

The influence of fracture on Wumishan Formation geothermal reservoir pressure field in urban area-suburb of Tianjin

Yang Yongjiang, Jin Bao-zhen, Liu Jiu-long, Zhangziliang, LI Bo

Tianjin Geothermal Exploration and Development-Designing Institute

Add: 189, Wei Guo Road He Dong District Tianjin, China

E-mail : julon0920@163.com

Keywords: geothermal reservoir, fracture, dynamic, pressure field, Tianjin.

ABSTRACT

This paper uses dynamic data of recent years, combined with primary water conductive fracture structure characteristics in the urban area and suburb of Tianjin, to discuss the influence of water-conductive faults on Wumishan Formation geothermal reservoir pressure. This work will be a credible reference for future geothermal development, reinjection layout and confirmation of boundary conditions. It should also contribute to the value of geothermal resources in the contributing to local economic development, help actualize sustainable development of geothermal resources, and contribute to Tianjin "Blue Sky Project".

1. INTRODUCTION

Tianjin economic development has been rising in recent years, and the resource and environment plays an important role. Geothermal resources are a renewable and clean energy and are significant development prospects for Tianjin economic development. Geothermal resources in this area are sedimentary basins. With the geothermal market growing and large-scale and centralized geothermal development, the rate of reservoir pressure decrease is increasing year after year. Moreover, through understanding geothermal exploitation dynamics near fractures and the impact of fractures, we can effectively control the pressure drop. At present, one of the primary reservoirs of Tianjin geothermal development and reinjection is Wumishan formation. According to the characteristics of fractures which can transmit water, and the dynamic character of Wumishan reservoir, this paper will analyze the impacts of fractures on the Wumishan Formation geothermal reservoir pressure field..

2. WATER CONDUCTIVE FRACTURE STRUCTURE CHARACTERISTICS OF TIANJIN URBAN AREA SUBURB

Geothermal studies have shown for years the impacts of fractures on Wumishan formation geothermal reservoir pressure field. The Haihe, Cangdong and Baitangkou fractures have an important impact on the reservoirs. These fractures Characteristics summarized as follows:

2.1 Haihe Fracture

The fracture is located at Qingguang ~ Tianmu Village ~ south Wanxin Village ~ Gegu ~ south Dapu, Westward into the Hebei Province, Eastward into the Bohai Sea by the Tanggu, basically scattered along the Haihe river, about 86km. Fracture direction is NWW in Tanggu region, the fracture strike is NW in Tianjin urban area, the trend is SSW

~ SW, and the angle of inclination is 40 ~ 60°, Overall it is a normal fault of north part rise. The drop height of the Paleogene in the eastern section of the fracture is 1200 ~ 1600m. The breakpoint depth is 1200 ~ 1600m; Ordovician underside disconnection distance is 600 ~ 1200m. The fracture cuts Si-Al terrain, cutting off and controlling granite terrain, and cuts the crystal floor of Archean and Pt. The incursion depth is above 7km. The fracture is cutting Tianjin segment of Cangdong fracture. It reflects that the fracture was reactivated after the formation of Cangdong fracture. It is the boundary between the Panzhuang and Shangyao, also between the Beitang depression and the Panqiao depression.

2.2 Cangdong Fracture

This fracture is in the Ninghe Huaizhuang Village, through Junliangcheng, Zhengfutai and Hulianguang, and then comes into Hebei province. The whole length is about 200km. The Tianjin part is only its northern section. Its length is about 120km. The overall direction is North-North East (NNE). The trend is to the South East (SEE), with an inclination of 30 ~ 48°. The fracture is a normal fault. Stratigraphic gap for 1000 ~ 6000m, and is deep in the south and shallow in the north and has the characteristics of the growth fault (that is, broken edge, while deposition).. Its depth is greater than 10km. It cuts down the Si-Mg layer of the earth's crust to the mantle, cutting through the Neogene Minghuazhen formation. It controls the Mesozoic and Cenozoic basin development as a boundary between the tectonic units Cangxian apophysis and the Huanghua depression.

2.3 Baitangkouxi Fracture

The fracture starts in the east of Zengxingyao Village, passes through Dashi, Jianxin village and Mengjiapuzi, and then comes into Xiaowangzhuang. The whole length is about 48km. The overall direction is the North-North East (NNE). The trend is SEE. The angle of inclination is 30 ~ 50°. The fracture is normal fault, and is a shovel-shaped growth fracture. West set of the fracture is Shuangyao heave. The bedrock roof is the Paleozoic and the Neoproterozoic; the East set of the fracture is Paitangkou depression, and the bedrock roof is mainly the Mesozoic and Paleozoic.

