Supplementary material for

Multi-stable isotope constraints on the sources and evolution of potash forming fluids in the Mahai Basin, Qinghai-Tibetan Plateau

Zhendong Wang [1], Qiugui Wang[2,*], Zengping Ning [3], Weigang Su[4], Ying Ma[1], Yujun Ma[5], Enzong Xiao[2], and Xiaohang Lu [6,*]

[1] Qinghai Geological Survey,Technology Innovation Center for Exploration and Exploitation of Strategic Mineral Resources in Plateau Desert Region，Ministry of Natural Resources，Xining，810001，China
[2] Key Laboratory for Water Quality and Conservation of the Pearl River Delta, Ministry of Education; School of Environmental Science and Engineering, Guangzhou University, Guangzhou 510006, China
[3] State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550081, China
[4] Key Laboratory of Green and High-end Utilization of Salt Lake Resources, Qinghai Institute of Salt Lakes, Chinese Academy of Sciences and Qinghai Provincial Key Laboratory of Geology and Environment of Salt Lakes, Xining 810016, China
[5] Key Laboratory of Tibetan Plateau Land Surface Processes and Ecological Conservation, Ministry of Education, Academy of Plateau Science and Sustainability, Qinghai Normal University, Xining 810008, China
[6] State Key Laboratory of Plateau Ecology and Agriculture, Qinghai University, Xining, 810016, China
* Correspondence: wangqiugui@gzhu.edu.cn (Q. W.); luxiaohang6069@gmail.com (X. L.)

Table S1. The hydrogen and oxygen isotope composition in different samples of Mahai Basin.

Sample type	δD (‰)	$\delta^{18}O$ (‰)	Laboratories	Instrument	Reference
Snowmelt water	-58.67	-9.57	PRI-ECO	Picarro L2130-i	Zhu, 2015
Snowmelt water	-58.43	-9.72	PRI-ECO	Picarro L2130-i	Zhu, 2015
Snowmelt water	-60.66	-9.90	PRI-ECO	Picarro L2130-i	Zhu, 2015
Snowmelt water	-67.22	-10.43	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-50.13	-8.59	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-50.85	-8.68	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-52.02	-8.80	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-52.02	-8.53	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-51.15	-8.36	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-56.84	-9.24	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-57.14	-9.41	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-59.55	-9.60	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-62.11	-9.98	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-64.12	-10.06	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-65.30	-10.12	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-67.07	-10.47	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-67.80	-10.82	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-70.51	-9.93	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-80.59	-10.65	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-78.90	-10.58	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-70.11	-10.29	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-69.06	-10.09	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-67.95	-9.94	PRI-ECO	Picarro L2130-i	Zhu, 2015
Yuka River	-68.00	-8.70	IHEG	Picarro L2130-i	Zheng et al., 2017
Yuka River	-67.00	-8.70	IHEG	Picarro L2130-i	Zheng et al., 2017
Yuka River	-51.00	-4.80	IHEG	Picarro L2130-i	Zheng et al., 2017
Yuka River	-51.00	-4.70	IHEG	Picarro L2130-i	Zheng et al., 2017
Yuka River	-51.00	-4.70	IHEG	Picarro L2130-i	Zheng et al., 2017
Yuka River	-53.70	-6.50	BIGNI	MAT-253	Zhao et al., 2024
Yuka River	-55.10	-6.10	BIGNI	MAT 253	Zhao et al., 2024
Yuka River	-67.00	-9.88	BIGNI	MAT 253	Zhang et al., 2025
Yuka River	-68.40	-9.87	BIGNI	MAT 253	Zhang et al., 2025
Yuka River	-70.42	-9.89	BIGNI	MAT 253	Zhang et al., 2025
Yuka River	-71.71	-9.89	BIGNI	MAT 253	Zhang et al., 2025
Alluvial fan region	-68.70	-7.30	BIGNI	MAT 253	Zhao et al., 2024
Alluvial fan region	-72.70	-8.00	BIGNI	MAT 253	Zhao et al., 2024
Groundwater	-64.16	-11.12	PRI-ECO	Picarro L2130-i	Zhu, 2015
Groundwater	-71.62	-10.38	PRI-ECO	Picarro L2130-i	Zhu, 2015
Groundwater	-75.65	-10.87	PRI-ECO	Picarro L2130-i	Zhu, 2015

