Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

A Conceptual Model of the Tianjin Geothermal System Based on Isotopic Studies

Wang Kun

Tianjin Geothermal Management Division, Bureau of City Planning and Land Resources,Tianjin, 300070

kun1302@sina.com

Keywords: geothermal water, isotope, hydrothermal model

ABSTRACT

The isotopic technique is an effective measure to set up the conceptual model of a hydrothermal system. A deep circular geothermal system exists in Tianjin, including the semi-open and semi-closed karst geothermal subsystem in the bedrock and closed porous water subsystem in the clastic rocks. The geothermal water is originated from the ancient precipitation of 21000-10000 BP. Since Holocene epoch, the geothermal water is sealed for heating up. The mainly feeding channels are the karst conduits in weathered carbonate rocks of Proterozoic and Lower Paleozoic.

1. INTRODUCTION

Tianjin is located at the north-east of the Hua-Bei plane in China, with the Yan Moutain at its north and Bohai Bay at its east. The total region area is 11305 km^2. Most of the areas are covered by Quartery system stratum. The outcrop of the base rock is limited to the mountain area of the north Ji County.

Tianjin Geothermal field is a sedimentary-fault basin. It locates at the north of North China Platform and is devided into northern and southern part by Ninghe-Baodi fracture. See Fig.1. The northern part belongs to the secondarily tectonic unit -- Jibao upfold in Yanshan platform folded zone. The southern part belongs to "Bohai Bay Basin"[1]. From west to east, the southern part is constituted by three tectonic unit--Jizhong depression, Cangxian uplift, Huanghua depression, which are cut into many tectonic blocks by several eastweat, northwest and northeast trending fracture.

A conceptual model of a geothermal system is the basis for setting up a numerical model on the hydrothermal processes. The success of a numerical model lies on the aptitude of the conceptual model. we have carried out a series of investigations using isotope techniques on the recharge/discharge conditions of the geothermal reservoirs in Tianjin aiming at the establishment of a conceptual model of the geothermal system. Table 1 is the isotopic data used in this paper. The isotopic techniques mainly mean the tracing function of stable isotopes and dating function of radioactive isotopes. They are effective measures to differentiate the hydrothermal system and investigate its recharge mechanism, moreover to set up the hydro-thermal system model.

2. THE FORMING PROCESS OF GEOTHERMAL WATER

From the relation curve of δD and $δ^{18}O$ (Fig.2) in precipitation, there is a far distance between the points of geothermal water and cold underground water. But all of the points are located near the global meteoric water line.

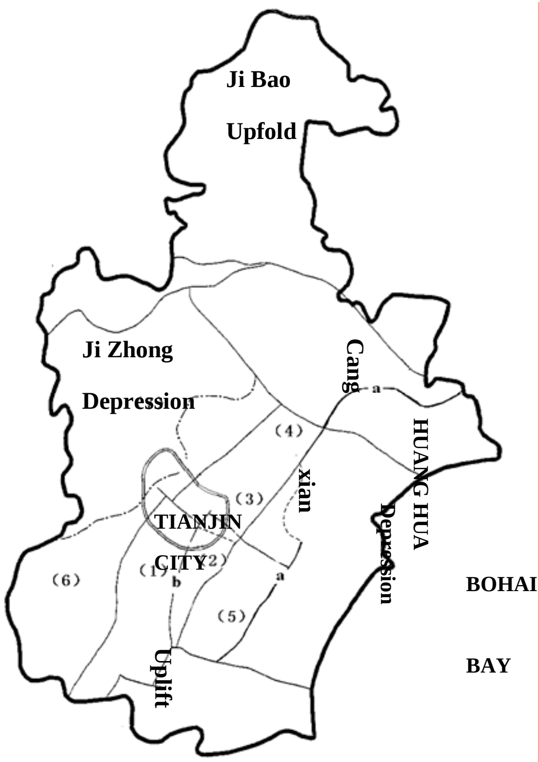

Figure 1: The sketch of the geological tectonic in Tianjin

a: Cangdong Fracture; b: West Baitangkou Fracture; c: Ninghe-Baodi Fracture; 1. Shuangyao uplift; 2. Baitangkou depression; 3. Daxiaodongzhuang uplift; 4. panzhuang uplift;5. Xiaohanzhuang uplift; 6. Dacheng uplift; 7. Wuqing depression.

