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Studies on Development Regularity of Karst Fissure of the Ordovician Geothermal Reservoir in Tianjin

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ABSTRACT

In this paper, we make unified stratigraphic division based on a comprehensive analysis of drilling data and log data of 43 exposing Ordovician geothermal wells. A statistical analysis of Type I and Type II fractures and the original water yield of Ordovician for different tectonic units. The results show that the exposing buried depth of the Ordovician roof to be 950m to 2720m; with the bottom from 1218m to 3450m. And the thickness of Ordovician system is from 50.3m to 1050m, the formation thickness which contains Type I and Type II fractures is from 14.5m to 140.1m, mainly from 40m to 80m. Thus we speculate that Type I fractures is distributed in Ordovician Majiagou, Liangjiashan and Yeli formation. It was found that the fracture development degree increases with the buried depth and thickness of Strata. The fracture may also be affected by various overlays. The variation in thickness of fracture development the segments which overlying Cenozoic is bigger while the buried depth of ordovician is minimum. The thickness of fracture development segment of Ordovician system which overlying Mesozoic is thicker than which overlying Carboniferous in the geothermal well. Water inflow of single well increases with fracture development degree of geothermal reservoir. Water yield is larger in Shuangyao Salient, while smaller in Dacheng Salient and Baitangkou Depression.

1. INTRODUCTION

Tianjin belongs to sedimentary-basin-conducting type geothermal field at Medium and Low temperature. There is a big advantage in the distribution and characteristics of geothermal resources, for much in the city and the surrounding towns, moderate buried depth (1000 to 4000 m), a suitable temperature (25 to 103 ℃), and good economy. Also it has been at the top of the list in the country both in exploration precision and scale of development. As construction development of "Beijing-Tianjin-Hebei economic circle" and "Beautiful Tianjin", Tianjin government will strengthen geothermal exploration and increase the scale of the development . Geothermal industry ushered in the second spring.

In recent years, along with the increasing of geothermal development scale, the mining depth is deeper, mining horizon more concentrated in Guantao group and Wumishan group which are relatively stable, and more exploitation concentrated in urban areas. It appears serious problems such as the thermal reservoir pressure drop too fast and the exploitation of funnel. So looking for new geothermal resources has become a top priority. As bedrock geothermal reservoir, the development of Ordovician geothermal reservoir is less. In recent years, we found that the Ordovician geothermal Wells appear more problems through drilling. Much adjacent Wells have more difference in drilling mud loss and final whole water yield, and the emergence problems such as the hole, this seriously influence its development process. The main reason is that the development of karst fissure is uneven in this layer. For many years we have no fundamental research in karst fissure development pattern systematically, lack of development of reliable basis. It greatly increases the risk of construction and the difficulty of development, and then affects the later development process and the quality of resource evaluation. Under the control of ancient landform, lithology, structure etc, Enrichment of geothermal fluid has certain regularity. So finding out fracture and karst water law of the geothermal reservoir is the foundation of the development of geothermal. As the difficulty of geothermal development, this article will revolve around these problems to discuss.

2. GEOTHERMAL GEOLOGY

2.1 Tectonic characteristics

According to geotectonic position, Tianjin is located in Ⅰ level tectonic units north China to Taipei. And it acrosses two Ⅱ level tectonic units, Yanshan fold belt and fault basin of north China. Baodi fault is the borderline for both (Tianjin Bureau, 1992). North of Baodi fault is the bedrock exposed area or shallow buried area. As part of fault basin of north China, south of Baodi fault is a Mesozoic-Cenozoic fault depression and depression basin covering Cenozoic (Tianjin Bureau, 1992). There develop NW-trending and NE-trending structure. Due to the NEE extensional faults, it formed two depressions and one uplift on the east-west direction, namely from west to east respectively in Central Hebei depression, Cangxian uplift, and Huanghua depression, and then, formed the second level of convex and concave by the NEE and NWW faults together (Figure 1).

