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Preliminary Study on Hydrogeochemical Characteristics of Yanqing Geothermal Field, Beijing

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ABSTRACT

Geothermal resource is a sort of renewable clean energy. The development and utilization of geothermal resource has been occurring in the Beijing plain for nearly 50 years. The Yanqing basin, a stable production low temperature geothermal field, is located 80 km northwest of Beijing. This paper discusses the hydrochemical characteristics of the Yanqing geothermal field by study of the data of geothermal wells in this area. The research shows that the hydrochemical types of geothermal water are HCO_3-Na and HCO_3-Na·Ca. The Na-K-Mg ternary diagram indicates that the water - rock reaction has not reached equilibrium and the equilibrium temperature of the reaction is low, or that the geothermal water samples may be receiving precipitation recharge and cold water mixing. The reservoir temperature is estimated by using SiO_2 and cation geothermometers.

1. INTRODUCTION

Geothermal energy is a clean, renewable, and environmentally benign energy source. With the rapidly growing demand for energy, and increasing concern for climate change, utilization of geothermal energy is becoming more desirable (Bertani, 2005; Lund and Boyd, 2005; Bilgen et al., 2008). Beijing is one of the first areas where geothermal resources exploration has been carried out in China. The exploration and development of geothermal resources in the Beijing basin started in the early 1970s, and has developed rapidly since 2000. Geothermal resources are mainly used for heating buildings and bathing. The Yanqing geothermal field is one of ten large geothermal fields in the Beijing Basin, which is divided on the basis of geological and geothermal conditions (Figure 1). The Yanqing geothermal field is a stable production, liquid-dominated, low temperature field. The main geothermal systems in the Yanqing basin occur in a sedimentary system.

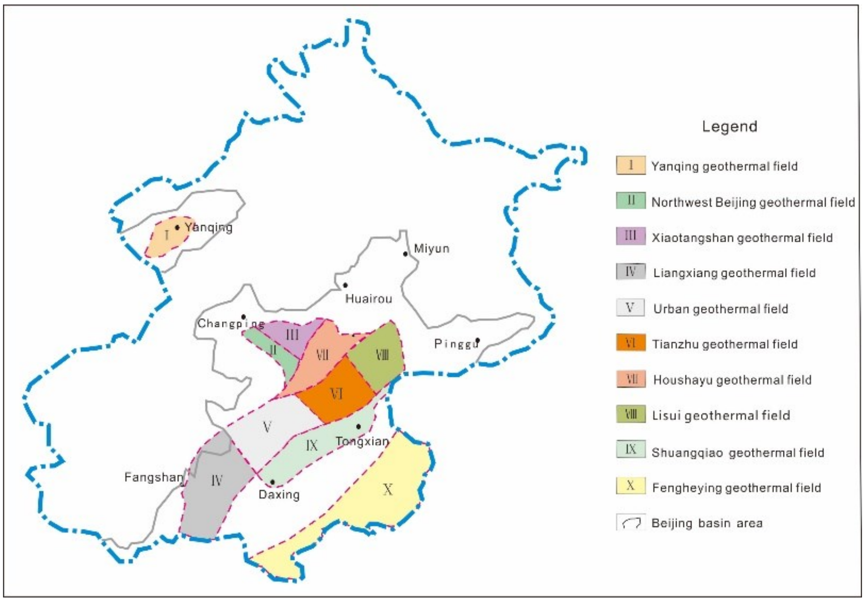

Figure 1: The distribution diagram of Beijing geothermal fields.

The chemical characteristics of geothermal water are the products of the long geological processes of geothermal formation. These geological processes are also reflected in the chemical characteristics of geothermal water. In the process of circulation, recharge and migration, geothermal water dissolves the composition of surrounding rocks, which can reflect certain characteristics of a geothermal reservoir. In terms of factors affecting the occurrence, formation, morphology and transformation of elements in geothermal water, water temperature, composition and concentration of main ions and chemical types of water, are the basis of geothermal research. Geothermal water is characterized by its deep burial and high temperature. K^+, Na^+, Ca^{2+}, Mg^{2+}, HCO_3^-, SO_4^{2-} and Cl^- are the major components which determine the physical and chemical properties of geothermal water. F^- and SiO_2 also have relatively high content in geothermal water. This paper discusses the hydrogeochemical characteristics of Yanqing geothermal field by analyzing the data from several geothermal wells which distributes in the Yanqing town and surrounding areas.

