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The Genesis Discussion of Dongying Geothermal Resources in Tanggu District, Binhai New Area, Tianjin

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ABSTRACT

There are abundant geothermal resources in Tanggu—the core of Tianjin Binhai New Area. Tanggu district has layered reservoir, which is a sedimentary basin type, and Dongying formation, one of layers of porous type with lower reseach level. In order to scientifically and rationally exploit the geothermal resources, it is necessary to perform the genesis discussion of geothermal resources with comprehensive analysis of the structure setting, reservoir characteristics, sedimentary surrounding, chemical characteristics etc. Results show that the formation of Dongying reservoir is quite different from Neogene reservoir. For Dongying reservoir, the thickness is 100m to 660m, the ratio of sand and mud is 35% to 38%, the porosity is 20% to 35%, the permeability is 200mD to 1000mD, the temperature of the fluids is 73℃ to 85℃. The hydraulic connection between the geothermal fluid and its overlying as well as underlying reservoir are very limit. There is also no obvious hydraulic connection between the reservoirs in the west of Cangdong Fault and Dongying reservoir. The genesis of the geothermal fluid is not seawater but the meteoric water from the northern mountains.

1. INTRODUCTION

Tanggu district is located in the core of Binhai New Area. With the developing functions of Binhai New Area through projects such as “making economic cycle in Beijing, Tianjin and Hebei” and “building beauty Tianjin”, Tanggu district has an increasing need in clean, environmental geothermal resources. Under the circumstance that the newly exploited reservoirs are almost developed, Dongying formation is attracting more and more people.

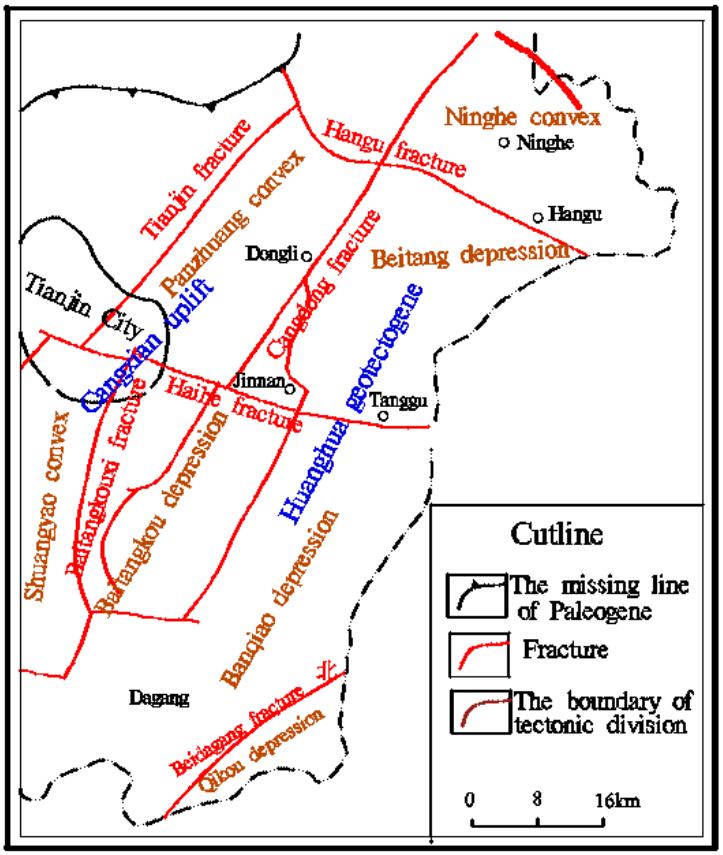

Figure 1: Geological structure position figure of Tanggu urban area-suburb

Dongying formation is widely distributed in Tanggu district with large sedimentary thickness and extensive lithological change. Certain works in petrographic and paleogeographic study of Dongying formation of this area were performed and faces model of delta sediment were built (Liao Yuntao, et al). Other studies include: analyse, develop and use strategy to utilize the potentials of

geothermal resources in Binhai New Area (Yang Yongjiang, et al, 2009), discover the potential and develop strategy to use Dongying geothermal resources in Tanggu district (Yang Yongjiang, et al, 2009), initial analyses of reservoir reinjection of Dongying formation in Tanggu, Tianjin (Mu Chunyi, et al, 2009) and so on. There are also some research about regional genesis of geotherm (Gao Baozhu, et al, 2002). Based on the achievement of geothermal exploration (Jin Baozhen, et al, 2008), this formation has the potential to develop. The lack of datum and pinpoint origin causes the pressure of Dongying formation drops rapidly as well as reduces the water yield during development. It in turn affects the development severely and other works of the formation in later stage. In this case, probe the genesis of Dongying geothermal fluid of this area is enhanced and will be of great significance to guide geothermal development and reduced developmental risks.

