Further Understanding of the Supply Source of Shaizhudong Spring in the Central Weibei

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Abstract—Shaizhudong spring is the largest one in the central of Weibei, Shaanxi Province, China, for its supply source predecessors have done a lot of research, it was considered that Jinghe leakage is the main source of supply, and it is the concentrated discharge points of Shaizhudong spring area hidden karst system. In this paper, we have different understanding on recharge of Shaizhudong spring, based on the research achievements of hydrogen, oxygen and strontium isotope, combined with hydro geochemistry and karst hydro geological conditions. Isotope hydro geochemistry study shows the recharge is given priority to karst groundwater outside southwest of the Shaizhudong spring area, Proportion of atmospheric precipitation, river water and karst water were 11%, 37% and 52%, and proportion of Southwest, northwest and the dam site area karst water were 77.9%, 19.7% and 2.4%, respectively. The average residence time of Shaizhudong spring karst water is 62-64 years.

Keywords-Karst water ; water resource ; recharge ; central Weibei; engineering

I. INTRODUCTION

The hidden karst area in the central of Weibei is located in the southern margin of the Ordos Basin, whose structural geology is extremely developed, the karst hydro geological conditions is complex and the mixing various types of water bodies is in the high degree. Shaizhudong spring is the largest karst spring in the region and its average annual flow is 1.49m^3/s. The Jinghe Dongzhuang Hydro Project is in the Karst groundwater subsystem of its unique and complex hydro geological units. Since the early 1960s, the influence of karst water reservoir leakage associated hydro geological Conditions issue has been the key geological problems to decide successful implementation of this project, but the government departments are also concerned, the relationship between academic circles debating regional economy, people's livelihood issues. Predecessors have embarked on a series of research works, though it achieved some results, but there is a great difference, which karst water dam site, the relationships between Jinghe River and Shaizhudong springs are the focus of attention. More predecessors believe that the supply source of Shaizhudong springs mainly from the leak Jinghe River recharge, and proportion of the total recharge is 55~57%, followed by the atmospheric precipitation recharge. The Shaizhudong spring is the centralized discharge of the Weibei Central karst groundwater subsystem. The Shaizhudong spring area, Zhougong Temple and Longyan Temple spring area were relatively independent Weibei Central karst subsystem. Some experts question that whether there is some groundwater along the fault Zhangjiashan that recharge the Shaizhudong spring, there is no evidence to substantiate this hypothesis. This paper uses isotope hydro geochemical methods to study the isotope hydrology geochemistry characteristic of the various types of water bodies in the study area. We get a new distinctively understanding for the Shaizhudong spring recharge sources and supply route.

II. GENERAL SITUATION

The study area is situated in the Weibei innermost region of southern margin of the Ordos Basin, the north of the Weihe River in Shaanxi Province. It has the temperate continental semi-arid climate, low rainfall, strong evaporation and the annual average temperature is 11.8°C. Surface water drainage is more developed, the principal river is the Jinghe River, a tributary of the Weihe River. Jinghe belongs to the upper reaches of the area. It is characterized by high concentration of fine clay and sand, the flow rate widely varied are closely related to the atmospheric precipitation.

Northern study area is bounded by the old Longshan fault, south to Qianxian - Fuping County fault, extending eastwards to the Zhikou Town - Guan Shan fault and Qianxian County - Fuping break junction, west largely on YongShou - Qianxian County for the sector, constituting like a triangle. Area terrain is complex, terrain overall trend northwest to southeast, north is dominated by low mountains, and there are nearly east-west Wufeng mountain, Zhuantianling, etc., at an elevation between 1200 and 1600m, mostly made up by bare or buried carbonate salt rocks; Southwest terrain gradually reduced, at an elevation between 800 and 1000m, between the main series to Tangwangling synclinal fold structures; made up by the Ordovician bedrock and carbonate rocks; Southeast terrain decreased stepwise , piedmont elevation is more in 400 ~ 500m, the contact zone between the bare carbonate rock area and piedmont alluvial sector. To facilitate the study, according to the hydro geological conditions, the study area was divided into: Northwest covered karst area ①, dam bare karst area ②, eastern bare karst area ③, Shaizhudong spring Karst area ④, southern buried karst areas⑤, Tangwangling syncline bedrock core coverage area ⑥, bedrock coverage area in the north of the old Longshan⑦ and the loose deposits piedmont alluvial plains ⑧ (Figure 1), where ①, ② and ④ belong to the Shaizhudong spring domain system, ⑤ belong to the Zhougong Temple - Longyan Temple spring domain system.

