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Distribution Characteristics and Genetic Mechanism of Geothermal Reservoirs in Wucheng Salient Geothermal Field

Wang Di[1,2], Wang Xinwei[2], Su shangguo[1], Mao Xiang[2], Zhang Xuan[2], Wang Tinghao[2] ,Liu Huiying[2]

1.School of Geosciences and Resources, China University of Geosciences, Bejing 100083 ,China

2.New Energy Research Institude, SINOPEC Star Petroleum Co.,Ltd(Sinopec Star), Bejing 100083 ,China

1183372711@qq.com

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ABSTRACT

Driven by the "Xiongxian model" and environmental pressure, Hebei Province has become the largest geothermal heating urban agglomeration in China. Therefore, the study of geothermal and geological characteristics of Wucheng Salient has important guiding significance for geothermal development in Gucheng County, Hebei Province. In this paper, we studied the distribution of different types of geothermal reservoirs, physical properties of reservoirs, characteristics of geothermal water recharge and circulation path, and evaluation of geothermal resources by combining the logging, seismic and regional geological data including the analysis of hydrochemical characteristics and isotopic results. The results show that the geothermal field has two geothermal reservoirs: sandstone reservoir and karst reservoir. The former is widely stable and distributed, with the main aquifer as the lower Guantao Formation between 1200-1600 m deep. The geothermal water temperature ranges from 52-54℃, and average water yield between 75-123m^3/h. The favorable zones of karst geothermal reservoir are mainly in the anticlinal core of the Cambrian-Triassic extending in a north-south zonal direction with main aquifer as the upper Majiagou Formation, the lower Majiagou Formation and Liangjiashan Formation bewtween 2100-2900 m deep. The geothermal water temperature rangefrom 82-85℃, and the average water yield of of between 75-98 m^3/h. The geothermal water originates from recharge area of Taihang mountains in the west and Yanshan mountains in the north, moving horizontally along the NE-SW fracture zone and the karst unconformity to enter the shallow geothermal reservoir. It mixes in Wucheng Salient to form medium-low temperature geothermal water through Cangxian Uplift and Xingheng Uplift to form NaCl waters . The dating results of ^{14}C indicate that the geothermal water of sandstone reservoir and karst reservoir is 21ka and 32ka. The Minghuazhen Formation and the Carboniferous-Permian strata are cap rocks of the two geothermal reservoirs, respectively. Based on detailed geothermal resource evaluation It is estimated that the total geothermal capacity amount to 4.86×10^{10} GJ, equivalent to 16.6×10^8 of standard coal. The annual exploitation of geothermal resources can meet the indoor heating area of 110 million square meters with huge potential for further development.

1. INTRODUCTION

Geothermal resources are a clean and renewable energy source (Lin et al.,2013). Driven by the "xiongxian model" and environmental pressure, China has accelerated the development and utilization of medium-low geothermal resources. At present, Hebei Province has become the largest geothermal heating urban agglomeration in China, mainly including Niutuozhen geothermal field, Gaoyang geothermal field, Rongcheng Salient geothermal field, Tianjin geothermal field, Tangquan geothermal field and other typical geothermal fields (Guo and Li,2013;Li et al.,2015;Yang et al.,2018;Liu et al.,2018). Wucheng Salient geothermal field is located at the junction of Hebei, Henan and Shandong Province. By the end of 2018, a total of 63 geothermal Wells have been drilled, including 51 sandstone Wells and 12 limestone Wells. Water testing results show that the water yield of sandstone well is 55-75 m³/h, and the water temperature of wellhead is 50-80℃.The water yield of limestone well is 55-140 m³/h, and the water temperature of wellhead is 70 - 85℃. Seven geothermal heating stations have been built, and the designed geothermal heating area is 111km^2, with huge potential for future development. The research region is a newly developed geothermal field, which has not been studied in detail. This paper analyzes the characteristics of geothermal reservoir distribution and geothermal water recharge model of Wucheng Salient geothermal field based on logs seismic data, hydrochemical and isotope test results.The rsults provides a theoretical guidline for future exploration and development of geothermal resources in Wucheng Salient geothermal field.

2. GEOTHERMAL CHARACTERISTICS

2.1 Regional tectonics

Wucheng Salient geothermal field corresponds to Wucheng Salient in Linqing Depression structurally. Wucheng Salient trends NE,the and Cangdong fault, Hengshui fault and Wucheng west fault are boundary control faults (Fig1). Cangdong fault starts from the north of Ninghe, Hebei province, runs south through Cangzhou, Nanpi, Wuqiao, Dezhou and linqing. The direction is about NE30°, and the total length is about 350 km. It is a detachment slip fault developed in the upper crust, and serves as the boundary between Wucheng Salient and Dezhou Depression. Hengshui fault starts from Zhengding, and goes through Wuji and Shenxian, extending ENE, which is the boundary between Wucheng Salient and Xingji Salient. Wucheng west fault is a normal fault in NNE direction and dips to WNW, with inclination angle of 30-45° , 40 m long and age of between J_3-N_m, which is the boundary between Daying Sag and Wucheng Salient .

Linqing Depression is the rift basin formed in the Mesozoic-Cenozoic, and its tectonic-sedimentary evolution characteristics affect the formation of geothermal reservoir. The early Paleozoic is a period of karst geothermal reservoir development, which experienced stable subsidence and the deposition thickness of marine carbonate reservoir is 500-800 m. In the late Paleozoic, after the Caledonian movement which the formation uplifting, epigenic karst process developed, the whole subsidence occurred, and the alternate marine-continental coal-bearing measures developed. After that, a series of NE-NNE faults and secondary faults were formed in Mesozoic as the squeezing-relaxation action during Yinzhi-Yanshan movement, which were good water-conducting passageway. As the multi-stage activities of the Himalayan movement, the Cenozoic era has developed regional cap layers with high thermal flow values (Fig. 2).

2.2 Stratigraphic Characteristics

According to the regional geological maps and well logs, the drilled formation in the study area. The stratigraphiy in the area (Fig 2) can be summaried as; are Cambrian-Ordovician, Carboniferous-Permian, Paleogene, Neogene and Quaternary from bottom to top. The Cambrian-Ordovician formation is the main geothermal reservoir developed, with a total thickness of 1150-1350 m, which is composed of argillaceous limestone, oolitic limestone and shale.

