*Proceedings World Geothermal Congress 2000*
*Kyushu - Tohoku, Japan, May 28 - June 10, 2000*

# GEOTHERMAL DEVELOPMENT IN XIONG COUNTY, HEBEI PROVINCE, CHINA

Wang Li[1] and Wang Ning[2]
[1]UNESCO International Research and Training Centre for Rural Education
Agricultural University of Hebei, Baoding, Hebei 071001, China
[2]College of Urban and Rural Construction,
Agricultural University of Hebei, Baoding, Hebei 071001, China

**Key words:** low-temperature, direct use, geology and development potential

**ABSTRACT**

Geothermal development in Xiong County started in 1972. For more than twenty years, this field has been the biggest county-level geothermal field on geothermal comprehensive utilisation of low and moderate temperature in north China. This paper provides details of the geology in this field, the present geothermal utilisation and discusses the future planned development potential with an emphasis on sustainability.

## 1. GEOTHERMAL RESOURCES IN HEBEI PROVINCE

Hebei province is rich in geothermal resources. The geothermal development and utilisation were mainly started in the early 1970's and by the end of 1997, there were 119 locations of geothermal utilisation, including almost all cities in this province. Table 1 shows various uses of geothermal energy in Hebei Province, locations of the cities are shown in Fig. 1. In the mountainous region, there are 75 natural hot springs, which have a total flowrate of 39240 KJ/s hot water. In the plain region, there are as many as 546 geothermal localities. From the beginning of 1970's, exploration for petroleum has been carried out in Hebei Province. These activities led to many geothermal wells being drilled. According to the temperature gradient and the depth of hot water layer in these wells, two different kinds of geothermal fields can be recognised. One is Nutuozhen geothermal field, where the temperature gradient is over 4°C/100m, and the depth of the hot water layer is 500-1500m. The other one is Gaoyang geothermal field, where the temperature gradient is 3.5-4°C/100m, and the depth of the hot water layer is between 2000-3500m. The temperature of hot water in this province ranges from 35-105°C, which belongs to low to medium temperature water. The total hot water storage is 180 billion tons, which is equal to one billion tons of standard coal. The chemical composition includes K, Na, Ca, Mg, Li, Sr, Cr, $NK_4$, Fe, As, Mn, Al, Cu, Pb, Zn, Cl, $SO_4$, $HCO_3$, $CO_3$, F, Br, I, $H_3$, $NO_3$, $NO_2$, $H_2S$, and $SiO_2$. The hot water pH value is 6.5-9.

## 2. XIONG COUNTY GEOTHERMAL FIELD

Xiong County is located in the central plain of Hebei Province, south of Beijing and between the cities of Tianjing and Baoding. The total land area is 524 $km^2$, and the population is about 315,000. Baiyang Lake is located in the southern part of the county, and the Daqing River follows the southern boundary of the county (Fig. 2). Xiong County has abundant low-temperature geothermal resources. Investigations carried out by the Chinese Ministry of Geology, the Chinese Academy of Science and other parties show the total area of this geothermal field to be 360$km^2$ at a depth of 500-1500 m. The field occupies 60% of the total county area. The total hot water reserves are over 10 billion tons, in the temperature range of 63-94°C, which is equal to the energy in 600 million tons of standard coal. The quality of hot water in this field has been found to be excellent and is classified as Cl-HCO-Na type water (Wang Li and Wei Hong-chang, 1992).

## 3. GEOLOGICAL CHARACTERISTICS

- Nutuozhen geothermal reservoir is mainly located above the geological body where the Daxing, Nudong and Rongcheng faults are found; that is, above the Nutuozhen horst. Guan basin is located in its northern part, the Bazhou basin in its southeast part, and Rongcheng horst in its west part. Xiong County geothermal field is at the top part of the axes in the horst of the Nutuozhen geothermal field, and is between the southwest part of Bazhou basin and the east side of Rongcheng horst.

- The main geological formations of this geothermal field are of Cenozoic, Quaternary, and early Tertiary age. The late Tertiary age is found in the basin around the horst. The unconsolidated Quaternary sands and mud contain water rich layers, which overlie the hot water reservoir. The early and late Tertiary formations can also form hot water reservoir in this field. The bedrock is of Cambrian age, QingBaikao age, Yuxian age, Changcheng age and can also contain hot water reservoirs.

