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Research on the Geothermal Geological Condition in Henan Province Neihuang County Town

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ABSTRACT

The formation of geothermal resources in Neihuang County is mainly controlled by the geological structure. Based on the work of collecting and analyzing the results of previous geological work, research on geological conditions and geothermal resource characteristics of the investigation area and geophysical prospecting in the well-defined target area have been carried out. The position of the exploration well is determined based on the interpretation of geophysical data, and the desired effect is achieved by drilling the well. In this paper, by combining the feasibility study and its final data of the first deep geothermal well in Neihuang County, we made a detailed analysis and discussion on the geothermal and geological conditions of Neihuang County.

1. INTRODCTION

Neihuang County is located in the north-central part of Henan province. From the tectonic point of view, it is located in the east of Neihuang uplift, the west of Changyuan fracture and the west side of the intersection site of Neihuang uplift and Dongming fault. According to the study, we predict the occurrence of geothermal water resources on the west of Changyuan fracture. But because there is no systematic exploration work for geothermal resources in Neihuang County, the research of geothermal geological conditions in this region is basically in the blank. It is significant for the development and utilization of geothermal resources in NeiHuang region to analyze the geothermal and geological conditions and study the distribution and characteristics of geothermal resources.

2. REGIONAL GEOLOGY

2.1 Formation

Neogene continental sediments are widely distributed under the Quaternary unconsolidated sediments within the scope of Neihuang plains. And the lower part of the Neogene continental sediments is the Paleogene deposits. They are all interbedding of semi-cemented sandstone and mudstone layers and the thickness is at least thousand meters. The moisture content and permeability characteristics of the pore structure in this sandstone formation provide favorable conditions for storage and transport of geothermal water, thus constituting a Cenozoic thermal reservoir, while the impermeable shale formations constitute the cap.

Under this Cenozoic strata, permo-carboniferous strata composed by sandstone and shale was well developed; Further down is the older formation which is mainly composed by the Cambrian-Ordovician limestone, where the karst fissure of carbonate rocks developed better and constituted the bedrock thermal reservoir of geothermal resources. The bedrock thermal reservoir provides good possibilities of conducting geothermal tail water reinjection in the future.

2.2 Geological structure

On the perspective of regional structure, Neihuang County is located in the east of Neihuang uplift, which is in the southern China and DPRK paraplatform, on the west side of Changyuan fracture. The fracture is a boundary fracture on the west side of Liaolan deep fracture. The trend is NNE, the section is east-dipping and the dip angle is more than 50°. As normal fracture, its west dish rise and east plate down. The drop is 2000~3000m. Its fault cuts formations from Paleozoic to Neogene, form the boundary of Neihuang uplift and Dongming fault depression and controls the formation and development of the two tectonic units.

The secondary unit of Neihuang geological structure belongs to the Neihuang uplift and neighbors to the west of Dongpu Depression. The trend of the boundary fracture for them is NNE. The third unit division of Neihuang geological structure is depression in the north of Neihuang County, uplift in the southwest of the county, and Neihuang County which is located on the slope between these two structures.

Relevant data shows that deep drillings carried out in Neihuang in the past are not much. There is only a small number of geothermal wells drilled in the Neogene sandstones, which did not come into contact with the base rock. Therefore, it fails to see any fracture through the county on the existing geological maps. The area is in the transitional zone between Neihuang Uplift and Dongpu Depression and the derection of their boundary faults is NE. For this reason, under the effect of the regional stress field, a series of secondary faults in parallel with the boundary faults should exist in the county.

In order to fully confirm the existence of the presumed faults, we carried out the corresponding geophysical exploration and interpretation work in Neihuang County.

3. ANALYSIS OF GEOTHERMAL GEOLOGICAL CONDITIONS

According to the interpretation of CSAMT survey data, we can see a series of low resistivity zones appear on the 3 CSAMT exploration profiles (Figure 1, Figure 2 and Figure 3) of Neihuang County. It may be a reflection of fault information.