2. GEOLOGICAL GEOTHERMAL CONDTIONS

Geothermal reservoir, cap rocks and permeable structures are essential in a sedimentary geothermal system. The Yanqing area formed a rifted basin in the Cenozoic era. The strata of Yanqing basin are mainly Quaternary system, Cretaceous-Jurassic system and Wumishan formation of Jixian system. The reservoir cap-rock of Yanqing geothermal field are Quaternary and Cretaceous-Jurassic strata which are volcanic rocks and sedimentary rocks with low permeability. It is an advantage for heat preservation. The geothermal reservoir is dolomite of Wumishan formation of Jixian system. Intensively developed karst is the similar characteristics in the formations.

The fault structures are comparative existent in the basin. The grid connection formed by the NE-trending and nearly NS-trending structures is conducive to supply the uplift fracture zone from deep geothermal reservoir. Furthermore, the deep heat flow is conductive and diffused in the whole Yanqing basin. The grid connection forms a better heat conduction and water channel. The characteristics of temperature distribution in the field indicate that the formation temperature is mainly related to bedrock relief. Major faults and fractures also play an important role in sustaining the geothermal activity through providing the main flow paths.

The Yanqing geothermal field presently contains more than 20 geothermal wells. The average single well flow capacity is more than 2000 m^3/d. The range of water temperature is from 50° to 80°C. The temperature and flow capacity of these wells are stabile.

3. SAMPLING

Sampling and analysis are essential in the characterization of a geothermal field in the primary stage. According to the requirements of geothermal well completion, geothermal water samples should be collected before the end of a pumping test for analysis of geothermal water quality. Water samples from 19 geothermal wells were collected into test bottles during the discharge and preserved accordingly. Complete water quality analysis was carried out at BIGPE lab (Beijing Institute of Geological and Prospecting Engineering) for individual chemical components in liquid samples. These hydrochemical data are collected as representatives, which provides basic conditions for us to study the chemical composition and heat storage characteristics of the Yanqing geothermal field.

4. RESULTS

4.1 Chemical characteristics of the thermal fluids

The geothermal water of the Yanqing geothermal field is karst fissure water of Jixian formation, which is clear and transparent with good qualities. The pH of geothermal water is one of the important elements affecting the migration and precipitation of elements, and ranges from 7.24 to 8.48. TDS ranges from 433 to 681 mg/L. The content of F^- in geothermal water is much higher than that in ordinary groundwater due to the influence of temperature on dissolution and filtration. The content of F^- in geothermal water samples in the study area ranges from 1.11 to 5.93 mg/L.

The relative chemical compositions of the water fluids from geothermal wells are shown in Figure 2. The hydrochemical characteristics were objectively reflected in this field. The geothermal water samples are shown in a Piper diagram, which indicates that the geothermal water components in the thermal reservoir of the Wumishan formation are roughly the same. The main cations in geothermal well water samples in the research area are Na^+ and K^+, especially the content of Na^+ is generally over 50% mg equivalent. The content of Ca^{2+} is mostly in the percentage of 15~30% mg equivalent. The main anion is HCO_3^-, and the ion content ranges from 50 to 75% mg equivalent. Geothermal water in the study area is mainly of HCO_3^--Na^+ type and HCO_3^--$Na^+\cdot Ca^{2+}$ type, with some of geothermal water samples showing slight differences