- Most of geothermal water in this field gains its heat from conductive thermal gradient of the crust with. However, local water convection is found in the Nudong fault. The characteristics of the geothermal water are closely related to the depth of bedrock. The bedrock in Xiong County horst ranges from 500 to 1200 m depth, and becomes gradually deeper in the basins on both sides of the horst.

- The geothermal gradient in the Cenozoic rocks decreases as the bedrock depth increases. The highest gradient of 12.6°C/100m is found in the Xiong County horst; the average is 5°C/100 m, and the lowest 3.5°C/100m. The main hot water reservoir is in a porous layer of early Tertiary age and karst-crevices of Yuxian age.

- The hot water reservoir in the early Tertiary formations is broadly distributed within the central part of the horst. The geothermal field has an area of about 320$km^2$, and an average geothermal gradient of 3°C/100m. The top of the reservoir is at 380-470m depth, and has an average thickness of 225 m for the hot water layer, a 600 m thick layer with 46.7°C average temperature, and a 58°C maximum water temperature in a permeable zone and

1-1.5g/l degree of mineralization. The pH is 7.2-8.8, and the flowrate from single wells are 20-50 $m^3$/h.

- The hot water found in the karst-crevice of Yuxian age is mainly found in the western part of Xiong County. This geothermal field has an area of about 210 $km^2$ and lies at a depth of 3000 m. The thickness of the average hot water layer is 180 m, with an average temperature of 83°C. The water has a maximum temperature of 85°C in an opening of a well, 2.8-2.9 g/l of mineralization, a pH of 6.5-7.0, and flowrates for individual wells of 25-110 $m^3$/h.

- The concentration of chemical species in water from the early Tertiary formations is not high, and the water does not contain any noxious chemicals. However, in some region like Baima, the $H_2SiO_2$, Li, Sr, I concentrations have already reached the drinking water standard. Besides utilizing as source of heat energy, they can also be used as mineral water for drinking and irrigation.

## 4. DEVELOPMENT AREAS

According to the geological environment and development practices, the geothermal development in this county can be divided into three zones. 1) District heating zone in county town, 2) Geothermal production zone in the northern part of the county town, and 3) Geothermal tourist and recuperation zone in the south part of the county town (Fig. 3).

### 4.1 District heating zone in the county town

Geology

In this field, the bedrock is Yuxian age and lies at a depth greater than 2000 m. The hot water reservoir is found in early Tertiary rocks, which cover the bedrock. The temperature in the early Tertiary rocks is 50-55°C, but 65-95°C in the bedrock. These two types of hot water reservoirs can be utilized according to their potential, and users' needs. The first well distribution distance in the early Tertiary rocks is 1500 m with the depth of 500-1500 m. The flowrate per well is in the range of 30-60 $m^3$/h. The second well distribution distance in the bedrock is 2000 m with the suitable depth of 1200 m. The flowrate per well is in the range of 20-50 $m^3$/h.

Present geothermal utilisation

Presently 8 geothermal wells are being used in this zone providing district heating area of 180,000 $m^2$ for one third of the total population. This geothermal district heating can save 6,5000 tons coal compared with coal-fired boiler heating, which is equal to 1.5 million yuan RMB, as well as 1.2 million yuan RMB heating equipment which can be saved. Therefore, a total of 2.7 million yuan RMB can be saved by using geothermal heating instead of boiler heating. Thus geothermal district heating not only saves the coal energy, but also promotes an ecological environment. It can decrease the dust discharge by 115 tons and $SO_2$ by 58 tons in one heating season alone.

Moreover, with the abundance of water supply in the county, many people can take a bath in their own house, in addition to the 15 public bathing houses available.

Development potential

The hot water reservoir in this zone is quite good and suitable for district heating, bathing, and recuperation. To enhance these uses, three phases of project development have been conceived. Firstly, to enlarge the coverage of the district heating area. Henceforth, 2 or 3 more new wells will be drilled in addition to the existing wells. At the end of the proposed project, the district heating area will be extended to 300,000 $m^2$, to realise the dream of "*no smoking town*". Secondly, speeding up the construction of three hot water swimming pools; and thirdly, establishing a comprehensive demonstration area for planting, breeding plants and bodily recuperation.

### 4.2 Geothermal productive zone in the northern part

Geology

In this field the bedrock depth is very shallow. The hot water in the early Tertiary formation is widely distributed and directly covers the bedrock. The hot water temperature in the early Tertiary rocks is 40-60°C and the flowrate per well is in the range of 20-50 $m^3$/h. The hot water temperature in the bedrock is 60-75°C, and the flow rate per well is in the range of 25-110$m^3$/h.