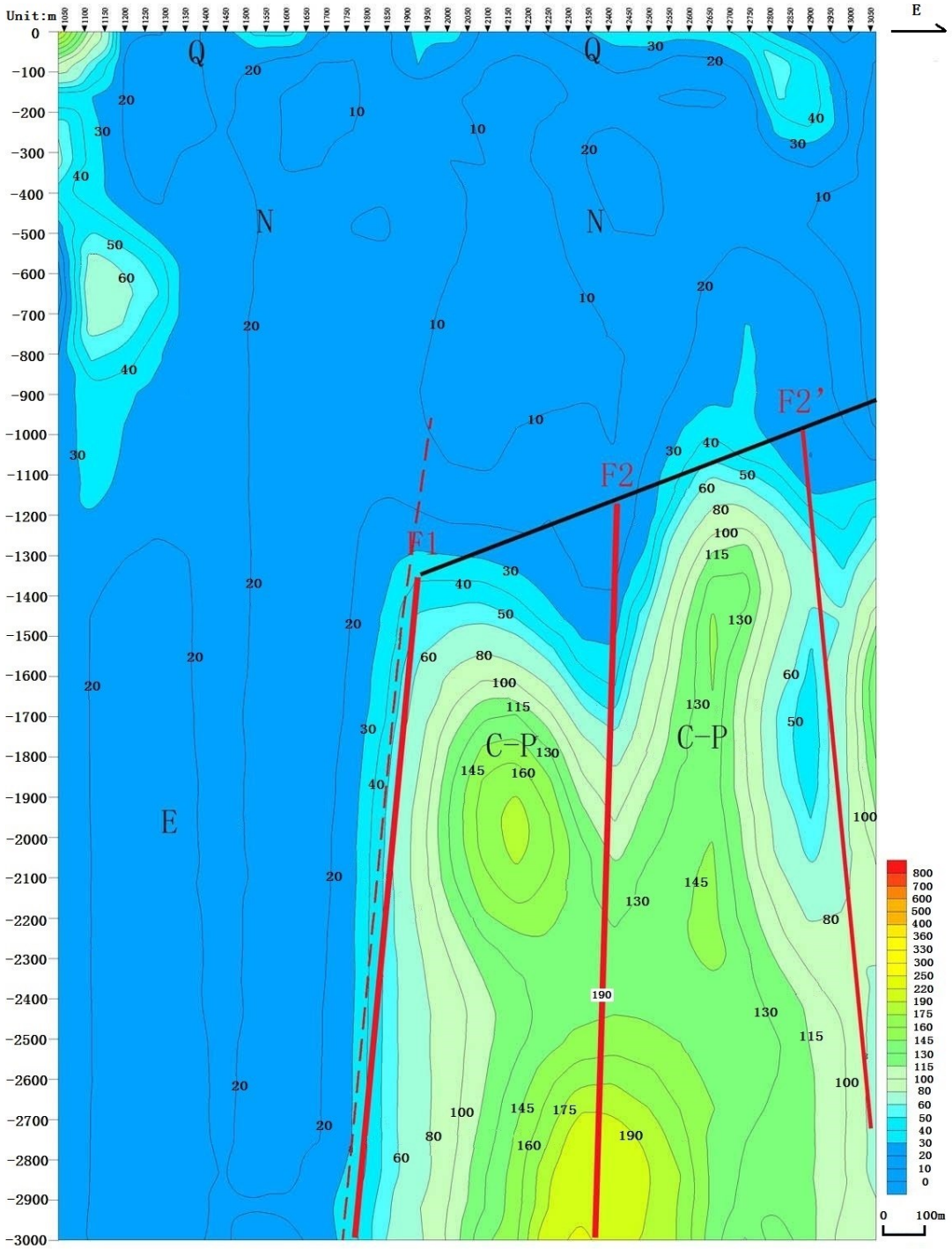

Figure 1: Geological key drawing concluded from L01 profile of CSAMT in Neihuang County.

Note: This is a profile. The transverse coordinate indicates the horizontal distance (in meters) of surface direction from the westernmost point of CSAMT line. The longitudinal coordinates indicate the depth (in meters) from the surface.