The Carboniferous–Permian formation is disconformable contact with the underlying formation and form a good cap rock, with a total thickness of 890-1050 m, which is composed of clastic rocks mixed with carbonate of marine-terrigenous facies. The Paleogene includes Kongdian formation, Shahejie formation and Dongying formation from bottom to top,it is widespread in the whole area. The Neogene is divided into Guantao formation and Minghuazhen formation from bottom to top, and the roof depth of Guantao formation is 1200 -1500 m. The thickness of Quaternary formation is 420-520 m, which is fluvial deposition.

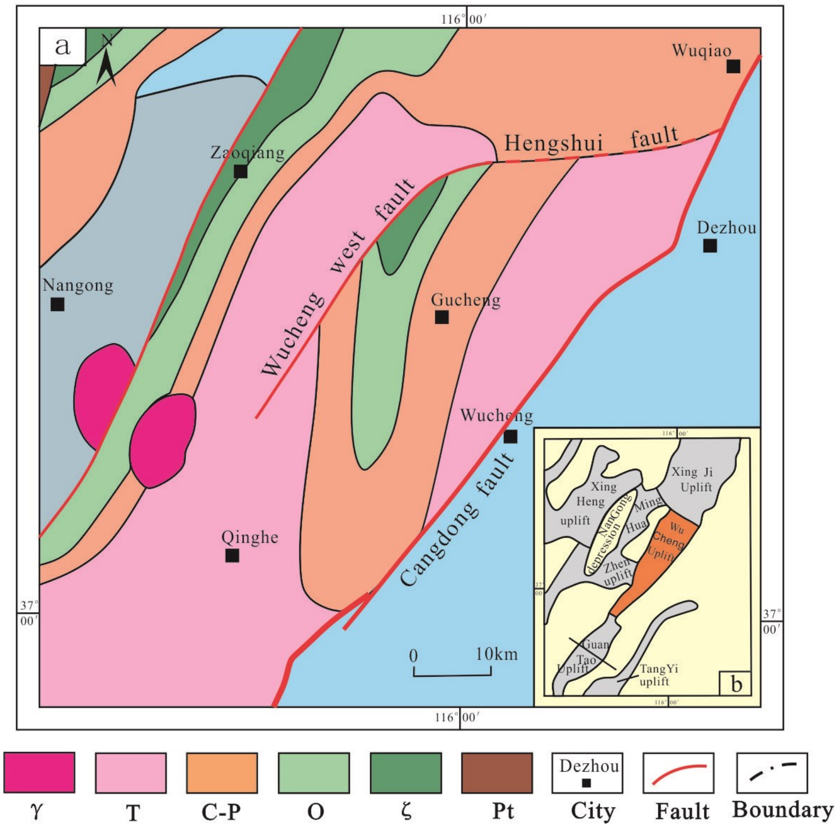

Fig.1 Stripping Cenozoic geological map (a) and Tectonic zoning map (b) in Wucheng Salient

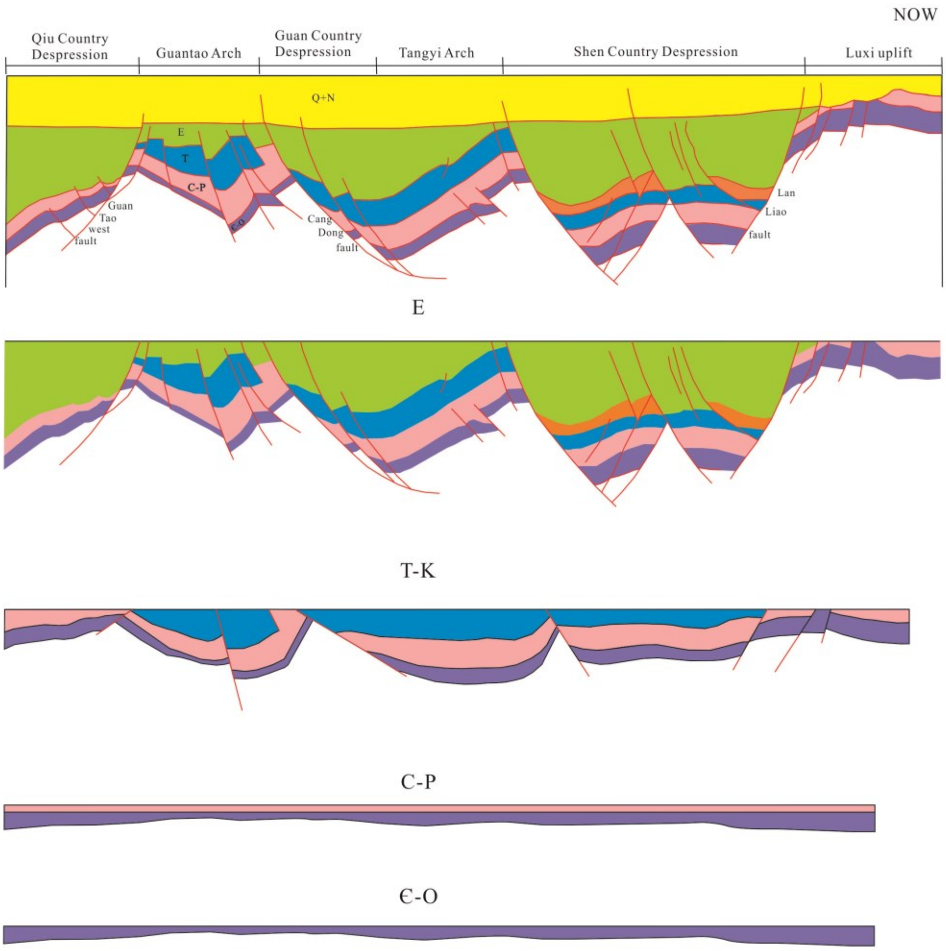

Fig 2. Wucheng Salient cross-section profiles

3. GEOTHERMAL RESERVOIRS CHARACTERISTICS

Using the geological and drilling data in the study area, the geothermal reservoir characteristics of Wucheng Salient geothermal field can be discused. The geothermal reservoirs can be divided into sandstone and karst geothermal reservoir. The former reservoir is widely distributed in the study area, with shallow burial depth, lower temperature and good yields. The karst geothermal reservoir is deeply buried, with the characteristics of zonal distribution, easy recharge and large larger yields facilitated by faults.