3. THE INFLUENCE OF WATER CONDUCTIVE FRACTURES ON WUMINSHAN FORMATION GEOTHERMAL RESERVOIR DYNAMIC FIELD

The Neoproterozoic Wumishan formation have distributed in mountains area and plains area of Tianjin. due to its lithology and sequence stability, sediment thickness, crack development, good water quality, and so on, and has become one of the most important bedrock aquifers. The group is rich mainly in magnesium carbonate rocks. Generally, the Wumishan formation depth is above one kilometer in the

southern Baodi fault. As a result of the greater depth in the depression area, most geothermal wells are concentrated in the Cangxian apophysis. As of October 2006, there are 83 Wumishan geothermal wells in total, of which there are 69 producing wells. The annual exploitation quantity is $1361.3 \times 10^4 \text{ m}^3$. There are 13 recharge wells. The annual recharge quantity is $227.5 \times 10^4 \text{ m}^3$. In this paper, there is a focus on dynamic analysis of Wumishan formation geothermal exploitation areas in the central urban area and its vicinity north to the line of Tongditou, south to the line of Wanjiamatou~Daegu Zhuang, west to Tianjin fault, and east to the line of Dongnigu-Xixiaozhan.

3.1 The Influence of Water Conductive Fractures on Wumishan Formation Geothermal Reservoir Dynamic Field

As can be seen from Figure 1: the lots which have shallow depth and a smaller drop in the Wumishan reservoir water level are located near the Chang-dong fracture, the Haihe fracture, and the Baitangkou fracture. Basically, the water level depth increased gradually along the Cangdong fracture and Baitangkou fracture to both sides of the faults. Minimum water level depth lots are located at the meeting point of the Haihe fault, the Cangdong fracture, and the Baitangkou fracture. The dynamic data of geothermal wells near the Cangdong fracture and Baitangkou fracture (see Figure 2) show that the geothermal wells' water level restores rapidly after stopping exploitation. The minimum water level drop is about 3m, so we know that the rocks near Cangdong fracture, the Haihe fracture and the Baitangkou fracture (in particular, near the meeting point of fracture) has higher permeability, better water-based derivative, so that the lots has good hydrodynamic thermal energy storage and recharge conditions. Maximum water level depth lots are located in the Tianjin fracture. The water level drop is greater than 9m. By long-term effects of exploitation in the Hexi district there has formed a partial groundwater level funnel. It can be said that there is better exploitation potential near the Cangdong fracture, Haihe fracture and Baitangkou fracture. It is not easy to form a groundwater level funnel. In contrast it is easy to form groundwater level funnel near Tianjin fracture.

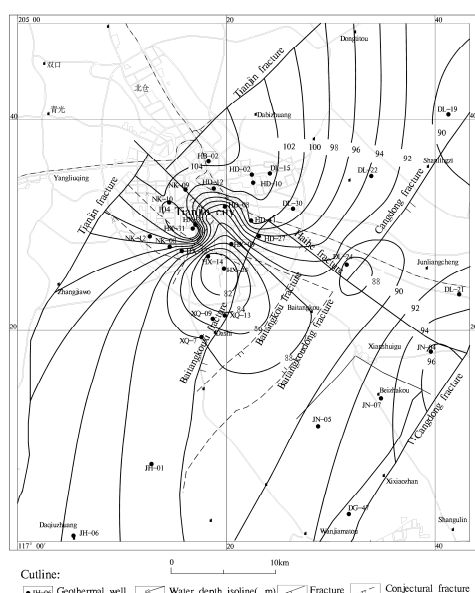


Figure 1: Wumishan Formation geothermal reservoir hydrostatic level buried depth in Tianjin urban area-suburb

3.2 The Influence of Fractures on Wumishan Formation Geothermal Reservoir Dynamic Field

3.2.1 The influence of fractures on Wumishan Formation geothermal reservoir pressure field

In the Tianjin urban area-suburb, the overall trends of the Wumishan geothermal storage pressure field are that there is higher pressure near the Cangdong fracture and Baitangkou fracture but along the NEE on both sides of the fracture is a decrease in pressure, the pressure isoline tend towards the NNE. There is a low pressure area near Tianjin fracture, and a high pressure area near Cangdong fracture and Baitangkou fracture. The highest pressure value is 32.90MPa, The lowest pressure value is 32.42MPa. Mainly due to the water conductive fractures, there forms high pressure value areas along the fractures. At the same time, because the Tianjin fracture is not water conductive, there forms a low pressure value area near the fracture. Therefore, we can infer that there are important relationship between the magnitude of reservoir pressure and hydraulic conductivity and water blocking of fractures (Ruan Chuanxia, 2006).

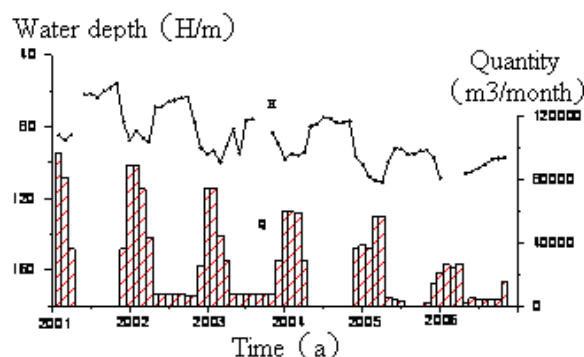


Figure 2: Curve of water level dynamic long-term observation in Dasi geothermal well

3.2.2 The influence of fractures on Wumishan Formation geothermal reservoir dynamic field

There have been Wumishan thermal energy storage dynamics for many years (Table 1). Statistics show that the water level depth is shallow near the Chang-dong, Haihe and Baitangkou fracture zone and is deeper near the Tianjin fracture zone. (Ruan Chuanxia, 2006).