2.2 Regional profile of Ordovician system development

Ordovician is the sedimentary cover during stable period of north China platform, mainly distributed as layer in the south of Baodi fault, buried more than 1000 m (Li, 2003). Rregional stratigraphic lithology is relatively stable. The difference is mainly the variation of structure of rock and the complex of litho logy in vertical. And the facies change in horizontal overall. The Ordovician sedimentary section is not complete for top multi-eroded within the area, the overall lack of upper Ordovician. Due to long-term weathering and denudation and structural reform, the arch core of Ordovician mainly is missing. Arch core limb in bedrock shallow buried area formed carbonate buried hill. Further it is divided into middle and lower Ordovician, between the two is false contact.

Ordovician experienced multiphase tectonic movement of Caledonian, Hercynian and Yanshanian period (Chen et al., 1990), and the strata suffered several period karstification. So the layer is the final product of the superposition and mutual transformation of multiple period karstification (Lin et al., 1999).

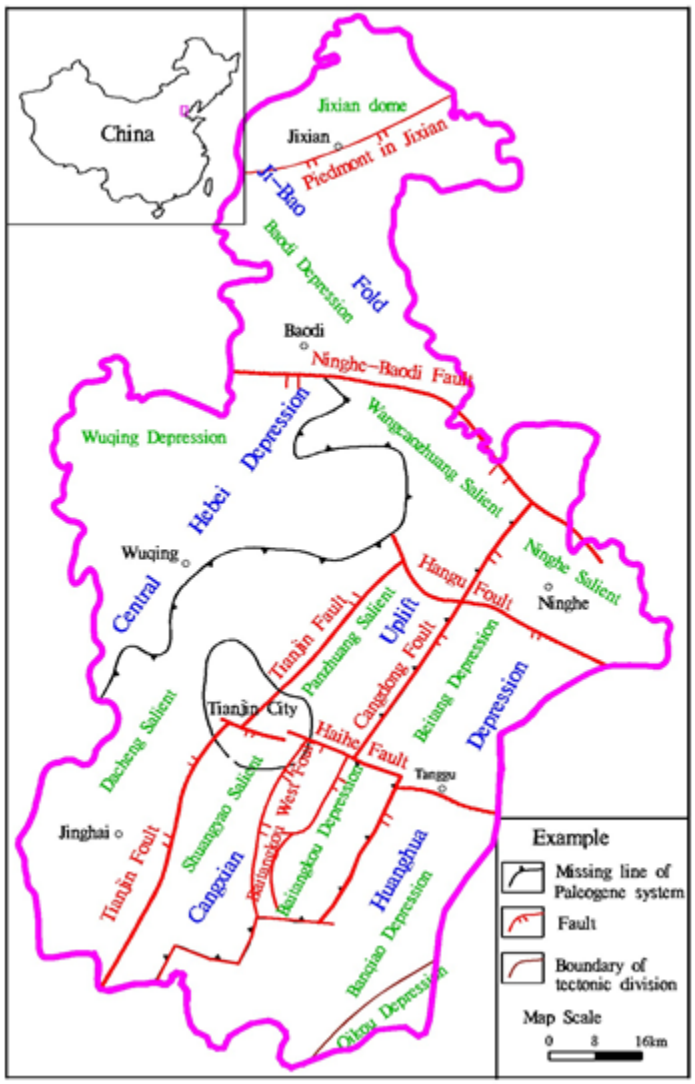

Figure 1: Graph of tectonic divison

2.3 The Ordovician karst fissure development pattern

Karst fracture is the channel of geothermal fluid storage and migration. So it is the important factor of the Ordovician limestone water. This work analyzes the geothermal well data of Ordovician from different tectonic units. Due to the original data of Ordovician is not assigned to the group, we preferred in preliminary layered, and made statistics of the total thickness of I, II fracture segments, and analyzed the relation respectively between Karst fracture with different buried depth, the overlying stratum, the Ordovician water yield in geothermal well, mud leakage and the leakage point distance to the Ordovician roof and bottom, and other aspects. On the basis of analysis comprehensively of drilling hierarchical data and logging data of the 43 geothermal wells in the whole city, the work was made for exploring the karst fracture pattern of Ordovician, providing the basis for looking for geothermal mineralization regularity.