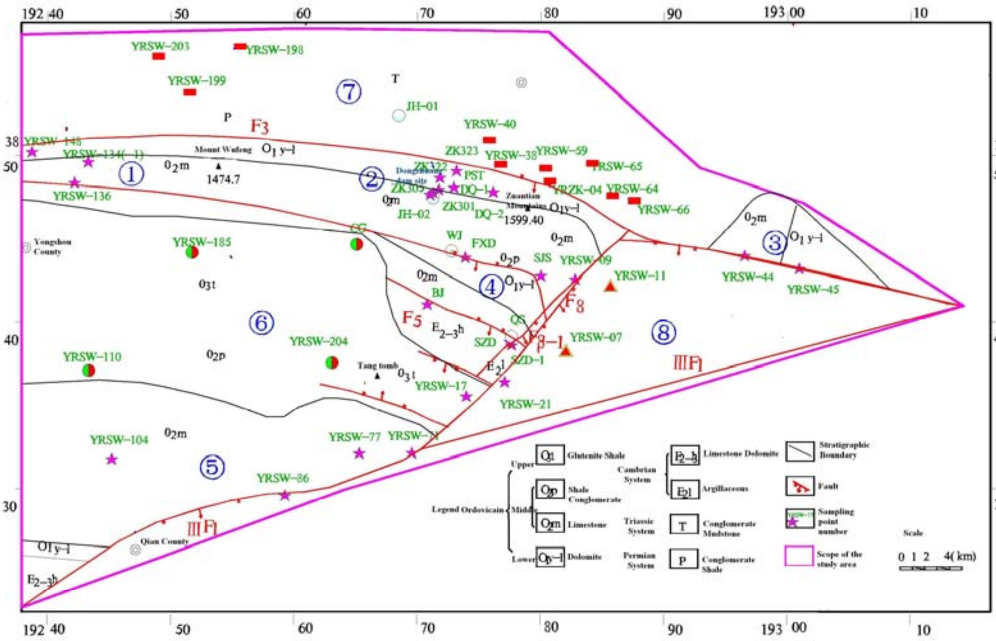

Figure1. Study area and sampling point location

III. SAMPLING AND TESTING

Samples covered the entire study area, including 63 groups water chemistry samples, including temperature, pH, conductivity, anions, cations and minors, and they were checked by the Henan Institute of Geological Environment Monitoring Experiment Test Center. Isotope samples include: δ D, $\delta^{18}O$ each (60 groups), $\delta^{3}H$ (27 groups), $^{87}Sr/^{86}Sr$ (5 groups rock samples and 47 groups water samples). Water samples are harvested by low-density polyethylene bottles, without going through a special pre-treatment. Where ^{2}H, ^{18}O and ^{3}H are tested by the institute of Water Environment of the Chinese Academy of Geological Sciences using MAT253 mass spectrometer; $^{87}Sr/^{86}Sr$ are tested by the State Key Laboratory of Continental Dynamics of the Northwestern University using Nu Plasma multi-collector plasma mass spectrometer, the entire process using BHVO-2, BCR-2, AGV-2 and Nod-A-1 standard materials are used in the entire process to respectively monitor the instruments and the analysis process, the whole process of sample preparation were done in the ultra-clean laboratory.

IV. HYDRO GEOCHEMICAL CHARACTERISTICS OF THE KARST

Chemical characteristics of karst groundwater in the study area vary larger (Table 1), in order to understand more clearly the karst groundwater chemical evolution of the study area , the water chemistry Piper diagram (Figure2) and fingerprinting (Figure3) of the all karst water samples in the study area were drawn, and press the hydro geochemical characteristics can be divided into dam bare karst area A, northwestern covered karst B, Shaizhudong springs karst area C, Southern (Qianxian County –the West Fuping fracture and Zhangjiashan fracture) buried karst D, Eastern (Kou Town – Guanshan Mountain fracture) bare karst area E.

TABLE1. KARST GROUNDWATER CHEMICAL CHARACTERISTICS IN THE STUDY AREA

Number	Sampling location	**Content(mg/L)**							
		K^+	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	TDS
1	Gun County	0.82	60.8	30.26	19.8	11.34	12.01	310.59	310.5
2	Yujiagong County	1.13	44.57	27.66	24.42	5.67	6.24	289.84	281.54
3	Zhaijiashan	0.59	19.21	47.9	18.35	5.67	6.24	263	249.34
4	Exposed limestone	4.02	123.7	79.09	42.16	55.54	112.78	311.29	468
5	The left bank dam(301)	5.04	65.06	140.08	27.34	74.8	215.65	325.24	894.71
6	The right bank dam(305)	2.49	46.17	159.92	15.19	56.01	173.87	369.78	852.78
7	Left bank of the river 322	6.6	138.5	50.9	39.4	68.77	193.73	355.14	894.3
8	Fengxiangdao	1.41	30.46	85.57	16.77	22.33	42.27	307.54	366.52
9	Shaizhudong spring	3.17	55.6	57.51	31.83	39.35	77.81	334.39	455.28
10	Shaizhudong spring UB	3.04	52.95	54.91	25.76	31.55	48.03	331.34	405.2
11	Zhanghong County	1.44	60.35	74.95	24.3	35.45	101.82	325.24	636.81
12	Baijin	1.63	41.34	57.51	24.3	11.34	41.79	316.69	515.95
13	Qianling Nanling County	1.59	61.33	42.89	24.42	16.66	6.24	352.09	351.4
14	Nianzigou	3.51	78.23	59.92	39.37	69.13	120.08	337.44	729.85
15	Suoshan County	2.51	61.51	55.11	27.34	39.35	60.04	331.34	600.13
16	Wangjiaping County	2.74	56.85	52.91	29.04	35.45	24.02	334.39	559.72
17	The east of Gaojia County	4.76	45.62	54.91	27.34	35.45	36.02	331.34	388.54
18	Shanggaopo	2.74	69.55	50.1	30.38	41.12	60.04	337.44	444.41
19	Xuejia	2.43	62.21	80.56	45.81	98.91	120.56	310.59	596.76
20	Zhangjia	7.05	134.4	74.95	40.95	171.58	137.85	340.49	764.09