Table 1 Statistics of water level buried depth in Tianjin urban area-suburb unit: m

Time(a)	Northren Haihe fracture		Southren Haihe fracture	
	Western Cangdong fracture	Eastern Cangdong fracture	Western Baitangkou fracture	Eastern Baitangkou fracture
2001	50 ~ 74	50 ~ 56	47 ~ 74	47 ~ 56
2002	59 ~ 83	59 ~ 68	56 ~ 83	56 ~ 68
2003	65 ~ 86	65 ~ 77	62 ~ 86	62 ~ 77
2004	68 ~ 89	72 ~ 83	65 ~ 86	65 ~ 83
2005	74 ~ 95	76 ~ 85	68 ~ 95	68 ~ 85
2006	86 ~ 98	86 ~ 90	80 ~ 98	83 ~ 90

4. THE INFLUENCE ANALYSIS OF CONSTRUCTION ON WUMISHAN FORMATION GEOTHERMAL RESERVOIR DYNAMIC FIELD

This area is located in the north-east of North China rifted-basin and experienced a multi-stage tectonic movement. The former Mesozoic shows a structure pattern of fold and multi-phase fracture development. Wumishan deposition time was 12.2 million years ago. In different structure parts, the infiltration properties are also different. Fractures play an important role on the permeability of rocks. In the Wumishan geothermal reservoir wells drilling process, fractures cause serious slurry loss. A strong infiltration near the Cangdong fracture and Baitangkouxi fracture, unit of water is greater than $15\text{m}^3/\text{h} \cdot \text{m}$. But the Tianjin fracture zone has a weak infiltration zone. Its unit of water is $2 \sim 10\text{m}^3/\text{h} \cdot \text{m}$. In addition, the larger structure curvature region is favorable as a fracture development zone. In anticline axis position, there is strong stress and greater curvature, easily leading to micro-structural cracks, and there is a strong water-rock chemical reaction, in crack development and penetration performance. Test results of Wumishan geothermal wells near Wanglanzhuang semi-anticline and Shanlingzi semi-anticline show that the hydrodynamic conditions and permeability of the area is better. Away from the anticlinal axis, with the structure curvature reducing and the Wumishan burial depth increasing, the permeability has undergone a corresponding decline, so geothermal wells of the layer in the region generally use acid measures to increase water production (ZHAO Weiming, 2001).

In the vicinity of fracture zones and the top of anticlines, there is better permeability at the top of Wumishan, especially in the interchange of fracture and anticline top. At the intersection of fractures there is more broken rock, karst fractures, and better infiltration than other parts of the performance, and a better hydrodynamic environment. The trend of anticline axis and fracture zones are broadly similar, so the reservoir pressure is high. The water conductive feature is better along the Cangdong fracture and Baitangkou fracture. But the pressure features of the western part of Haihe fracture are different from the eastern part of Haihe fracture. In the meeting point of the eastern section of the Haihe fracture, the Cangdong fracture, and the Baitangkoudong fracture, the water conductive features are better, and the pressure is high. However, in the meeting point of the western section of the Haihe fracture and Tianjin fracture, the water conductive features are bad, and the pressure is low. The reason is that the meeting point of the eastern section of the Haihe fracture and Cangdong fracture is near the anticline core. Rock is relatively crushed, there is fracture porosity development. The geothermal fluid channels and storage space is better, so it is easy to conduct water. The Tianjin fracture is away from the anticline core, the group depth is deep, and karst fissures developed poorly. Thus it can be said that there is an important relationship between the magnitude of reservoir pressure and the fracture zone characteristics.

5. THE CONCLUSION

Generally speaking, water conductive fractures improve reservoir connectivity. Fractures of the greatest influence are the Chang-dong fracture, the Haihe fracture and the Baitangkou fracture. The geothermal reservoir pressure is higher, and water depth is shallower near those fractures. However, geothermal reservoir pressure is lower, and water depth is deeper near the water blocking fractures (such as the Tianjin fracture). These observations can be used as a reference for similar geothermal exploration areas in Northern China.

The Wumishan reservoir is the main source of thermal energy storage for Tianjin geothermal exploitation. In order to ensure sustainable use of geothermal resources and slow down the drop rate of the water level, it is proposed that on the one hand, the recharge work should be strengthened. On the one hand, the exploitation should be strictly controlled. In addition to the areas of the eastern Tianjin fracture where the water level drop is relatively faster and the water level depth is deeper, the areas of better hydrodynamic conditions can be considered, such as the Cangdong fracture and the Baitangkouxi fracture. We should increase geothermal reinjection in these areas.

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