

Research of Tanggu Geopressurized Formation Geothermal Field

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ABSTRACT

Through analysis and contrast of Tanggu district geologic structure, geothermal gradient characteristics, and stratum hydrostatic pressure we discover that this Paleogene System stratum area has a higher hydrostatic pressure and temperature, and has formed a geopressurized formation geothermal field condition. We present the preliminary analysis of this important stratum, and the geothermal potential of Paleogene System, Dongying Formation & Shahejie Formation. We then put forward three parts of a prospective plan and locate positions to implement this plan. This provides another way to enlarge Tanggu geothermal resource exploitation and utilize it, and could have breakthrough repercussions for this kind of geothermal resource exploitation throughout China.

1. INTRODUCTION

Geothermal resource exploration and development in Tanggu is occurring earlier than in the other areas of Tianjin, and is currently mainly exploiting the upper Tertiary Guantao geothermal reservoir. Right now there are 30 exploited wells. The annual production capacity is $430 \times 10^4 \text{ m}^3$. The water table is dropping at a rate of 6m every year. This makes it impossible to further expand the exploitation of geothermal resources in the area. Geopressurized formation type of geothermal field is due to a closed formation, formation water pressure system change from hydrostatic pressure to the terrane pressure, form excess due to a pressure consolidation zone. Thermal conductivity of excess pressure zone is low, which favors absorption and storage of the earth crustal heat, which when added to the chemical heat that is released from clay mineral dehydration changes, often forms hot water reservoirs which are higher pressure and temperature, lower salinity, and contain large quantities of dissolved methane, forming a geopressurized geothermal field. Data shows that Lower Tertiary Tanggu district has the conditions that form a pressure-type geothermal field. Choosing to study in the Tanggu district increases the chance for future expansion, development, and utilization of geothermal resources in the area. This may help to promote the exploitation of geothermal resources of this type in China.

2. THE FORMATION CONDITIONS OF PRESSURE-TYPE GEOTHERMAL FIELD OF TANGGU DISTRICT

2.1 Structural Feature of Tanggu District

Based on data analysis of gravity, aeromagnetic, three-dimensional seismic and drilling, Tanggu district is in the Tanggu- Newport buried hill Structural Belt in Beitang depression, divided by the Haihe River. The northern part is Tanggu nose structure, the southern is Changlu fault

terrace. Three main faults have developed: the Haihe River fault, the Changlu fault, and the Beitang fault.

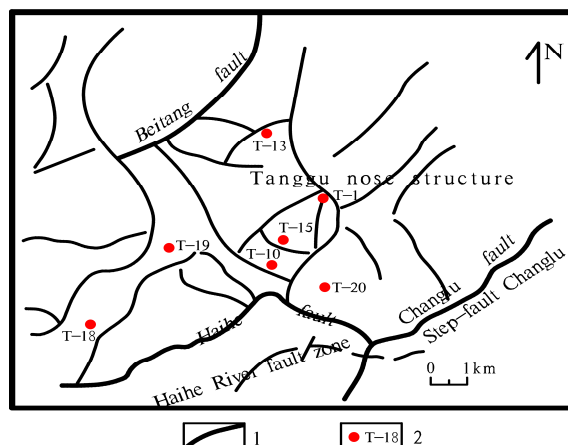


Figure 1: Geological structure of Tanggu district (Shahejie Formation third section) 1-Fault , 2-Prospection sole.

2.2 The Main Reservoir Characteristics

According to analysis of the structure and fluid pressure profile, the reservoirs entering into the overpressure zone are mainly: sandstone and conglomerate in the middle-lower part of Dongying, sandstone in the middle-lower part of Shahejie first stage, and sandstone in the middle of Sha-3 member. Dongying is a river delta of gravel sand deposition, which, in the middle and lower part is the thick layer white gray sandy conglomerate, the gravel component being mainly quartz, gravel track 7 ~ 8mm; it has poor sorting, loose cementation and limestone-rich rock.

The first and second sections of the Shahejie are a set of charcoal gray with middle thin sandstone, usually calcareous siltstone, unconform on the Sha-3 member. Storage capability is poor, which is a good characteristic for cap rock. Shasan sandstone reservoirs form a high overpressure belt.

Sha-3 member in this area is made up of brown folding gray mudstone and sandstone conglomerate, with a sandstone reservoir thickness varying from 50m to a total of 300m.

2.3 Temperature and Pressure System of Tanggu District

2.3.1 Temperature Distribution

According to the data analysis of oil-well logging, the temperature gradient of Tertiary of Beitang Depression is 3.08°C/km -3.46°C/km, the temperature gradient of Dongying is 3.13°C/km, and the temperature gradient of

Shahejie is 3.13°C/km. The relationship of thermal energy storage temperature and the depth is:

$$T=14+0.3101(H+h) \quad (1)$$

(h—instant temperature zone depth vaule 35mm; H—heat storage buried deep)

Distribution of temperature at different depths of the Tanggu district is shown in Fig2. There is significant geothermal anomaly in Tanggu- Newport buried hill Structural Belt.

