

**Supplementary material:**

**Figure S1:** Na-K-Mg ternary diagram of geothermal waters in the Beijing area. All geothermal waters plot in the immature water field or partially equilibrated or mixed water.

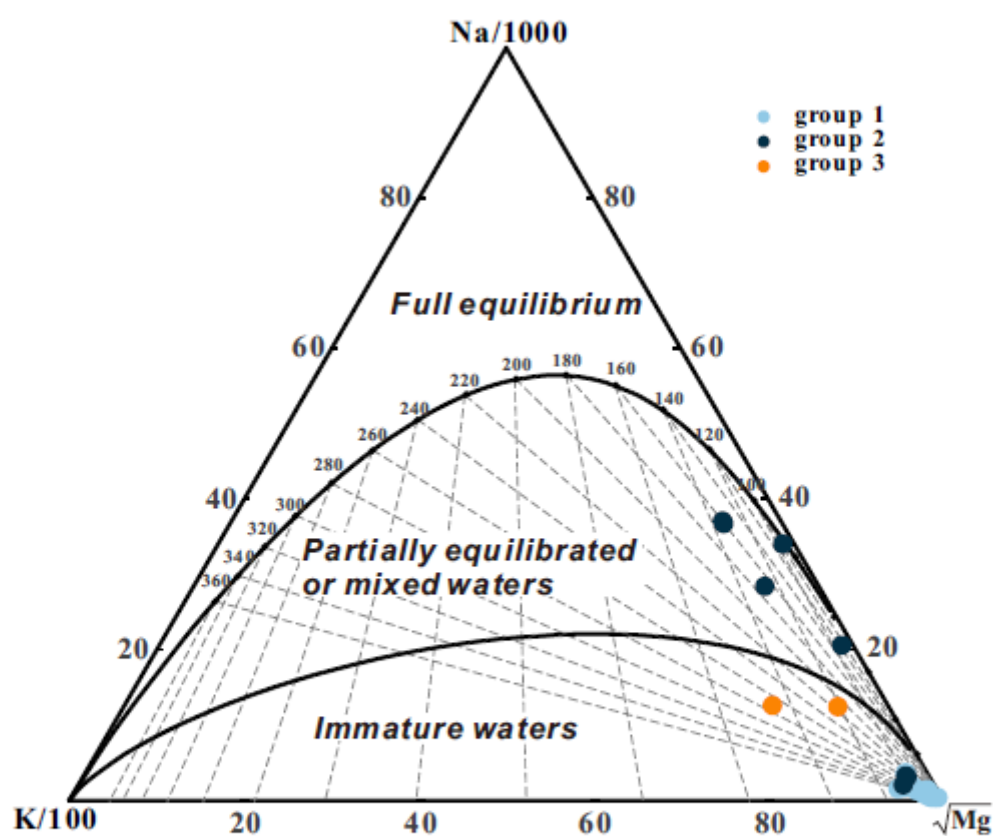


Fig. S1

**Figure S2:** Relationship between the volume of recharge water ( $10^4\text{m}^3$ ) and the number of earthquakes ( $>M_L=1$ ) in the Beijing area. The positive correlation between recharge water and earthquake frequency indicates that the injection of geothermal recharge water is the cause of earthquakes in the Beijing area. Earthquake data from the China Earthquake Administration. Geothermal recharge data from Beijing Hydrogeological Engineering Team.

