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Isotopic Characteristics Analysis of Geothermal Fluids in the Southern Plain of Tianjin

Junfeng Li, Chuanxia Ruan, Liyan Wang

189 Weiguo Road Hedong District of Tianjin, China

tjlijf@163.com

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ABSTRACT

By means of measuring stable isotope data of 20 samples of geothermal fluids and ^{14}C, we can research the sources of geothermal reservoir fluid in the areas of Tianjin, analyze the relationship between stable isotopes and the thermal reservoir temperature and geothermal fluid buried depth, analyze the age of the geothermal fluid, analyze the supply and migration of geothermal fluid, and analyze the nature of the regional geothermal system boundaries. The research results provide basic data for the development of geothermal resources in Tianjin.

1.GEOTHERMAL GEOLOGICAL CONDITIONS

1.1 Schematic tectonic map of southern Tianjin

Tianjin southern plain is located south of Baodi-Ninghe fault that belongs to level II construction unit of Northern China depression area. III tectonic units in the area which includes a uplift and two depressions, which is Cangxian uplift, Jizhong depression, Huanghua depression. There is a lot of IV level tectonic units between uplift and depression, which extensive direction and the strike of deep fracture are in the direction of NNE and form the arrangement of tectonic (FIG. 1).

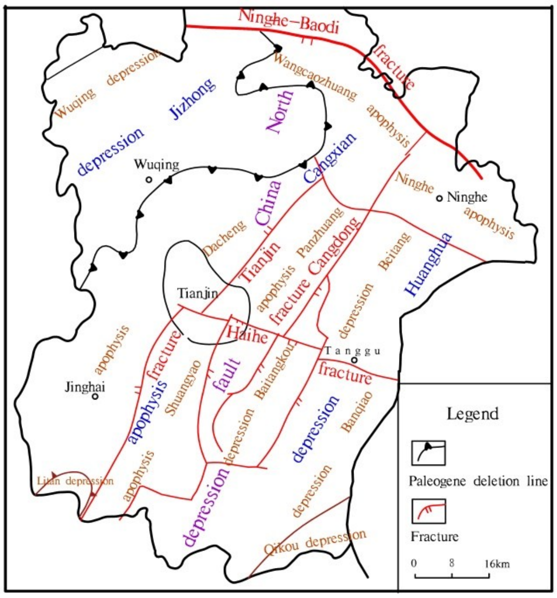

FIG. 1 Tectonic schematic diagram of the plain area in southern Tianjin

1.2 Reservoir characteristics

There are two types of reservoirs in the plain area of southern Tianjin: the pore type and the fracture type.The pore reservoir includes: Minghuazhen formation(Nm), Guantao formation(Ng) of neogene and Dongying formation(Ed) of paleogene; The fractured reservoir includes the Ordovician formation(O), Cambrian Changping formation(Є) and Wumishan formation(Jxw). The reservoir characteristics are shown in table 1.

2. SAMPLE ANALYSIS AND TESTING

The location of the 20 stable isotopes samples(D and ^{18}O) and ^{14}C is showed in figure 2. These samples are tested in Groundwater mineral water and environmental monitoring center, ministry of land and resources. Stable isotopes are determined by gas isotope mass spectrometer. ^{14}C is determined by an ultralow-background liquid scintillation spectrometer. The apparent age was calculated with a half-life of 5730 years. The results were all based on extended uncertainty, with a confidence probability of about 95%.

Table 1 The main reservoir characteristics

reservoir type	buried depth of roof (m)	per unit of water inflow（m^3/h·m）	water temperature（℃）	reservoir parameters
Nm	300～600m	0.76～5.45	40～70℃	The permeability coefficient：0.4～1.8m/d porosity：25～33.5％
Ng	530～1383m	0.52～5.13	55～80℃	The permeability coefficient：0.3～2.2m/d porosity：18～36.6％
Ed	1900～2500m	0.33~0.34	75～93℃	The permeability coefficient：0.13～.18m/d porosity：21.16～35%
O	882～3104m	1.62～7.94	48～76℃	The permeability coefficient：0.2～2.5m/d fissure ratio：2.0～6.25％
€	950～3734m	2.11～3.13	70～80℃	The permeability coefficient：0.39～0.55m/d fissure ratio：2.6～5.0％
Jxw	912～3734m	1.08～9.07	>79℃	The permeability coefficient：0.49～2.81m/d fissure ratio：2.7～5.8％