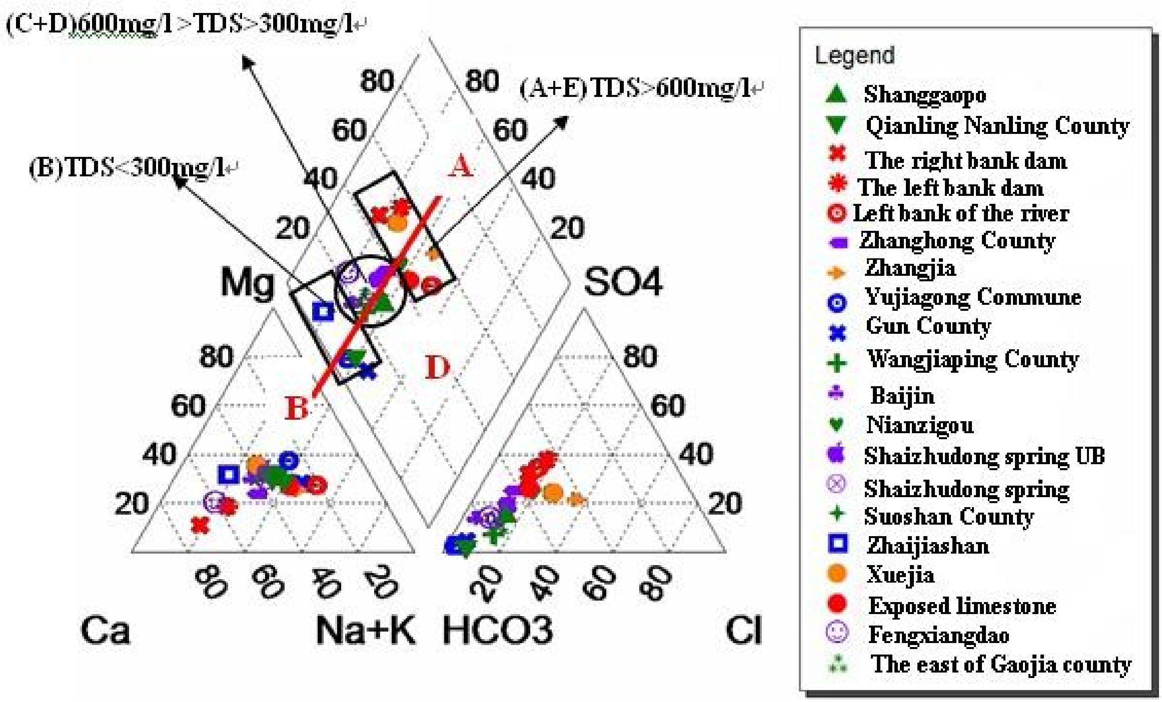

Figure2. Karst water chemical Piper diagram in the study area

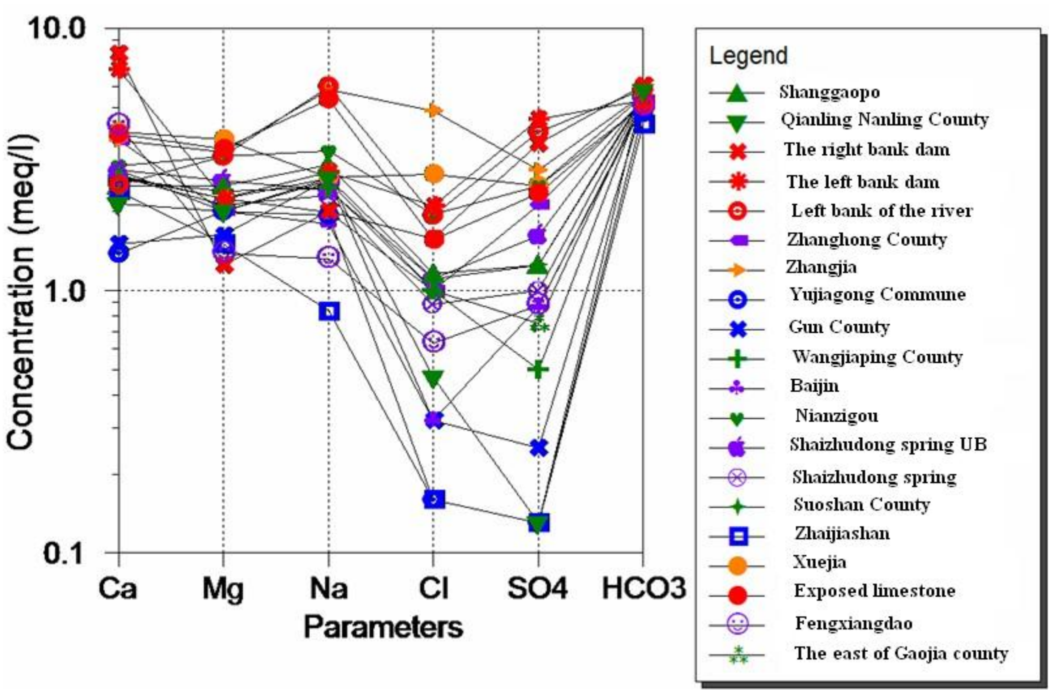

Figure3. Karst worter chemical fingerprint in the study area

Figures 2 and 3 are respectively the Piper diagram of water chemistry and the water chemistry fingerprint of all karst water samples in the study area, hydro geochemical information are provided as follows: ① Karst water samples in the study area have no obvious advantage cations, and HCO_3^- is its advantage anion; ②Each ion concentration of the karst water samples in Northwest coverage area is generally low, TDS <300mg / l, the water type is HCO_3 type , having the obvious characteristics of recharge area; ③Water samples point distribution are concentrated in the