For example, on the western part of L01 profile, low resistivity distributes within all 3000m depth. It is not difficult to infer that the pattern of the profile is the Quaternary, Neogene and Paleogene from surface to the deep. Except the thin layer of Quaternary is the sediment of loose silty sand and clay. The thick Neogene and Paleogene formations are all the sediment of semi-cemented sandstone and shale. Impermeable mudstone has low thermal conductivity and it is a good insulation cover. And the sandstone has strong ability in water storage and the permeability is relatively high. Water in sandstone pore can become the geothermal water of Cenozoic thermal storage. The reason of low resistivity interface on this profile can be explained as the existing of F1, F2 and F2' fracture.

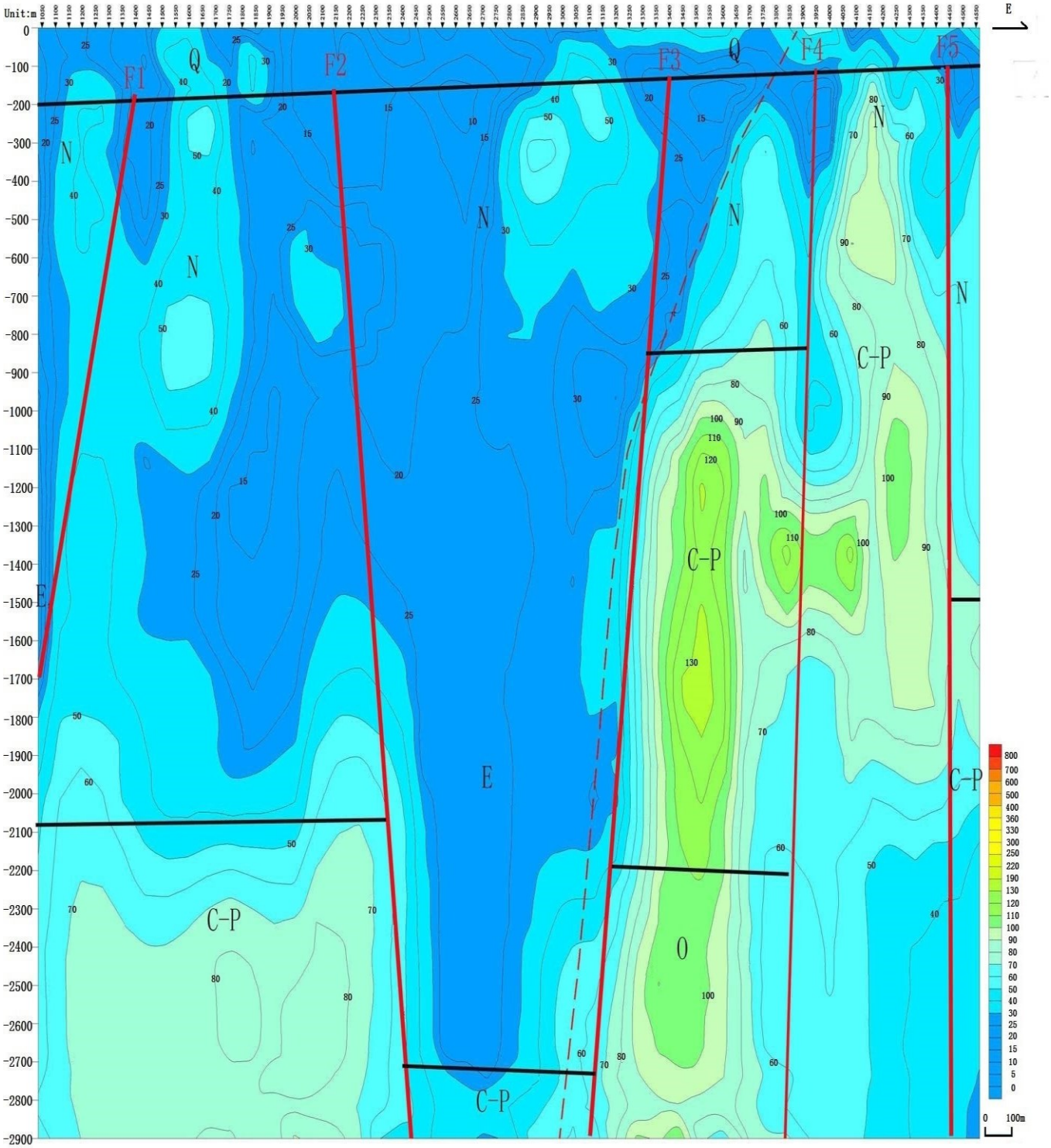

Figure 2: Geological key drawing concluded from L02 profile of CSAMT in Neihuang County.