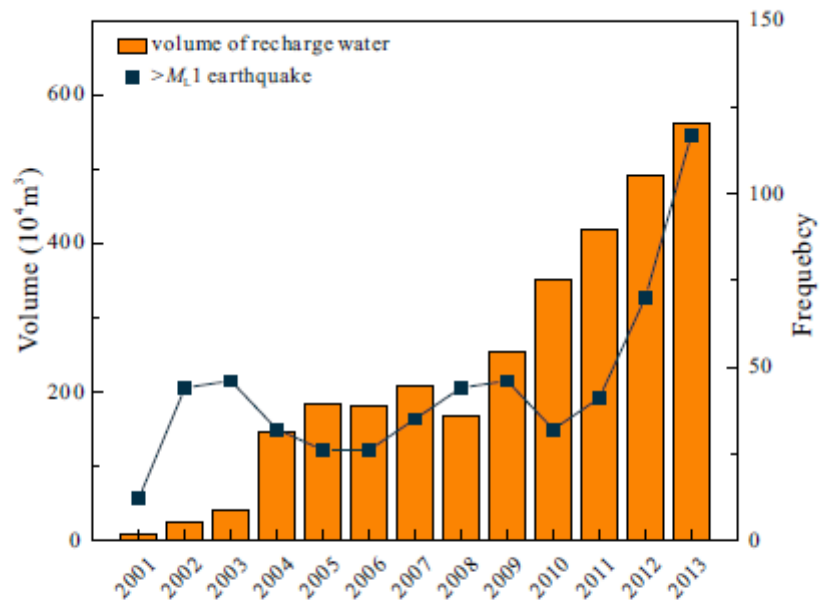


Fig. S2

**Table S1:** Physical properties, hydrogeochemistry and isotopic compositions of geothermal waters from Beijing area.

group	No.	Type	TDS	pH	T	Depth	Li <sup>+</sup>	Na <sup>+</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Ca <sup>2+</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	CO <sub>3</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	SiO <sub>2</sub>	Rb	Sr	Ni	δD	δ <sup>18</sup> O
					(°C)	(m)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(μg/L)	(μg/L)	(μg/L)	(‰)	(‰)
1	4	Well	-	-	64	3000	0.10	18.20	5.54	18.90	47.70	9.52	28.60	-	219.00	49.00	7.25	319	2.81	-81.8	-11.7
1	5	Well	-	9.10	40	2500	0.15	67.60	11.80	22.50	53.30	29.20	120.00	-	244.00	-	13.00	1413	3.90	-75.6	-10.2
1	6	Well	346	7.50	68	2500	0.17	76.10	13.00	15.00	39.10	24.20	67.00	-	262.00	55.80	19.30	854	2.85	-72	-10.1
1	7	Hot spring	-	-	55	-	0.13	73.40	11.50	16.70	36.80	14.70	59.50	-	272.00	-	14.90	617	2.73	-73.4	-10.4
1	8	Hot spring	562	7.50	55	-	0.16	64.30	9.84	12.40	40.30	13.70	82.00	-	211.00	-	13.00	896	2.74	-79.2	-12
1	9	Well	-	-	64	2500	0.14	30.00	6.61	13.10	39.60	9.22	46.10	-	198.00	-	13.10	390	2.06	-78.1	-10.8
1	10	Well	401	7.00	66	2980	0.14	59.30	10.70	20.30	57.50	28.60	119.00	-	229.00	49.00	16.10	2007	2.86	-72.1	-9.6
1	12	Well	346	7.40	40	3300	0.03	66.40	6.03	27.40	40.20	13.70	142.00	-	215.00	-	7.60	2778	1.91	-77.7	-10.9
1	14	Well	301	7.20	69	2700	0.19	55.30	12.30	10.20	46.10	17.10	71.40	-	207.00	59.50	25.80	882	1.92	-78.3	-9.9
1	15	Well	-	-	76	3790	0.18	58.80	9.50	9.41	43.60	25.80	86.80	-	170.00	-	22.10	829	1.77	-77.9	-10.6
1	16	Well	440	7.50	48	1800	0.34	135.00	9.96	13.20	19.20	62.50	53.40	-	276.00	35.50	14.80	604	1.03	-76.8	-11.1
1	21	Well	720	7.60	33	2207	0.27	31.90	8.51	34.10	34.00	4.01	46.00	-	292.00	-	12.30	528	3.97	-72.8	-10.6
1	22	Hot spring	-	-	30	-	0.26	12.20	1.86	21.00	40.50	5.36	23.90	-	219.00	-	2.53	246	2.23	-69.3	-9.8
1	23	Well	-	-	34	3000	0.36	69.60	21.20	20.50	28.30	50.40	67.60	-	207.00	-	12.30	249	2.15	-78.1	-10.8
1	25	Hot spring	-	-	44	-	0.00	137.00	10.10	13.70	19.20	64.80	60.40	-	276.00	-	14.90	596	1.08	-75.8	-11.2
1	26	Hot spring	-	-	13	-	1.05	5.41	1.56	2.32	29.20	2.84	9.90	-	87.70	-	7.72	2620	1.96	-69.2	-9.6
2	1	Well	1191	9.20	44	200	0.20	147.00	2.68	0.05	7.57	46.30	177.00	20.30	17.70	-	24.80	447	0.51	-90.6	-12.5
2	2	Well	-	-	58	2000	0.21	145.00	2.70	0.05	7.48	46.30	173.00	19.80	20.60	-	26.00	448	0.83	-92.4	-12.6
2	3	Well	968	8.20	35	533	0.09	106.00	9.51	11.40	37.80	22.10	77.70	-	303.00	-	12.00	811	3.61	-89.3	-12.4
2	13	Hot spring	-	-	65	-	0.17	84.50	14.50	14.80	46.90	51.50	48.70	-	281.00	-	37.20	814	1.91	-84.3	-11.3
2	18	Well	-	9.03	42	800	0.09	132.00	0.83	0.25	3.16	21.20	29.70	51.60	170.00	32.50	-	-	-	-	-
2	19	Well	-	7.92	38	1200	0.03	105.00	0.43	0.04	5.27	17.40	134.00	-	79.30	31.80	-	-	-	-	-
2	20	Well	386	6.90	55	2800	0.02	114.00	9.34	11.00	32.30	32.10	77.30	-	303.00	-	17.30	1007	2.16	-91.7	-12.6
2	24	Hot spring	-	-	40	-	0.03	151.00	3.32	0.12	8.52	43.70	189.00	20.90	15.20	-	27.00	-	0.90	-90.3	-12.2
3	11	Well	-	-	60	2200	0.66	434.00	20.10	8.12	22.20	325.00	5.53	-	648.00	-	36.90	581	0.53	-79.6	-10.2
3	17	Well	1740	8.00	92	3588	1.58	494.00	52.00	8.52	23.60	225.00	1.05	-	1022.00	82.20	110.00	-	1.42	-	-