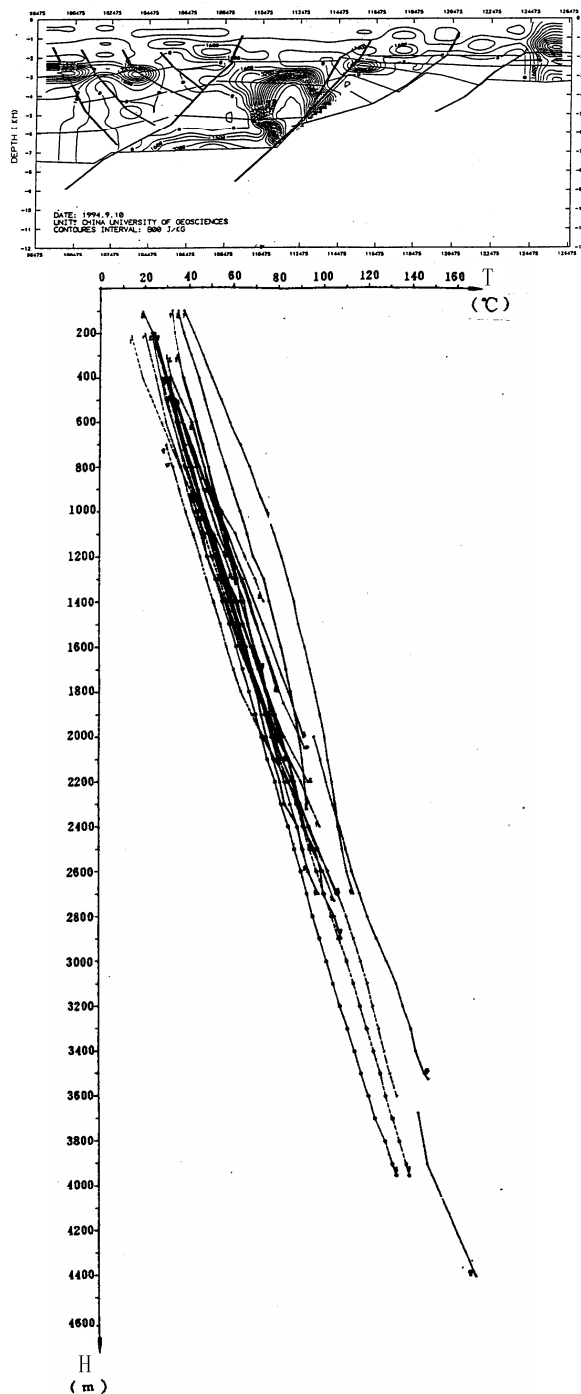


Figure 2: Relationship between depth and water temperature of north Dagang oil field.

2.3.2 Pressure Distribution

According to the explanation of seismic data based on water potential profiles shown in Fig 3, we can see that there are three-layers in this pressure system :

- The upper Tertiary hydrostatic pressure force system, the lower Tertiary overpressure system, and the bedrock region runoff flow hydrostatic pressure force system.
- 2) In the Haihe River fracture a depressed plate and Lower Tertiary formation developed a well trap overpressure belt.
- 3) In the Haihe River fracture raised plate Dongying group formation appears as a small overpressure belt, showing that the Dongying group has entered the pressure-type geothermal field.

3. PRESSURE-TYPE THERMAL ENERGY STORAGE RESOURCE POTENTIAL IN TANGGU DISTRICT

3.1 Resource Potential of Shahejie Group Three-Stage Geothermal Reservoir

The buried depth of the Shahejie group three stage is usually between 2300m-3200m in Tanggu broken nasal district.

On the structure salient, Sha-3 member' s buried depth is 2100-2600m, Sha-3 member' s permeable sand layer thickness is 50m-200m, porosity is 20%-22%, formation temperature is 78°C -88°C, static storage amount of per square kilometer is $1 \times 10^7 \text{ m}^3$ - $4 \times 10^7 \text{ m}^3$. In Canglu fault terrace district Sha-3 member' s buried depth is between 3200-3800m. The average thickness of sandstone layers is 150-300m. The average porosity is 18%. Static storage amount per square kilometer is $2.7 \times 10^7 \text{ m}^3$ - $5.4 \times 10^7 \text{ m}^3$. Sandstone of Tanggu district Shahejie Formation three stage is smaller, and more of it is made up of fine-grained sandstone powder, low permeability, commonly around 10-100 μm^2 , where single well water yield can only reach 20 ~ 40 m^3/h , which makes it rich in reserves, and a low production capacity thermal reservoir.