2. GEOLOGICAL STRUCTURE CHARACTERISTIC

Tanggu district lies across two tectonic units of grade Ⅳwhich are Beitang depression and Banqiao depression (Figure1). Beitang depression is located in the northern part of the Huanghua depression. Its western boundary is Cangdong fault which is connected to the Panzhuang convex. Its northern boundary is Hangu fault which is connected to the Ninghe convex. Its southern boundary is Haihe fault connects to the Banqiao convex. As a whole, the depth of bedrock roof is shallow gradually changes from shallow in the west area to deep in the east area. The thickness of Cenozoic is 1300~5000m. Banqiao depression is located in the northern part of the Huanghua depression. Its western boundary is Cangdong fault which is connected to the Baitangkou depression. Its northern boundary Haihe fault is connected to the Baitangkou depression. As a whole, the depth of bedrock roof gradually changes from shallow in the west area to deep in the east area. The thickness of Cenozoic is 1500m to 5000m.

3. RESERVOIR CHARACTERISTIC

Dongying formation is widely distributed in this area. Based on lithological features, from top to bottom it can be divided into three lithology segments which are Dongying Ⅰ, Ⅱ and Ⅲ. The main lithological feature of Dongying Ⅰ is fine-grained powdery sandstone with interbedded shale. The shale is developed in the upper part, and the fine-grained powdery sandstone is developed in the lower part. The main lithological feature of Dongying Ⅱ is shale blending with the gray green powder sandstone. The main lithological feature of Dongying Ⅲ is fine-grained powdery sandstone blending with thin mudstone. The roof depth of Dongying is 1500~2300m, manifested by the characteristic that the depth becomes smaller from the east to the west. The depth is 1500m on the west side near Cangdong fracture and 2000m on the east side. The thickness of Dongying formation is 100~660m, which is a larger range. Overall, the thickness is thin in the center, and thick on both sides of north and south.

Based on the datum at hand, the sand mud rate of Dongying formation in this area is 35~38%, the porosity is 20~35%, the permeability is 200~1000mD (Jin Baozhen, et al, 2008). To the south of Haihe fault, roof depth of Dongying formation is 1500~2200m, the permeability is 200~900mD; to the north of Haihe fault, roof depth is 1600~2300m, the permeability is 300~1000mD. The lithology of the lower part is grey-green mudstone interbedded within sandstone and glutenite, which has a thickness of about 300m, porosity generally at 20~28% and partly at 25~30%. The argillutite take up majority of the middle part, which has a poor hydrous condition; and the majority of the upper part is made up of sand-clastic sediment (Jin Baozhen, et al, 2008) which was constituted by grey-green to variegated, amaranthine mudstone and grey-white sandstone, lithic feldspathic sandstone mixed with glutenite. Its reservoir's thickness is about 200m and porosity of 22~35% (Jin Baozhen, et al, 2008).

4. SEDIMENTARY FACIES ANALYSIS

Well T21 is the first geothermal well of Dongying formation in this area. Lithology combination and log datum combine with regional datum will contribute to the initial analysis for sedimentary environment of Dongying formation for this area.

Dongying formation of this well is a set of terrigenous fine-clastic sediment which was mostly made from mudstone and siltstone. It contains feldspar, quartz and less lithic. Lithic are in angular-subangular and imperfectly rounded shapes. For the sedimental order, the grain size of clastics changes from fine to coarse progressively from bottom to top. Grey-black and dark brown mudstone appears in the bottom of section Ⅲ. Just above the bottom layer, there are grey-green mudstones and siltstones and clastics increase. Medium-coarse sandstone appears on the top of section Ⅱ. This is a reverse cycle of bottom fine and top coarse, which is the important feature of delta sediment.

Log datum shows that the curve is straight at bottom and gradually turns into zigzag. Just above the bottom layer, the wave rang increases to make a forest combination, which may belong to the part of delta front (distal bar sediment). The middle part is an accretion combination of box type medium rang, which stands for channel-mouth bar sediment of delta front. On the upper site, electrical logging curve verges to gentle, which stands for alluvial flat marsh sediment of delta plain. In combining with sediment characteristics such as lower sand mud rate, high suspended load, generous mud sand input to river and invisible fossil indicating marine faces, we conclude that terrigenous clastic of Dongying formation in this area should be fluvial-dominated delta sediment.

The evolutionary process of fluvial-dominated delta sedimentary faces is recovered during the period where Dongying formation is formed in the space provided. Looking in plane, from terrene to lake basin, an integrated fluvial-dominated delta sedimentary system will behave like delta plain (mainly marsh plain and distributary channel sediment), delta front (mainly channel-mouth bar and distal bar) and prodelta (thick-layer mud sediment). These three sedimentary environments distribute roughly around each other (Jin Baozhen, et al, 2008).