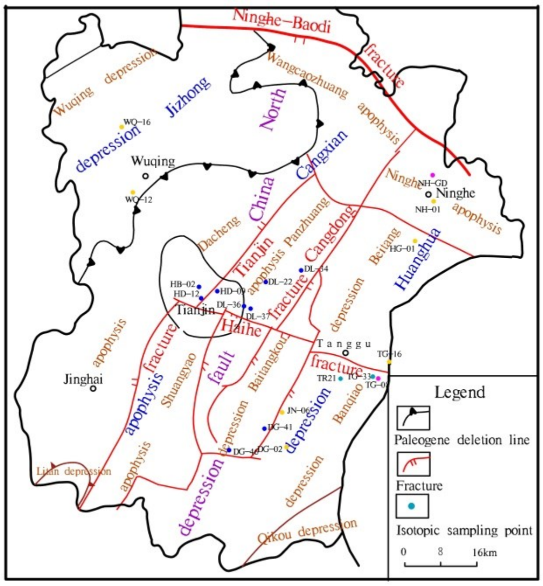

FIG. 2 Isotopic sampling point distribution

3. RESULTS AND ANALYSIS

3.1 Stable isotope characteristics

The isotopic results of geothermal fluid in the plain area of southern Tianjin are shown in table 2. According to the data analysis, the value ofδ^{18}O is between -6.8 --9.9‰, and the value of δD is between -56- -80‰ in the geothermal fluid. The analysis results of the geothermal fluid in all sampling points fall below the global meteoric water line (FIG.3), indicating that the main source of geothermal fluid in various reservoirs in Tianjin area is atmospheric precipitation.

Under the same geological conditions, the deeper the reservoir is, the smaller the δD value is. The deeper the reservoir is buried, the higher the recharge elevation of geothermal fluid is. For example, in the area near Cangdong fault and Haihe fault, there is a positive drift of δ^{18}O of geothermal fluid in bedrock reservoir in the relative meteoric water line, but the drift value is not significantly different. This is mainly due to the strong runoff environment and good connectivity between upper and lower reservoirs. The exchange of δ^{18}O between the fluid and the rock is the same. It is consistent with the conclusion of the general analysis of water quality.

In contrast, the δD and δ^{18}O in the pore geothermal fluid are more closely related to their geological structure. Compared with the distant TG-08 and NK-01 Wells, the positive drift of δ^{18}O in the geothermal fluid in DG-02 well and JN-06 well who are near the water conductivity fault is much larger, indicating that the strong runoff near the fault is the reason why δ^{18}O in the geothermal fluid drift. The anomalies of δD and δ^{18}O in the geothermal fluid in Dongying formation may be related to the relatively closed sedimentary environment of the oil reservoir.

The age of the geothermal fluid is closely related to the tectonic location and buried depth of the geothermal fluid. The age of the geothermal fluid in the uplift area is generally smaller than that in the depression area, also it is relatively small in the area with good runoff conditions. The age of geothermal fluid increases along the direction of runoff in the same reservoir and geological structural unit. The age of geothermal fluid in shallow reservoir is less than that in deep reservoir. Such as, it gradually increases from NH-GD (Nm) and TG-16 (Ng) to TG-33 (Ed) in the Huanghua depression.

Table 2 Results of isotope analysis in Tianjin area

reservoir type	reservoir	well number	$\delta^{18}O$(‰)	δD(‰)	the depth of the well(m)	^{14}C (ka)	reservoir temperatures(℃)
The pore heat storage	Nm	TG-08	-9.6	-68.0	1023.5	37.939±2.003	43
		NH-GD	-9.9	-80	1157	27.575±0.828	46
	Ng	JN-06	-8.7	-74	1580	37.747±2.491	60
		WQ-12	-8.8	-67	2368	41.334±4.090	82
		WQ-16	-9.8	-72.0	2418	32.560±1.325	77
		TG-16	-9	-66	1998	35.647±1.483	70
		DG-02	-8.7	-70	1890	39.414±4.175	62
		HG-01	-8.8	-71	2150	39.444±2.511	68
		NH-01	-9.5	-71	1347	32.629±1.588	50
	Ed	TR21	-7.4	-56	2362.9	31.549±0.589	73
		TG-33	-6.8	-66	2200	44.095±4.269	85
The fractured heat storage	Jxw	DL-22	-9	-68.0	2546	27.941±1.107	94
		DL-34	-9	-63.0	2327.1	28.328±1.275	100
		DL-36	-9	-66.0	2668	26.949±1.361	93
		DL-37	-9	-70.0	2706.6	28.745±1.610	96.5
		DG-41	-8.8	-68	2800	36.165±2.266	96
		DG-46	-9	-71	2508	40.169±4.056	96
		HB-02	-9	-70	3506.8	36.475±2.839	85
		HD-09	-9	-69	3403	more than38.118	85
		HD-12	-9	-72	3140	29.740±1.401	88