Oil exploration has shown that Sha-3 member is usually an oil-water layer, where the water layer is a hot water reservoir and rich in water-soluble gas (primarily methane). Methane solubility in water is controlled by water temperature and salinity, but mainly controlled by the pressure (hydrostatic pressure of groundwater). Well T13 is at the end of Tanggu nose structure. A blowout after Sha-3 member well completion showed the natural gas component is mainly methane, ~92.33%. This showed that Sha-3 member hot water and water-soluble gas in the major reservoir of geothermal resources.

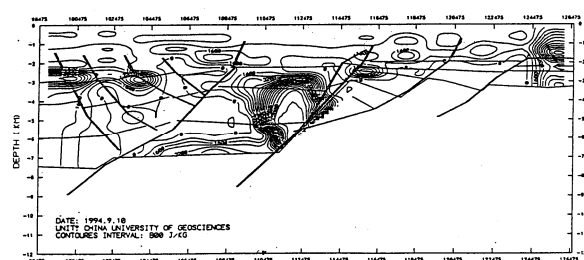


Figure3: Section of Tang19-1019.5 survey line.

3.2 The Resource Potential of Thermal Energy Storage of Dongying.

Dongying thickness is 150m-400m, the Dongying upside is a set of reverse cyclone deposition which is mainly psammite, and its reservoir porosity is 23%-25%. Permeability is $300 \times 10^{-3} \mu\text{m}^2$ - $600 \times 10^{-3} \mu\text{m}^2$. The total thickness of the reservoir is 30m-70m. Estimated static storage is about $7.2 \times 10^6 \text{m}^3$ - $1.86 \times 10^7 \text{m}^3$ per square kilometer. Water yield from a single well can reach $50 \text{m}^3/\text{h}$. Water temperature is between 75°C - 78°C ; Under this is a celadon argillaceous type, a sandy conglomerate interbedded, further positive spin. Reservoir porosity is 15%-25%, and a few parts can reach 25%-30%. Permeability is in the range of $100 \times 10^{-3} \mu\text{m}^2$ - $500 \times 10^{-3} \mu\text{m}^2$, and a few reach $500 \times 10^{-3} \mu\text{m}^2$ - $2000 \times 10^{-3} \mu\text{m}^2$.

Dongying is semi-open semi-closed hot water reservoir, underlain by the Shahejie source rock which has the conditions to suggest there is water-soluble gas in the hot water; this gas is likely mostly methane gas, and the gas content should be between $0.5\text{-}1 \text{m}^3/\text{m}^3$. Dongying is a prospective exploration geothermal reservoir.

4. TANGGU GROUND PRESSURE GEOTHERMAL FIELD EXPLORATION TARGET INITIAL DEFINITION

4.1 Choice of Well Location

According to the analysis of the Tanggu reservoir structure and ground pressure the geothermal field exploration should choose Haihe River fracture uplifted side, choosing Tanggu broken nasal structure as the exploring break section. First choice hole position is at T-15 and T-10 section, there are three reasons:

Reservoir lithology is good. According to the data of well T-15, Dongying Roof depth is 1876m. Thickness is 188m, lithology is a deep gray, celadon mudstone. Middle clip thickness layer is off-white sandy conglomerate. Bottom is thick layer off-white conglomerate, containing gray rock blocks. It also corresponds with the conglomerate at the bottom of Dongying in Tang Well 12. Shahejie, Sha-2 member roof depth is 2064m with a thickness of 347m. Lithology is deep gray mudstone. Bottom is off-white sandy conglomerate, containing gray rock fragments. Below 2225.5m is a reverse fault. At the bottom is light gray-celadon sandy conglomerate. Deep gray-brown and gray mudstone, lower part is a set of light gray dolomitic quality cementation sandy conglomerate, which is hard and compact. Sha-3 member: Roof depth is 2411m and thickness is 112m. Lithology is deep gray mudstone and light gray crude medium sandstone with gravel. At the upper part is dolomitic quality cementation. Lower part is deep gray mudstone and brown oil shale. At the bottom is thick layer argillaceous dolomite.

In the highest part of buried hill, according to analysis of seismic section and hole profile, the Ordovician roof depth on the top of buried hill is 3800m. A deep hole of 4000m construction can expose Ordovician hot water reservoir. Ordovician hot water reservoir is a good geothermal reservoir for the area.