Groundwater	-80.20	-11.26	PRI-ECO	Picarro L2130-i	Zhu, 2015
Groundwater	-78.88	-10.90	PRI-ECO	Picarro L2130-i	Zhu, 2015
Groundwater	-79.31	-9.97	PRI-ECO	Picarro L2130-i	Zhu, 2015
Groundwater	-68.00	-8.50	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-71.00	-8.40	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-69.00	-8.10	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-70.00	-8.40	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-66.00	-7.80	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-68.00	-8.70	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-63.00	-6.60	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-63.00	-6.40	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-65.00	-6.60	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-51.00	-5.10	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-51.00	-5.30	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-44.00	-3.70	IHEG	Picarro L2130-i	Zheng et al., 2017
Groundwater	-51.00	-4.90	IHEG	Picarro L2130-i	Zheng et al., 2017
NLZN Lake	-50.00	-4.30	BIGNI	MAT 253	Zhao et al., 2024
NLZN Lake	-59.00	-5.10	BIGNI	MAT 253	Zhao et al., 2024
NLZN Lake	-49.30	-1.30	BIGNI	MAT 253	Zhao et al., 2024
NLZN Lake	-61.50	-1.30	BIGNI	MAT 253	Zhao et al., 2024
DZMH Lake	-55.30	-5.10	BIGNI	MAT 253	Zhao et al., 2024
DZMH Lake	-47.90	-4.90	BIGNI	MAT 253	Zhao et al., 2024
Intercrystalline brine	-27.40	2.30	BIGNI	MAT 253	Feng et al., 2024
Intercrystalline brine	-24.10	6.50	BIGNI	MAT 253	Feng et al., 2024
Intercrystalline brine	-38.60	-1.30	BIGNI	MAT 253	Feng et al., 2024
Intercrystalline brine	-11.60	5.60	BIGNI	MAT 253	Feng et al., 2024
Intercrystalline brine	-28.50	2.50	BIGNI	MAT 253	Feng et al., 2024
Intercrystalline brine	-41.20	-2.00	BIGNI	MAT 253	Feng et al., 2024
Intercrystalline brine	-29.80	1.50	BIGNI	MAT 253	Feng et al., 2024
Intercrystalline brine	-23.90	3.00	BIGNI	MAT 253	Feng et al., 2024
Intercrystalline brine	-28.60	2.40	BIGNI	MAT 253	Feng et al., 2024
Intercrystalline brine	-32.10	-2.70	BIGNI	MAT 253	Song et al., 2024
Intercrystalline brine	-27.20	-2.50	BIGNI	MAT 253	Song et al., 2024
Intercrystalline brine	-32.00	-2.40	BIGNI	MAT 253	Song et al., 2024
Intercrystalline brine	-27.00	-1.80	BIGNI	MAT 253	Song et al., 2024
Intercrystalline brine	-34.50	-2.65	BIGNI	MAT 253	Song et al., 2024
Intercrystalline brine	-29.90	-2.30	BIGNI	MAT 253	Song et al., 2024
Intercrystalline brine	-32.50	-1.90	BIGNI	MAT 253	Song et al., 2024
Intercrystalline brine	-32.40	-2.10	BIGNI	MAT 253	Song et al., 2024
Intercrystalline brine	-22.60	-2.27	BIGNI	MAT 253	Song et al., 2024
Intercrystalline brine	-30.20	-2.00	BIGNI	MAT 253	Song et al., 2024

