to the south boundary of Beijing. They yielded warm water of 31-35°C. It showed a certain geothermal potential.

3. EXPLORING BREAKTHROUGH IN THE URBAN GEOTHERMAL FIELD

Answering the call of Prof. J.S. Lee, the Minister of Geology, to develop geothermal energy, a new geothermal group was established in the year of 1970. The purpose of this group was to seek geothermal resources in the Urban Area of Beijing. Using the experiences of deep hole drilled in geological or petroleum projects in the past 20 years, the importance of geological structure setting was taken into account. Geothermal reserve needed a certain thickness of 'cap rock'. Previous exploration in Wali area were drilled in the same aquifer with a very small thermal gradient. Therefore, the exploration well was designed to penetrate a depth of nearly 1,000 m of thick cap-rock. It was then drilled into geothermal reservoir. At the same time, temperature logging in existing wells was emphasized in order to get a thermal gradient for comparison. Geophysical survey was purposed to examine subsurface structure. Due to dense civil electric network in the urban area, electric sounding survey met much interference. With high

accuracy, gravity and magnetic surveys were carried out. Through the hard efforts for one more year, the first group of 3 wells flowed out artesian geothermal water in 39°C, 46°C and 53°C respectively. Meanwhile, gravity survey interpreted the framework of geological structure in the Beijing Graben where the Urban Beijing was located. Those upwarping, sagging, main faults were clearly distributed. Highest thermal gradient, which was higher than 6 °C/100m, appeared at the relative upwarping. However, the lowest gradient of 2 °C/100m corresponded to the deepest subsiding center.

Along with a progress of supplementary geophysical survey (including seismic survey) and geochemical study, plus a detailed geological mapping at piedmont, the geothermal geological condition and its origin mechanism of the Urban Geothermal Field were recognized. New geothermal wells were drilled successfully every year. The area of the thermal field has been enlarged progressively. It exceeded 60 km² at the end of 1970s. The principal part of the exploration was in the urban area at that time. Geothermal utilization was usually by inner staff for bathing mainly. In the winter, the parts of wells with temperature higher than 53°C were used for direct heating. Some factories used geothermal for air conditioning, dyeing and washing in textile workshops. A few wells close to suburban were used for tests in geothermal greenhouse planting and aquaculture feeding. Such geothermal comprehensive utilization obviously created social effect. It replaced coal boiler reducing air pollution in the urban area. It also had a profound economic effect.

In the middle of 1970s, Xiaotangshan hot spring faced a crisis of drying-up. Local users proposed to protect the hot spring and to extend geothermal utilization. Geothermal workers recognized the geothermal geological conditions because of the experience accumulated in urban exploration. First few wells (called as combined exploration-production well) were designed out of prior anomaly area (0.6 km²), but successfully gained higher temperature and flow. They were important in exploration, but also were used in production. Relying on local superiority on land resources and on large-scale geothermal aquaculture feeding (10 hectares), geothermal greenhouse planting was extended. A new geothermal well replaced the dried-up hot spring pool in Xiaotangshan Hot Spring Sanatorium. The fact that chimney of boiler-house collapsed in the earthquake made geothermal artesian flow with 53.8°C of temperature and 2,623 m³/d of rate be used for direct space heating, and also for initial hot spring physiotherapy. It discharged circulated waste water of about 35°C. It was used for irrigating rice field of 55 hectares in the neighboring village. This made the raising of seeds to move up by 15 days, and made the increase of the crops by 750-1,500 kg per hectare.

4. CONTINUOUS DISCOVERING OF MANY NEW GEOTHERMAL FIELDS

In 1980s, on one hand, from past experience, the exploration well was extended towards both ends of the Beijing Graben, and laid on some local upwarps based on same geothermal geological conditions. On the other hand, along with the restructuring from the socialist planned economy to market economy, by requirement from user feasibility study, drilling was carried out in some new areas. From the effort of both aspects, a series of new geothermal fields, e.g. Shunyi, Lisui, Liangxiang and

Shuangqiao, were successfully found in the big range of Beijing Graben. Thus, production wells and the area of geothermal fields were increased.