According to analysis of water potential profile, this section has a shallow (1800m~2200m) miniature overpressure zone, which is part of a Dongying formation buried section, and under it there exists a Shahejie formation buried section with a larger overpressure zone, so there is much water and soluble methane in hot water. Well T-13 construction did not use casing after the well digging caused a methane

blowout, which reflects that there is a plentiful amount of methane dissolved in the water.

4.2 Exploration Well Design

Selecting three opening well as exploration well, its three structure design plan as shown in Fig4:

The first design plan: Because this section is the most superficial parts of bedrock buried in Tanggu area the target strata for water intake is Ordovician bedrock which is good geothermal reservoir. Design hole depth is 4000m, pump chamber is 400m, set casing at a depth of $\phi 340\text{mm}$. After cementing, we should use a drill of $\phi 244.5\text{mm}$, drill into 3800m, then set casing to $\phi 178\text{mm}$.

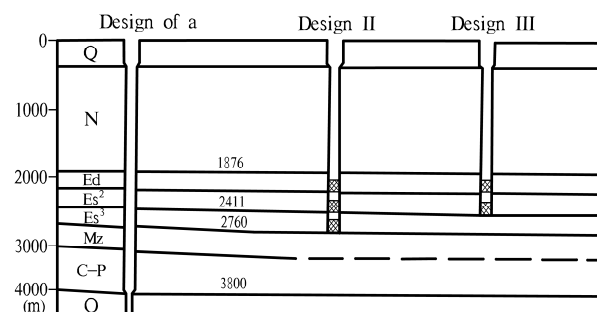


Figure 4. Section diagrammatic sketch of designing well.

Well cementing, cement slurry back to 380m, then change a drill of $\phi 146\text{mm}$, drill into 4000m, and then wash well and pump water. Investigate buried hill hot water resources condition, then according to the needs perforate water-test and finding production on Dongying and Sha -3 member reservoir.

The second design plan: Target strata of getting water is Sha -3 member reservoir, design well depth of water intake is 2800m, use casing $\phi 340\text{ mm}$ or 273 mm as pump chamber. After cementing, we use a drill of $\phi 244.5\text{mm}$, drill into 2800m, then set casing $\phi 178\text{mm}$ and filter tube. We have to set external packer at 1870m and fix well above 1870m. The position of the filter tube should be determined by data of logging, then according to the needs perforate water-test and finding production on Dongying and Sha -2 member reservoir.

The third design plan: Target strata of water intake is Dongying reservoir. Design well depth is 2420m, use casing $\phi 273\text{mm}$ as pump chamber. After cementing, we use a drill of $\phi 244.5\text{mm}$, drill into 2420m, set casing $\phi 178\text{mm}$ and filter tube. We set external packer near by 1870m and fix well above 1870m. The position of the filter tube should be determined by data of logging, then according to the needs perforate water-test and find the production on the Sha -2 member reservoir.

The hot water is rich in water-soluble gas, when well logging we have to use an oil well logging series and we have to log cutting information very carefully and thoroughly and do the light hydrocarbon analysis of canned rock sample for main reservoir.

Pumping experiment requirement: It requires that we install a moisture separator at the mouth of the well, measure temperature and pressure before and after gas-water separation, and measure the output of hot water and solution gas, while at the same time take water samples and air samples for analysis assay.

5. CONCLUSION

Through the data collection and analysis of oil and geothermal exploration of Tanggu region, we can believe that there is a geopressurized formation geothermal field in Tanggu region, and there is a sufficient resource potential to justify special exploration and development.

Seismic exploration and oil drilling confirmed that the formation of Tanggu region is three-layer pressure system, including upper tertiary hydrostatic pressure system, lower tertiary closed and semi-closed overpressure system and underlying bedrock lateral runoff flow hydrostatic pressure system, lower tertiary develop geopressurized formation geothermal field.

The main reservoir of Tanggu pressure-type geothermal field are Doingying and Sha -3 member sandstone and sandy conglomerate, porosity is 18%-25%, thickness and distribution area is large. Formation is rich in water-soluble methane, and there may be good prospects for water, heat, gas co-development. The three parts together have greater prospects for being developed.

Exploration and development of Tanggu geopressurized formation geothermal field should break through at the T-

10 and T-15 buried hill high point section. Depth and structure of the exploration well will be chosen by need, beginning with shallow wells and progressing to deeper ones as required. It is essential to do a good job of data collection, organization and analysis to guide the next steps of development.

REFERENCES

- Li Minglang, Li Chunhua. Feasibility analysis report of the exploration on Tanggu pressure-type geothermal field. 2002.
- Li Minglang, : Geothermal energy planning in China. 2002.
- Wang Xinyi, Lin Li. : Exploitation research of geothermal optimize of Tanggu. 2000.
- Qi Baoxiang, Lin Jianwang. : Geothermal resources survey report of Tianjin Tanggu. 1990.