Shaizhudong spring area and the southern buried karst region, water chemistry characteristics are similar to each other, TDS is generally between 300mg / l and 600mg / l and the water type is HCO_3 type, indicating that there is a good hydraulic connection between the two area, it has fast flow characteristic along the Qianxian County - Fu Ping fracture and Zhang Shan fracture, combined with the results of hydro geological investigations, we can speculate that the Southern buried karst water recharges the Shaizhudong spring karst water; ④Sample points of karst water in the Shaizhudong spring are basic located at the dam bare areas, the northwest coverage area and the southern buried karst water point on the connection ADB, and in the fingerprint, Shaizhudong spring area sample fingerprint clip in between the lines of the three samples, indicating that it is mixed results of the three karst water, with multi-source supply characteristics; ⑤ During the Southern buried samples, there are some other sample water chemistry differences because of QianlingNanling county sample points well away from Qianxian County - Fu Ping fault zone. According to previous data suggesting that Nianzigou karst water may be the concentrated discharge of Longyan Temple karst water subsystem, so it also has a certain degree of particularity.

V. ENVIROMENT ISOTOPES

A. *Isotope H and O*

1) δ D and $\delta^{18}O$

Most groundwater recharge from atmospheric precipitation, stable isotope H and O in hydro geological research applications are based mainly in the composition of atmospheric precipitation characteristics. This paper references Shaanxi Institute of Geological Survey results in 2002 (the central region of Weibei, Shaanxi province atmospheric precipitation line equation: $\delta D = 8.103\delta^{18}O + 10.16$), based on H,O isotopes (Table 2), the relationship with Jinghe river and karst water δ D and $\delta^{18}O$ isotope was drawn (Figure 4), something can be seen from the figure as follows.

① Surface water samples was significantly affected by the evaporation effect deviating meteoric line, the performance of non limestone area water samples are roughly concentrated in the line ,of which the slope is less than atmospheric precipitation evaporation line, and δ D ranged between -74.1and-70 (Mean -71.371), $\delta^{18}O$ ranged between -10.1 and -9.43 (mean -9.809), tritium values are concentrated in between 8 and 10TU, deuterium remaining d values > 4 ‰, indicating its close relationship with the modern atmospheric precipitation.

②Because of the scattered distribution of karst water samples, the samples base can be divided into 2 categories. One is the dam site bare karst water, the sample point close to the meteoric water line and is located in the upper right, with high δ D and $\delta^{18}O$, δ D ranged between -67 and -65.4 (mean -65.925), $\delta^{18}O$ ranged between -9.7 and -9.55 (mean -9.65), tritium values are more in between 10 and 15TU, d values ranged between 6 and 10 ‰, indicating its close relation with the modern atmospheric precipitation and the water cycle conditions were better. The other is northwestern covered and southern buried karst water, the samples deviate from atmospheric precipitation lines, with moderate δ D and $\delta^{18}O$, δ D ranged between -72 and -69 (mean -70.525), $\delta^{18}O$ ranged between 10.4 and -9.4 (mean -9.71), tritium values (except the main spring being 2.7TU) <1TU, d values mainly ranged between 6 and 8 ‰, indicating that the contact with the modern atmospheric precipitation is relatively poor, longer residence time. In addition, karst water samples are on the brink of the dam site river and Jinghuiqushou river sample point, indicating that hydraulic connection is existed between the two areas.

Figure 5 is the karst water contour map of deuterium remaining in the study area, which provides some hydro geological information. Regional karst water deuterium remaining value are descending trend from the northwest and southwest to the southeast, which indicates the runoff paths of the karst water. In addition, deuterium remaining value are almost equal from the Shaizhudong spring to Gao Village, indicating that the hydraulic connection between the west of Zhangjiashan fracture and Qianxian County - Fuping fracture is strong, with fast flow characteristics and this is coincide to inferred results of the water chemistry.

2)Recharge elevation and mean residence time calculation

Stable isotope values of the atmospheric precipitation are lowering with the terrain elevation height increase which is called height effect, using "isotope height gradient K" to qualify. And it's calculated by local atmospheric precipitation δ isotopic values and their elevation, which according to groundwater and atmospheric precipitation δ isotope values and related parameters (K) to ascertain the height of the groundwater recharge. δ D isotope calculate the Shaizhudong Spring recharge elevation is 708m, above the Dongzhuang dam site elevation 550m and dam karst water level 550-570m. Combined with analysis of the regional karst groundwater level contour, its supply may come from northwestern five Mountain area, south of Longyan Temple spring area and the northeast of Zhuantianling, and it's mainly recharged from the northwest and the south deep karst water, which is consistent with the above conclusion.