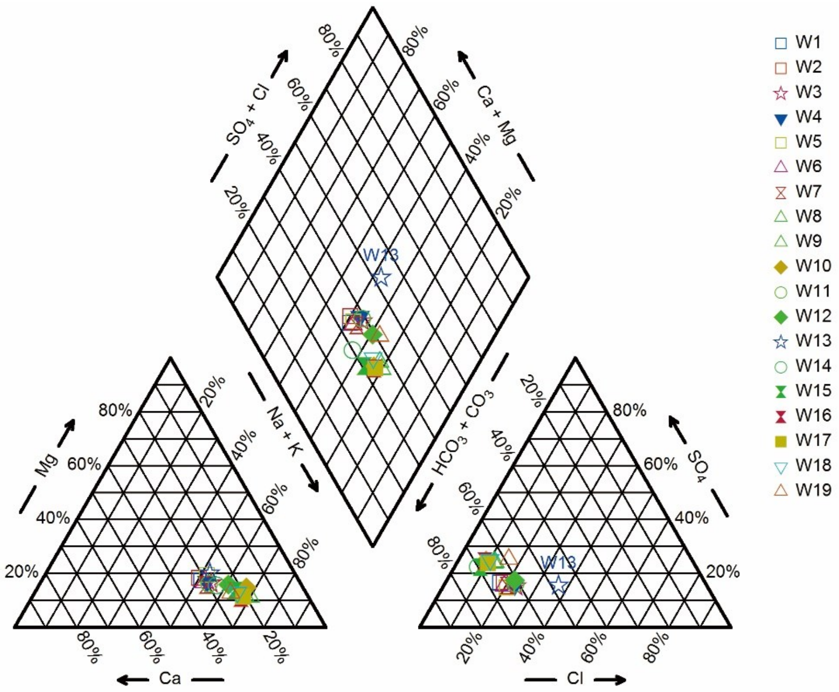

Figure 2: Piper diagram of water samples from Yanqing geothermal field.

4.2 Classification of the thermal fluids

The Cl-SO_4-HCO_3 ternary diagram reflects the proportions of the three most common anions in geothermal water, which is usually used in the initial classification of geothermal fluids (Giggenbach, 1991). The ternary diagram shows several different types of geothermal fluids, such as mature water, peripheral water, volcanic water and steam water. Figure 3 shows that all the samples plot in the peripheral regions. Low concentrations of Cl^- and SO_4^{2+} and high concentrations of HCO_3^- make the samples closer to HCO_3^- side. The main reason is that the lithology of Wumishan formation are mainly dolomite and siliceous dolomite, which is rich in carbonates. Geothermal water naturally contains HCO_3^- with a relatively high concentration, indicating that geothermal water in the study area is peripheral water.

4.3 Equilibrium state of thermal fluids

Giggenbach (1988) proposed a ternary diagram with Na/100, K/100 and √Mg as the three vertices, and divided three types of geothermal water in complete equilibrium, partial equilibrium and immature with rocks, based on the Na-K and K-Mg geothermometer. The Na-K-Mg ternary diagram is used for evaluating equilibrium between the thermal waters and rock formations. The results are shown in Figure 4. All the samples plot in the immature water region. It reflects that the water-rock reaction has not reached equilibrium. The elemental accumulation of magnesium indicates that the geothermal water may be experiencing precipitation recharge and cold water mixing. Therefore, some cation geothermometers cannot get reasonable equilibrium temperature values.

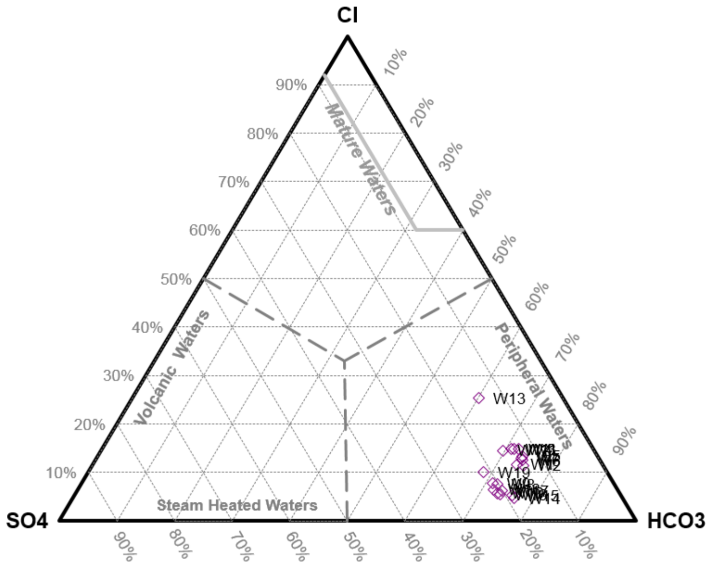

Figure 3: The Cl-SO_4-HCO_3 ternary diagram for waters from Yanqing geothermal field.

