

Geochemical characteristics of geothermal water in Weiyuan geothermal field, Huzhu County, Qinghai Province

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Abstract: According to the chemical composition of thermal water from Geothermal Well DR2010 located in the Weiyuan Geothermal Field of Huzhu County in Qinghai Province, the groundwater recharge, age and geothermal resource potential of the thermal water are discussed by using the methods of Langelier-Ludwig Diagram, isotopic hydrology and geochemical thermometric scale. The analysis results indicate that the Weiyuan Geothermal Field is located in the northern fringe of Xining Basin, where the geothermal water, compared with that located in the central area of Xining Basin, is characterized by greater water yield, shallower buried depth of thermal reservoir and easier exploitation. Due to its active exchange with the modern cold water, the thermal water here shows relatively younger age. These findings provide a hydro-geochemical evidence for the exploitation of Weiyuan Geothermal Field.

Keywords: Weiyuan Geothermal Field; Geothermal resources; Hydrochemical characteristics; Huzhu County in Qinghai Province

1 Overview of Weiyuan geothermal field

Weiyuan Geothermal Field of Huzhu County in Qinghai Province (hereinafter referred to as "Weiyuan Geothermal Field") is located in the upstream area of the Shatangchuan River, where is the sub-down warp of Weiyuan Town at the north wing of Shuangshu downwarp with Cenozoic-Mesozoic basement buried at depth of 4 000 m. Exploration results show that the Cenozoic-Mesozoic basement of Weiyuan sub-downwarp is buried at depth of 1 885 m. Thus it can be preliminarily concluded that the conditions for heat to concentrate are controlled by the two groups of great regional fracture zones, of which one stretches from south to north and the other from south to west. Among the two fracture zone groups, the near south-north transtensional fracture zone

acts as commanding structure and underground watercourse, while the north-west fracture structure mainly act as heat course. In this way, a relatively independent underground thermal water enrichment block forms, showing obvious territoriality and zonal distribution characteristics (Fig.1 and Fig. 2).

Data indicates that Weiyuan Geothermal Field stretches from south to north in general, 4-6 km wide in east-west direction and 4-7 km long in south-north direction. The exploitable area for underground thermal water covers 27.23 km². The thermal reservoir is divided into three layers, belonging to Paleogene Period, Cretaceous Period and Jurassic Period respectively. The top layer of the reservoir is buried at depth of 710 m while the basement is buried at depth of 1 885 m, with a 362.45 m thick commanding thermal reservoir. The temperature changes from 40.95 to 73 °C, averaging at 62 °C. The ground temperature shows an obvious increase trend from top to the bottom. This Geothermal Field shows good water enrichment, belonging to middle-scale and low-temperature Geothermal Field.

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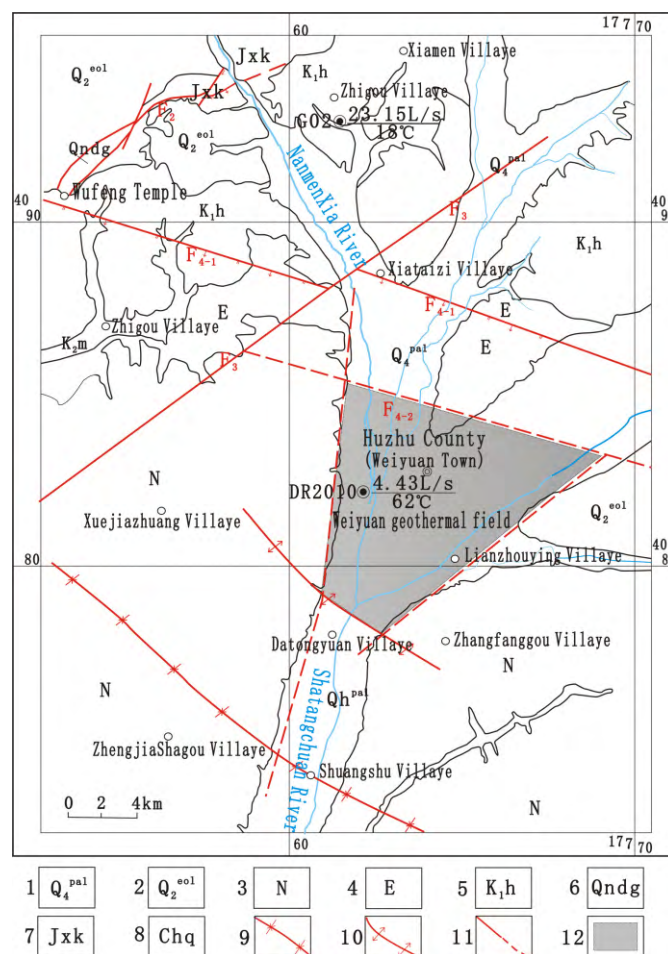