2.3.1 The present distribution of geothermal Wells drilling in Ordovician

There are total 43 geothermal wells drilling in Ordovician in Tianjin (Jin et al., 2013). The purpose for Ordovician layer is 16 eyes, mainly in five IV level tectonic units , Panzhuang Salient , Shuangyao Salient , Xiaohanzhuang Salient, Baitangkou Depression, Dacheng Salient, and Wangcaozhuang Salient which belong to III level tectonic units, Cangxian Uplift (table 1). Buried depth of bedrock is relatively shallow in these areas.

Table 1 Statistical table of the number of wells drilling in Ordovician of each tectonic unit

Tectonic units	The number of wells its target formation in Ordovician	the well number drilling in Ordovician
Panzhuang Salient	2	13
Shuangyao Salient	8	20
Xiaohanzhuang Salient	2	4
Baitangkou Depression	4	6
Total	16	43

2.3.2 Analysis of karst fissures of Ordovician

(1) The relationship between Karst fracture and the depth of the roof

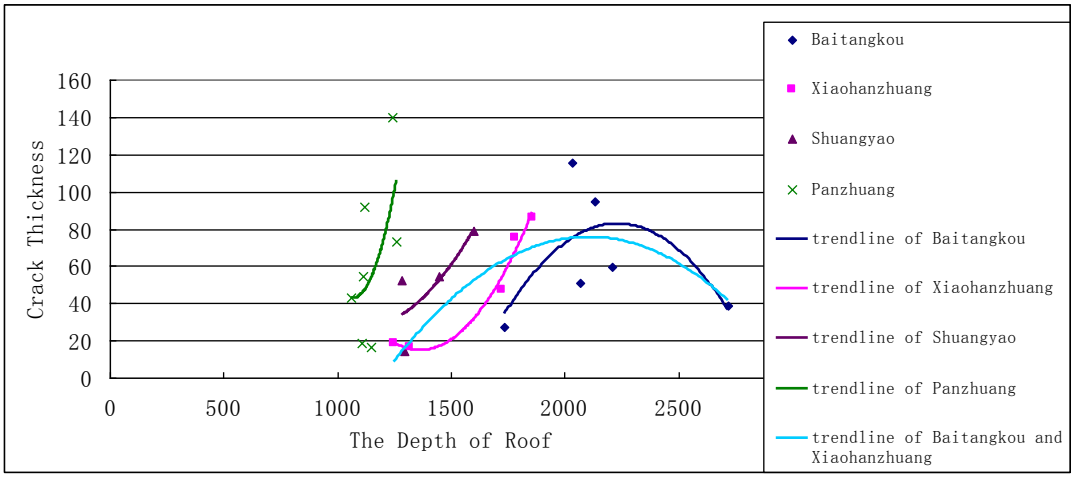

Figure 2: The relationship between the fractured thickness of Ordovician geothermal well and embedded depth of Ordovician roof

1) Panzhuang Salient: The buried depth of Ordovician roof which geothermal well drilling in this tectonic units is relatively small (figure 2), less than 1300 m. The difference of the thickness of the crack developing section is bigger, and the development of karst fissure is uneven. It shows that karst fracture of the buried shallow of Ordovician has little to do with buried depth (Zhao et al., 2001). But on the whole fracture is developed, the thickness is more than 40m. The reason of the thickness of local area crack smaller mainly is the original karst is developed. But in the long geological history, because of the corrosion and transportation handling of the groundwater, karst fissures were filled by later sediments or material weathered, filling degree decrease as the depth increase. If the overlying strata is Sand rocks, the reservoir water have little effected, if mudstone and shale, it played a barrier to the flow of groundwater, make its rich water level of the reservoir is reduced greatly.

2) Shuangyao Salient: The buried depth of Ordovician roof which geothermal well drilling in this region, is relatively small less than 1600 m (figure 2). Fracture section thickness is larger, more between 50 ~ 80 m, it increases slightly with the increase of buried depth of roof.