Along with the restructuring the economic system, the importance of economic effect was profound. Some small scale testing could not gain high efficiency. It was limited in further development. However, big project of high efficiency gained great progress. Geothermal greenhouse planting and geothermal aquaculture feeding started to grow in Xiaotangshan geothermal field. The greenhouse and plastic shed reached a total area of 13 hectares in the Geothermal Special Vegetable Base in Xiaotangshan. In the past, they just supplied several high-rank hotels. However, at that time they enlarged their supplying power to main vegetable markets in Urban Beijing. The geothermal fed fishes also entered many public markets.

5. GROWTH OF COMMERCIAL GEOTHERMAL DEVELOPMENT

New commercial geothermal extended exploration and won the success in Yanqing, Shahe and Houshayu fields. It made the total area of geothermal field to reach 2,200 km². On the other hand, market economy has brought a great commercial opportunity to China. Newborn things, which were adapted to market economy, got full growth. Geothermal development was not the exception. In the period of planned economy, every institution relied on national investment. Geothermal industry followed the national plan for exploration. When a geothermal well was successfully completed in a location with a suitable geological condition, it could not be moved away and was left to the landowner: a factory or an institution. They became the geothermal users. Although geothermal workers helped them to plan and design proper use, they used geothermal well free of charge, and they did not have initiation and activity. Geothermal well saved initial boiler, letting the thermal water to flow to the staff bathhouse. Such utilization had only limited efficiency. When entering market economy, individual developers found that operating geothermal could earn money. For example, along with flourishing of economy and rising of people's living standard, the demand for fresh flowers had increased. In Beijing, flowers can not grow in winter. Air transport from southern China spent big money before the geothermal development. So if one of the geothermal wells could operate for greenhouse of flowers, it could gain half a million *yuan** income annually. More developers paid attention to geothermal tourism, recreation and health care. In the past, there existed only a small hot spring swimming pool installed in sanatorium. In 1990s, developers constructed geothermal swimming pool and diving pool of standard size with additional playing pool to form a hot spring paradise. It included also corresponding lounge rooms, sauna, physiotherapy and villas. This idea just satisfied the demand of the public and rich people. Thus, it was realized that geothermal business could earn big money. One geothermal well created 30 million *yuan* of annual income. (*About 8.2 *yuan* exchange 1 USD)

Furthermore, the Jiu Hua Spa and Resort created a modern geothermal recreation and health care center covering 10 hectares of land. It owns hot spring bath pool, Chinese-medicine pool and mineral mud pool. Each individual villa has a hot spring pool in its courtyard. The administration tried to appeal to a network of retired doctors from all over the country to come and live at the resort. The doctors can serve the medical needs of the people living in the resort

and have access to the resort's various geothermal physiotherapy facilities when patients need them. The resort owns one geothermal well with very common condition (44°C of temperature and 1,100 m³/d of flow rate), but they rely on the distinguishing feature of health care to attract more consumers. Its annual income reached 100 million *yuan*.

6. ENTERPRISE-LIKE OPERATION

Since the beginning of the 21st century, a scene of prosperity for Chinese geothermal development on the great stage of market economy has spread out before us. In order to enter the competitive market, the developers had to make a certain innovations. One of the examples of this occurred in Nangong village, in Beijing.