The reason of moderate resistivity of middle and eastern part of L02 (Fig.2) profile below 1000m can be explained as the existing of Carboniferous-Permian formation, which is mainly consisted by sandstones and interbedded shale. This formation also has a small amount of limestone. But in general, it can not constitute an aquifer and cannot become a target bedrock layer for heat storage. Since the resistivity of the layer is not high, it is generally not considered to be Ordovician limestone. But there are no deep drillings which expose bedrock formation in this area. So we suspect it may be the fractured karst of Ordovician limestone in the area which constitutes the geothermal reservoir in Neihuang region. According to this, we explain the low resistivity in the interface as the existing of F1, F2, F3, F4 and F5 fracture.

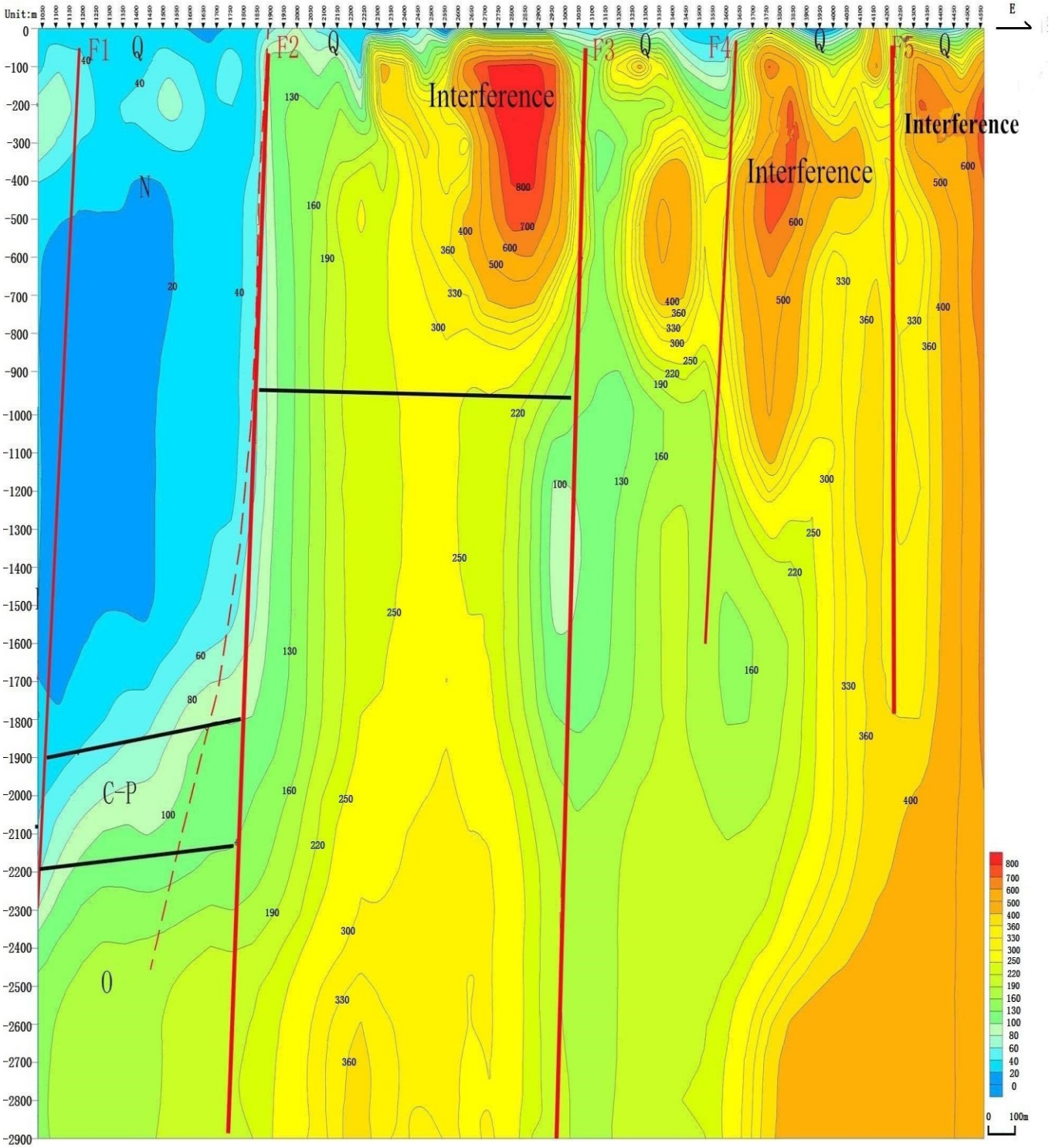

Figure 3: Geological key drawing concluded from L03 profile of CSAMT in Neihuang County.

The high resistivity of surface layer of middle and eastern part of L3 (Fig.3) profile is obviously affected by human disturbance. There never appeared “bedrock bumps” of high resistivity with the depth of less than 50m in Jizhong Depression in the North China. After excluding these disturbances, we can vaguely distinguish a number of low resistivity interfaces, which can be inferred and interpreted as F1, F2, F3, F4 and F5 fracture.

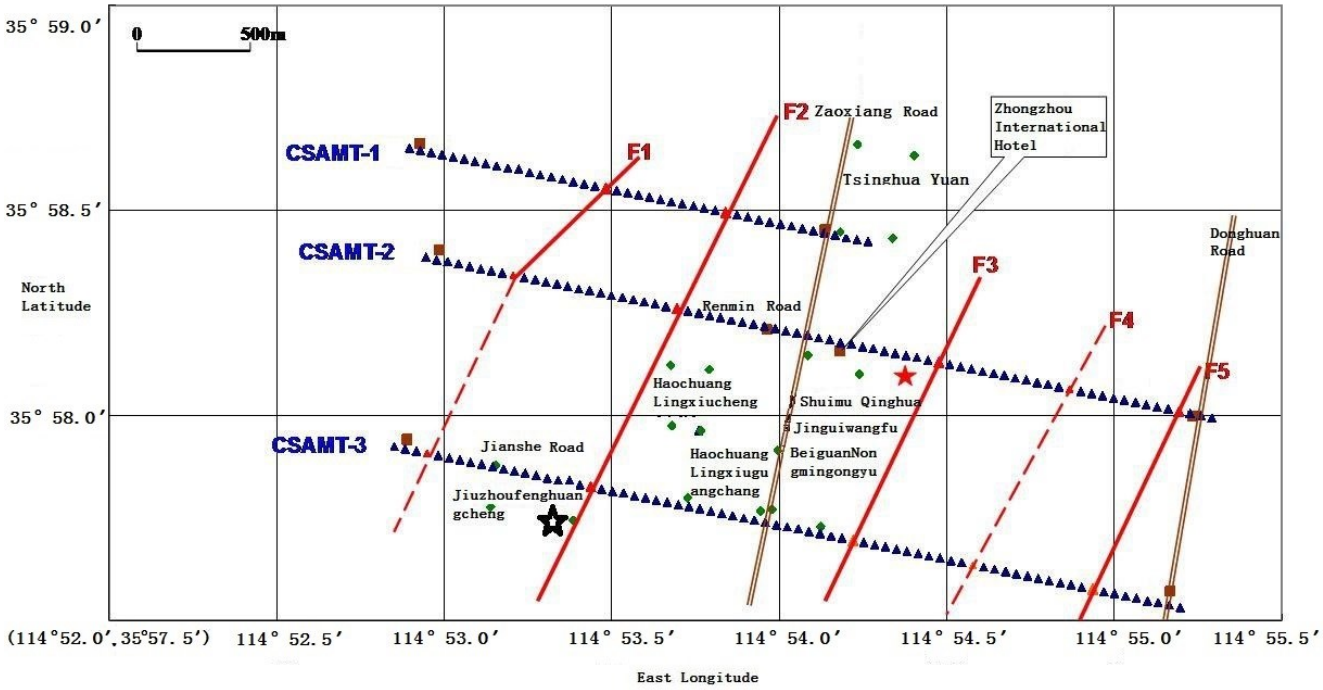

Figure 4: Geological structure diagram of CSAMT in Neihuang County.