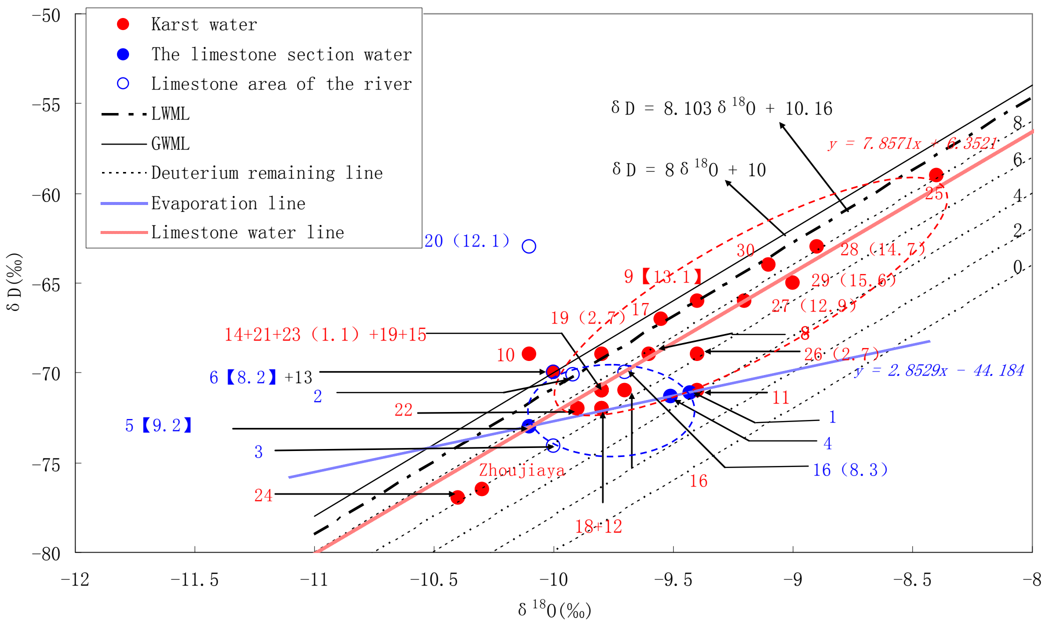

Figure 4. Jinghe river and karst water δ D and $\delta^{18}O$ isotope diagram (The figures of parentheses represents the corresponding sample values of tritium TU,broken circle on behalf of sampling sites dotted area)

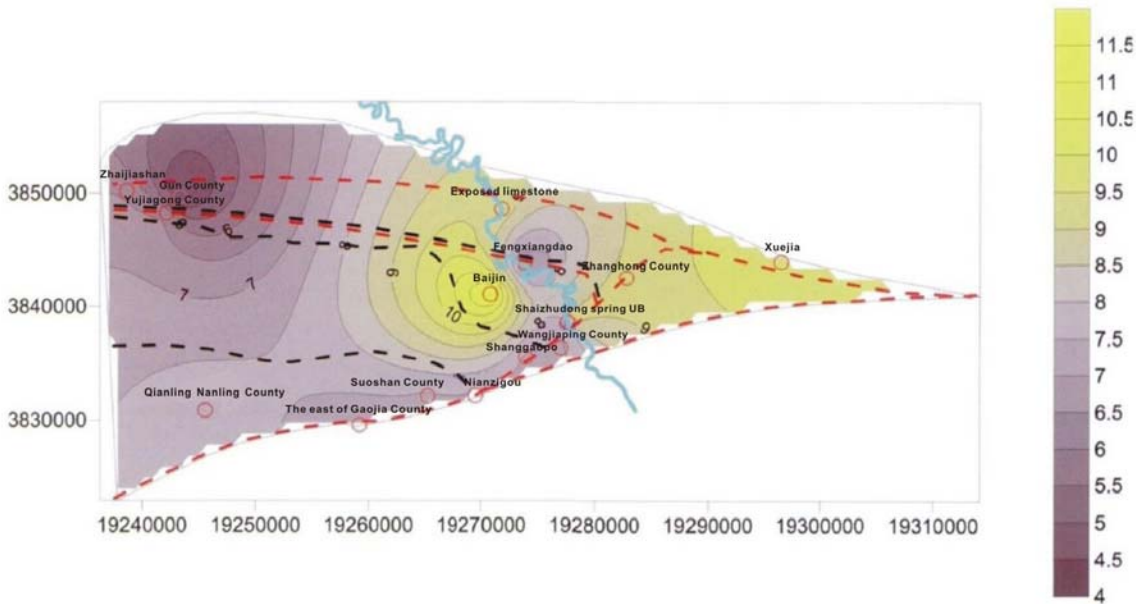

Figure5. Karst water deuterium remaining contour map in the study area

Environment isotope tritium as the radioactive isotope of hydrogen, its half-life is 12.43 years, tritium content of groundwater is only influenced by the impact of decay law under normal circumstances, without the exchange with the rock medium, so all modern recycled water are subject to the tritium labeled, thus being the ideal tracer for studying modern human origins groundwater seepage. Depending on the hydro geological conditions in the study area, this paper chosen index piston (EPM) model to calculate the average residence time of the Shaizhudong spring karst water, which is 62-64 years.