Intercrystalline brine	-29.60	-1.60	BIGNI	MAT 253	Song et al., 2024
Intercrystalline brine	-30.20	3.20	BIGNI	MAT 253	Zhang et al., 2025
Intercrystalline brine	-33.30	-0.60	BIGNI	MAT 253	Zhang et al., 2025
Intercrystalline brine	-32.40	0.30	BIGNI	MAT 253	Zhang et al., 2025
Intercrystalline brine	-36.80	-1.50	BIGNI	MAT 253	Zhang et al., 2025
Intercrystalline brine	-46.50	3.00	BIGNI	MAT 253	Zhang et al., 2025
Intercrystalline brine	-38.40	0.10	BIGNI	MAT 253	Zhang et al., 2025
Intercrystalline brine	-43.20	-0.80	BIGNI	MAT 253	Zhang et al., 2025
Intercrystalline brine	-35.40	2.20	BIGNI	MAT 253	Zhang et al., 2025
Intercrystalline brine	-22.80	2.90	BIGNI	MAT 253	Zhang et al., 2025
Intercrystalline brine	-35.80	3.80	BIGNI	MAT 253	Zhang et al., 2025
Intercrystalline brine	-40.47	-1.99	BIGNI	MAT 253	Feng et al., 2026
Intercrystalline brine	-38.32	-1.27	BIGNI	MAT 253	Feng et al., 2026
Intercrystalline brine	-30.52	1.54	BIGNI	MAT 253	Feng et al., 2026
Intercrystalline brine	-29.09	2.52	BIGNI	MAT 253	Feng et al., 2026
Intercrystalline brine	-26.93	2.48	BIGNI	MAT 253	Feng et al., 2026
Intercrystalline brine	-24.51	2.98	BIGNI	MAT 253	Feng et al., 2026
Intercrystalline brine	-5.69	3.24	BIGNI	MAT 253	Feng et al., 2026
Intercrystalline brine	-11.87	5.72	BIGNI	MAT 253	Feng et al., 2026
Intercrystalline brine	-23.80	6.64	BIGNI	MAT 253	Feng et al., 2026
Confined brine	-26.32	2.09	OLIG	MAT 253	Yang et al., 2024
Confined brine	-27.67	1.48	OLIG	MAT 253	Yang et al., 2024
Confined brine	-24.72	2.33	OLIG	MAT 253	Yang et al., 2024
Confined brine	-22.79	2.43	OLIG	MAT 253	Yang et al., 2024
Confined brine	-20.96	1.89	OLIG	MAT 253	Yang et al., 2024
Confined brine	-21.68	1.51	OLIG	MAT 253	Yang et al., 2024
Confined brine	-19.51	1.99	OLIG	MAT 253	Yang et al., 2024
Confined brine	-17.82	1.60	OLIG	MAT 253	Yang et al., 2024
Water solution mining block	-42.50	-0.50	BIGNI	MAT 253	Zhao et al., 2024
Water solution mining block	-31.10	-0.30	BIGNI	MAT 253	Zhao et al., 2024
Water solution mining block	-43.40	-1.20	BIGNI	MAT 253	Zhao et al., 2024
Water solution mining block	-17.90	-1.10	BIGNI	MAT 253	Zhao et al., 2024
Deep confined brine	-17.90	-1.10	BIGNI	MAT 253	Zhao et al., 2024
Deep confined brine	-22.30	-1.30	BIGNI	MAT 253	Zhao et al., 2024
Deep confined brine	-21.70	-0.90	BIGNI	MAT 253	Zhao et al., 2024
Deep confined brine	-21.30	-0.80	BIGNI	MAT 253	Zhao et al., 2024
Deep confined brine	-18.90	-1.30	BIGNI	MAT 253	Zhao et al., 2024
Deep confined brine	-27.10	-1.30	BIGNI	MAT 253	Zhao et al., 2024
Deep confined brine	-37.40	-1.00	BIGNI	MAT 253	Zhao et al., 2024
Deep confined brine	-43.50	-2.30	BIGNI	MAT 253	Zhao et al., 2024
Deep confined brine	-23.00	-0.20	BIGNI	MAT 253	Zhao et al., 2024