Note: “-” represents below detection limit or undetected.

**Table S2:** Temperature results obtained with empirical chemical geothermometers (values in °C) and depths (m) of origin for the Beijing area geothermal waters.

Group	No.	T(°C)	Li	Na	SiO <sub>2</sub>	Na	Li	Geothermometers				Circulation depth(m)	Note
			(mg/L)	(mg/L)	(mg/L)	(mmol/L)	(mmol/L)	Na-Li	SiO <sub>2</sub>				
								a	b	c	d		
1	4	64	0.10	18.20	49.00	0.79	0.01	194	101	109	71	5265	
1	5	40	0.15	67.60		2.94	0.02	124				3291	
1	6	68	0.17	76.10	55.80	3.31	0.02	122	107	115	77	3207	
1	7	55	0.13	73.40		3.19	0.02	105				2748	
1	8	55	0.16	64.30		2.80	0.02	130				3455	
1	9	64	0.14	30.00		1.30	0.02	181				4915	
1	10	66	0.14	59.30	49.00	2.58	0.02	126	101	109	71	3333	
1	12	40	0.03	66.40		2.89	0.00	38				826	Delete
1	14	69	0.19	55.30	59.50	2.40	0.03	153	110	117	81	4111	
1	15	76	0.18	58.80		2.56	0.03	144				3841	
1	16	48	0.34	135.0	35.50	5.87	0.05	132	86	96	56	3510	
1	21	33	0.27	31.90		1.39	0.04	240				6597	
1	22	30	0.26	12.20		0.53	0.04	373				10398	Delete
1	23	34	0.36	69.60		3.03	0.05	189				5136	
1	25	44	0.00	137.0		5.96	0.00	-				-	
1	26	13	1.05	5.41		0.24	0.15	1436				40753	Delete
2	1	44	0.20	147.0		6.39	0.03	92				2363	
2	2	58	0.21	145.0		6.30	0.03	96				2467	
2	3	35	0.09	106.0		4.61	0.01	65				1592	
2	13	65	0.17	84.50		3.67	0.02	115				3019	
2	18	42	0.09	132.0	32.50	5.74	0.01	57	83	93	52	2393	
2	19	38	0.03	105.0	31.80	4.57	0.00	20	82	92	51	2370	
2	20	55	0.02	114.0		4.96	0.00	7				-70	Delete
2	24	40	0.03	151.0		6.57	0.00	5				-119	Delete
3	11	60	0.66	434.0		18.87	0.09	99				2555	
3	17	92	1.58	494.0	82.20	21.48	0.23	149	127	132	99	3994	