Fig. 1 Distribution map of Weiyan geothermal field in Huzhu County

1. Holocene grayish white gravel grait; 2. Middle-Pleistocene earthy yellow loess; 3. Neogene brownish yellow mudstone and sandstone; 4. Palaeogene brownish yellow mudstone and glutenite; 5. Cretaceous brownish red sandstone, mudstone and mudstone interbedded layer; 6. Lower-neoproterozoic (Qingbaikou System) grey and grayish white dolomite and killas interbedded layer; 7. Jixianian grey and grayish white dolomite; 8. Changchengian grey sandy slate; 9. Syncline, anticline; 10. Geothermal hole number, artesian discharge and water temperature; 11. Fault and property-unknown fracture; 12. Weiyan Geothermal Field in Huzhu County

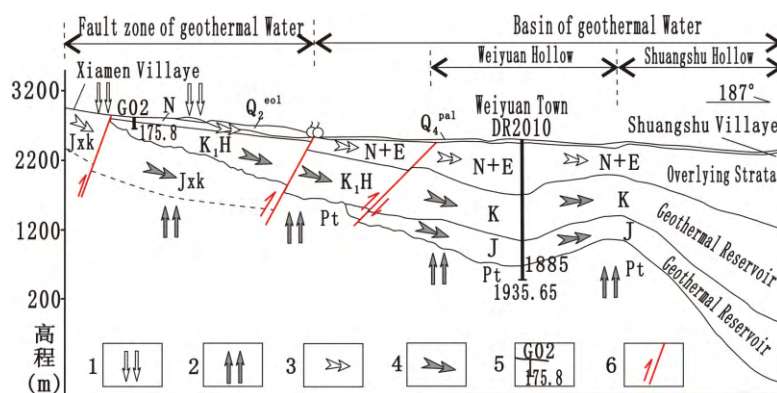


Fig. 2 Profile map of fringe condition of Weiyan Geothermal Field in Huzhu County

1. Meteoric water and surface water feed groundwater; 2. Terrestrial heat flow; 3. Flow direction of groundwater at normal temperature; 4. Flow direction of geothermal water; 5. Hole number and depth; 6. Fault

In 2010, the Qinghai Institute of Hydrogeological, Engineering Geological and Environmental Geological Survey drilled a Geothermal Well (DR2010) with depth of 1 935.65 m in Weiyuan Town of Huzhu County; hereinafter is referred to as Weiyuan Geothermal Well. According to the drilling condition and related geophysical logging data, the thermal reservoir of this Geothermal Field can be divided into three layers, namely, the top layer, middle layer and bottom layer. The first layer belongs to Paleogene Period, with buried depth of 710.0-785.0 m, formed of coarse sandstones and gravels. The reservoir thickness of this layer adds up to 11.35 m, with temperature of 40.9-43.3 °C, with Neogene brownish red mudstones, silty mudstones and interbedded mudstone and gypsiferous horizon as its cap rock. The second layer belongs to Cretaceous system, with buried depth of 1 001.55-1 556.60 m, formed of middle and coarse sandstones and glutenite. The reservoir thickness of this layer adds up to 237.90 m, with temperature of 49.7-66.9 °C, with Palaeogene and Cretaceous brownish red mudstones and silty mudstones interbedding flagstones and gypsum as its cap rock. The third layer belongs to Jurassic Period, with buried depth of 1 623.05-1 885.30 m, formed of middle and coarse sandstones and glutenite. The reservoir thickness of this layer adds up to 223.75 m, with temperature of 68.3-73.0 °C, with Cretaceous brownish red mudstones and silty mudstones interbedding flagstones as its cap rock.

After conducting well flushing on the completed DR2010 well at the 1 047.60-1 895.20 m section in the geothermal reservoir, we also conducted a great downdrawn pump test with one drop distance and two dewatering test with two drop distances. To ensure the accuracy of the pump test, the water level shall be observed once every 0.5 h when it is stable. The stable duration shall be 10 h. The other two tests are dewatering test. The drawdown for the pump test with the largest drop distance is 104.55 m, with water yield at 1 441.33 m³/d. At the same time, the mixed max. water temperature at the mouth of the well is measured at 62 °C and the stable water head at +27 m. Thus, the osmotic coefficient and the influence radius can be worked out, being 0.0481 m/d and 229.30 m respectively.