Deep confined brine	-36.65	-2.66	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-38.85	0.72	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-38.66	2.40	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-5.05	3.09	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-0.30	2.72	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-0.30	2.50	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-5.05	2.34	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-3.11	2.58	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	0.20	2.10	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-2.73	2.02	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-1.82	1.79	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-6.54	1.88	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-8.48	1.68	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-10.27	1.55	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-3.72	1.47	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-5.55	1.48	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-5.24	1.13	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-6.35	1.23	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-7.95	0.87	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-8.55	1.16	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-10.69	1.23	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-11.48	1.31	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-10.80	0.72	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-10.08	0.59	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-5.74	0.61	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-4.33	0.34	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-6.65	0.20	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-3.30	0.05	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-1.21	-0.10	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-1.90	0.23	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-2.43	0.34	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	1.11	0.37	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	2.75	0.52	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-4.14	-0.53	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-8.55	-0.56	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-5.13	-0.76	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-5.93	-1.05	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-3.30	-0.90	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-7.45	-1.20	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-10.80	-1.19	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-8.06	-1.39	NGL	MAT 253	Zhang et al., 2024

Deep confined brine	-6.54	-1.60	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-10.38	-1.57	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-12.40	-1.64	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-11.18	-1.81	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-9.16	-1.82	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-9.89	-1.91	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-13.20	-2.08	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-17.84	-1.71	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-13.31	-2.47	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-9.47	-2.51	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-13.43	-2.94	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-10.57	-3.02	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-12.51	-3.16	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-10.38	-3.26	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-25.41	-3.57	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-13.31	-2.66	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-21.80	-4.62	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-21.19	-5.29	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-26.02	-5.39	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-30.96	-5.20	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-26.93	-6.08	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-28.83	-6.90	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-24.61	-7.69	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-33.10	-7.78	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-35.72	-7.66	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-36.82	-7.24	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-44.28	-6.25	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-51.97	-8.00	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-36.71	-8.93	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-34.62	-8.31	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-30.17	-8.68	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-14.41	-3.24	NGL	MAT 253	Zhang et al., 2024
Deep confined brine	-7.38	-0.95	NGL	MAT 253	Zhang et al., 2024
Sand-gravel brine	-17.22	2.87	BIGNI	MAT 253	Fan et al., 2024
Sand-gravel brine	-21.67	2.57	BIGNI	MAT 253	Fan et al., 2024
Sand-gravel brine	-24.40	2.50	BIGNI	MAT 253	Fan et al., 2024
Sand-gravel brine	-43.19	6.03	BIGNI	MAT 253	Fan et al., 2024
Sand-gravel brine	-39.46	-0.08	BIGNI	MAT 253	Fan et al., 2024
Sand-gravel brine	-29.47	0.20	BIGNI	MAT 253	Fan et al., 2024
Sand-gravel brine	-27.44	-0.98	BIGNI	MAT 253	Fan et al., 2024
Sand-gravel brine	-25.21	-0.32	BIGNI	MAT 253	Fan et al., 2024

Sand-gravel brine	-23.06	-0.07	BIGNI	MAT 253	Fan et al., 2024
Sand-gravel brine	-56.74	-5.65	BIGNI	MAT 253	Fan et al., 2024
Sand-gravel brine	-36.49	-1.97	NIER	MAT 253	Chen et al., 2026
Sand-gravel brine	-31.79	-0.81	NIER	MAT 253	Chen et al., 2026
Sand-gravel brine	-63.08	-6.77	NIER	MAT 253	Chen et al., 2026
Sand-gravel brine	-32.41	-0.99	NIER	MAT 253	Chen et al., 2026
Sand-gravel brine	-63.59	-7.06	NIER	MAT 253	Chen et al., 2026

The standards material was V-SMOW.

PRI-ECO: Beijing Pri-eco Science & Technology Co., Ltd.

IHEG: Institute of Hydrogeology and Environmental Geology, Chinese Academy of Geological Sciences.

BIGNI: Geological Analysis and Testing Research Center of the Beijing Institute of Geology of the Nuclear Industry.

OLIG: Open Laboratory of Isotope Geochemistry of the China Geological Survey.

NGL: National Geological Laboratory, China.

NIER: Northwest Institute of Eco-environment and Resources, Chinese Academy of Sciences.

Table S2. The potash, lithium, and lithium isotope composition in different samples of Mahai Basin.