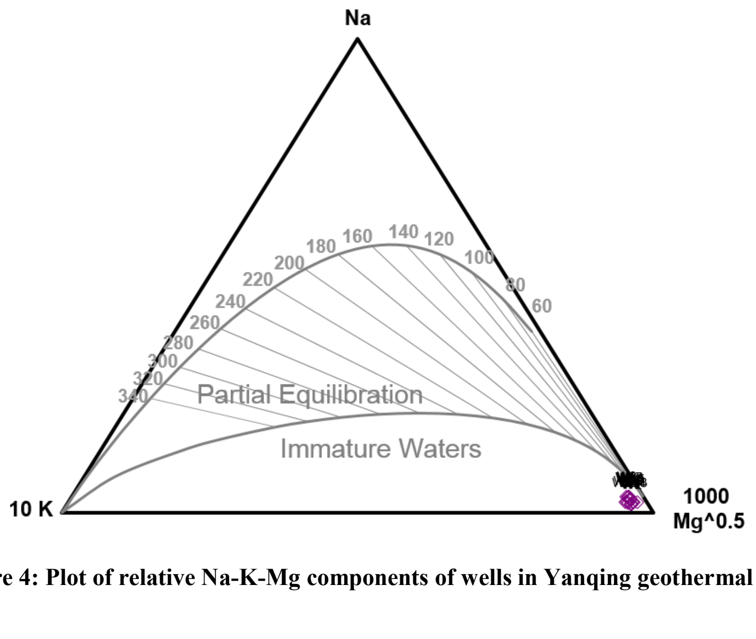

Figure 4: Plot of relative Na-K-Mg components of wells in Yanqing geothermal field.

4.4 Geothermometry

Geothermal activity is closely related to tectonic movement, seismic activity and hydrothermal mineralization. Reservoir temperature is an important parameter for studying geothermal activity. Geothermometry is widely used in the process of geothermal field development for estimating and monitoring the subsurface temperature of the reservoir. The basic principle is as follows: when the geothermal water rises to surface, the content of chemical components do not change. Thus, the temperature of reservoir can be estimated based on the equilibrium temperature of chemical reactions. In this study, the 'quartz – no steam loss' geothermometer, chalcedony geothermometer, Na-K-Ca geothermometer and K-Mg geothermometer were selected to calculate the subsurface temperature. The Na-K-Ca and K-Mg cation geothermometers were considered useful geothermometers for cold thermal waters. The calculation results are shown in Table 1.

Table 1: Results of different geothermometers from Yanqing geothermal field.

Well NO.	T_{qtz}[1] (℃)	T_{chal}[1] (℃)	$T_{Na\text{-}K\text{-}Ca}$[1] (℃)	$T_{K\text{-}Mg}$[2] (℃)
W1	84	53	89	67
W2	99	69	85	67
W3	98	68	83	65
W4	97	66	79	63
W5	96	66	68	55
W6	92	61	90	69
W7	95	65	91	70
W8	82	51	94	67
W9	99	69	92	66
W10	89	58	94	64
W11	88	57	94	72
W12	85	54	97	70
W13	78	47	84	61
W14	84	53	81	63
W15	69	38	84	63
W16	86	55	83	63
W17	95	65	87	64
W18	83	52	86	64
W19	89	59	82	63

1) Fournier (1981); 2) Giggenbach (1988).

The indicated geothermometer temperature of selected geothermal water samples in the study area is 52.5-70℃. The reservoir temperature was estimated to be in the range of 69-99℃ based on the quartz geothermometer. The range of reservoir temperature calculated by chalcedony geothermometer is 38-69℃. The range of reservoir temperature calculated by Na-K-Ca geothermometer is 68-97℃. The range of reservoir temperature calculated by K-Mg geothermometer is 55-72℃. The quartz geothermometer and Na-K-Ca geothermometer were 10-20 ℃ higher than the measured values. The reservoir temperature calculated by the K-Mg geothermometer is closer to the actual measured temperature, while the reservoir temperature calculated by the chalcedony geothermometer is lower than the actual measured temperature, which can be used as a conservative method for temperature estimation.

5. CONCLUSIONS

(1) The hydrochemical types of geothermal water in Yanqing basin are HCO_3-Na and HCO_3-Na·Ca. The pH of geothermal water in the study area ranges from 7.24 to 8.48. TDS ranges from 433 to 681mg/L.

(2) Based on the analysis of the Cl-SO_4-HCO_3 ternary diagram, geothermal water samples are closer to HCO_3^- side. It indicates that geothermal water in the study area is peripheral water. The Na-K-Mg ternary diagram of the geothermal water sample shows that the water-rock reaction has not reached equilibrium, indicating the geothermal water samples has the possibility of receiving precipitation recharge and cold water mixing.

(3) Different geothermal geothermometer are used to estimate the reservoir temperature of Yanqing geothermal field. The calculation results show that the K-Mg geothermometer and chalcedony geothermometer are reliable for estimating the reservoir temperature.

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