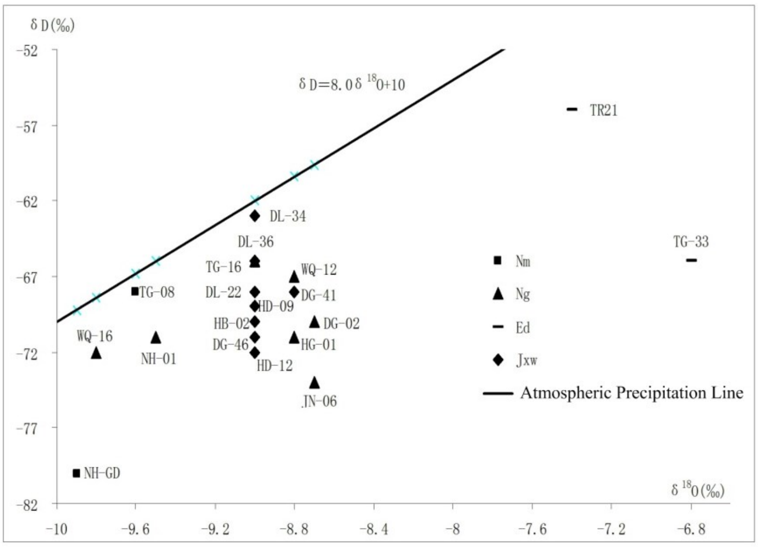

FIG.3 The relationship between δD and $\delta^{18}O$ in the geothermal fluid

3.2 Relationship between stable isotopes and reservoir temperature and buried depth

3.2.1 Relationship between δ^{18}O and reservoir temperature and buried depth

The relationship between geothermal fluid δ^{18}O content and reservoir temperature is showed by FIG.4. The content of δ^{18}O in geothermal fluid has little relationship with the temperature of the reservoir temperature in the same reservoir (Minghuazhen formation, Guantao formation or Wumishan formation). But the δ^{18}O content of reservoirs with low temperature is lower than that with high temperature for different reservoirs. However the δ^{18}O content in the geothermal fluid increases with the increase of reservoir temperature, mainly due to the closed geological environment of the reservoir and poor geothermal fluid runoff conditions in Dongying formation,the geothermal fluid with high reservoir temperature has a higher δ^{18}O content than that with low temperature. The δ^{18}O content of geothermal fluid has little relationship with the buried depth of geothermal fluid (FIG 5).