Sample type	K (g/L)	Li (ppm)	δ7Li	Laboratories	Test instrument	Reference
Yuka River	1.82	0.10	7.40	USTC	MC-ICP-MS	Song et al., 2024
Yuka River	1.86	0.12	7.00	USTC	MC-ICP-MS	Song et al., 2024
Yuka River	2.15	0.13	7.70	USTC	MC-ICP-MS	Song et al., 2024
Yuka River	2.61	0.13	8.00	USTC	MC-ICP-MS	Song et al., 2024
Yuka River	57.39	0.81	21.00	USTC	MC-ICP-MS	Song et al., 2024
Yuka River	68.93	0.46	22.20	USTC	MC-ICP-MS	Song et al., 2024
Yuka River	67.98	0.33	27.60	USTC	MC-ICP-MS	Song et al., 2024
Yuka River	0	0.13	6.96	BIGNI	MC-ICP-MS	Zhao et al., 2024
Yuka River	0	0.10	7.79	BIGNI	MC-ICP-MS	Zhao et al., 2024
Alluvial fan region	0.03	0.10	25.81	BIGNI	MC-ICP-MS	Zhao et al., 2024
Alluvial fan region	0.05	0.08	23.06	BIGNI	MC-ICP-MS	Zhao et al., 2024
NLZN Lake	1.2	2.06	29.96	BIGNI	MC-ICP-MS	Zhao et al., 2024
NLZN Lake	1.23	2.14	30.18	BIGNI	MC-ICP-MS	Zhao et al., 2024
NLZN Lake	0.04	0.84	13.16	BIGNI	MC-ICP-MS	Zhao et al., 2024
NLZN Lake	2.05	1.68	31.16	BIGNI	MC-ICP-MS	Zhao et al., 2024
NLZN Lake	2.2	1.72	29.88	BIGNI	MC-ICP-MS	Zhao et al., 2024
NLZN Lake	0.05	0.82	11.41	BIGNI	MC-ICP-MS	Zhao et al., 2024
DZMH Lake	0.01	0.14	10.13	BIGNI	MC-ICP-MS	Zhao et al., 2024
DZMH Lake	0.01	0.14	12.36	BIGNI	MC-ICP-MS	Zhao et al., 2024
Intercrystalline brine	2.59	13.66	26.40	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	0.38	2.42	29.90	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	1.65	5.73	28.30	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	9.87	13.99	30.50	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	1.39	5.87	26.70	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	0.40	2.64	29.90	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	1.74	5.55	27.90	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	4.91	17.37	27.90	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	1.93	6.28	29.60	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	1.12	4.55	26.40	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	2.23	5.79	30.30	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	3.39	8.21	30.80	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	13.00	24.65	32.20	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	20.54	25.07	32.20	USTC	MC-ICP-MS	Song et al., 2024
Intercrystalline brine	7.38	21.09	31.90	USTC	MC-ICP-MS	Song et al., 2024
Water solution mining block	12.52	18.04	30.31	BIGNI	MC-ICP-MS	Zhao et al., 2024
Water solution mining block	4.13	4.72	30.38	BIGNI	MC-ICP-MS	Zhao et al., 2024
Water solution mining block	18.57	22.94	30.96	BIGNI	MC-ICP-MS	Zhao et al., 2024
Water solution mining block	7.28	27.16	31.60	BIGNI	MC-ICP-MS	Zhao et al., 2024
Deep confined brine	6.40	12.66	31.68	BIGNI	MC-ICP-MS	Zhao et al., 2024