TABLE2. CHARACTERISTICS OF HYDROGEN AND OXYGEN ISOTOPIC DATA TABLE IN THE STUDY AREA

No	Sampling Location	δD (‰)	$\delta^{18}O$ (‰)	^3H (TU)	No	Sampling Location	δD (‰)	$\delta^{18}O$ (‰)	^3H (TU)
1	Jinghe river water upstream	-71.1	-9.43		17	Exposed limestone	-67	-9.55	19.4
2	Jinghe river of dam site	-70.1	-9.92		18	Zhaijiashan	-72	-9.8	
3	Jinghe river in downstream of the dam	-74.1	-10		19	Shaizhudong spring	-69	-9.8	2.7
4	Jinghe river downstream nearby plains	-71.3	-9.51		20	Wenjing reservoir	-63	-10.1	12.1
5	Qianshanju dam site	-73	-10.1	9.2	21	Wangjiaping County	-71	-9.8	
6	Dongzhuang dam site	-70	-10	8.2	22	The east of Gaojia County	-72	-9.9	
7	Head of jinghui canal	-70	-9.7	8.3	23	Shanggaopo	-71	-9.8	1.1
8	Qianling Nanling County	-69	-9.6	3.1	24	Zhangjia	-77	-10.4	
9	Zhanghong County	-66	-9.4		25	Fault crushed zone	-59	-8.40	
10	Baijin	-69	-10.1		26	Jinghe riverbed	-69	-9.40	14.7
11	Gun County	-71	-9.4		27	Zuoan hillside	-66	-9.20	12.9
12	Yujiagong County	-72	-9.8		28	The right bank dam	-63	-8.90	14.7
13	Xuejia	-70	-10		29	The left bank dam	-65	-9	14.7 15.6
14	Nianzigou	-71	-9.8		30	Xujia mountains	-64	-9.1	14.7 15.6
15	Suoshan County	-71	-9.8		31	Jianling primary school	-73	-9.5	
16	Fengxiangdao	-71	-9.7						

3)Mixing ratio calculation

When mixing samples are mainly from three different ways, you can use the relations between δ D and $\delta^{18}O$ to select the corresponding sample point as the extreme end-components, then establishing the ternary hybrid model to calculate the mixing ratio of the share of mixed sample at each end. The formula as follows:

$$\begin{cases} \delta^{18}O_X = F_A\,\delta^{18}O_A + F_B\,\delta^{18}O_B + F_C\,\delta^{18}O_C \\ \delta D_X = F_A\,\delta D_A + F_B\,\delta D_B + F_C\,\delta D_C \\ F_A + F_B + F_C = 1 \end{cases}$$

Where A, B, C=the end-component of three different sources,

X=mixed samples points,

FA, FB, FC=the proportion of the Corresponding end-component in mixed samples,

In order to use isotope δ D and $\delta^{18}O$ to calculate karst water mixing ratio in different directions,we respectively put the dam karst water C, northwestern karst water A and Longyan Temple B karst water as three end-component. Shaizhudong spring(under the bridge) and Bellows spring samples are plotted in the triangle, indicating that the two kind karst water are main due to the dam karst water, northwestern karst water and Longyan Temple karst water mixed. The results of isotope δ D and $\delta^{18}O$ ternary mixture show that: For the Shaizhudong spring points under the bridge, proportion of C, A, B was 2.4%、19.7% and 77.9%, suggesting that the each karst water point of the Shaizhudong spring and south , especially along the Qianxian county – Fuping fracture to western part of Zhangjiashan fracture zone contact closely, there is a quick guide water channel. While percent of dam karst water is only 2.4%, and the significant difference between the two values of tritium shows that their hydraulic connection is weak.

B. Stable Isotope Sr

1)Characteristic of isotope Sr

Stable isotope Sr does not occur on fractionation phenomenon in the natural, but being responsive to the water-rock interaction. Therefore, it is a reliable tool to evaluate groundwater mixing, track the origin of water and estimate water - rock interaction. Combined with Sr content and $^{87}Sr/^{86}Sr$ ratios (Table 3), it can effectively identify the sources of groundwater Sr and the water-rock interaction in the aqueous medium and it is of great significance to understand how groundwater form and circulate.