2 Water quality characteristics of geothermal water in Weiyuan Geothermal Field of Huzhu County in Qinghai Province

2.1 Hydrochemical characteristics of geothermal water

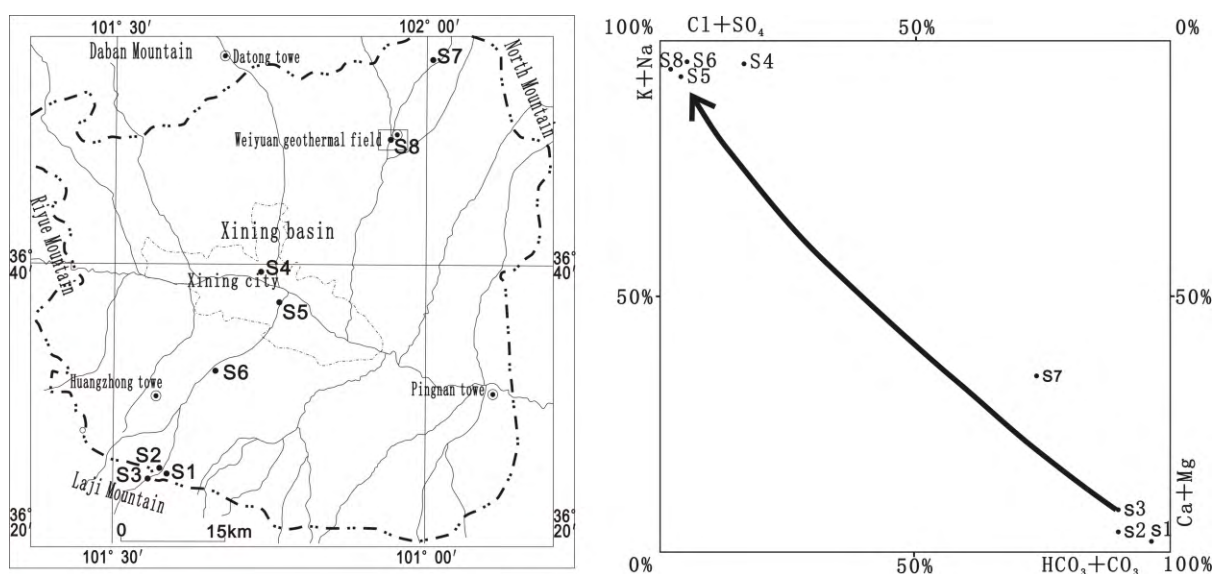
The geothermal water from Weiyuan Geothermal Field belongs to confined water existing in the fractures and holes between clastic rocks, with water temperature at 62 °C (the max. temperature with the largest drawdown). This geothermal water shows good quality of appearance, with chromaticity lower than 5 degrees, containing no macroscopic substance, emitting a slight smell of hydrogen sulfide. After the pump test in Weiyuan geothermal well, the Karst Geological Resources and Environment Supervision and Inspection Center of Ministry of Land and Resources took a water sample on March 29, 2011 to detect the water isotopes of $\delta^{18}\text{O}$ and δD , content of tritium (T) and the age of ^{14}C . The test result (Table. 1) shows that the geothermal water contains rich mineral substances, with degree of mineralization at 41.8 g/l. Among all the positive ions, Na^+ , Ca^{2+} , Mg^{2+} and K^+ are in the majority, taking up 99.96% of the total number of positive ions; among all the negative ions, SO_4^{2-} , Cl^- and HCO_3^- are in the majority, occupying 99.94%. The pH value of the water is 7.65, showing alkalinescence.

The geothermal water from the Geothermal Well DR2010 has high degree of mineralization, containing rich microelements. Among all the microelements, Sr, Metasilicic acid and Metaboric acid or their component concentration reach the mineral water concentration standard as a kind of water with medical treatment value, according to the "Quality Standard of Geothermal Mineral Water for Medical Use" of Geologic Exploration Standard of Geothermal Resources (GB 11615-2010). The content of Sr even exceeds the required concentration standard. These elements endow the geothermal water in Weiyuan Geothermal Field with great medical treatment value and make this kind of water reaching multiple standards, which is also called "compound Sr geothermal water".

Table1 Result of water quality test of geothermal water from Weiyuan Geothermal Field of Huzhu County in Qinghai Province

Item	$\rho_B(\text{mg/L})$	Item	$\rho_B(\text{mg/L})$	Item	$\rho_B(\text{mg/L})$	Item	$\rho_B(\text{mg/L})$
K^+	37.33	SO_4^{2-}	10 276.84	Zn	0.02	Pb	<0.04
Na^+	14 330.00	F^-	<0.10	Ni	0.02	Mn	0.29
Ca^{2+}	567.69	NO_3^-	23.86	As	0.064	Phenolic compound	<0.002
Mg^{2+}	107.92	PO_3^{3-}	0.22	Hg	<0.0002	Cyanogen Compound	<0.002
NH_4^+	4.22	Degree of mineralization	41 823	Cd	0.000	Nitrite	<0.10
Fe^{2+}	<0.05	Metasilicic acid	27.56	Cr^{6+}	0.009	Oxygen consumption (calculated with O_2)	2.60
Fe^{3+}	<0.05	Sr	10.92	Metaboric acid (calculated with HBO_2)	25.91	Total alkalinity	205
HCO_3^-	249.84	Br	<0.001	Cu	<0.008	Total acidity	22.64
CO_3^{2-}	0.00	I	0.70	Al	<0.02	Erosive CO_2	0.00
Cl^-	15 992.61	Co	<0.002	H_2S	0.42	Ionized CO_2	7.47

Note: Total positive ions: $1.50 \times 10^4 \rho_B/(\text{mg} \cdot \text{L})$; Total negative ions: $2.65 \times 10^4 \rho_B/(\text{mg} \cdot \text{L})$.