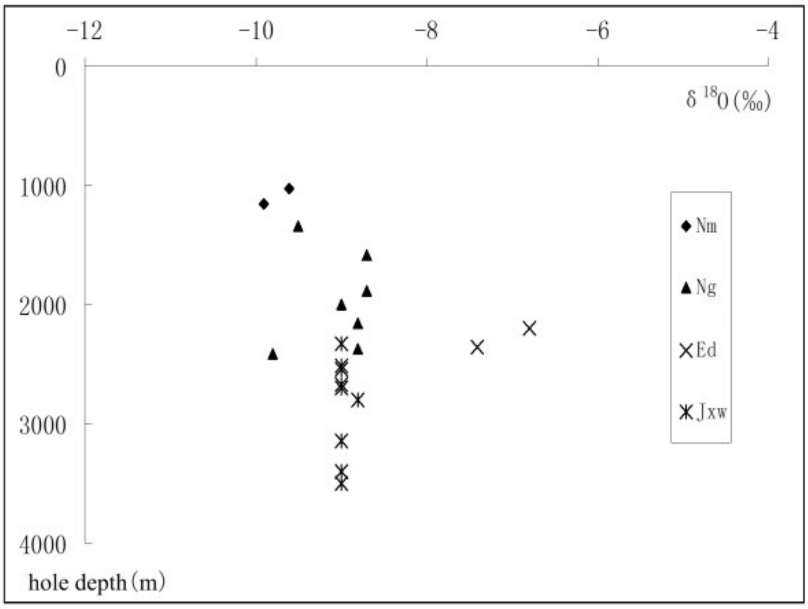

FIG.4 The relationship between δ^{18}O and reservoir temperature

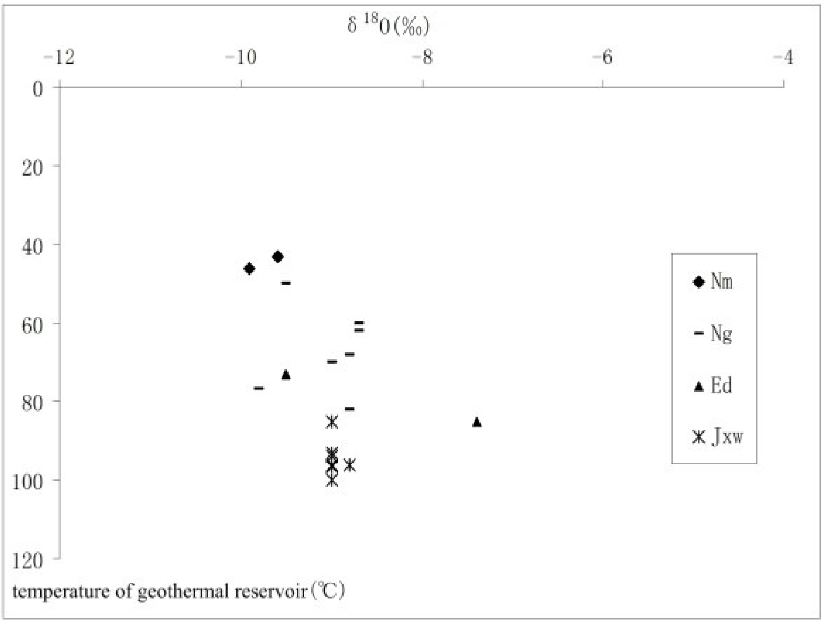

FIG.5 The relationship between δ^{18}O and buried depth

3.2.2 Relationship between δD and reservoir temperature and buried depth

The existed research shows the δD will not be able to accurately describe the movement of the geothermal fluid because of it's various degrees of drift, so it will be easier to study the characteristics of the geothermal fluid by using the δD. The content of δD in geothermal fluid is positively correlated with the reservoir temperature (FIG. 6), while it is negatively correlated with the buried depth in the same reservoir (FIG. 7).