3) Baitangkou Depression and Xiaohanzhuang Salient: The buried depth of Ordovician roof which geothermal wells drilling in this region is less than 2720m (figure 2).The thickness of the crack is vary from 16.5 to 16.5 m, mainly concentrated in 50 to 90 m. It increases with the burial depth of the roof, but decreases with buried depth of roof increasing when more than 2200 m depth.

4) Dacheng Salient: The buried depth of Ordovician roof which geothermal wells drilling in this region is vary from 1755 to 2400m, fracture section thickness is 68.6 m. Because only one well has made statistic of fracture, it is unable to obtain the correlation of buried depth of Ordovician roof and thickness of fracture.

5) On the whole, the buried depth of Ordovician roof is 950 to 2720 m, fracture section of 14 to 140 m, mainly concentrated in 40m to 90 m. The fracture development degree of Ordovician of different tectonic units increases slightly with the burial depth of the roof. It affected by strong corrosion of the deep thermal storage with high-temperature through deep analysis. But crack growth decreases with increasing of burial depth of the roof after more than 2200 m. It is mainly because rock compaction is stronger when ground stress reached more than 20 Mpa in a certain depth, makes the rock dense, for the reason that karst development.is unfavorable. In addition, with the depth increase, groundwater cycles and alteration conditions become worse, karst fracture and its connectivity is poor, and therefore reservoir of water is poor also.

(2) The influence of overlying strata on karst fissure

1)Type Nm/O and Ng/O: It can be seen from the figure 3, the Ordovician buried depth which covered Nm or Ng is minimum, varies from 1062 to 1316 m, and buried depth change little while the difference of the corresponding fracture thickness is larger. This indicates that the karst fissure development is very uneven in the same deep buried.

2)Type Mz/O: It can be seen from the figure 3, the buried depth of Ordovician which covered Mesozoic is more than 1500 m, the thickness of the fracture is relatively large, general from 80 to 120 m. Fracture section thickness increase with the increase of buried depth before 2200 m, and growth slow slightly after 2200. Overall, the thickness of fracture is relatively larger compared with other overlying strata.

3) Type C/O: It can be seen from the figure 3, the buried depth of Ordovician which covered Carboniferous is greater than 1500 m, the thickness of fissure development is 20 to 80m. Fracture increases with the burial depth of the roof before 2300m, and growth slow slightly after 2400 m.

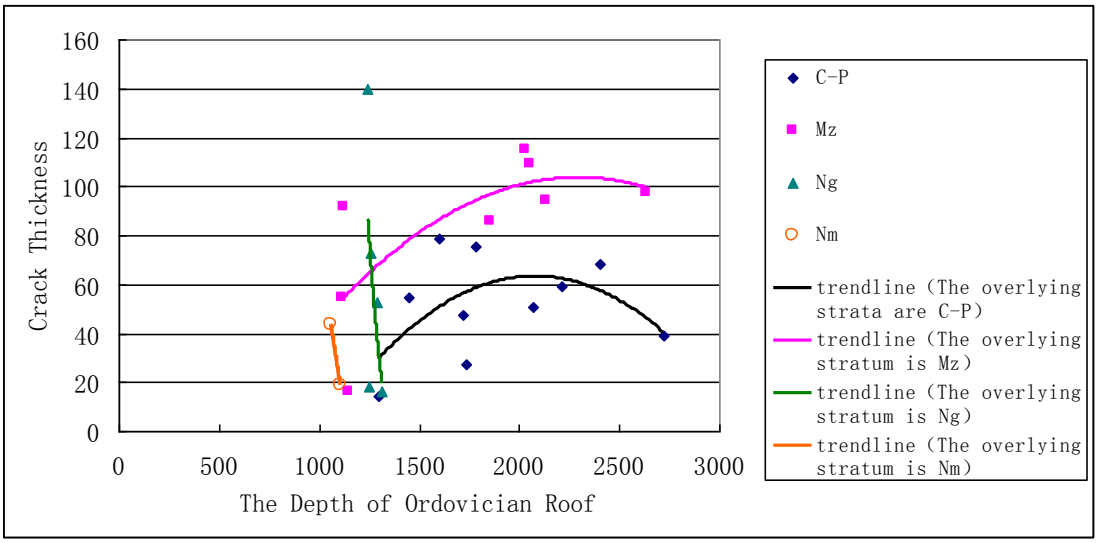

Figure 3: The relationship between fracture of different overlying strata and the buried depth of Ordovician roof