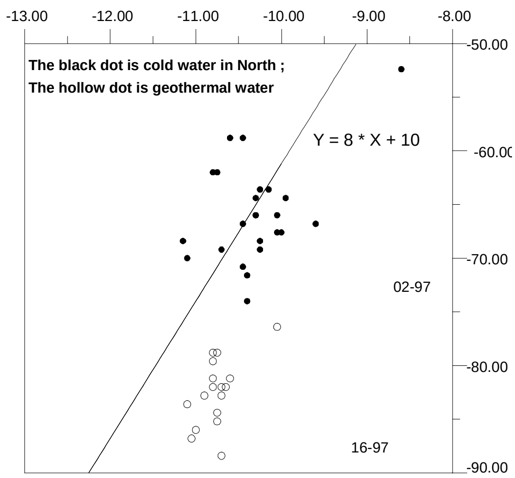

Figure 2: The stable isotope distribution of deep geothermal water in Tianjin

Despite of O^{18} drift in geothermal water, both of them originate from precipitation. Due to the different recharge period/environment, they have different nature. The major part of geothermal water comes from the precipitation in upper Pleistocene, and itsδD value (-82□-79) is lower than cold groundwater(-73±2.5).

The ^{14}C values are quite close for the karst geothermal water in the bedrock, for example, it is 13~5.5pmc in medium Proterozoic Jixiannian Wumishan formation; 9.3~4.5pmc in Cambrian; 15~5.2pmc in Ordovician. They are higher than the ^{14}C values in Tertiary porous geothermal water (7.6□4.5 pmc). The lower radioactivity of ^{14}C in geothermal water (older age) and the higher ^{13}C concentration indicate the more significant water-rock interaction. So the Tamers modeling age is adopted. The isotopic analysis shows that the younger geothermal water in bedrock reservoir (4000□20000a BP) recharges to the older geothermal water in upper porous reservoir by plunger flow. The observed pressure data match with this. The simulation about the production history by 3D model also indicates the hydraulic relation of these reservoirs.

2.1 The alternate recharge period in upper Pleistocene epoch

The ^{14}C-dating indicates that the origin of the geothermal water is the upper Pleistocene (21000-10000a BP) precipitation. At that time, the regional base level of erosion (sea level) continuously descended by a big range. The precipitation from the north Yanshan Mountain and west Taihang Mountain drove the pre-existing karst water (56□70ka BP) into the sea and replaced it directly through the old crust of weathered karst path in carbonate formation of medium Proterozoic and Paleozoic(Fig.3). Meanwhile, a upflow supplied the upper porous reservoir in detritus rock and replaced the porous water in it, along the deep and big faults. Also there is an indirectly recharge of underground water through the water divide in south basement.

The ^{14}C data in 1985(Zhang Xigen,1990) shows the geothermal water in lower Paleozoic Ordovician system moves from north to south. But from 1998, the new data (Shao et al., 1998, Wang Kun, 2001) displayed that the flow direction changed, with the recharge velocity of 4.2m/a from south to north and 2.3m/a from west to east. Similarly, in medium Proterozoic Jixiannian reservoir, it is 4.6m/a and 2.8m/a correspondingly. This indicates that the main recharge channels are the old weathered karst system in medium Proterozoic and lower Paleozoic, as well as the north-east regional tension fracture system. Fig.2 is the water level contours for Wumishan reservoir in Sept.1998. The hydraulic dynamic trend of geothermal water is identical with the isotopic analysis, under the production state.

2.2 Sealed up for heating period in Holocene epoch

Since Holocene epoch□10000a BP□, the regional sea level ascends. Several times transgressions supply the salty materials for the wedge-shaped salty water mass, which is thin in west and thick in east in the Quaternary aquifer. The rising of the regional base level of erosion hindered the horizontal movement of geothermal water. The upright heat flow is obstructed by the huge thick Quaternary stratum and water mass. The sealing state is in favor of the heat-up of geothermal water. Although the sealed water moves slowly, but it has quite fast velocity in decompression zone. Fig.4 is the sketch of the sealed heat-up model.