**Fig. 3** Distribution diagram of sampling spots and the Langelier-Ludwig diagram

S1. 8305 Geothermal Well in Yaoshuitan; S2. Yaoshuitan spring with normal temperature; S3. Surface water of Yaoshuitan; S4. Spring water in Sujiahewan; S5. 8701 Geothermal Well in Shengli Park; S6. DR2005 Geothermal Well in Dujiazhuang Village; S7. G02 Geothermal Well in Zhigou Village; S8. DR2010 Geothermal Well in Weiyuan Town.

At present, it is difficult to use the geothermal water from DR2010 well for heating, drinking and cultivation directly. Additionally, this kind of water has functionality of health care and disease cure.

Therefore, it can be categorized as Sr type recovery geothermal water resources.

2.2 Analysis with Langelier-Ludwig

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diagram

As shown in the Langelier-Ludwig Diagram (PAN Xiao-ping and WANG Zhi, 1999) (Fig. 3), the piedmont surface water in Yaoshuitan area of Huangzhong belongs to the typical cold spring and thermal spring containing $\text{HCO}_3\text{-Ca}$ and $\text{HCO}_3\text{-Ca}\cdot\text{Mg}$, as shown in the right bottom of the Diagram. The G02 Geothermal Well of Zhigou in Huzhu County where the water is at abnormal temperature is in the middle part of the Diagram. The DR2010 Geothermal Well of Weiyuan Town, the DR2005 Geothermal Well in Dujiazhuang Village and the 8701 Geothermal Well in the Shengli Park of Xining City are at the top left side of the trendline of the above spots. The water from all these wells belongs to the same hydrochemical evolution mechanism, indicating that the geothermal water from Weiyuan Geothermal Field is recharged by cold water.

2.3 Dynamic hydrochemical characteristics of geothermal water in Xining Basin

The 8701 Geothermal Well in the Shengli Park of Xining City which is located in the middle area of Xining Basin has 24-year exploitation history. The degree of mineralization of the geothermal water here decreased from 34.882 g/L in 1987 to 25.75 g/L in 2011, by 26.18%. Major ions including SO_4^{2-} , K^+ , Na^+ , Ca^{2+} and Mg^{2+} decreased as well while HCO_3^- increased significantly (YAO Jin-mei *et al.* 2006) (Table 2), indicating that due to the exploitation activities, the runoff conditions is getting optimized and the runoff is well recharged. As a result, the degree of mineralization of the geothermal water decreases, with water quality getting better and water temperature decreasing slightly. Additionally, it is also indicated that the change of the hydrochemical regime of the geothermal water in this area lies in the fact the exploitation of geothermal water broke the original balance state between water and rock. Due to the decrease of pressure and increase of flow rate of geothermal water in the thermal reservoir, the balance state and the exchange condition between some of the components in the geothermal water and the surrounding rocks and thus the balance system between water and rock is

readjusted for the future exploitation. Accordingly, we can conclude that with exploitation activities going on and the exploitation quantity increasing, the geothermal water of DR2010 Geothermal Well will be desalted one day (ZHANG Sen-qi *et al.* 2007).

3 Geochemical characteristics of isotope

3.1 Isotopic characteristics of hydrogen and oxygen isotope

The groundwater from different sources has different composition of hydrogen and oxygen isotopes. Accordingly, we can find out the source of the geothermal water based on the hydrogen and oxygen isotopes in the deep geothermal water. In order to study the formation and the cycle of the geothermal water in Weiyuan Geothermal Field, the authors of this paper have collected data about isotopes in various water bodies in Xining Basin which is related to Weiyuan Town. The comparative analysis is as shown in Table 3 and Fig. 4.

As shown in Table 3, the values of δD and $\delta^{18}\text{O}$ are expressed with $\delta\text{‰}$. The analysis error of both values is less than $\pm 0.2\%$ and $\pm 0.02\%$ respectively. The concentration of T (Tritium) can be measured by concentrating the sample water by 50 times and then measuring on the low background scintilloscope. The measured value is in T.U which is also the unit of T. A unit of T is defined as that every 1 018 units of hydrogen atoms contains a single tritium atom. The relation between δD and $\delta^{18}\text{O}$ (LI Wen-peng *et al.* 1995) in each sampling spot is as shown in Fig. 3.