In short the buried depth of Ordovician overlying Cenozoic is minimum, and the difference of the fracture thickness is large. It is related to the lithology of the bottom of Cenozoic, the fracture is poorer if it is mudstone. The buried depth of Ordovician overlying Mesozoic is larger, karst fissure is most developmental. The buried depth of Ordovician overlying Carboniferous is deep and karst fissure development is the least. Under the basically same roof depth, the thickness of fracture in geothermal wells which overlying Mesozoic is greater than overlying Carboniferous, and its thickness increases first and then decreases with the burial depth of the roof, the turning end is 2100 to 2300 m.

(3) The relationship between the original water yield of Ordovician geothermal reservoir and the thickness of Ordovician

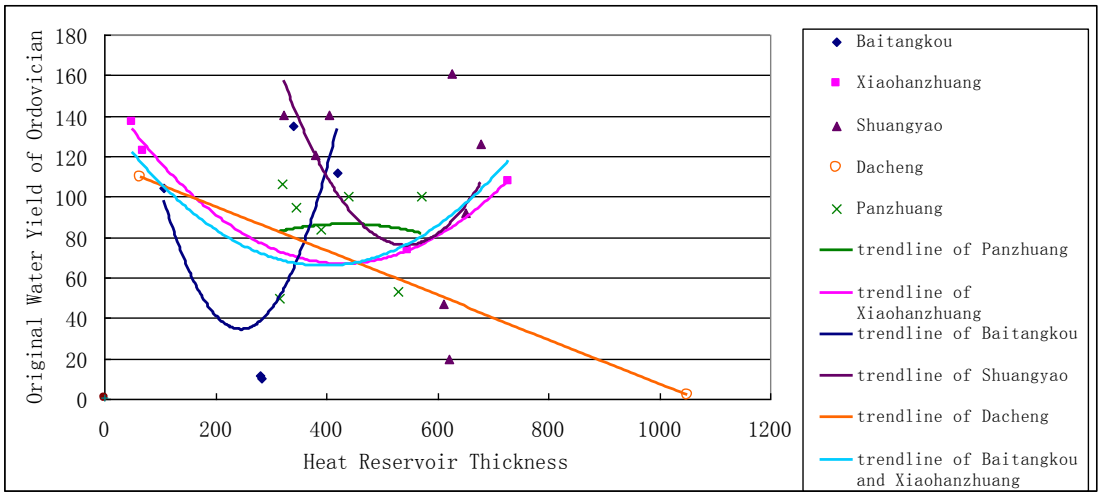

Figure 4 The relationship between the original water yield of Ordovician geothermal reseroir and the thickness of Ordovician

1) Panzhuang Salient: The thickness of Ordovician in the area is from 292 to 440 m, the original water yield is 50.1 to 106.48 m3 / h. It can be seen from the figure 4, the relationship between the content and the thickness of Ordovician is not obvious.

2) Shuangyao Salient: The thickness of Ordovician in the area is from 187.4 to 679.26 m, the original water yield is 20 to 160.67 m3 / h. It can be seen from the figure 4, the amount of water of Ordovician in the area is the largest, but there is no obvious relationship with its thickness of the layer.

3) Baitangkou Depression and Xiaohanzhuang Salient. The thickness of Ordovician in the area is from 50.3 to 729 m, the original water yield is 10.38 to 137.29 m3 / h, water yield increased with the increase of the layer thickness.

Dacheng Salient

4) The thickness of Ordovician in the area is from 65 to 1050 m, the original water yield is 2 to 110 m3 / h. The layer thickness revealing by a geothermal well in its southern region is thicker, but its water yield is very small. This is mainly because the hole drilled in monoclinic parts, there has a synsedimentary deep fault on the east side at about 20 km (Jin et al., 2004), a steep secondary synsedimentary fault on the west side at about 1km, and the shale content in Ordovician limestone is higher, affecting the karst fracture.