Nangong village is an advanced community of spiritual civilization known nation-wide. Under the leadership of National Model Worker Mr. Wu, the village council proposed the policy of 'Changing traditional agriculture. Going on towards urbanization'. Based on local rural conditions, they decided to utilize local superiority of geothermal and land resources in order to do well in geothermal enterprise-like operations and to develop a geothermal economy. At that time, more than 200 geothermal wells had been drilled in Beijing. But only one well was implemented all over cascade utilization and had a comprehensive development. Since well's completion in October of 2000, geothermal water with 72°C of temperature and 2,380 m³/d of flow rate is first used for space heating. It heats an area of 30,000 m², including residential houses, guesthouse, hotel, offices and geothermal exhibition center. It also supplies hot water to these facilities. Then the returned water with decreased temperature of 48°C enters the second stage use. It is used for floor heating and hot spring recreation in the Hot Spring Water World and Hot Spring Fishing Center. After that, the thermal water with even more decreased temperature enters the third stage of use in Hot Spring Special Aquafarm. Various special species of edible fishes are fed there. Finally, thermal water with temperature lower than 30°C is heated by passing through heat pump or by adding a part of original geothermal water. It then enters the fourth stage of use. It is used in greenhouse for soil heating and irrigation. Such cascade utilization has full use of thermal energy and water resources from geothermal water. In addition to overall geothermal utilization in the 'World Geothermal Natural Science Park', there is another Geothermal Popular Science Exhibition Center. The center has a multi-functional show hall with geothermal movies and an exhibition hall presenting geothermal popular science. This project uses low temperature geothermal for direct use. It brought great change of local rural economy in Nangong village. For example, all farmers have entered geothermal service business. There are 2,700 people in the village. Their annual output value has exceeded 200 million *yuan*, with an average per capita of 8,000 *yuan*. This achievement was shown in Beijing TV Program.

7. CONCLUSIONS

In the past 50 years, geothermal development in Beijing showed a continuous economic and scientific progress. Table 1 and table 2 briefly summarize the conclusions. The first upsurge happened at the beginning of 1970s caused by world petroleum crisis. However, the second upsurge occurred in 1990s accompanied by the restructuring of economic system to the market economy. It gave a full

power to individual developers to invest into the geothermal business. A series of industrialized developments with enterprise-like operations have established 'Hot Spring Economy'. It has changed local initial rural economy into a modern commercial service economy. Geothermal is not only science and technology, but it is also a great business economy.

Table 1 Progress and Analysis of 50 year's Geothermal Development in Beijing

| | Main Work and Progress | Analysis |
|--------------|---|--|
| 1950s-60s | Xiaotangshan investigation and exploration; Wali test exploration drilling; Fengheying oil exploration drill found thermal water | Testing work at the early stage of New China |
| 1970s | Successful exploration in Urban Beijing found thermal field; Geothermal comprehensive use in various aspects; Xiaotangshan extend exploring | A great breakthrough but socialist planned economy and a welfare pattern |
| 1980s | Extended explorations success in Tianzhu, Lisui, Liangxiang & Shuangqiao Utilization expanded scale and gained economic effect | Restructuring economy from planned economy to a market economy |
| 1990s | Extended explorations success in Yanqing, Shahe, Houshayu; Commercial geothermal in tour, recreation, health care and hot spring real estate | Market economy created the opportunity for rapid growing |
| 21st century | Large-scale comprehensive and cascade use; Industrialized development and enterprise-like operation forms the 'Hot Spring Economy' | Market economy got further consolidation & growth |

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Table 2 Summary of 50 year's Geothermal Development in Beijing

| | 1950s-1960s | 1970s | 1980s | 1990s | 21st century |
|--|-------------|--------|--------|---------|--------------|
| Flow kg/s | 2.1 | 104.7 | 237.6 | 285.0 | 359.8 |
| Capacity MWt | 0.2 | 18.1 | 48.7 | 76.9 | 169.5 |
| Annual utilization GWh/y | 0.7 | 49.9 | 139.4 | 177.7 | 229.6 |
| Capacity factor | 0.50 | 0.32 | 0.33 | 0.26 | 0.15 |
| Number of geothermal field | 1 | 2 | 6 | 10 | 10 |
| Area of thermal fields km ² | 0.6 | 72 | 210 | 2,000 | 2,200 |
| Number of well drilled | 8 | 38 | 67 | 71 | 123 |
| Total depth drilled m | 13,185 | 38,512 | 82,600 | 108,331 | 276,284 |
| Person-years | 3 | 25 | 42 | 64 | 86 |
| Funds (2000 value) M \$ | 3.9 | 15.1 | 28.7 | 64.0 | 131.5 |