GEOTHERMAL RESOURCES AND DEVELOPMENT IN BAI YANG LAKE REGION, HEBEI PROVINCE, CHINA

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Key Words: Bai Yang Lake, Geothermal Resources, Geology, Utilization, Development

ABSTRACT

Bai Yang Lake is the biggest natural lake in North China. Because of its special geological structure, geothermal resources in and around the lake are abundant. There has been a decade or more geothermal resources development in Xiong County, Ren Qiu County, Rong Cheng County, Gao Yang County and so on. A wealth of experience has been accumulated, and a great many economic benefits have also been achieved in this region.

This paper describes, in detail, the geological structures; the nature of the stratum and its distribution in Bai Yang Lake region. In relation to its geology, the general nature of Bai Yang lake earth's temperature field and the essential factors forming the geothermal resources in this area have been expounded. Finally, the information about the development of the geothermal resources in Bai Yang Lake region has been given.

1. GEOGRAPHIC POSITION OF BAI YANG LAKE

Bai Yang Lake is located in the middle plain of Hebei Province. Around it, there are five counties. Beijing to Guang Zhou railway and Beijing to Shen Zhen highway is in the west part of the lake. The geothermal resources are rich in the Bai Yang Lake and around its region.

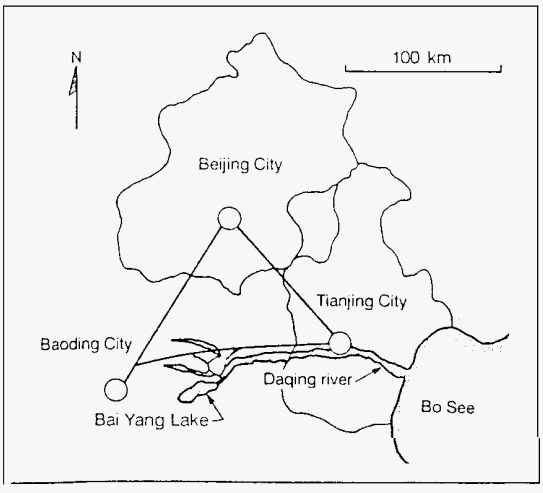


Fig. 1 The Location of the Bai Yang Lake Region (Ref 1)

2. GEOLOGICAL CHARACTERISTICS IN BAI YANG LAKE REGION

2.1 Geological Structures

Bai Yang Lake is located in the western part of Hebei middle depression, in the uplift of Niu Tuozhen, the uplift of Rong Cheng and in the depression of south Bai Yang Lake, with the fracture structures developed. The Niu Dong big fracture system goes through the north part of the region. The Qian Shan fault surface is in a range among 7-8km In the west part of the region, there is a Gao Yang fracture system in a direction of near northern part extending to the Bai Yang lake depression. In the eastern part of the region, sub-fracture belonging to Ren Xi big fracture system goes through the depression in a direction of northeast. Affected by east-west tension-torsion stresses, a Tai Hangshan great fracture system in a northeast direction, a Gao Yang fracture system, a Reng Xi fracture system, make the different degree fault movement and some offset in a direction in Niu Tuozhen uplift and Bai Yang Lake depression, which indicates that a Niu Tuozhen uplift and a Shen Da great fracture system have the biggest affects on geothermal structure in this region.

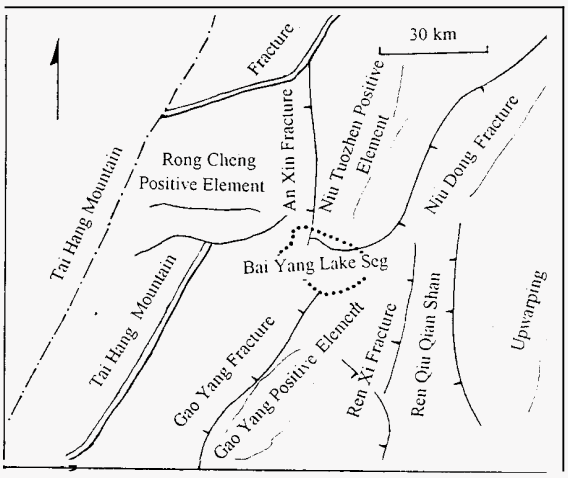


Fig. 2 The Geological Structures in the Region (Ref. 2)