Deep confined brine	6.70	12.84	31.77	BIGNI	MC-ICP-MS	Zhao et al., 2024
Deep confined brine	8.08	15.70	31.41	BIGNI	MC-ICP-MS	Zhao et al., 2024
Deep confined brine	8.29	16.10	31.63	BIGNI	MC-ICP-MS	Zhao et al., 2024
Deep confined brine	5.88	10.36	33.00	BIGNI	MC-ICP-MS	Zhao et al., 2024
Deep confined brine	4.48	8.22	31.84	BIGNI	MC-ICP-MS	Zhao et al., 2024
Deep confined brine	3.00	5.66	31.21	BIGNI	MC-ICP-MS	Zhao et al., 2024
Deep confined brine	7.73	15.30	30.89	BIGNI	MC-ICP-MS	Zhao et al., 2024
Sand-gravel brine	1.83	2.94	36.67	USTC	MC-ICP-MS	Fan et al., 2024
Sand-gravel brine	1.12	1.45	33.84	USTC	MC-ICP-MS	Fan et al., 2024
Sand-gravel brine	3.65	3.35	42.39	USTC	MC-ICP-MS	Fan et al., 2024
Sand-gravel brine	2.27	1.16	43.82	USTC	MC-ICP-MS	Fan et al., 2024
Sand-gravel brine	3.37	4.59	39.54	USTC	MC-ICP-MS	Fan et al., 2024
Sand-gravel brine	2.77	2.05	40.17	USTC	MC-ICP-MS	Fan et al., 2024
Sand-gravel brine	2.59	1.74	39.14	USTC	MC-ICP-MS	Fan et al., 2024
Sand-gravel brine	2.60	2.00	43.13	USTC	MC-ICP-MS	Fan et al., 2024
Sand-gravel brine	2.76	3.57	42.24	USTC	MC-ICP-MS	Fan et al., 2024
Sand-gravel brine	2.92	3.66	41.19	USTC	MC-ICP-MS	Fan et al., 2024
Sand-gravel brine	1.77	3.24	31.85	NIER	MC-ICP-MS	Chen et al., 2026
Sand-gravel brine	2.84	4.30	39.95	NIER	MC-ICP-MS	Chen et al., 2026
Sand-gravel brine	0.92	2.55	37.90	NIER	MC-ICP-MS	Chen et al., 2026
Sand-gravel brine	2.28	4.45	44.50	NIER	MC-ICP-MS	Chen et al., 2026
Sand-gravel brine	0.76	2.45	24.18	NIER	MC-ICP-MS	Chen et al., 2026
Ca-Cl water	1.72	3.89	30.5	USTC	MC-ICP-MS	Song et al., 2024
Ca-Cl water	2.68	7.43	31.4	USTC	MC-ICP-MS	Song et al., 2024
Ca-Cl water	1.34	4.44	29.3	USTC	MC-ICP-MS	Song et al., 2024
Ca-Cl water	2.15	6.47	31	USTC	MC-ICP-MS	Song et al., 2024
Ca-Cl water	2.47	5.28	32.8	USTC	MC-ICP-MS	Song et al., 2024
Ca-Cl water	3.28	31.52	36.00	USTC	MC-ICP-MS	Song et al., 2024
Claystone	-	72.20	14.09	QSLI	MC-ICP-MS	Ma et al., 2024
Claystone	-	63.50	9.20	QSLI	MC-ICP-MS	Ma et al., 2024
Claystone	-	79.80	10.50	QSLI	MC-ICP-MS	Ma et al., 2024
Claystone	-	97.10	15.48	QSLI	MC-ICP-MS	Ma et al., 2024
Claystone	-	70.90	9.61	QSLI	MC-ICP-MS	Ma et al., 2024
Claystone	-	49.30	6.68	QSLI	MC-ICP-MS	Ma et al., 2024

The standards material was NIST standard L-SVEC.

-: No data.

USTC: School of Earth and Space Science, University of Science and Technology of China.

BIGNI: Geological Analysis and Testing Research Center of the Beijing Institute of Geology of the Nuclear Industry.

NIER: Northwest Institute of Eco-environment and Resources, Chinese Academy of Sciences.

QSLI: Qinghai Salt Lake Institute of the Chinese Academy of Sciences.

Table S3. The strontium and strontium isotope composition in different samples of Mahai Basin.