The first group of water samples is sampled from Xinning Park Geothermal Well DR 2007, Shengli Park Geothermal Well 8701, Sujiahewan spring water and Geothermal Well DR 2005 in the southern new district. The five sampling spot mentioned above are distributed annularly as shown in Fig. 3, which are located in the left bottom of the atmospheric water line. The geothermal water from Geothermal Well DR2005 in Dujiazhuang Village, where the ^{14}C is indicated to date back to (22.28 ± 0.30) ka from now, is defined as Region B.

Table 2 The comparative table of dynamic changes on water chemical composition of No.8701 in Shengli Park in Xining City

Sampling time	Water temperature (°C)	Degree of mineralization (g/L)	pH value	Content of ions (mg/L)					
				K ⁺	Na ⁺	Ca ²⁺	Zn ²⁺	Cl ⁻	HCO ₃ ⁻
1987/9/21	39.5	34.882	7.1	64.5	10 920	391.7	0.002	7 840.2	1 358.5
2002/7/22	37	27.662	7.35	50	8 300	271.4	64.1	5 232	1 576
2011/10/25	36	25.75	7.28	33.1	8 200	266.7	0.005	5 708.39	1883.39

Sampling time	Content of ions (mg/L)								
	F ⁻	NO ₃ ⁻	SiO ₂	Mg ²⁺	Fe ³⁺	Fe ²⁺	Cu ²⁺	NH ₄ ⁺	Mn ²⁺
1987/9/21	0.4	1.8	21.1	171	0.5	1.2	0	1.7	
2002/7/22	4.2	0.89	18.94	112	0.18	0.063	0	1.98	0.78
2011/10/25	1.21	0.02	25.79	109.03	0.08	0.06	< 0.008	1.01	

Sampling time	Content of ions (mg/L)							
	Pb ²⁺	SO ₄ ²⁻	CO ₃ ²⁻	NO ₂ ⁻	HPO ₄ ⁻	Ionized CO ₂	HBO ₂ ⁻	Oxygen consumption
1987/9/21	0	14 109.6	0	0	0	39.71		3.78
2002/7/22	0	10 791	0	0.004	1.08	45.07	15.88	1.09
10/25/2011	0	9 545.48	0	<0.01	1.69			1.53

Table 3 Isotopic test result of different water in Xining Region

No. of water sampling spot	Location	Type of water	Temperature (°C)	δ ¹⁸ O (‰)	δD(‰)	T (T.U)	Age of ¹⁴ C (ka B.P.)
S1	Weiyuan Geothermal Well DR2010	Geothermal water	62	-9.48	-66.7	<2.00	4.63±0.079
S2	Zhigou Geothermal Well G02	Geothermal water	18	-9.61	-61.7	<2.00	19.87±0.61
S3	Spring water from Wuqi Village of Huzhu County	Rising water	7.5	-7.88	-52.4	10.87	1.418±0.16
S4	Spring water from Niutou Mountain	Rising water	7.5	-8.62	-54.2	7.7	2.78±0.15
S5	Spring water from Wufeng Temple	Rising water	5.5	-8.93	-53.9	32.5	
S6	River water from Nanmenxia Gorge	River water	14.6	-8.13	-49.00	10.99	
S7	Dujiazhuang Geothermal Well DR2005	Geothermal water	62.5	-10.40	-74.00	3.93±2.30	22.28±0.30
S8	Xinning Park Geothermal Well DR2007	Geothermal water	53.0	-10.20	-71.00		37.65±1.05
S9	Yaoshuitan Geothermal Well 8305	Geothermal water	41.0	-10.11	-67.36		45.21±2.35
S10	Shengli Park Geothermal Well 8701	Geothermal water	37.0	-10.50	-73.00		48.71±3.73
S11	Sujiahewan Spring	Rising water	12.7	-10.11	-74.3		26.21±0.28