Present geothermal utilisation

At present, there are 6 wells being used in this region for planting and breeding. The main products are vegetables, fresh flowers, and fishes. Most of the products are sent to Beijing, Tianjing and other cities.

Development potential

Because the bedrock here is at a very shallow depth, it is easily exploitable for further development. With its suitable water temperature, quality and output, it can be used for planting, breeding and mineral water production. Future development plans includes the drilling of 4 new wells to extend the geothermal planting and breeding area, especially in vegetables, flowers and fish production, as well as increasing the mineral water production.

### 4.3 Recuperation zone in the southern part of the county town

Geology

The geological condition in this zone is similar to that in the district heating zone in the county town.

Present geothermal utilisation

The geothermal development has promoted tourism and recuperation in this county. Since 1992, 5 geothermal wells have been drilled in " *Baiyang Lake Hot Spring Town*", the total investment being over 600 million-yuan RMB, which is the biggest tourism project in the county.

Development potential

The tourism program in this county is mainly located in " Baiyang Lake Hot Spring Town" and the tourist zone around

the Baiyang Lake. Future development will be focused in this field and some projects will be developed such as a tourist and holiday village, a medical treatment and recuperation centre, tropical aquarium, plant/garden show and many others.

## 5. CONCLUSION

Xiong County geothermal development has made great achievements in the past two decades, but as it is still in the initial stage, it poses a great potential for further exploitation in many other uses. At present, an annual geothermal utilisation amounted to only about 1/500 of the total reserve amount in this field. So, further development should be made to exploit other uses. However, such exploitation and development should be in accordance with the different geological situations and utilisation level in different zones of the county. Moreover, to ensure sustainability only suitable exploitations must take place.

## ACKNOWLEDGMENTS

We thank Xiong County Geothermal Bureau for providing data. Thanks are also given to those who have provided any advice and help in the writing of the paper. The Authors would appreciate any comments on the practice and theory outlined in this paper.

## REFERENCES

Wang Li and Wei Hong-chang (1992). The past, The present and The Future Utilisation of Geothermal Energy in Xiong County, Hebei Province, People's Republic of China, Geothermics, Vol. 21, No. 5/6, 1992

**Table 1 Various Uses of Geothermal Energy in Hebei Province in 1997**

| City | Tempera-ture (°C) | Utilization field (Unit) | Planting area (ha) | Aquaculture Area (ha) | District Heating ($m^2$) | Medical Treatment (Unit) | Bathing (Unit) | Others |
|---|---|---|---|---|---|---|---|---|
| Chengde | 70-80 | 3 | 48.74 | | 200 | 1 | 2 | |
| Zhangjia-kou | 40-85 | 11 | 1.20 | 11.1 | | 5 | 10 | |
| Tangshan | 35-105 | 6 | 16730 | 28.72 | | 1 | 3 | |
| Qinhuang dao | 40-70 | 11 | 1.48 | 3.96 | | 1 | 6 | 2 places for mineral water |
| Langfang | 71-95 | 7 | 4.34 | 4.03 | 8,000 | | 4 | |
| Baoding | 66-98 | 16 | 35.90 | 16.62 | 110,000 | 2 | 2 | 2 places for mineral water |
| Cangzhou | 51-146 | 14 | 9.30 | 8.40 | 63,000 | | 30 | Swimming in winter season |
| Shijia-zhuang | 68-83 | 12 | 4.80 | 5.50 | 2,000 | 2 | 5 | Geothermal drying |
| Hengshui | 65-80 | 1 | 1.30 | 2.50 | | | | |
| Xingtai | 40-70 | 52 | 35.90 | 16.62 | | 1 | 1 | |
| Handan | 40-70 | 2 | 1.80 | | | | | |
| Total | | 139 | 125.58 | 80.83 | 183,200 | 13 | 63 | |