Note: The temperature of No. 26 water is 13 °C (Table 1), which is close to the temperature of the stratosphere in the Beijing area (13.5-14 °C) (Wang et al., 2017). However, the temperature estimated by the Na-Li geothermometer is 1436 °C, which has obvious errors and should be discarded. Similarly, the No. 22 water geothermometer should also be discarded.

a Na-Li,  $T = 1000 / [\log(\text{Na}/\text{Li}) + 0.389] - 273.15$  (Fouillac and Michard, 1981)

b Quartz, no steam loss,  $T = 1309 / [5.19 - \log(\text{SiO}_2)] - 273.15$  (Fournier, 1977)

c Quartz, maximum steam loss,  $T = 1522 / [5.75 - \log(\text{SiO}_2)] - 273.15$  (Fournier, 1977)

d Chalcedony,  $T = 1032 / [4.78 - \log(\text{SiO}_2)] - 273.15$  (Fournier, 1977)

The annual average temperature in Beijing is 10 °C, the geothermal gradient is ~3.50 °C/100 m (Wang et al., 2017), and the thickness of the constant temperature zone is 20 m.

**Table S3:** Geothermal gases chemistry compositions of Xiji geothermal well (No.17) from the Beijing area.

Date	He (ppm)	H <sub>2</sub> (ppm)	CO <sub>2</sub> (%)	CH <sub>4</sub> (%)	N <sub>2</sub> (%)	O <sub>2</sub> (%)	References
2022/1/19	5993	330	2.60	27.06	69.18	0.04	Yang et al. (2022)
2022/4/10	6049	7	3.12	29.08	67.19	0	
2022/7/12	6047	7	3.84	27.74	67.81	0	
2022/12/20	6050	6	3.76	25.00	68.10	0	This study
2023/2/3	5238	17426	1.60	31.40	66.28	0	
2023/4/24	4243	208	0	35.00	64.50	0	

**Table S4:** Earthquake records on February 12, 2023, in the Beijing area. Data from:  
<https://news.ceic.ac.cn>.

year	month	day	hour	minute	second	Latitude(N)	Longitude(E)	deep(km)	magnitude( $M_L$ )
2023	2	12	16	42	23	39.77	115.63	14	3.4
2023	2	12	16	43	18	39.77	115.63	5	1.4
2023	2	12	16	43	38	39.77	115.63	5	2.4
2023	2	12	16	46	0	39.77	115.62	12	0.7
2023	2	12	17	8	7	39.75	115.62	10	1.6
2023	2	12	17	27	0	39.77	115.63	13	1.7
2023	2	12	17	49	4	39.77	115.62	10	0.3
2023	2	12	18	12	25	39.75	115.60	1	0.1
2023	2	12	18	31	6	39.77	115.63	11	1.8
2023	2	12	20	46	27	39.77	115.63	11	1.1
2023	2	12	20	51	34	39.75	115.62	7	0.3

## References

51. Fouillac, C., and G. Michard (1981), Sodium/lithium ratio in water applied to geothermometry of geothermal reservoirs, *Geothermics*, 10(1), 55-70, doi:[https://doi.org/10.1016/0375-6505\(81\)90025-0](https://doi.org/10.1016/0375-6505(81)90025-0).
52. Fournier, R. O. (1977), Chemical geothermometers and mixing models for geothermal systems, *Geothermics*, 5(1), 41-50, doi:[https://doi.org/10.1016/0375-6505\(77\)90007-4](https://doi.org/10.1016/0375-6505(77)90007-4).
42. Wang, G., W. Zhang, W. Lin, F. Liu, X. Zhu, Y. Liu, and J. Li (2017), Research on formation mode and development potential of geothermal resources in Beijing-Tianjin-Hebei region, *Geology in China*, 44(6), 1074-1085 (in Chinese with English abstract), doi:10.12029/gc20170603.
40. Yang, M. B., et al. (2022), Geochemical characteristics of geothermal and hot spring gases in Beijing and Zhangjiakou Bohai fault zone, *Frontiers in Earth Science*, 10, doi:10.3389/feart.2022.933066.