During the period where Dongying formation was formed, with crust lifting, lake basin shrinking and sunk weakening, the sediment environment of this area changes deep water lake to shallow water river delta, which indicate a relatively flat mountain topography, the north and west was denudated in a long time forming archicontinent and the paleocurrent from north to south and west to east. Close to the denudated area, river carries the mud and sand to the margin of lake basin over a short distance. Clast and lithic content in this section is unsorted and lack of roundness. Meanwhile, they explains that in the denudated area the topography cuts intensely, riverway gradually gets wider, and the flow become faster, but the sedimentary that has travelled long distance is relatively fine, well sorted and very round. Sedimentary in mid-lower part of section Ⅲ of this formation has a high matrix content, and the siltstone has horizontal bedding, which indicates that the sedimentary environment have low energy, still

water, weak oxidation and weak deoxidation. During this period, the water was shallow, wave and tidal action were weak, mud and sand carried by river to lake unloads forming delta which was more fluvial-dominated and less tidal. Influenced by wave, the delta efflorescencely extend to the center of lake. It can be further explain by the fact that Tanggu district is far from the provenance.

Delta sediment has an intimate connection with underground water. Silt-fine sandstone in delta sedimentary provide a well hydrogeololgical condition for underground water's enrich and runoff nature. From section east Ⅲ to east Ⅰ, the lake basin can be seen as expands then shrinks. From section east Ⅲ to east Ⅱ, sedimentary environment is very close delta front and lakeshore bar, which is beneficial to the geothermal fluid enrichment. The most profitable district is to the south of Tanggu. The most of section east Ⅰ has evolved to a plain marsh sediment, while distributary channel sediment only arised in the northeast. This is beneficial to the geothermal fluid enrichment where the sand layers can be developed and have a high permeability.

5. CHEMICAL ANALYSIS

5.1 Chemical Component Analysis

Geothermal fluid in Dongying formation of this area is form mainly by Na^+ in cation and Cl^- and HCO^{3-} in anion. It has a high salinity that can reach 2800~4400mg/L (figure 2), which indicates the chemical character of geothermal fluid in this area is mostly alkali ions and strong acid ions. A high quality TR21's rNa/rCl content is 1.47, the whole area's rNa/rCl content is about 1.4>1, which indicates that the syndepositional water of fluvial delta of lake faces have the typical characteristics of lixiviated water.

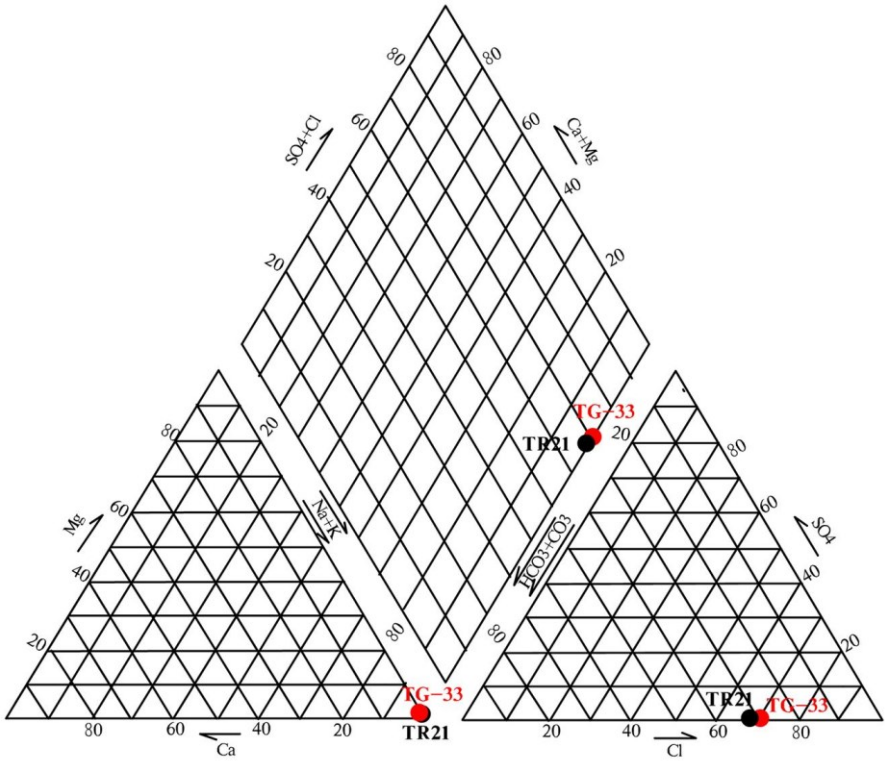

Figure 2: Piper diagram of three lines of ions' content (mmol/L) in Dongying geothermal fluid

The geothermal fluid's salinity of Dongying formation is the lowest in the intersection of Haihe fault and Cangdong fault, and rise as it moves towards southwest and northeast which is similar to the variation characteristics of the region. The regional datum shows that Cangdong fault has extremely limited water transmitting ability of Dongying reservoir, which explains why the intersection part of Haihe fault and Cangdong fault has the largest water transmitting ability.