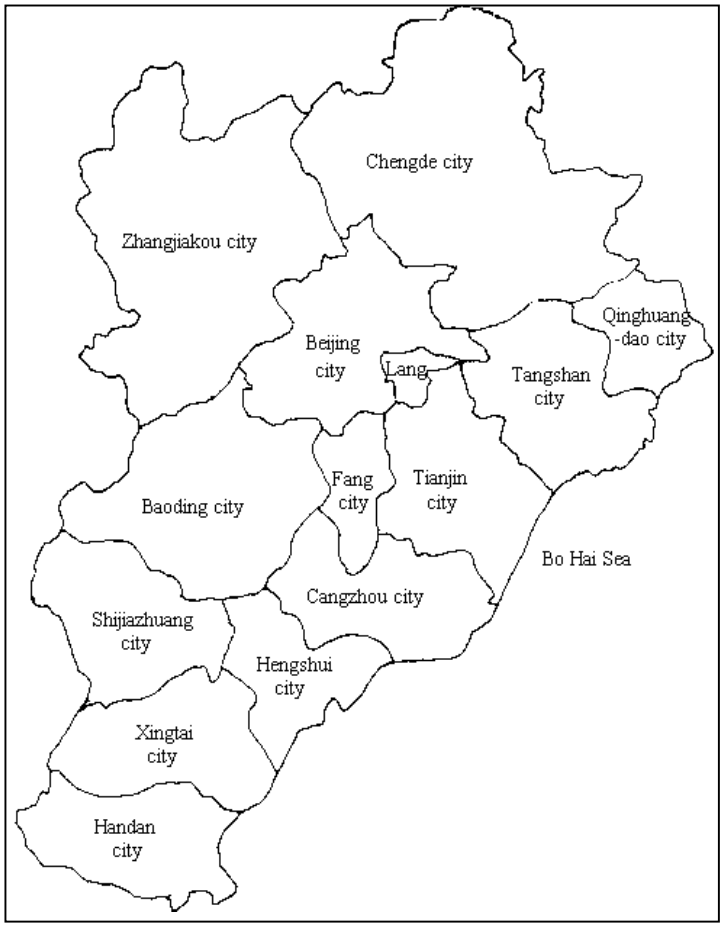


Fig. 1 The location of the Xiong County geothermal field

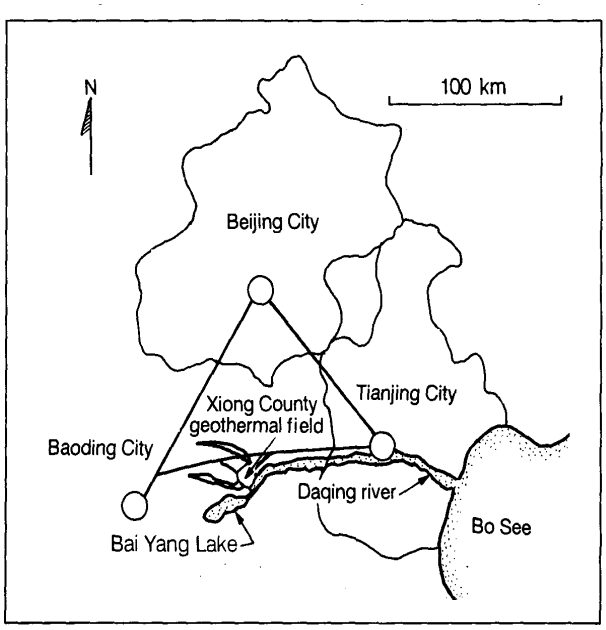


Fig. 2 The location of the Xiong County geothermal field

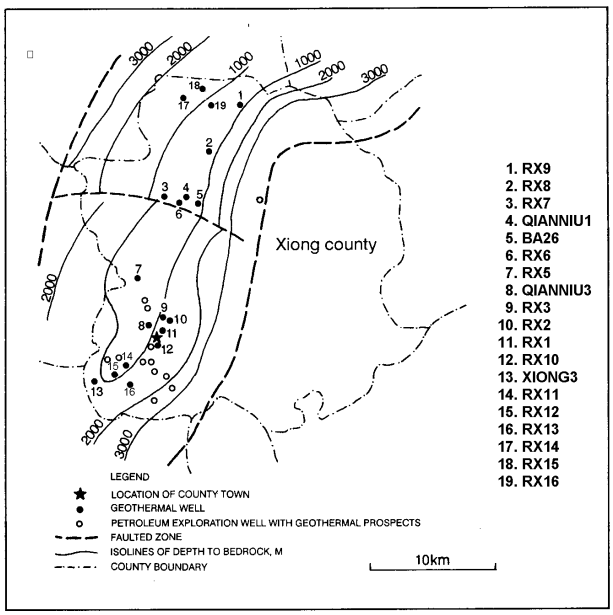


Fig. 3 Distribution of geothermal wells in Xiong County