Linking the outliers on above three profiles, we get a total of five fractures, F1, F2, F3, F4 and F5 respectively. According to these fractures, we draw "Geological structure diagram of CSAMT in Neihuang County" (Fig.4). In five fractures, F2, F3 and F5 fracture is certain; confirmation of F4 fracture is slightly worse; and the northern part of F1 fracture is rather certain while its southern part is no confirmed. Most fractures (4 fractures) outspread with a direction of 28°30′. Only the direction of the northern part of F1 fracture is 45°.

4. ANALYSIS OF GEOTHERMAL GEOLOGICAL CONDITIONS

According to the existing Neogene thermal wells and considering the above geological and geophysical conditions, it may be confirmed that geothermal wells for Neogene geothermal reservoir can be generally drilled in Neihuang County. It is also possible to drill geothermal wells of thermal storage with a great depth of drilling into bedrock.

4.1 Cap rock

No matter in Huaxian Uplift or Yuancunji Depression, Neihuang County has a certain thickness of Neogene sedimentary. The mudstone in Neogene sedimentary is impermeable and its thermal conductivity is high. So it is a good thermal insulation cover layer. The geothermal gradient in the center of Huaxian uplift is greater than 3 C/100m and the geothermal gradient near Neihuang County is about 2.5 C/100m.

4.2 Thermal storage

There may be two heat reservoirs in urban areas of Neihuang County. The shallow heat reservoir is Neogene sandstone formation which contains water. It has a certain temperature in a certain depth, which constitutes Neogene geothermal reservoir. There may be Paleogene and Carboniferous- Permian under the Neogene, whose sandstone is of a small amount of water, but generally does not constitutes a heat reservoir. The deeper Ordovician strata is composed of limestone, which has a certain degree of fissures and karst and constitutes the deep bedrock geothermal reservoir.

4.3 Heat source and channel

Faults and fissures may constitute heat sources and channels of geothermal field. Summing up the results of the geophysical survey interpretation, we find that there are many fractures of different size in deep underground of Neihuang County. Among them, the bigger the scale is and the deeper the fracture cuts, the better the heat conduction is. The water-bearing fractures form water channels, making the deep hot water can produce hydrothermal convection system through fractures.

5. PREDICTION OF SELECTED POSITION AND WELL COMPLETION CONDITIONS OF GEOTHERMAL WELL

5.1 Selected position of geothermal well

5.1.1 Drilling position

The first bedrock heat reservoir Wells for the combination of exploration and mining in Neihuang County is selected at 3250 point on L02 profile of CSAMT. The position is shown as a red star in figure 4, which lies in the southwest of the intersection of Renmin Road and Fanyang Avenue. Its geographical coordinate is N 35°58.131', E 114° 54.411'.