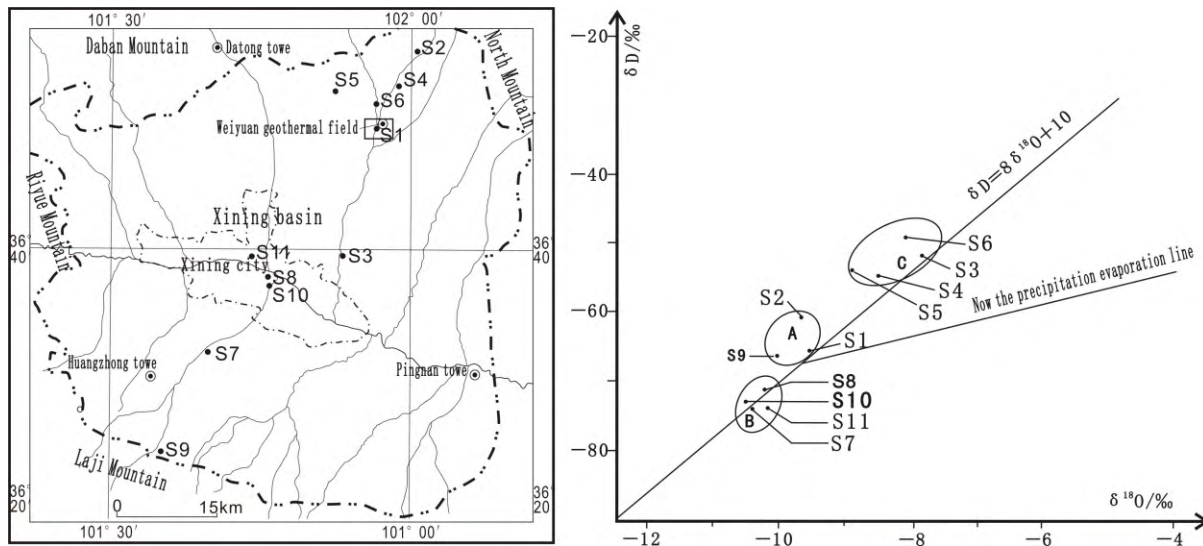


Fig. 4 Distribution map of water sampling spots in Xining Basin and relation graph of δD - $\delta^{18}O$

The second group of sample water is sampled from Weiyuan Geothermal Well DR2010, Zhigou Geothermal Well G02 and Yaoshuitan thermal spring and Geothermal Well DR2010 in Huangzhong. This group is located in the right top, which is defined as Region B. Obviously, this Region belongs to relatively younger water area.

The third group of sample water is sampled from the river water of Nanmenxia Gorge, the spring water of the Rising spring in Wufeng Temple, the spring water of Niutou Mountain root, well water from a peasant household of Weiyuan Town and the spring water of Shengli Park. These sampling sources are modern river water, which are defined as Region C.

Region A, B and C are all distributed above the atmospheric water line, but in different position from each other. This condition indicates that the groundwater recharge area controlled by each sampling spot are different from each other in terms of recharge location, recharge time, age of formation and the migration rate of different systems. Along the migration direction of the regional groundwater, the quantity of $\delta^{18}O$ and δD decreases obviously from Region C to Region A and to Region B step by step. As a result, Region A definitely belongs to geothermal water formed in deep stratum due to the deep cycle between meteoric water and ice-and-snow-melt water in the modern mountainous area. It features quick cycling, fast alternating, relatively lower degree of mineralization and low content of tritium, indicating that the groundwater here is recharged by modern

cold water. Region B is distributed below Region A. The analysis combined with the test result of the age of ^{14}C indicates that the deep geothermal water is formed in a relatively earlier time, mainly in about 10 000-50 000 years ago. But the water in Region B is relatively younger, formed in less than 10 000 years ago.

3.2 Determination of geothermal water recharge area and highly-recharged area

The groundwater from different sources has different composition of hydrogen and oxygen isotopes. Accordingly, we can find out the source of the geothermal water based on the hydrogen and oxygen isotopes in the deep geothermal water. By comparing the content of hydrogen and oxygen isotopes in the geothermal water in deep stratum with the curve of hydrogen and oxygen isotopes in local meteoric water, we can determine the recharge source of geothermal water in the deep stratum accurately.

With the aid of the altitude effect in precipitation, we can determine the recharge area and recharge height of the geothermal water in deep stratum. The calculation formula is as below:

$$H = \frac{\delta G - \delta P}{K} + h$$

Formula:

H - the altitude of the recharge area, m;

h - the altitude of sampling spots, taking 2 501 m;

δG - the value of $\delta^{18}O$ in the geothermal water,

in ‰;

δP - the value of $\delta^{18}\text{O}$, (taking the mean value of $\delta^{18}\text{O}$ -6.9‰);

K - the height gradient of isotopes (taking 0.05%/100m for $\delta^{18}\text{O}$)

The calculation result shows that the geothermal water in Weiyuan Geothermal Field of Huzhu County is mainly recharged by the infiltration of meteoric water from the northern mountainous area with altitude at 3 017 m.

3.3 Determination of the age of ^{14}C geothermal water

The result of age determination for ^{14}C in the Weiyuan Geothermal Field shows that the age of the geothermal water in this Field is (4.63±0.079) ka. According to the analysis result that aquitard formed of interbedding mudstone and gypsum rock has developed in the upper part of each geothermal reservoir of this geothermal well, we can conclude that the meteoric water recharges the geothermal water through infiltration in vertical direction and this area is mainly recharged by the alternation effect in quasi horizontal direction. The analysis by combining with the data about Zhigou G02 Geothermal Well with depth of 175.8 m and the age of ^{14}C in the shallow confined artesian geothermal water which is (19.87±0.61) ka indicates that the age of ^{14}C in geothermal water near the cap rock of the mountainous area shows a rule of older in the upper part and younger in the lower part. Hereby, we can conclude that the geothermal water mainly moves upward along the hollow zone in the deep stratum at a relatively high speed, accompanied with frequent alternating. As a result, the geothermal water in deeper stratum is younger than that in the upper part (ZHANG Sen-qi *et al.* 2008).