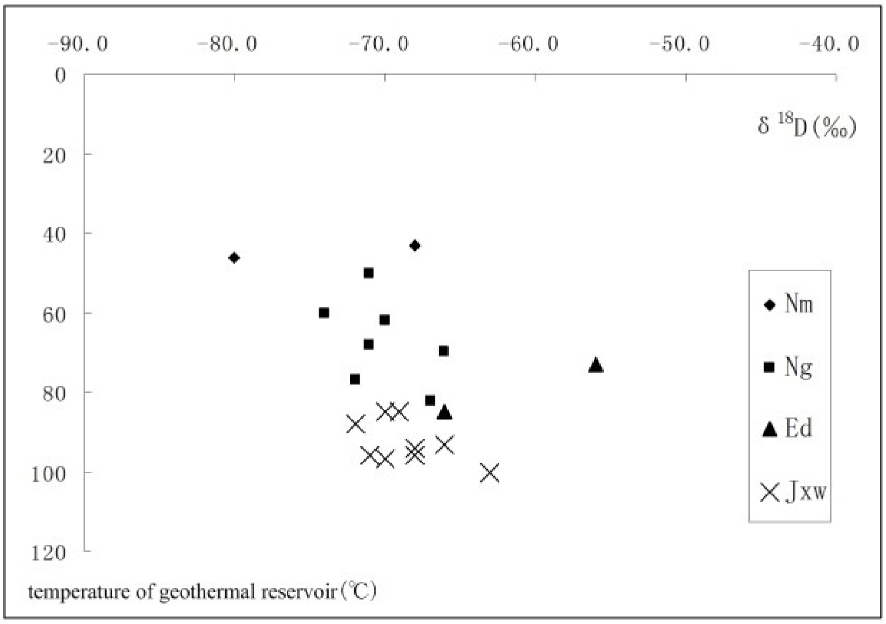

FIG.6 Relationship between δD and reservoir temperature

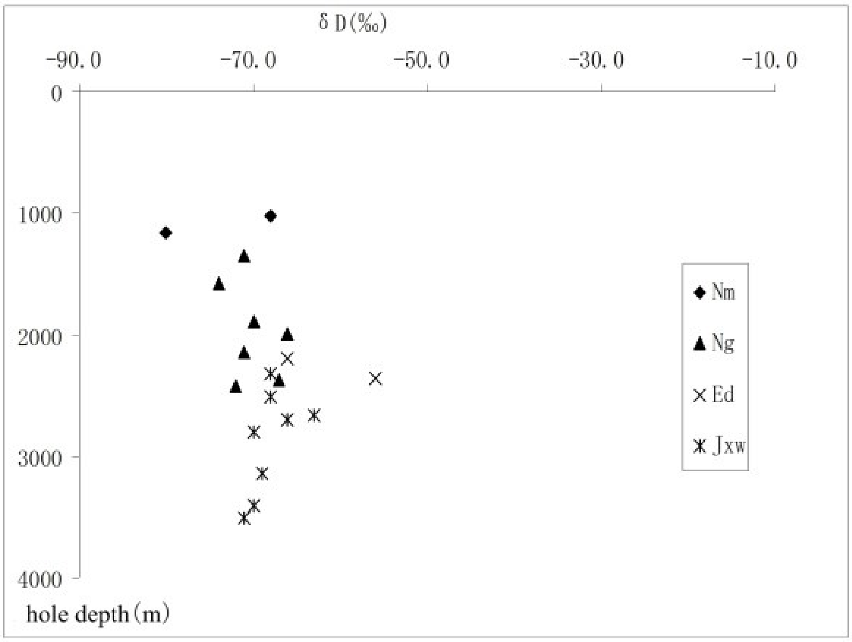

FIG.7 Relationship between δD and buried depth

3.3 Radioactive isotope

At present, the most commonly used radioisotope methods include tritium and ^{14}C in the study of hydrogeological conditions. However the half-life of tritium is only 12.26 years while the ^{14}C is 5730±40 years. Given that the geothermal systems are located at depth and are relatively older than normal groundwater, the age of geothermal fluid is usually studied by ^{14}C.

Because of the poor permeability of clay, mild clay and mudstone layers between the thermal reservoirs in the southern plain area of Tianjin, there is no obvious hydraulic connection between the geothermal fluid, that is, the horizontal alternation of the geothermal fluid in the area is dominant, and the unmixed "piston model" is used to estimate geothermal energy. The calculating formula for the age of the fluid is:

$$t=1.443xTxln(A_0/A)$$

t is age of geothermal fluid; T is the half-life of ^{14}C is 5730±40 year; A_0 is initial concentration of ^{14}C (100%);A is the concentration of ^{14}C at t or measured (100%).

Based on the test results of geothermal fluid samples, the age of geothermal fluid in the main development and utilization areas in Tianjin was analyzed, and the distribution law of age was analyzed. The age of geothermal fluid in Tianjin in between 26.95 ka and 44.10 ka.

Based on the 14C analyses of geothermal fluid samples, the age of geothermal fluid in Tianjin is between 26.95 and 44.10 thousand years.

The age of bedrock geothermal fluid is generally smaller than that of pore geothermal fluid. For pore geothermal fluid, the age of Huanghua depression is generally smaller than the Jizhong depression. According to the age of ^{14}C in geothermal fluid in the Wumishan Formation, the age of geothermal fluid in the fault zone is generally smaller than it in other areas.

4.CONCLUSION

The δD and $\delta^{18}O$ content of the geothermal fluid is closely related to the geological structure, the deeper of the reservoir is, the smaller value of the δD is. $\delta^{18}O$ will drift more forward in the tectonic area with good runoff conditions.

The age of the geothermal fluid is closely related to the tectonic location and buried depth of the geothermal fluid. The age of the geothermal fluid in the uplift area is 26.96-40.17 ka. And that of the geothermal fluid in the depression area is 31.55-44.10 ka，which is generally smaller than that in the depression area.

The $\delta^{18}O$ content of geothermal fluid has a few relations with reservoir temperature and buried depth. The content of δD in geothermal fluid is positively correlated with the reservoir temperature, while it is negatively correlated with the buried depth in the same reservoir.

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