3.1 Sandstones Geothermal Reservoir

Affected by Himalayan movement, the North China Basin began to change into a period dominated by overall subsidence from Neogene to Quaternary creating a sediment deposition environment for the sandstone and other deposition thus the sandstone geothermal reservoir of Guantao formation is distributed in the district.The reservoir cap rock is the Minghuazhen formation with thickness of about 680880 m, it is a light brown mudstone interbedded with fine siltstone. It's not only a good aquifuge but also an insulator, the geothermal gradient also increased significantly when heat flow conducts from deep underground to the layer. The average geothermal gradient is 3.21℃/100 m~3.76℃/100 m (Fig 3). within the geothermal reservoir and 2.5℃/100m within the cap,

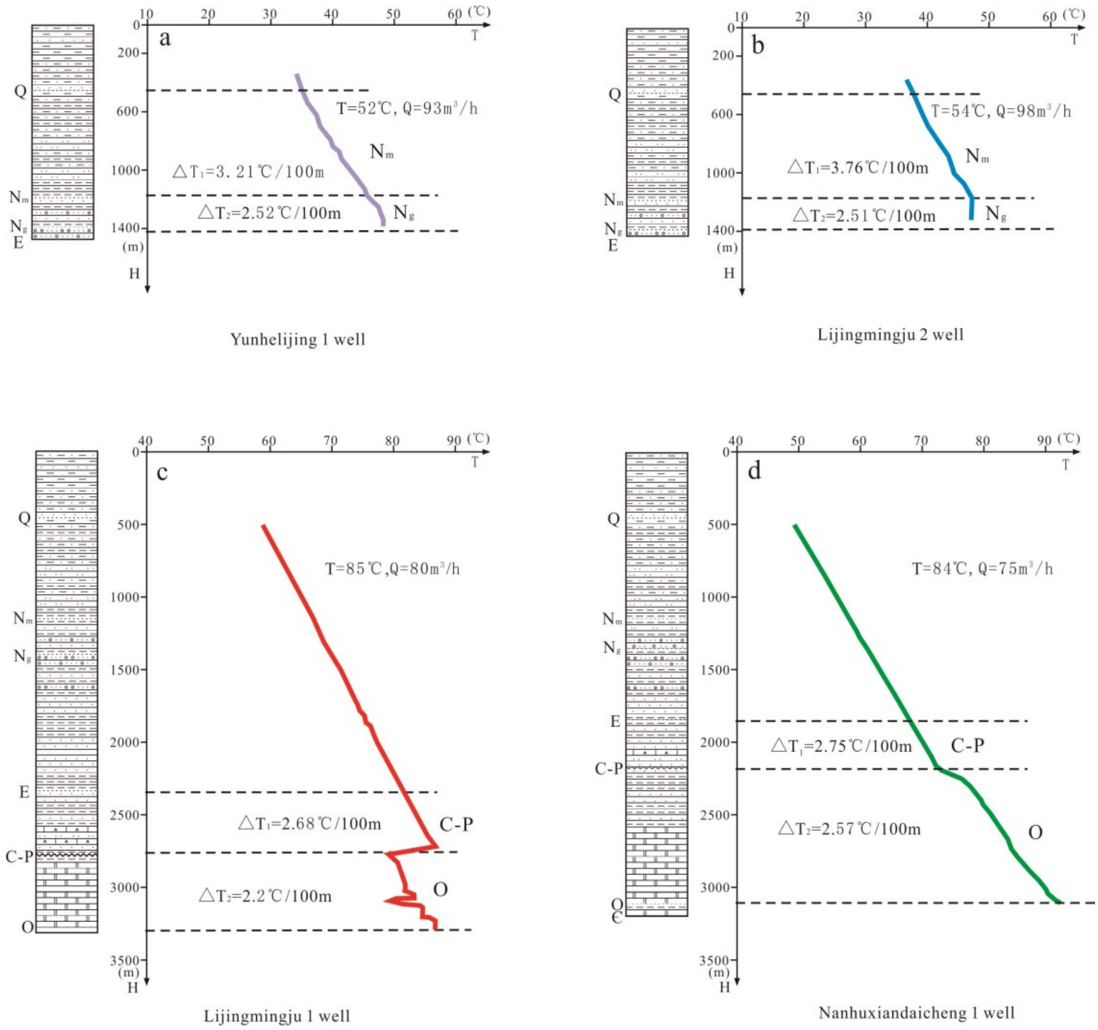

Fig.3 Relationship between formation temperature and depth of Geothermal Wells in Wucheng Salient geothermal field

The sandstone geothermal reservoir of Wucheng Salient geothermal field gradually deeps from the north east to the south westfrom 1200 m to 1600 m roof depth respectively.The depth of the main ridge of anticline being less than 1200 m (Fig. 4). The thickness of geothermal reservoir is between 200 and 300 m. The upper lithology is brown-yellow mudstone and gray-green siltstone interbedding. The lower part is interbedded with gray sandy conglomerate and gray mudstone, net gross ratio is 64.8 to 75.7%, porosity is 29.7 to 35.7%, and permeability is 523 to 1261mD (Table 1). Guantao formation is a fluvial deposition in the study area, with a positive cycle characterized by upper-coarse and lower-fine. It can be further divided into the upper Guantao formation and the lower Guantao formation. Spontaneous potential curves of the upper Guantao formation are wavy, and small variation amplitude. The value of its natural gamma ray curves are lowly, with zigzag, dentate, fingertip and short finger, showing that thin sand and is interbeded with mud and the average net gross ratio is 40% (Fig. 5). The natural potential curve of the lower Guantao formation is wavy, and the amplitude is larger than that of the upper Guantao formation. The sand conglomerate has a low positive amplitude anomaly, and the natural gamma curve is zigzag, dentate, box and fingertip. The gamma value of the sandy conglomerate is low, while that of the mudstone is high, and the thickness of sand is thick, the average net gross ratio is 70% , it concludes that the lower Guantao formation is the principal water-producing layer. According to water testing reports, the water yield of single well is 79~123 m³/h, and the wellhead water temperature is 52~54℃.