Hebei middle depression was formed in Mesozoic and Cenozoic. It is a fault-foundering basin. The basement consists marine stratum contained mainly carbonate of lower Paleozoic group and upper-middle Proterozoic age. Mesozoic era(secondary era) activity was affected by Yang mountain, so the fault activities are very strong and different uplift areas were formed in the basin. In the uplift area, the layer of carbonate rock in the basin is exposed at the surface, and the karst and structural karst related (fracture) system were formed by slacking and erosion. The down basement of the depression is filled with the land facies clasolite. In the Tertiary period, the sag turned into a subsidence throughout the ground at the middle plain of Hebei, which appears to have a depression in the whole district and enhances the fracture activities. In the direction of north-northeast and north-east, the fracture structure developed, therefore the basement was cut to form a series of the uplift depression with the similitude direction to the main structure

direction and with the shape of anserine arrangement and other sub-uplift in the depression. With the sag formed and developed, the uplift and the depression were covered by the conglomerate, the sandstone, and the pelite of fluvial-lacustrine depression in the Cainozoic. Bai Yang Lake was formed during the Tertiary period, going through the period from the sea to the lake, and from the lake to the land, as the lake now located in. Among which, there are different thickness and layers in the Cainozoic corresponding with the range of the sedimentation in the uplift area and the depression area. The thickness of the Cainozoic in the uplift is about 1000m and in the depression is about 4000m.

2.2 The Topography Characteristics and the Distribution Regularity

In this area, strata from earliest to most recent are as following: Ji Xian Wu Mi Shan layer, Mesozoic Erathem, Neogene system, Eogene system, Guan Taozu, Ming Huazhen, and Quaternary period Ping Yuan layer.

Carbonate Layer of Ji Xian Wu Mi Shan Affected by the basement structure, this strata is from Rong No. 2 well, Xin No. 1 well in the northern part of *An* Xin town, Dian No. 1 well, Gao No. 10 well in the southern of *An* Xin town to the southwest of Bai Yang lake. The depth to the top of this strata is 1667-2724-3152-3471-2974m respectively, which shows that the center of the depression is located inside the Bai Yang Lake. For the east-west direction, Long Xiao well(2222m), Yan No. 11 well(2950m), in the eastern, and No. 1 well(3152m) show the same pattern as above.

This strata belongs to the marine carbonate rocks Structural cracking and the karst fracturing are developed quite well, because of the earth crust movement and the erosion activity of the ground water, so it is a very good permeable stratum and aquifer

Mesozoic Erathem Affected by the basement structure, there is a big difference in the thickness This strata consists of Clasolite rock and Basalt

Eogene Svstem This strata is unconformity with the basement. It consists of sandstone and marine pelite. Affected by the basement structure, this strata is thinness inside the uplift area, which mainly consists of pelite with the thin sandy layers and fine clays. The extent of density and rock formed are higher than that in Tertiary system, which appears to have lower characteristics of permeable water. It is a relative water proof layer.

Neogene Svstem The depth of the basement in this strata is 1234-1292-1592-1545m respectively from Rong No 2 well, Xin No. 1 well in the northern of *An* Xin town, Dian No. 1 well in the southern of **An** Xin town to Gao No. 8 well in the southwest of Bai Yang Lake, which shows the same regularity with down layer. It belongs to a fluvial lacustrine environment, which divided into Ming Huazhen and Guan Taozu.

A. Guan Taozu layer: Affected by the basement structure, this strata by conglomerate is unconformity with Eogene system. It is a accumulation strata contained with coarse sand at the basement of this strata, the conglomerate have the characteristics of the loose colloform and lower diagenesis, therefore it is a good permeable bed and an aquifer which has a rather good permeability in transverse.

B. Ming Huazhen Layer: This strata lies in conformity with the top of Guan Taozu. The depth of basement is 943-1039-1364-1280 respectively from north to south(Rong No. 2 well, Xin No. 1 well, Dian No. 1 well, Gao No. **8** well). This layer is divided into an upper and lower unit. The lower unit is a series of sandstone and pelite of fluvial origin with thickness of 200m. The pelite is the main composition of the strata, the sandstone is not developed; the upper unit also contains sandstone and pelites of fluvial and lacustrine origin with the sandstone developed to a thickness of 400m. It is a good aquifer.

3. GENERAL SITUATION OF CEO-TEMPERATURE FIELD OF BAI YANG LAKE AND ESSENTIAL FACTORS FORMED GEOTHERMAL RESOURCES

3.1 General Situation **of** Geo -Temperature Field **of** Bai Yang Lake

The regional geo-temperature situation is affected by the geologic developments and structure of Niu Tuo Zhen uplift, Gao Yang uplift, Ren Qu Qian Shan belt, and Shen Da fracture system and sub-fracture system in the district, all which control the geo-temperature field of the region.