3. GEOTHERMAL SYSTEM AND SUBSYSTEM

The geothermal water mainly located in the range of Cangxian uplift. Accumulated in medium Proterozoic Jixiannian Wumishan (Pt2W), lower Paleozoic Cambrian (Pz H) and Ordovician (Pz O) reservoir, it is "fractured karst geothermal water in bedrock"; and "porous geothermal water in clastic rock" exists in Tertiary and Quaternary. The cold groundwater deposit in the fissure of the basement in front of the Yanshan Mountain and the shallow porous/fracture aquifer (at 500-800m depth) in Tertiary and Quaternary. As discussed above, geothermal water comes from the precipitation seepage in latest glacial period of upper Pleistocene (10000-21000a BP), and sealed up to the present since Holocene. It is a closed deep circular system. The cold groundwater is assigned as modern shallow circular water system. So two hydrological systems in Tianjin area can be marked off:

- The shallow circular cold water system;
- The deep circular sealed geothermal water system.

The fractured geothermal water in bedrock has the near ^{14}C value (15□4.5 pmc), higher than the value of porous water (7.6□4.5 pmc). So the bedrock geothermal water is younger than the porous water. After the denudation of the long geological period, the bedrock has a huge weathering shell and well-developed fracture and dissolved cavity. Meanwhile there is a large outcrop area in the north and west mountains, so it is semi-closed reservoir. In the other hand, the reservoir in Tertiary and Quaternary system have a good closed condition. Hereby, the deep circular geothermal system can be divided into:

- Semi-open and semi-closed bedrock subsystem, where the karst geothermal water exists;
- Closed clastic rock subsystem, where the porous geothermal water exists.

4. THE RELATION BETWEEN THE SHALLOW CIRCULAR UNDERGROUND WATER SYSTEM AND THE DEEP CIRCULAR GEOTHERMAL SYSTEM

The cold underground water in front of Yanshan Mountain is a local shallow circular system, originating from the modern precipitation. Along the runoff direction from north to south, the TDS increases by degrees when $A^{14}C$ and the tritium concentration decrease. At the same time, the type of water changes regularly. Under the natural state, a dynamic balance exists between the seepage of the shallow cold water and the geothermal upflow along the depression zone(for example, the deep and big foreland fracture, and regional north-east fracture zone, ancient weathering crust). The age range of bedrock geothermal water□4-20 ka.□ shows that it move slowly as a whole. But with increasing of the large-scale development of geothermal water, the balance interface removes towards geothermal water. According to the tritium data in 1984, the geothermal water in Tianjin has no tritium in it. But in 1998, the tritium concentration increased apparently except the lower value in Cambrian geothermal water(≤1-2T.R.). It reaches 2□13T.R in Wumishan reservoir which has a good karst condition, and 4□11T.R. in Ordovician reservoir. Meanwhile the geothermal water temperature descended with the increasing of tritium concentration. It is made clear that the large-scale collective development of geothermal water caused the mixing of the cold water inflow along the fracture zone and aging well bore. So the higher tritium concentration (9□13T.R) was tested out in geothermal water of even more than 10,000 years old.

5. CONCLUSIONS

The geothermal system is composed of A semi-open and semi-close bedrock subsystem, where the karst geothermal water exists with the ^{14}C age of 4□20 ka BP and aclose clastic rock subsystem, where porous geothermal water exists with the ^{14}C age of 15□21 kA BP.

The origin of geothermal water is the precipitation in upper Pleistocene (10-21kaBP). The main phase of Yumu glacial period (11□23ka BP) is the active interaction phase to form the geothermal water. Since Holocene epoch, the regional sea level has ascendd. The geothermal water has come into a closed heat-up period. The main recharge channels are weathed karstic system in the bedrock and northeast trending regional fracture system.