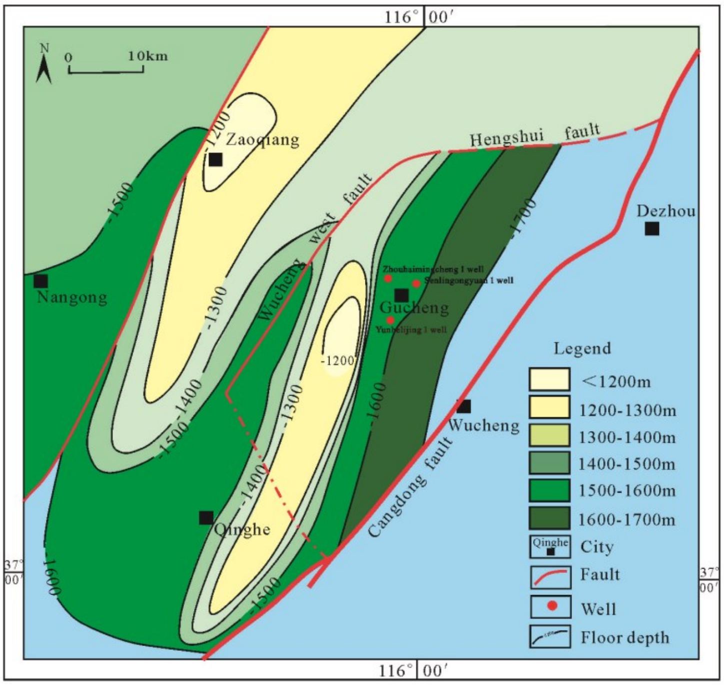

Fig.4 Floor depth map and well 1ocation distribution map of sandstone geothermal reservoir in Wucheng Salient geothermal field

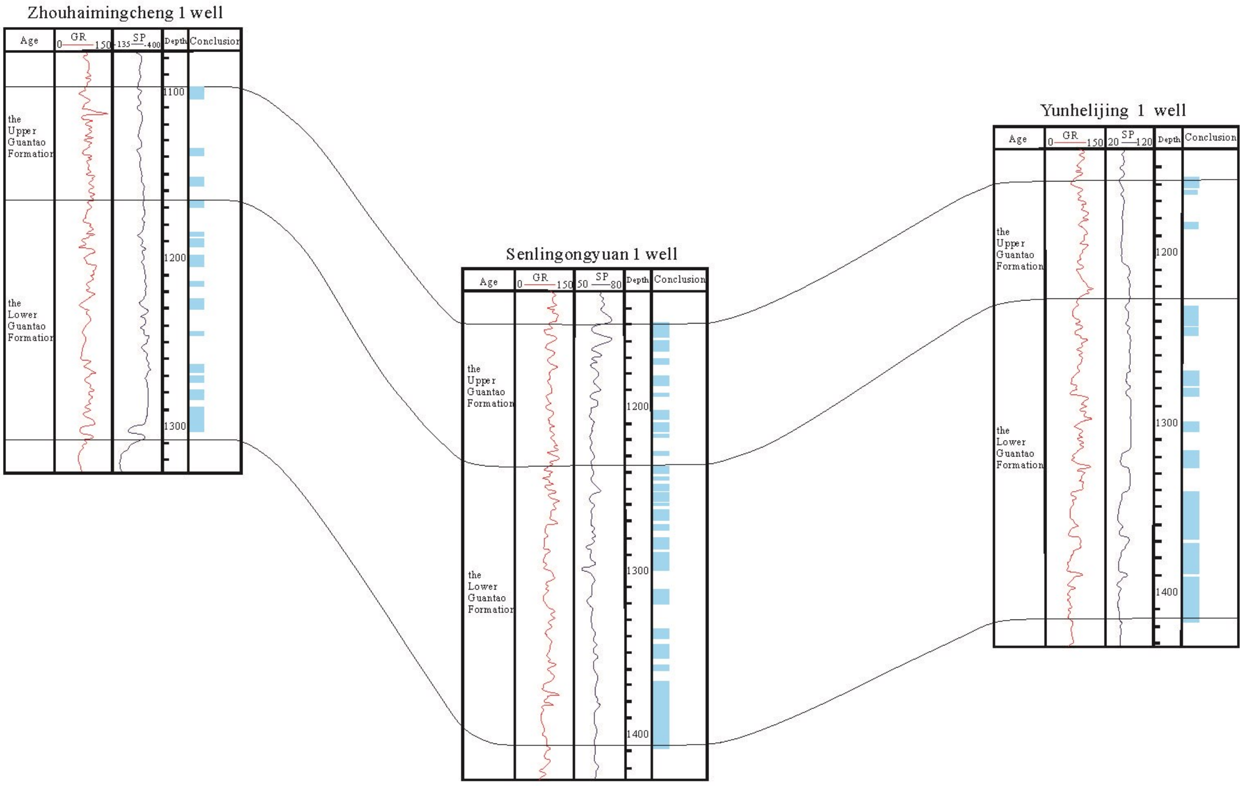

Fig.5 Stratum correlation of sandstone geothermal reservoir in Wucheng Salient geothermal field

3.2 Karst Geothermal Reservoir

The structural configuration of bedrock in WuCheng Salient geothermal field is anticline structure (Fig. 1b), the core of it located in the northwest of Gucheng county 6-10 kilometers and covered by the Cenozoic formation, which the Cambrian-Ordovician formation were denuded, and is 1000-1500 m deep. It experienced a long-term leaching-karstification, and developed a large number of solution pore, which probably are the most favorable zones in development of karst geothermal reservoir. Two limbs of anticline developed Carboniferous-Permian strata, and it is the direct cap rock of the Ordovician geothermal reservoir. According to well logs, Carboniferous-Permian strata is 290-350 m thick, and the upper lithology is grey mudstone and grey siltstone, the lower is gray-black carbonaceous-mudstone and dark gray limestones with coal seam, and the average geothermal gradient is 2.68℃/100m-2.75℃/100m, which is good heat proof and temperature preserving covers. The lithology of the Ordovician karst geothermal reservoir is mainly dark grey limestone, the depth is 2100-2900 m (Fig. 6),.The geothermal reservoir thickness is 600 -800 m, the average net gross ratio is 15.4 - 41.6%,effective porosity of1.47% ~ 11.05%.On the other hand the average geothermal gradient is 2.2℃/100m~2.57℃/100m with a single well yielding water yield is 75-98m^3/h, and wellhead temperature is 54 ~-80 ℃ (Table 1).