TABLE 3. THE Sr^{2+} CONTENT WITH $^{87}Sr/^{86}Sr$ VALUE TABLE IN THE STUDY AREA

No	Sampling Location	Sr/mg/L	$^{87}Sr/^{86}Sr$	No	Sampling Location	Sr/mg/L	$^{87}Sr/^{86}Sr$
1	Dongzhuang dam site	2.24	0.710751	24	The left bank dam	0.70	0.710929
2	Yangyu country	0.85	0.711687	25	Shanggaopo country	0.82	0.713507
3	Xiasunjia	0.50	0.711352	26	Luzigou	0.51	0.711009
4	Xuejia	2.55	0.710363	27	The right bank dam	0.35	0.710885
5	Wenjing reservoir	2.36	0.710908	28	Xujiashan spring	0.28	0.710339
6	Qianjia country	0.85	0.710106	29	Zhanghong country	0.65	0.710445
7	Gun country	0.62	0.710972	30	Nianzigou well	0.87	0.714114
8	Sidihe country	1.72	0.710673	31	Zuoan hillside	0.34	0.710427
9	Zhaijiashan	0.54	0.711236	32	Jianling primary school	0.89	0.712017
10	QianlingNanling county	0.65	0.712883	33	Ximiaocun well	1.20	0.711393
11	Fengxiangdao spring	0.86	0.706992	34	Jinghe riverbed	1.46	0.710774
12	Dapai country	0.83	0.710948	35	Jinghuiqushou river	1.85	0.710855
13	Wangjiaping country	0.93	0.715071	36	Suoshancun well	0.67	0.714452
14	Qianshanju dam site	2.55	0.710856	37	Chiganzhen well	0.82	0.711021
15	Zhongyuche country	0.59	0.711319	38	Chuanzicun well	1.10	0.710641
16	Liyuan country	0.57	0.711290	39	Baliqiao	0.34	0.711133
17	Majiaya	5.30	0.714670	40	Chigan-Bailicun well	0.87	0.710707
18	Zonggou country	0.43	0.711381	41	Gaojiacundong well	0.84	0.716200
19	Yujiagong country	0.75	0.711311	42	Zhangjia well	1.46	0.715440
20	Yuche country	0.58	0.711372	43	Liangdian	0.92	0.710869
21	Spring	0.49	0.711562	44	atmospheric precipitation 1	0.25	0.709985
22	Shaizhudong spring	0.81	0.714049	45	atmospheric precipitation 2	0.25	0.710870
23	Shaizhudong spring UB	0.82	0.713042				

Figure 6 shows the relationship between Sr content and $^{87}Sr/^{86}Sr$ ratio in different water bodies in the area. Atmospheric precipitation samples ranged from 0.709985 to 0.710870, higher than the rainfall $^{87}Sr/^{86}Sr$ ratios (0.7092) in the study area, reflecting the characters of arid and semi-arid regions of atmospheric precipitation of strontium isotopes; Jinghe River water samples $^{87}Sr/^{86}Sr$ ranged from 0.710751 to 0.710908 , closer to the river $^{87}Sr/^{86}Sr$ ratios (0.7110), indicating a significant role in evaporation; karst water samples point $^{87}Sr/^{86}Sr$ ratios are relatively high, ranging between 0.709992 to 0.716200,and mainly showing the buried karst water characters. Specifically, the dam site karst water shows characteristics of recharge area, within low Sr content and low $^{87}Sr/^{86}Sr$ ratios, and it is same with results of δD and$\delta^{18}O$; Shaizhudong spring samples are clearly contained in the southern karst water sampling point distribution area, and it's close to the Sr content and $^{87}Sr/^{86}Sr$ ratios of the southern samples, suggesting that the hydraulic connection between the southern karst region is very close, especially along the Qianxian county - Fuping fracture and the western part of Zhangjiashan fracture and the groundwater flow through them. Therefore, Shaizhudong spring areas are not concentration discharge point of the Shaizhudong spring field in the traditional sense.

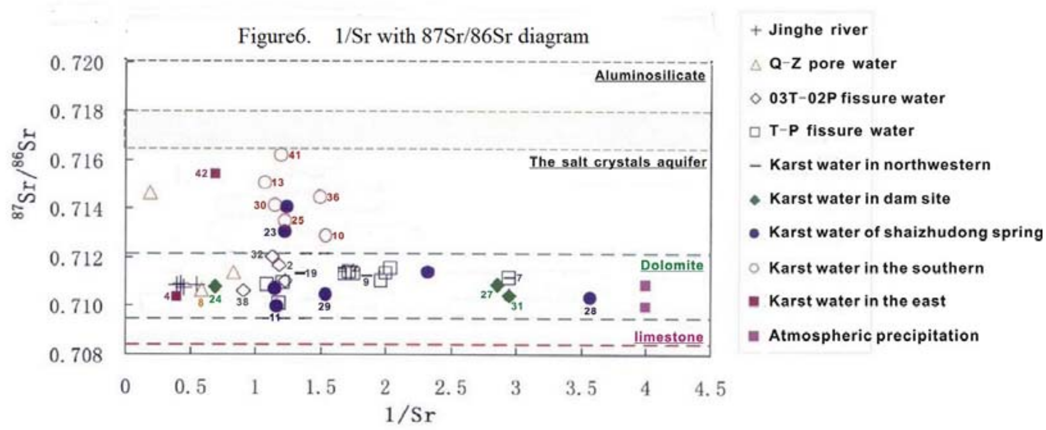

Figure6. 1/Sr with 87Sr/86Sr diagram

2) Sr Mixing ratio calculation

Sr isotopes have been widely used to determine the mixing ratio of mixed samples. $^{87}Sr/^{86}Sr$ ratios and Sr concentrations are all affected during the mixing process. In the chart of ($^{87}Sr/^{86}Sr$) M and 1/SrM, the curve of the two mixing solution with different Sr concentrations and $^{87}Sr/^{86}Sr$ ratios is a straight line. The mixed equations may be derived from the values of the relevant parameters of a series of aqueous medium made up during the two solutions mixed. Mixing ratio can be calculated by the following equation:

$$(^{87}Sr/^{86}Sr)_M=a/Sr_M+b \quad (3)$$

For the binary mixture, the mixing curve equation is unique if two kinds of end-component $^{87}Sr/^{86}Sr$ ratios (($^{87}Sr/^{86}Sr)_M$) and Sr concentrations (Sr_M) are known. The $^{87}Sr/^{86}Sr$ ratio of the mixed samples can be expressed as:

$$(^{87}Sr/^{86}Sr)_M = X(^{87}Sr/^{86}Sr)_A+(1-X)\ (^{87}Sr/^{86}Sr)_B \quad (4)$$