The large-scale centralized exploitation of geothermal water has caused the loss of the balance between geothermal water and cold groundwater or between geothermal water and the seawater. A new balance will be established. The geo-static pressure may drive the geothermal water in Jizhong and Huanghua depressions to replenish the geothermal water in Cangxian uplift. It has caused a slight increase in the TDS value.

REFERENCES

Zhang xigen □ 1990 □ analysis about the geochemistry andorigin of geothermal water in Tianjin, Publication of IHER,No.6, P.1□24;

Shao hongxiang, Zhao fengsan, Liao Zhijie and Tao ye, 1998, the research report of geothermal mineral water in Tianjin city area.

Wang Kun, Zhu Jialing, 2001, a conceptual model of the Tianjin geothermal system based on isotopic studies, Science in China (Series E), (44 Supp.): 160□164.

Table 1. Isotopic and chemical sampling data of geothermal water in Tianjin (1997-1998)

Sample No.	Depth m	Temp □	$A^{14}C$ Pmc	Tomers Model	$\delta^{13}C$ ‰,PDB	^{3}H T.R.	$\delta^{2}H$‰,SMOW	$\delta^{18}O$ ‰,SMOW	TDS mg / l
Proterozoic Jixianian system(Pt_2W), sampling from north to south									
2	300	18	13.4	11.7	□8.5	13	-76	-10.3	403
3	300	25	--	16.9(19.8)	□9.3	24	-73	-8.1	525
5	2850	90	7.1(5.0)	19.0	□4.0	9	-86	-10.1	1008
7	2894	96	5.5	12.9	□5.0	2	-80	-9.6	1640
9	2000	84	11.6	19.0(21.2)	□5.8	4	-80	-9.3	2024
16	1500	82	5.5(4.2)	11.9	□5.7	13	-83	-9.5	1988
17	2397	96	13.0	17.4	□5.2	2	-84	-9.5	2095
Paleozoic Cambrian system(PzH), sampling from west to east									
8	2004	90	6.7	14.7	□5.3	2	-80	-9.4	1796
12	--	70	9.3	20.7	□4.5	<1	-76	-9.5	1765
11	--	90	4.5	9.8	□4.5	1	-79	-9.6	1698
Lower Paleozoic Ordovician(Pz O), sampling from north to south									
1	200	18	16.9	19.5	□7.8	8	-74	-10.3	393
4	1600	50	5.2	3.9(10.7)	□4.6	4	-85	-10.0	1024
18	2200	80	34.2(15	12.6(13.3)	□6.4	11	-79	-9.5	4690
15	2500	76	12.0(11)	19(21)	□5.5	10	-81	-9.8	1986
Tertiary system(KzN), sampling from north to south									
6	2400	79	5.5(4.5)	15.2(16.4)	□	5	-71	-9.5	
10	--	56.7	8.8(7.6)		□6.5	7	-77	-9.6	

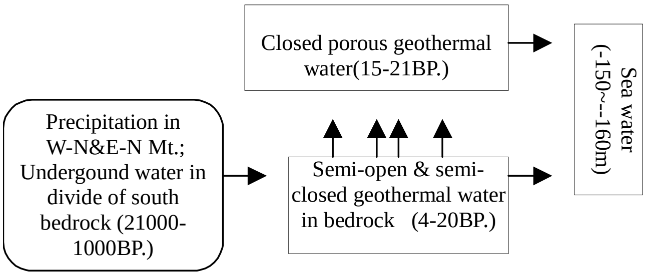

Figure 3: Sketch of recharge-interactive period in upper Pleistocene

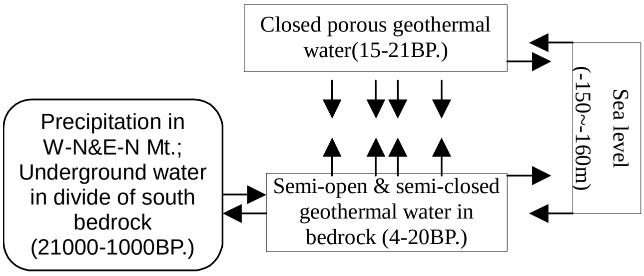

Figure 4: Sketch of sealed-up period in Holocene