The karst geothermal reservoir are hosted in Carboniferous-Permian and with the Ordovician reservoir forming aseal. Favorable zones are mainly controlled by the fracture distribution in Gucheng Country.

According to stratigraphic correlation in the karst geothermal reservoirs (Fig. 7), the drilled formation are FengFeng formation, the upper Majiagou formation, the lower Majiagou formation, Liangjiashan formation and Yeli formation from top to bottom. The primary crack developed mainly in the upper Majiagou formation and the lower Majiagou formation with athickness of 18.4 m and 17.9 m respectively. The secondary crack developed mainly in the lower Majiagou formation and Liangjaishan formation with the thickness of 15.4 m and 29.8 m respectively, on the other hand tertiary cracks developed mainly in the upper Majiagou formation , lower Majiagou formation and Liangjiashan formation with thethicknesses of 31m, 42.5 m and 59 m respectively. This suggests that the upper Majiagou formation, the lower Majiagou formation and Liangjiashan formation may be the main production layers of karst geothermal reservoir.

Fractures are developed in Nanhuxiandaicheng 1 well, Xinyujiayuan 2 Well and Lijingmingju 1 well, indicated by displaced and missing formation in corelated logs. With high yielding wells of more than 75 m³/h. No secondary fracture has developed in Fubanghuyuan 2 Wells which is queit different from aforementioned and has low yields of 35m³/h. This characteristics shows that the productive geothermal reservoir are mainly fault controlled.

Generally the Ordovician karst geothermal reservoir has a an increasing thickness from north to south, from main ridge to wings. The main aquifers of karst geothermal reservoir are the upper Majiagou formation, the lower Majiagou formation and Liangjiashan formation. Some favorable zones located in the main ridge of anticline and others are mainly controlled by the fracture distribution on both wings of the anticline.

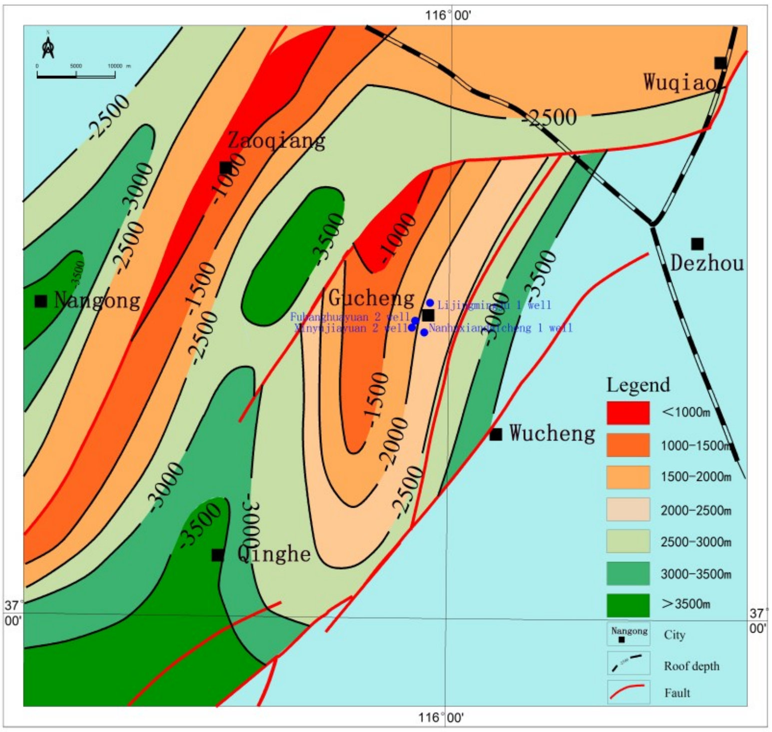

Fig.6 Roof depth map and well 1ocation distribution map of karst geothermal reservoir in Wucheng Salient geothermal field