By using the same structural unit in the test shows that the main chemical component and isotopic age of Dongying geothermal fluid is very different with overlying and underlying reservoirs in the vertical component. There are also big differences between the lateral component, and the main chemical components as well as contents in every reservoir west of Cangdong fault. These evidences indicate that the Dongying formation has no obvious hydraulic connection with other reservoirs neither lateral nor vertical, therefore it belongs to semi-closed formation environment.

The chemical component of Dongying geothermal fluid and seawater has a big difference. Na^+ content and salinity in geothermal fluid is 10 lower than average in seawater, Mg^{2+} and Ca^{2+} content are differed by 2~3 orders of magnitude to seawater, Cl^- content is 15 lower than average in seawater, I^- and F^- content exceed 3 times than seawater, and Br^- content is 22 lower than average in seawater. Factor coefficient rNa/rCl and Cl/Br of geothermal fluid is 1.45 and 501.45 respectively, which is bigger than seawater, which indicates the non-seawater causes of Dongying geothermal fluid.

5.2 Isotope Analysis

Map the samples taken of this area and surrounding to a diagram δD-$\delta^{18}O$ in figure 3. The values of isotopes ^{2}H and O^{18} of Dongying geothermal fluid are beyond the variation range of meteoric waters, which indicates the origin of geothermal fluid is meteoric waters. Through fractures, pores, solution cracks and faults of the bed rocks, meteoric waters penetrated deep underground where they were circularly heated by normal geothermal gradient, after that they flowed to this area along the pitch slope of hydrous unit of huge faults in the piedmont and uplifted zone.

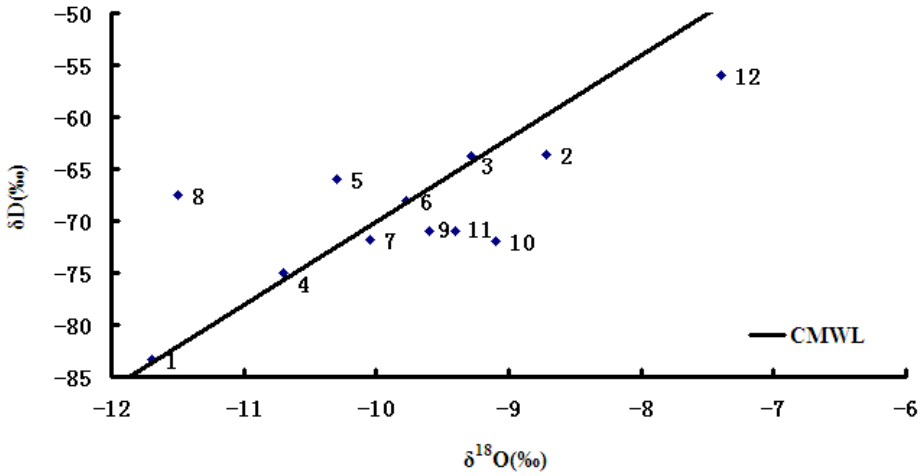

Figure 3: Relationship diagram between δD-$\delta^{18}O$ and dropdown line of geothermal and surrounding rainwater

6. CONCLUSION

Majority provenance of section east Ⅲ-east Ⅱ in this area comes from northern area and only minority from west Gegu district. Section east Ⅰ comes from northern area. East Tanggu is a lake sediment environment, and Tanggu district belongs to delta and marsh plain sediment environment. In section east Ⅲ to east Ⅰ, a variation regulation is in place where the lake basin expands then shrinks. In section east Ⅲ to east Ⅱ, sedimentary environment can be found mostly close by delta front and lakeshore bar, which is beneficial to geothermal fluid enrichment. The most profitable district is to the south of Tanggu. In section east Ⅰ, most of this area has evolved to plain marsh sediment, while distributary channel sediment only arised in northeast. This section is beneficial to geothermal fluid enrichment and has a certain developmental potential (Jin Baozhen, et al, 2007).

Geothermal fluid of Dongying formation in this area is syndepositional water of fluvial delta of lake faces with typical characteristics of lixiviated water and non-seawater. The main supply origin is meteoric waters in northern mountain and paleosedimentary water in stratum in geological period, and then the meteoric waters were circularly heated by normal geothermal gradient in deep to form geothermal fluid.

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