Sample type	Sr (mg/L)	$^{87}Sr/^{86}Sr$	Laboratories	Test instrument	Reference
Yuka River	0.27	0.71182	OLIG	MAT261	Yang et al., 2024
Yuka River	0.83	0.71150	OLIG	MAT261	Yang et al., 2024
Yuka River	0.53	0.71160	NIST SRM 987	TIMS	Zhao et al., 2024
Yuka River	0.47	0.71150	NIST SRM 987	TIMS	Zhao et al., 2024
Alluvial fan region	4.74	0.71170	NIST SRM 987	TIMS	Zhao et al., 2024
Alluvial fan region	4.68	0.71170	NIST SRM 987	TIMS	Zhao et al., 2024
NLZN Lake	78.70	0.71160	NIST SRM 987	TIMS	Zhao et al., 2024
NLZN Lake	93.40	0.71170	NIST SRM 987	TIMS	Zhao et al., 2024
NLZN Lake	11.30	0.71220	NIST SRM 987	TIMS	Zhao et al., 2024
NLZN Lake	94.00	0.71160	NIST SRM 987	TIMS	Zhao et al., 2024
NLZN Lake	78.20	0.71160	NIST SRM 987	TIMS	Zhao et al., 2024
NLZN Lake	11.60	0.71220	NIST SRM 987	TIMS	Zhao et al., 2024
DZMH Lake	1.50	0.71170	NIST SRM 987	TIMS	Zhao et al., 2024
DZMH Lake	1.56	0.71180	NIST SRM 987	TIMS	Zhao et al., 2024
BLMH Lake	75.93	0.71169	NIST SRM 987	ISOPROBE-T	Ma et al., 2024
BLMH Lake	97.76	0.71169	NIST SRM 987	ISOPROBE-T	Ma et al., 2024
Water solution mining block	7.68	0.71170	NIST SRM 987	TIMS	Zhao et al., 2024
Water solution mining block	8.66	0.71140	NIST SRM 987	TIMS	Zhao et al., 2024
Water solution mining block	3.28	0.71160	NIST SRM 987	TIMS	Zhao et al., 2024
Water solution mining block	6.54	0.71110	NIST SRM 987	TIMS	Zhao et al., 2024
Intercrystalline brine	27.33	0.71145	NIST SRM 987	ISOPROBE-T	Ma et al., 2024
Intercrystalline brine	12.31	0.71145	NIST SRM 987	ISOPROBE-T	Ma et al., 2024
Intercrystalline brine	12.60	0.71170	NIST SRM 987	ISOPROBE-T	Feng et al., 2024
Intercrystalline brine	13.75	0.71117	NIST SRM 987	ISOPROBE-T	Feng et al., 2024
Intercrystalline brine	14.75	0.71166	NIST SRM 987	ISOPROBE-T	Feng et al., 2024
Intercrystalline brine	14.20	0.71171	NIST SRM 987	ISOPROBE-T	Feng et al., 2024
Intercrystalline brine	14.50	0.71173	NIST SRM 987	ISOPROBE-T	Feng et al., 2024
Intercrystalline brine	18.50	0.71164	NIST SRM 987	ISOPROBE-T	Feng et al., 2024
Intercrystalline brine	33.00	0.71166	NIST SRM 987	ISOPROBE-T	Feng et al., 2024
Intercrystalline brine	36.75	0.71176	NIST SRM 987	ISOPROBE-T	Feng et al., 2024
Intercrystalline brine	74.50	0.71170	NIST SRM 987	ISOPROBE-T	Feng et al., 2024
Intercrystalline brine	79.50	0.71165	NIST SRM 987	ISOPROBE-T	Feng et al., 2024
Confined brine	24.53	0.71149	OLIG	MAT261	Yang et al., 2024
Confined brine	24.37	0.71143	OLIG	MAT261	Yang et al., 2024
Confined brine	15.19	0.71147	OLIG	MAT261	Yang et al., 2024
Confined brine	14.85	0.71152	OLIG	MAT261	Yang et al., 2024
Confined brine	10.64	0.71146	OLIG	MAT261	Yang et al., 2024
Confined brine	13.46	0.71129	OLIG	MAT261	Yang et al., 2024
Deep confined brine	6.08	0.71140	NIST SRM 987	TIMS	Zhao et al., 2024