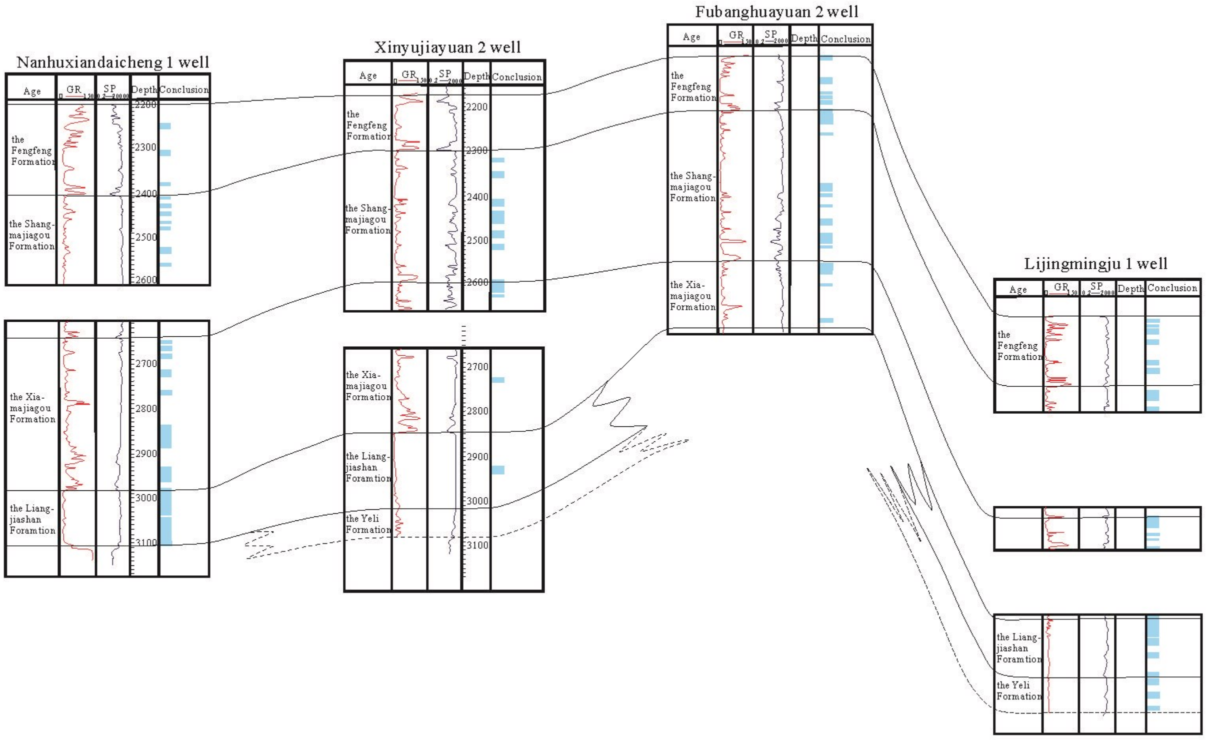

Fig.7 Stratum correlation of karst geothermal reservoir in Wucheng Salient geothermal field

Table 1 Statistics table of typical geothermal boreholes in Wucheng Salient geothermal field

Well No.	Depth/m	Wellhead Temperature (℃)	Water Yield (m^3/h)	Net Gross Ratio /%	Porosity (%)	Permeability (mD)	Effective Thickness (m)	Aquifer (m)	Reservoir
Lijingmingcheng 1 well	1578	54	81	75.7	34.5	1261	167.4	1318~1539	Ng
Senlingongyuan 1well	1562.5	52	79	73.8	35.4	761.1	207.3	1268~1549	Ng
Zhouhaimingcheng 1well	1500	52	123	75.8	34	785.5	159.2	1098~1308	Ng
Yunhelijing 1well	1610	52	83	64.8	29.7	523.2	190	1304~1597	Ng
Fubanghuayuan 2 well	2800	54	35	22.36	5.74	3.01	138.2	2137~2800	O
Nanhuxiandaicheng 1well	3150	84	75	32.5	11.05	14.65	301.1	2195~3112	O
Lijingmingju 1well	3300	85	80	41.6	1.47	2.71	213.7	2751~3300	O
Xinyujiayuan 2 well	3130	82	98	21.2	6.33	1.78	131.5	2316~2936.4	O

Note: all data are from final well reports of Sinopec Star Company.

4. RECHARGE OF GEOTHERMAL WATER

4.1 Geochemical characterization

The dissolved solids (TDS) in the hot water of the karst geothermal reservoir in Wucheng Salient geothermal field are 4.6 ~-17.3g/L, belonging to saltwater or brine. Cations are mainly Na^+, Ca^{2+}, Mg^{2+}, K^+, and $Na^+ > Ca^{2+} > Mg^{2+} > K^+$. Anions are dominated by Cl^-, SO_4^{2-}, HCO^{3-}, F^-, and $Cl^- > SO_4^{2-} > HCO^{3-} > F^-$. The pH values are 6.32-7.11/7.15, indicating alkalinity (Table 2). Piper diagram shows that the cations are mainly Na^+ and K^+, and the anion with Cl^- content is the highest, belonging to NaCl type water (Fig. 8). The formation of the water chemical composition of the geothermal field in Wucheng Salient is mainly caused by the water-rock interaction between the surrounding rocks and rainwater when it recharges the groundwater, which dissolves plaster and other salts, forming high mineralization.

Basing on the data of water chemical characteristics of the ordovician karst geothermal reservoir (Table 3), the TDS of geothermal reservoir is 5.9 -6.3 g/L in the northeast of Hengshui-Wuji conversion fracture, and is more than 10 g/L in the eastern of the Linqing depression.This indicates that geothermal water is recharged to a lesser degree with seldom supply from Luxinan Uplift.

Table 2 Chemical and isotopic compositions of groundwater from the study area

Well No.	PH	T/℃	TDS	Na^+	K^+	Mg^+	Ca^+	Cl^-	SO_4^{2-}	HCO_3^-	SiO_2	δH/‰	$\delta^{18}O$/‰	Hydrochemistry type
			ρ_B（mg/L）											
Lijingmingju 1well	6.32	90	17312	4803.35	194.53	155.4	1043.73	9129.81	668.43	207.69	34.89	-68.86	-8.2	Na-Cl
Lijingmingju 2 wel	7.18	54	4697	1682.36	21.18	35.55	136.45	2425.84	388.92	209.80	24.55	-72.58	-9.9	Na-Cl
Lijingmingju 3 well	7.41	53	4559	1631.81	17.83	33.66	128.44	2349.98	379.47	214.40	26.98			Na-Cl
Fubanghuayuan 1well	6.71	74	8403	2558.17	81.51	70.36	429.53	4383.67	22.31	239.68	28.67	-73.6	-9.4	Na-Cl
Fubanghuayuan 2 well	7.66	47	2260	755.25	6.42	10.84	34.03	791.73	213.45	444.21	23.74			Na-Cl
Nanhuxiandaicheng1 well	7.44	53	4757	1686.62	23.15	31.07	137.91	2429.08	389.97	223.88	27.49			Na-Cl
Yunhelijing 1 well	7.34	54	4557	1606.34	22.83	27.46	123.3	2305.86	374.2	233.45	25.54	-74.64	-9.8	Na-Cl