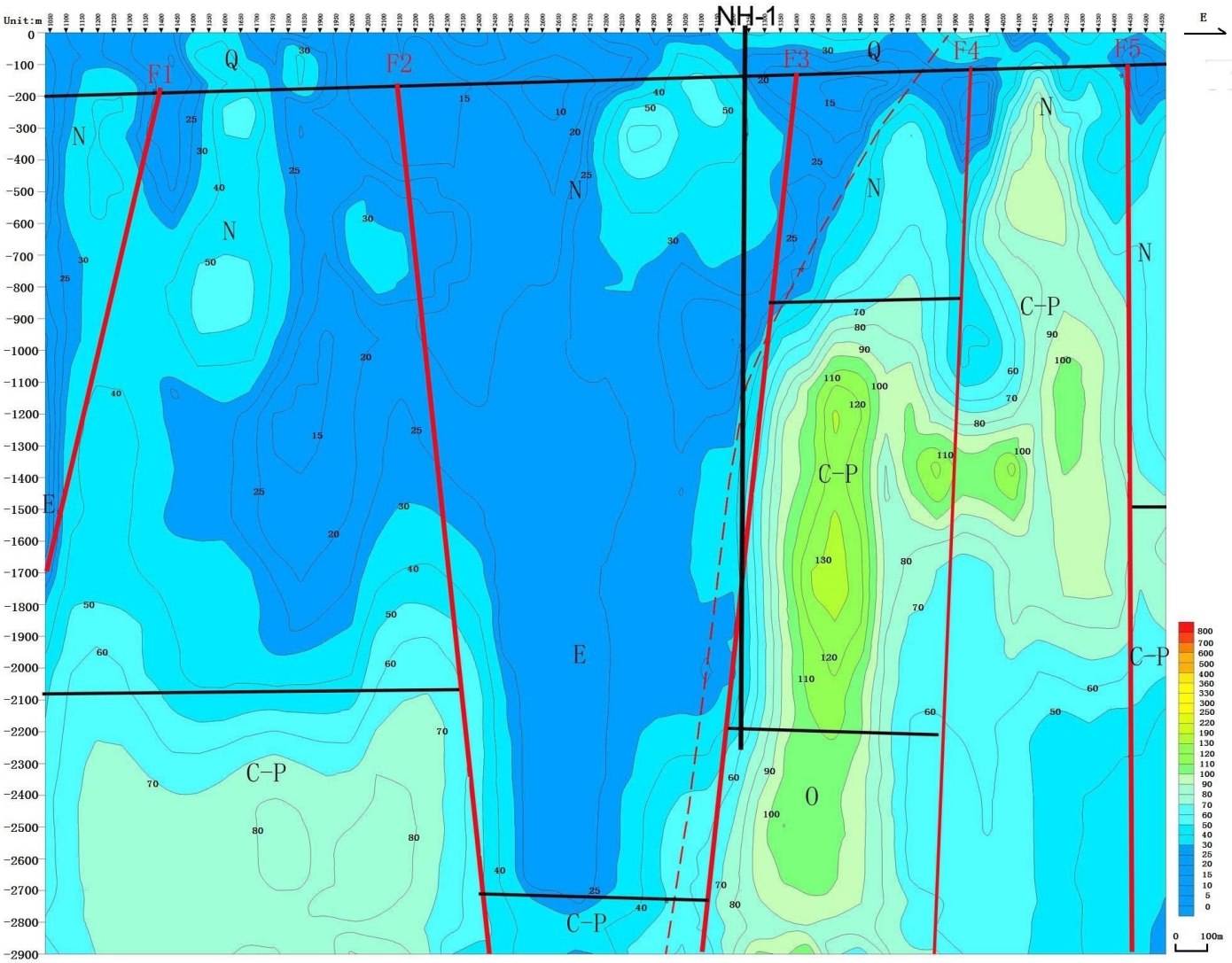

Figure 5: Selected position figure for the first exploration and mining well in Neihuang County.

5.1.2 Designing backgrounds of drilling program

In figure 5, the dip angle of F3 fault of CSAMT on L02 profile is 84° and its tendency is northwest. Design of NH-1 is expected to drill into the fault zone at depth of 1800m. It is generally not taken that breaking into the footwall after drilling into the fault zone. However, we can only do so in order to verify the fact that the Carboniferous-Permian or Ordovician can be seen after through the fracture. Because the fracture angle is not as accurate as interpretation and the explained depth of the interface between Carboniferous-Permian and Ordovician of F3 fracture is no more accurate. We take such a design in order to have a better grasp to drill to the fracture and the Ordovician limestone. The result of this drilling, if not seeing Ordovician limestone, at least can reach the fault, thereby ensuring the temperature and the yield of the wells.

5.1.3 Geological design of drilling well

The above layers are idealized and might have big errors. It needs some certain adjustments when conducting actual drilling. Perhaps early enter into the Ordovician limestone, or properly drill to 100m with the help of fault zone. Perhaps no Ordovician limestone, deeper drilling can be appropriately taken, for example, deepen to 2500m completion.