Deep confined brine	9.12	0.71140	NIST SRM 987	TIMS	Zhao et al., 2024
Deep confined brine	9.42	0.71140	NIST SRM 987	TIMS	Zhao et al., 2024
Deep confined brine	8.60	0.71140	NIST SRM 987	TIMS	Zhao et al., 2024
Deep confined brine	8.34	0.71140	NIST SRM 987	TIMS	Zhao et al., 2024
Deep confined brine	9.36	0.71140	NIST SRM 987	TIMS	Zhao et al., 2024
Deep confined brine	9.38	0.71140	NIST SRM 987	TIMS	Zhao et al., 2024
Deep confined brine	8.60	0.71140	NIST SRM 987	TIMS	Zhao et al., 2024

The standards material was NIST SRM 987.

OLIG: Open Laboratory of Isotope Geochemistry of the China Geological Survey.

BIGNI: Geological Analysis and Testing Research Center of the Beijing Institute of Geology of the Nuclear Industry.

Table S4. The boron isotope composition in different samples of Mahai Basin.

Sample type	$\delta^{11}B$ (‰)	Laboratories	Test instrument	Reference
Yuka River	-5.71	QSLI	TIMS	Xiang et al., 2024
Yuka Spring	-11.72	QSLI	TIMS	Xiang et al., 2024
NLZN Lake	23.70	QSLI	TIMS	Xiao et al., 1999
NLZN Lake	24.50	QSLI	TIMS	Xiao et al., 1999
DZMH Lake	-4.00	QSLI	TIMS	Xiao et al., 1999
BLMH Lake	31.40	QSLI	TIMS	Xiao et al., 1999

The standards material was NIST SRM 951.

QSLI: Qinghai Salt Lake Institute of the Chinese Academy of Sciences.

Table S5. The sulfur isotope composition in different samples of Mahai Basin.

Sample type	$\delta^{34}S$ (‰)	Laboratories	Test instrument	Reference
Sand-gravel brine	15.49	NIER	MAT253	Chen et al., 2026
Sand-gravel brine	16.57	NIER	MAT253	Chen et al., 2026
Sand-gravel brine	12.02	NIER	MAT253	Chen et al., 2026
Sand-gravel brine	15.56	NIER	MAT253	Chen et al., 2026
Sand-gravel brine	15.25	NIER	MAT253	Chen et al., 2026

The standards material was NBS127.

NIER: Northwest Institute of Eco-environment and Resources, Chinese Academy of Sciences.

Table S6. The chlorine isotope composition in different samples of Mahai Basin.

Sample type	$\delta^{37}Cl$ (‰)	Laboratories	Test instrument	Reference
Sand-gravel brine	-0.26	QSLI	TIMS	Fan et al., 2024
Sand-gravel brine	0.25	QSLI	TIMS	Fan et al., 2024
Sand-gravel brine	-0.16	QSLI	TIMS	Fan et al., 2024
Sand-gravel brine	-0.17	QSLI	TIMS	Fan et al., 2024
Sand-gravel brine	0.18	QSLI	TIMS	Fan et al., 2024
Sand-gravel brine	-0.05	QSLI	TIMS	Fan et al., 2024
Sand-gravel brine	-0.01	QSLI	TIMS	Fan et al., 2024
Sand-gravel brine	-0.17	QSLI	TIMS	Fan et al., 2024
Sand-gravel brine	-0.17	QSLI	TIMS	Fan et al., 2024
Sand-gravel brine	0.16	QSLI	TIMS	Fan et al., 2024
Halite	0.64	QSLI	TIMS	Fan et al., 2024
Halite	0.64	QSLI	TIMS	Fan et al., 2024
Halite	0.44	QSLI	TIMS	Fan et al., 2024
Halite	0.66	QSLI	TIMS	Fan et al., 2024
Halite	0.41	QSLI	TIMS	Fan et al., 2024
Halite	0.70	QSLI	TIMS	Fan et al., 2024
Halite	0.74	QSLI	TIMS	Fan et al., 2024
Halite	0.63	QSLI	TIMS	Fan et al., 2024

The standards material was ISL 355 NaCl.

QSLI: Qinghai Salt Lake Institute of the Chinese Academy of Sciences.