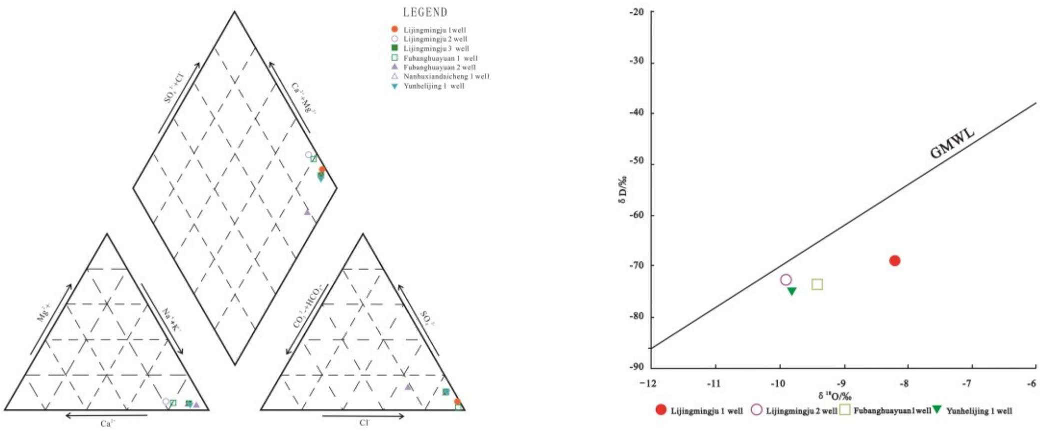

Fig.8 Piper diagram and Water stable isotope composition for groundwater samples of Wucheng Salient geothermal field

Table 3 Statistical table of total dissoloved solid(Qian and Ma,2005)

City	Dacheng	Qing country	Xian country	Fucheng	Hengshui	Gucheng	Xinhe	Nangong
TDS(g/L)	6.1	5.9	6.1	6.3	7.7	11.9	10.7	11.8
Hydrochemistry type	$Cl{\cdot}SO_4$-Na	$Cl{\cdot}SO_4$-Na	Cl-Na	Cl-Na	Cl-Na	Cl-Na	Cl-Na	Cl-Na

4.2 Hydrogen and Oxygen Isotopes Characteristic

Groundwater mainly originates from meteoric precipitation and infiltration recharge of surface water. The method of hydrogen and oxygen isotopes is of great significance in determining the genetic type and the origin of geothermal water (Qian and Ma,2005).

Four samples were tested for isotopes in the Wugcheng Salient geothermal field (Table 2).In figure 5,it can beshown that the hydrogen vs oxygen isotopes plot of karst geothermal reservoir is below of global meteoric water line(GMWL), showing that geothermal water of Wucheng Salient geothermal field was mainly originated from meteoric water with significant water rock interaction from the deep cyculation and thermal influence(Liao et al.,2013).

4.3 Geothermal Age

^{14}C age date is one of the most reliable methods used for groundwater dating, which is widely used in 1-35ka groundwater dating. Three samples were tested in this paper to study the water circulation characteristics of geothermal water in Wucheng Salient geothermal field (Table 4). The ^{14}C activity of the three samples were 5.4 - 0.44pmC.

Underground water contains radioactive isotope ^{14}C, and once it enters a closed system, ^{14}C starts to decrease basing on the decay law of isotope, as shown in equation (1) (Grillon et al.,2009) :

$$T=8267\times\ln(F\times A_0/ A_{sample})= 8267\times\ln(A_T/ A_{sample}) \quad (1)$$

T is the age of groundwater, expressed by the time from AD 1952 (ka B.P.); A_{sample} is the measured ^{14}C value of groundwater, expressed in PMC (Clark and Fritz,1997). A_0 is the ^{14}C content of total dissolved inorganic carbon at recharge time, which is generally 100pmc. A_T is the initial ^{14}C concentration of groundwater; F is the correction coefficient: $F=A_T/A_0$.

Because geothermal water is different from normal groundwater, dissolved inorganic carbon also contains "dead carbon" origining from deep inorganic carbon, and the correction methods of ^{14}C ages cannot solve its "dilution" problem, so it needs to be recalibrated. The chemical dilution correction model proposed by Tamers et al., and the isotope mixture model proposed by

Pearson which were used for ^{14}C dating correction (Liu,1990). The corrected age is shown in table 4. The activity of ^{14}C in Lijingmingju-2 well is lower than 0.44, lower than the detection line, and the calculated age is not credible. The water of Fubanghuayuan-2 well is Ordovician karst geothermal reservoir with the correct age of 32ka, and the water of Yunhelijing-1 well is Guantao formation sandstone geothermal reservoir with the correct age of 21ka. The age of geothermal water in the Ordovician geothermal reservoir is much older than that in the Guantao formation, indicating that the two layers of geothermal reservoir may be relatively independent circulatory systems.

Table 4 ^{14}C age correction model age of Wucheng Salient geothermal field

Well No.	^{14}C activity /PMC	Apparent age （year）	Tamers model corrects for age （year）	Pearson model corrects for age （year）	Reservoir
Lijingmingju 2 well	＜0.44	44856	40012	37264	O
Fubanghuayuan 1 well	0.70	41018	37387	27608	O
Yunhelijing 1well	3.60	27480	22395	20312	Ng

5. GEOTHERMAL FIELD GENETIC MECHANISM

The average terrestrial heat flow value of Bohai Bay basin is 69 mW/m^2, and that of eastern Linqing Depression is 59 mw /m^2. It is a normal area without high thermal anomaly. Magma activities have no influence on the present geothermal field of the area and do not contribute additional heat source (Wang et al.,1992,Li,2014). The Wugcheng Salient geothermal field is a typical hydrothermal geothermal system without magma heat source. The recharge area may be mainly dominated by the exposed bedrock of Taihang mountain in the northwest and Yanshan mountain in the north, receiving the recharge from meteoric precipitation, while the proportion of recharge in the Luxinan Uplift area in the east of the study area is rarely (Zhang et al.,2015). In the process of deep circulation, geothermal water is heated by surrounding rocks in the deep part of the crust under the background of normal geothermal flow. Hot water moves horizontally upward along NE-SW trending fracture zone and karst unconformity surface into shallow geothermal reservoir, and gathers in Wucheng Salient through Cangxian Uplift and Xingheng Uplift, forming low-and medium-temperature geothermal field. In the study area, the Minghuazhen formation and the Carboniferous-Permian strata are the capping layers, which play a good role in heat preservation (Fig. 9).