Table 1: Formation types vary with depth of drilling

depth	Formation lithology
0~160m	The Quaternary, loose silty sand and cohesive soil
160~1800m	The palaeogene, interbedding of half cementation sandstone and mudstone
About 1800m	Drill in the fault zone, its penetration thickness may be several meters to tens of meters
1800~2200m	The Carboniferous-Permian, sandstone and shale interbed, a small amount of limestone
2200~2300m	The Ordovician, limestone karst fracture, heat reservoir rock

5.2 Prediction of well completion conditions of geothermal well

5.2.1 Water temperature

For the 1800m Neogene and Quaternary cover, considering conservative estimation, the total increase of the temperature is 45℃ if the geothermal gradient is 2.5℃/100m; For the fracture and limestone of 1800~2300m, the geothermal gradient is 1℃/100m and the total increase of the temperature is 5℃. Adding room temperature 15℃ (slightly higher than the annual average temperature), the underground temperature can reach 65℃. Water temperature of geothermal wells should loss (decrease) several degrees. The final surface temperature may reach 55-60℃.

5.2.2 Water yield

The water yield of limestone heat reservoir per single well is 800 m^3/d in general. If there is no late filling jam in fault zone, the wells can have more than 1000 m^3/d water yield. If the fault can be combined with limestone, the amount of water will increases more.

5.2.3 Geothermal water quality

The quality of geothermal water is completely different from surface water and shallow groundwater. This is the result of the balance between water and rock in deep geochemical environment. The positive ion of geothermal water contains more sodium and the negative ion of geothermal water contains more sulfate. The water quality types may be sodium bicarbonate water. The content of metasilicate in geothermal water often reaches the standard of medical mineral water. The content of more than 50 mg/L can be called silicane water. The water is also likely of high fluoride, which is called fluorine mineral water.

5. CONCLUSION

NeiHuang County is located in the North plain. Its geothermal resource is the sedimentary basin type of underground hot water, which is mainly identified as layered confined water and fissure confined water.

5.1 The formation and distribution of geothermal resources is controlled by structure

Hot underground water transfers the deep heat to the surface along the fracture channel through deep circulation convection. There are close relationships among nature, scale, recent activity and depth of the temperature and yield of hot water. The geothermal water has large amount and high temperature near deep faults.

The sedimentary fault basin where Neihuang County located was a settling basin of the middle Cenozoic, when the earth's crust activity was relatively stable and the basement rift was mature. The study area is located in the transition between Neihuang uplift and Dongpu depression, which is located in the slope of the west side of Changyuan fracture. A series of secondary fractures in different size under the same stress field of the deep fracture through traverse this area on the similar direction (NNE), providing channels for deep heat source. Huge thick sedimentary rocks of Cenozoic not only hindered the dissipation of the earth’s interior heat to the surface, but also acted as a high pressure cap, which directly covered the heat reservoir and had the effect of heat preservation and heat insulation.

5.2 Feature of thermal storage

Neihuang County is located in the depositional fault basin. It is mainly the storage of Neogene sandstone layer and Ordovician deep bedrock. The type of hot water is inferred as sodium bicarbonate.

5.3 Feature of heating

It is initially speculated that there is the presence of fault or fracture zone with high permeability in the work area. These fault or fracture zones can make water occurring cycle. The temperature of hot water mainly depends on the size of the regional heat flow and the depth of the deep cycle. The source of water usually is the infiltration of atmospheric precipitation. Leaching, exchange adsorption of anions and biochemical effect between hot water and rock is stronger, or there is the phenomenon of high salinity.

5.4 Drilling verification

Resulting from comprehensive function of multiple factors, the drilling well is finally moved to NH-1’ (black five-pointed star position in figure 5) from NH-1 (red five-pointed star position in figure 5). The well had been completed and began temperature measurement in the end of March this year. Ultimately, the geothermal well drills to 3001m. The temperature of water is 55℃. Pumping capacity is 64m^3/h, i.e. 1536m^3/d. The mined water is mainly the Neogene Guantao limestone water in 1342-1657m, namely located in the shallow geothermal reservoir in Neogene formation as previously predicted. The hot water also includes a small part of water in the Tertiary aquifer. The drilling well exposed the Ordovician bedrock in 2695m at end hole. The mineralization degree is up to 9g/L, which explains a stronger water-rock interaction.

Above all, the result of drilling confirmed the reasonableness and correctness of the prediction scheme. The drilling results and NH-1 predicted results are relatively similar. It also underlines that the geothermal drilling results have a close relationship with geothermal geological conditions of Neihuang County in this article.

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