4 Temperature of thermal reservoir calculated with hydrochemical thermometric scale

4.1 Temperature of thermal reservoir calculated with geochemical thermometric scale

The convective circulation of hydrothermal

system is always accompanied with dissolution-precipitation reaction of various mineral substances. If the equilibrium concentration of a reaction product is only related to the reaction temperature, we can accordingly calculate the temperature of the reaction field by use of the water-rock equilibrium and thermo-motive equation. The method to estimate the temperature of the thermal reservoir based on this principle is called geochemical thermometric scale. In this paper, we use the chemical thermometric scale recommended in Geologic Exploration Standard of Geothermal Resources (GB/T 11615-2010) to calculate the temperature of the thermal reservoir in Weiyuan Geothermal Field and hereby predict the potential of geothermal resources of this geothermal field.

4.1.1 Sodium-potassium Geo-thermometric Scale

The formula to calculate the temperature t (°C) derived based on water-rock equilibrium and thermo-motive equation is as below:

$$t = \frac{1390}{1.75 - \lg(C_2/C_4)} - 273.15$$

Formula:

t - the temperature of the thermal reservoir, °C;

C_2 - the concentration of K in the water, mg/L;

C_4 - the concentration of Na in the water, mg/L;

The temperature of the thermal reservoir of Weiyuan Geothermal Well is 47.87 °C, which is 14.13 °C lower than the average temperature (62 °C) of the sampling section.

4.1.2 Potassium-magnesium geo-thermometric scale

The Potassium-magnesium geo-thermometric scale represents the thermo-motive equilibrium state in the relatively shallower thermal reservoir, which is suitable for calculation of geothermal field with medium and low temperature. The formula to calculate the temperature t (°C) is as below:

Formula:

$$t = \frac{4410}{13.95 - \lg(C_2^2/C_3)} - 273.15$$

Where, t - the temperature of the thermal reservoir, °C;

C_2 - the concentration of K in the water, mg/L;

C_3 - the concentration of Mg in the water, mg/L

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The temperature of the thermal reservoir of Weiyuan Geothermal Well is 70.31 °C, which is 4.49 °C lower than the max. temperature (74.80 °C) of the bottom of the geothermal well and 8.31 °C higher than the average temperature (62 °C) of the sampling section.

The potassium-magnesium geo-thermometric scale is the one that can be reached during drilling, *i.e.*, when you choose an appropriate well position and drill to the certain depth, the temperature calculated with the thermometric scale can be reached (YAN Hong-lie *et al.* 2002). Therefore, the construction depth of the Geothermal Well DR2010 reaches the thermal water with max. temperature in Weiyuan Geothermal Field basically.

4.2 Analysis of potential of geothermal resources

In terms of the regional tectonics, Weiyuan Geothermal Field is located in the sub-downwarp of Weiyuan Town at the north wing of Shuangshu downwarp with Cenozoic-Mesozoic basement buried at depth of 4 000 m. The stratum thickness and buried depth is 1 900 m, where the proved geothermal resource is buried at 600-1 900 m. In terms of hydrogeological conditions, Weiyuan Geothermal Field is located in the north wing of Shuangshu downwarp in northern Xining Basin where the groundwater belongs to confined artesian geothermal water. The particles of the Cenozoic-Mesozoic clastic rock sediment shows coarse-to-fine changing rule in general from the fringe to the center area of the Basin. The groundwater, after being recharged by meteoric water, surface water and groundwater in the basin fringe, forms runoff at different depth under the ground. And during this process, some of the salinity is filtrated correspondingly. Then the groundwater runs to the center of the Basin, forming multiple confined aquifers in the deep stratum of the Basin. During the process when the groundwater runs from the basin fringe to the center area, the degree of mineralization of the groundwater shows gradual increase accordingly. Since Weiyuan Town is located in the northern fringe of Shuangshu downwarp (WANG Gui-ling *et al.* 2004), it is endowed with relatively good hydrogeological conditions.

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According to the drilling condition of Weiyuan Geothermal Well DR2010 in Huzhu County and related geophysical logging data (Fig. 5), the ground temperature of the geothermal well at depth of 1 400 m and the temperature of the mixed water in the mouth of the well are the same, both being 62 °C. The ground temperature at depth of 1 925 m is about 74.8 °C. Therefore, the major aquifer revealed in this geothermal well and the thermal reservoir shall be at depth of 1 400 m. Since the mixed temperature (62 °C) measured at the mouth of the well is not the max. temperature of the geothermal field, we can say Weiyuan geothermal resources show great potential.