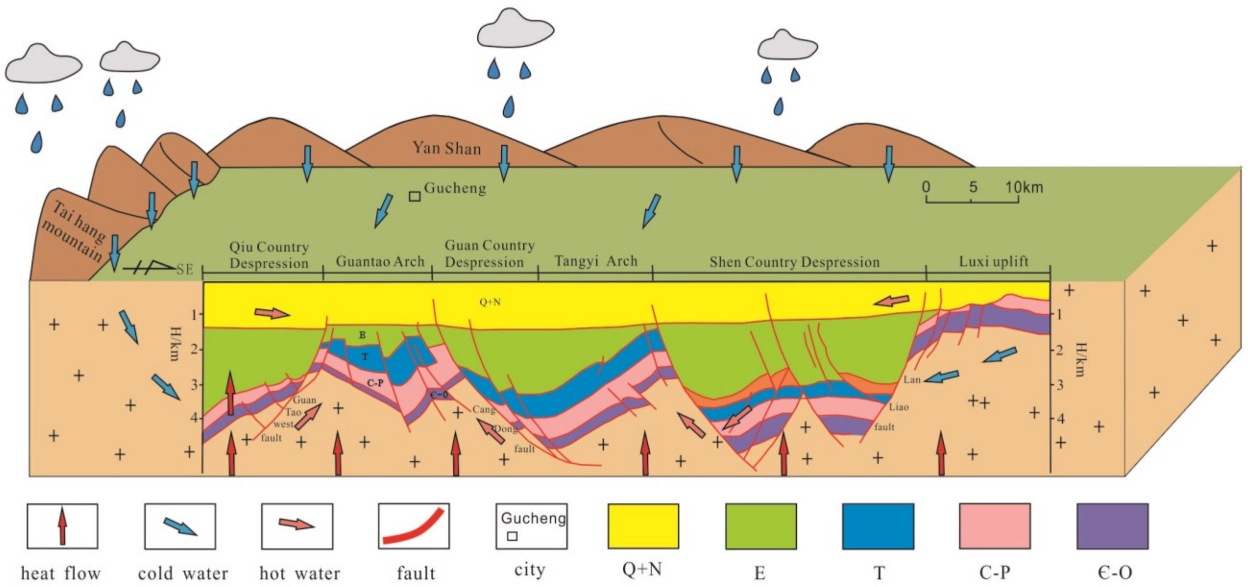

Fig.9 Genetic model of Wucheng Sa geothermal field

6. GEOTHERMAL RESOURCES

Based on the genetic mechanism analysis of the geothermal field, it can be concluded that the geothermal fields in Wucheng Salient are hosted in a sedimentary basin. "Volumetric method" is used to estimate geothermal resource capacity in Wucheng Salient geothermal field. The model parameters are shown in Table 6.

As the results of resource capapcitiy are shown in Table 6. According to the standard of DZ 40-85, the recovery rate of the sandstone geothermal reservoir is 25%, and that of the karst geothermal reservoir is 15%. The recoverable resources of the sandstone and karst geothermal reservoir is 4.1×10^9 GJ and 4.836×10^9GJ, equivalent to standard coal of 1.4×10^8t and 1.65×10^8t respectively. Based on the 100 years of development and utilization to calculate, the annual recoverable resources are equivalent to standard coal of 305×10^4GJ (Table 6). According to design calculation and operation experience, the heat consumption per square meter per heating season is equivalent to standard coal of 0.0283t, and geothermal resources of Wucheng Salient geothermal field can meet the heating area of 1.1× 10^4m square meters.

Table 6 Summary of evaluation parameters and calculation results of geothermal resources in Wucheng Salient geothermal filed

Reservoir	Area of Evaluation Unit (km^2)	Average effective thickness (m)	Average temperature (℃)	Average porosity (%)	Geothermal resources (GJ)	Standard coal (t)	Recoverable resources (GJ)	Resources Converted to Standard Coal (t)
N_g	840.56	181	52	33.4	1.64×10^{10}	5.6×10^{8}	4.1×10^{9}	1.4×10^{8}
O	944.22	196	83	6.15	3.22×10^{10}	11×10^{8}	4.83×10^{9}	1.65×10^{8}

7. CONCLUSION

The types of geothermal reservoirs are mainly sandstone geothermal reservoir in Guantao formation and karst geothermal reservoir in Ordovician in Wucheng Salient geothermal field. The former is distributed homogenenously, and the main production layer is the lower Guantao formation. The sandstones depths are between 1200-1600 m, the water yield of a single well is 79~123 m^3/h, and the wellhead water temperature is 52~54℃. The favorable zones of karst geothermal reservoir are mainly in the anticlinal core of the Cambrian-Triassic extending in a north-south zonal direction and the main aquifer is the upper Majiagou Formation, the lower Majiagou Formation and Liangjiashan Formation, with a roof depth of 2100-2900m. The geothermal water temperature range is 82-85℃, and the water yield of well is 75-98 m^3/h.

The geothermal water originates from recharge area of Taihang mountains in the west and Yanshan mountains in the north, moving horizontally along the NE-SW fracture zone and the karst unconformity to enter the shallow geothermal reservoir. It mixes in Wucheng Salient to form medium-low temperature geothermal water through Cangxian Uplift and Xingheng Uplift.

The geochemical characterization indicates that the of Wucheng Salient geothermal field is of NaCl type. The dating results of ^{14}C indicate that the geothermal water of sandstone reservoir and karst reservoir is 21ka and 32ka respectively. The Minghuazhen Formation and the Carboniferous-Permian strata are cap rocks of the two geothermal reservoirs, respectively.

According to the detailed evaluation results of geothermal resources, the total geothermal reserves amount to 4.86×10^{10} GJ, equivalent to 16.6×10^{8} of standard coal. The annual exploitation of geothermal resources can meet the indoor heating area of 110 million square meters with huge potential for development. Areas with geothermal gradient of more than 3℃/100 m , depth of sandstone reservoir of less than 2000 m and buried depth of karst geothermal reservoir less than 3000 m mostly within the the anticlinal fault structures in the north China plain are areas viable for geothermal development.

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