5) Contrast from the water yield, Shuangyao Salient is the highest, Xiaohan zhuang Salient and Panzhuang Salient second, Dacheng Salient and Baitangkou Depression at least. Most of wells which the water yield is less than 80 m^3 / h are located in Dacheng Salient and Baitangkou Depression, only a few wells in other units.

2.4 Analysis of other factors

Because of the difference of depositional environment, lithology and strata structure characteristics of Ordovician on the space are not the same. Karst fissure development is uneven on the transverse. The Ordovician limestone revealed in the south of Dacheng Salient contains more shale, mud loss less, and karst fissure are not developed. While in other uplifts limestone is pure, karst fissure is developed. In addition, you can see this kind of situation from the adjacent wells, mud leakage of one well is small while drilling, and the other is bigger. In vertical, the karst fracture position is different (Zhao et al., 2008). Generally the limestone of Majiagou group of Ordovician is pure, and shale content of lower formations is relative high. A class of cracks are mostly distributed in Majiagou Group.of Ordovician Only a small part of Liangjiashan Group and Yeli Group of shallow buried also relatively developed karst fissures, due to its relatively longer after weathering and denudation. Mud loss and water yield of the geothermal wells in the extensional fault or fracture intersection composite parts is bigger, substantially independent of depth factors, and karst fissures are well developed.

3. CONCLUSION

3.1 Karst fissure is mainly controlled by fracture structure on the space; the second is lithology and the buried depth of Ordovician.

3.2 It is favorable section for the karst fissure development where buried depth of Ordovician roof is shallow the roof exposed to the surface for a relatively long time, limestone is pure, overlying strata is non-shale, tensile fracture developed, and has strong regional hydrodynamic flow conditions.

3.3 Whether deep or shallow, karst fissure are more developed in the vicinity of tensional faults or faults with the intersection, where water is good, single well water yield larger.

3.4 The strata which karst fissure developed and single well water yield larger is located at Shuangyao Salient ,Panzhuang Salient, and Xiaohanzhuang Salient, it buried shallower and overlying strata is Minghuazhen Formation of Neogene, Guantao Formation of Neogene, Mesozoic.

3.5 In contrast, the strata which karst fissure not developed and single well water yield smaller is located at Dacheng Salient and Baitangkou Depression in buried deep overlying Carboniferous.

REFERENCES

Chen Z.X., Chen Z.S., Wang F.J.,et al. Geothermal resources detailed investigation report on Shanlingzi in Tianjin[R].*Tianjin Geothermal Exploration and Development-Designing Institute*(1990).

Jin B.Z., Zhang S.Q., Gao B.Z., et al. Investigation report of geothermal resources in southwest Tianjin [R]. *Tianjin Geothermal Exploration and Development-Designing Institute.* (2004).

Jin B.Z., Zhang Z.L., Liu F., et al. Geothermal mineralization planning investigation and research report,2012[R]. *Tianjin Geothermal Exploration and Development-Designing Institute*(2013)

Li J.. Reservoir evaluation of the Zhouliangzhuang geothermal field, Tianjin, China[R]. *The United Nations University, Geothermal Training Programme, Reykjavik, Island*, Reports 15, (2003), 358-380

Lin L., Wang K., Lin J.W., et al.. Deep geothermal resources survey report in Tianjin. *Tianjin Geothermal Exploration and Development-Designing Institute* (1999).

Wang K., et al. Tianjin Bureau of Geology and Mineral Exploration. Regional Geology of Tianjin Municipality[B]. *Beijing: Geological publishing house*(1992)

Zhao S.M..Study on the features and the formation of geothermal resources in Tianjin[T]. *Beijing, China University of Geosciences.*(2001)

Zhao Y.L., Yin S.C., Wang H.Q.. Hydro-geological study of water Abundant Area Division in Ordovician Limestone Aquifer[J].*Coal Technology, 27*,(2008), 115-116