5 Conclusions

The geothermal water from Weiyuan Geothermal Field belongs to confined water existing in the fractures and holes between clastic rocks, emitting a slight smell of hydrogen sulfide. It is Cl-SO₄-Na type water with the degree of mineralization at 41.8 g/L. The pH value is 7.65, showing alkalescence. Sr, Metasilicic acid and Metaboric acid, the three kinds of elements reach the mineral water concentration standard as a kind of water with medical treatment value. The concentration of Sr even reaches the standard of "Quality Standard of Mineral Water with Medical Treatment Value", according to which, the water containing Sr can be named as "recovery and medical type Sr mineral geothermal resource".

The Langelier-Ludwig Diagram shows that Weiyuan Geothermal Well DR 2010 locates in the left top of the trend line, indicating that Weiyuan Geothermal Field belongs to cold water recharged type. The isotopic hydrological diagram shows that Weiyuan Geothermal Water comes from meteoric water. According to the comparative analysis, the geothermal water in Huzhu County mainly cycles in quasi horizontal direction. With the increase of depth, the geothermal water becomes younger. According to the analysis combining with the ¹⁴C age test result, the geothermal water is relatively young, belonging to modern water formed less than 10 000 years ago. Additionally, the geothermal water here contains a little tritium, indicating that it is also recharged by modern cold water.

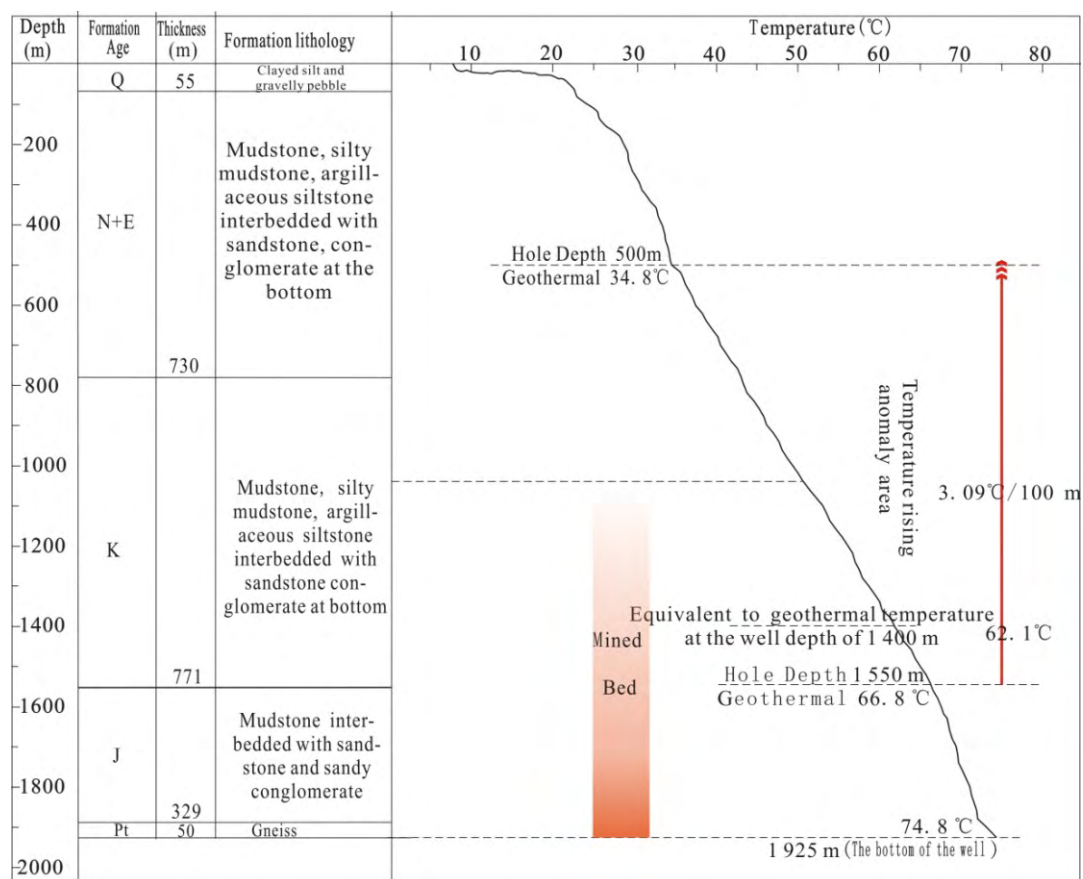


Fig. 5 Temperature measuring curve of DR2010 Geothermal Well at Weiyuan Town in Huzhu County

According to the calculation based on the geochemical thermometric scale, the thermal reservoir at depth of 1 935 m and above in Weiyuan Geothermal Field has great potential for geothermal resource development. According to the hydrochemical dynamic data of the comparable existing geothermal wells, with the continuing of exploitation in DR2010 Geothermal Well, the water in Weiyuan Geothermal Field will be desalted and the water temperature may decrease. These findings provide a hydro-geochemical evidence for the exploitation of geothermal water in Weiyuan Geothermal Field.

Acknowledgements

This work was funded by Science and Technology Project Subsidized by Central Budget (2009-840).

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