Where X=the proportion of A end-component,

1-X= the proportion of B end-component,

$(^{87}Sr/^{86}Sr)_A$=the $^{87}Sr/^{86}Sr$ proportion of A component,

$(^{87}Sr/^{86}Sr)_B$=the $^{87}Sr/^{86}Sr$ proportion of B component,

$(^{87}Sr/^{86}Sr)_M$=the $^{87}Sr/^{86}Sr$ proportion of the mixing samples.

When the object of study is believed to have three kinds of mixed origin, their samples should be distributed in three end-enclosed areas of a triangle, and it requires to use the ternary hybrid model to calculate the relevant mixing ratio. The ternary mixing ratio calculation is based on the basis of binary mixtures because of that there is a linear relationship between each other in the mixed samples. That is to say the ternary mixed results are determined by the twice linear superposition of binary mixtures. Figure 7 shows that the mean of Shaizhudong spring samples is located in a triangle bounded by the three end- component of atmospheric precipitation, river and karst water extreme points, which can be regarded as the final mixed solution of C (atmospheric precipitation) and D which is the mixture of A (water) and B (karst water extreme points).

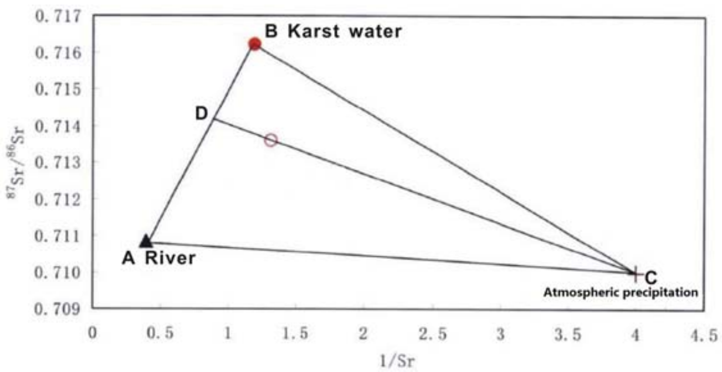

Figure7. Shaizhudong springs mean(mixed) 87Sr/86Sr with 1/Sr diagram

Assume that the mixing ratio of A and B is X and Y, respectively, the mixing ratio of C is 1-X-Y, then the mixed line equation of A and B, C and D were respectively as follows:

$$(^{87}Sr/^{86}Sr)_M=0.0067/Sr_M+0.7082$$

$$a=0.0067,\ b=0.7082 \quad (5)$$

$$(^{87}Sr/^{86}Sr)_M = -0.0013/Sr_M + 0.7151$$

$$a=-0.0013,\ b=0.7151 \quad (6)$$

From simultaneous equation (5), (6), we can obtain the $^{87}Sr/^{86}Sr$ ratios of D and Sr concentrations, and D point falls on the mixing line AB. The D ratio of A and B share was 42% and 58% by the method of proportional calculation of binary mixtures. The mean of Shaizhudong spring sample is a mixture of C and D, and we can calculate the proportion of C and D is 11% and 89%, respectively. And eventually it comes to the result that the mixing ratio of A, B, C, is 37%, 52% and 11%, respectively.

VI. CONCLUSION

(1) For the recharge of Shaizhudong spring area, proportion of atmospheric precipitation, river water and karst water were 11%, 37% and 52%, and the recharge is given priority to karst groundwater outside of the Shaizhudong spring area. And proportion of Southwest, northwest and the dam site area karst water were 77.9%, 19.7% and 2.4%, respectively, Within in the southwestern region (along Qianxian County – Fuping fracture and Zhangjiashan fracture direction) karst groundwater recharging mainly, in the northwest karst groundwater recharging second, and karst water from the dam site area recharging weak.

(2) Shaizhudong spring karst water received from different geological history and different times of supply, both the ancient water for thousands of years, hundreds of years and the modern water for a few decades or a few years. The average residence time of the multi- supply is 62 to 64 years.

(3) The recharge altitude of Shaizhudong spring is 708m, confirming that it is recharged from the three directions of southwest, northwest and the dam site area, and it is mainly recharged from the southwest (along Qianxian County – Fuping fracture and Zhangjiashan fracture direction) karst groundwater.

(4) Overall, runoff direction of the regional karst water is from northwest to southeast by the impact of topography and tectonic characteristics. On local terms, it is obviously controlled by the major fracture, and the three main runoff path in particular as follows: ① Zhajiashan → Dam Area → Shaizhudong spring (northwest to southeast), ② Yujiagong → Hundred wells →Shaizhudong spring (northwest to southeast), ③ East of Gaojiacun →Suoshancun →Nianzigou → Shanggaopo→ Wangjiaping→ Shaizhudong spring (southwest to northeast).

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