The structural activities in North China area is intense. The earth's crust has thinned and the depth to the mantle and position of Moho are shallower in areas resulting in non uniformed distribution of the geo-temperature. The mantle geo-current distributes the heat flow in the form of conduction and convection by means of Shen Da fracture of the basement and the layer of basement carbonate rocks and relevant fractures in which the heat transmission rate is two or three times higher than that in the pelite or sandstone regions, The resulting was the formation of a high-temperature abnormally in the Qian Shan zone. It is clear that the earth's heat flow value is the main and important factor for evaluating the geothermal resources in the region. The average heat flow value in North China is 1.23 heat flow units. In the Bai Yang Lake region, that heat flow value is in a range of 1.75-2.75 heat flow units, which constituted a good basis for geothermal resources in this region. The heat flow value varies greatly in this high temperature abnormally. The heat flow value in the uplift of Niu Tuo Zhen can be up to 3.2 heat flow units (Chen Me-xiang, 1988).

The geo-temperature gradient in Cainozoic rocks of Hebei middle depression is 3-4 °C/100m. The geo-temperature gradient in the uplift of Niu Tuo Zhen is more than 5 °C/100m, and the highest is up to 11.5 °C/100m (Wang Li et al., 1992).

To sum up, Bai Yang lake is located in a good geo-temperature field, but the geo-temperature gradient varies greatly, based on the geological structure and the fracture pattern.

3.2 The Main Factors Affecting Geothermal Resources in Bai Yang Lake

This region have a good geothermal base, that is geo-heat field. But it is not enough to produce the geothermal resources, the other four necessary factors are "storage, cover, permeability and source" (Chen Me-xiang, 1988).

Storage This means storage conditions of geothermal water. There are two systems with hot water. One is karst water in a carbonate layer, and the other is void water in a sandy layer of Tertiary system, which will be discussed later.

Cover **A** good cover is a main condition for the geothermal resources. It is clear that the heat conduction rate is negative proportional to porosity. The average porosity in a carbonate layer is about 5%, and the average factor of porosity in a sand layer of Tertiary system is in a range of 15-30%, so the later is quite a good cover.

Permeability That is referred as a conducting way of geothermal resources. Niu Dong big fracture system located in the north part of the region provides good potential permeability, and the high-temperature abnormal belt was formed around the big fracture system. Other fracture system or sub-fracture system can also found in the high-temperature abnormal belt.

Source Which means where the geothermal water come from. As it is mentioned before, there are two water systems, namely, underground water in Tertiary system, which is the lacustrine deposit water and karst water in a carbonate layer, which can get new water from rainfall and is richer than that in Tertiary system.

4. GEOTHERMAL RESOURCES AND DEVELOPMENT IN BAI YANG LAKE

4.1 Geothermal Water in Tertiary System

The depth of sand rock and mud stone in the Tertiary system of Bai Yang Lake region is about 3000m. The hot reservoir rocks are the Ming Huazhen layer and Guan Taozu layer.

Upper Section Geothermal Water in Ming Huazhen Layer The depth for this layer is about 900m. And the depth of the roof is about 300m. It is a rich aquifer. The effective depth is lOOm or more. Factor of porosity is 33% with 0.1m³/HV.m of the rate of water-flow. Estimated water temperature at a well depth of 600m is 41 "C and the quantity of water for a single well is in a range of 1500-2000m³ /day with 3.4°C/100m of the geothermal gradient.

Bottom Section Geothermal Water in Ming Huazhen Laver The depth for this section is in a range of 970-1300m with 0 3 of the proportion of sand and mud The effective depth for this layer is about 60m Its porosity is 0 03m³ /HV m Estimated water temperature is not less than 50 °C with 1000m³ /day of a single well water flow rate

Geothermal Water in Guan Taozu The depth for Guan Taozu is in a range of 1200-1900m in this region. The sandy layer is more developed and represents about 40-50% of the section. The bottom is gravel. The rate of water-flow is 0.017m³ /HV.m. It has more useful value with high temperature and big quantity of water. At a depth of 1700m, hot water with above 65 °C temperature can be found. Estimated water flow rate for a single well is about 1500m³ /day, it is a better hot reservoir developed with value in this region.

The total mineralized rate in Tertiary system is not high and increases about 750-2500mg/L with the depth. The water-chemical nature belongs to Cl - Na (Wang Li et al., 1992).

4.2 Geothermal Water of Karst Water in a Carbonate

This layer is quite good in the water conducting situation and high in the factor of permeability. The temperature is higher and the ability of storage water is also quite good. The mineralized rate is less than 3-5g/L Underground water recharge in the region is intense. And the feeding source is rich Temperatures in this layer range from 50 °C to 100 "C with greater than 1500m³ /day single well flow rate.

4.3 Suggestions for Geothermal Development

The development for geothermal water in this region can be carried out according to the geothermal resources in the different layers mentioned above, especially in the Xiong county zone(The total geothermal resources in Xiong county is about 10 billion cubic meters (Wang Li et al , 1992)). Further suggestions can be given through contacting the author.

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