

Research Advances

New Understanding of Lithium Isotopic Evolution from Source to Deposit—A Case Study of the Qaidam Basin

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Objective

The lithium-rich deep brine of the western Qaidam Basin is the successor of the lithium-rich salt lake on the surface. The identification of the lithium source has been a topic of intense interest among geologists. The dissolved lithium in lithium-rich protoliths transported to the basin through surface river water is considered as an important source of lithium in deep brine. The geochemical characteristics of lithium isotopes as they move from source to deposit are key to determining the recharge patterns of lithium in sedimentary basins in surface environment. However, until now, there have been few studies on the evolution of lithium isotopes in the process from source to deposit in the western Qaidam Basin. By studying the lithium traces of different types of sediments in source areas and the lithium isotope geochemistry of sediments and rivers in mountainous areas, alluvial plains, and salt lakes, we here summarize the laws of lithium isotope fractionation in surface processes of the western Qaidam Basin and determine the source of lithium in deep brines.

Methods

Samples were taken from the southern part of the Altun Mountains, the Qimantag Mountain in eastern Kunlun Mountains, and the western Qaidam Basin. The tests included lithium isotopes and lithium concentrations analysis, and completed by the ALS Laboratory.

Results

The lithium isotopic compositions of 12 protolith samples lie between 2.3‰ and 12.7‰ with Li concentrations ranging from 0.4 to 43.0 ppm (Appendix 1), which is located within the average Li isotopic composition of the upper mantle ($\delta^7\text{Li} = 4\text{‰}$

$\pm 2\text{‰}$) (Wan et al., 2017). The lithium isotopic compositions of the river waters lie between 12.5‰ and 14.9‰ with Li concentrations ranging from 0.022 to 0.130 ppm. The lithium isotopic composition of the brine in the Gasikule salt lake is 17.0‰ with Li concentration being 15.9 ppm. The lithium isotopic compositions of the channel and salt lake sediments lie between -5.5‰ and -4.0‰ with Li concentrations ranging from 34.7 ppm to 76.9 ppm. The Li concentrations of the channel and salt lake sediments were significantly higher than in the protoliths, indicating the adsorption of Li^+ by native clay minerals and secondary clay minerals during weathering and erosion of the protoliths. Against a background of low temperature, rapid and low weathering, the loss of Mg^{2+} during the water-rock reaction is small, and the isomorphism of Li^+ and Mg^{2+} increases the value of $\delta^7\text{Li}$ in the river water, thus forming a distinct lithium-isotope fractionation. In the water-rock reaction process, ^7Li is preferentially enriched in the fluid, and ^6Li is preferentially enriched in the residual phase. Therefore, the value of $\delta^7\text{Li}$ decreased in the order of river, protolith and channel deposit (Fig. 1). Among them, the $\delta^7\text{Li}$ of the river water gradually increased from the uplifted area to the alluvial plain area, and the $\delta^7\text{Li}$ of the channel deposit gradually decreased from the headwaters to the downstream areas (Figs. 1a and 1b). In addition, the study found that the $\delta^7\text{Li}$ of the deep brine was 4.7‰, which was between the lithium isotopic compositions of the surface river water (with an average value of 13.8‰), Gasikule salt lake brine (17.0‰) and hot spring water (with an average value of -10.36‰), and cold spring water (with an average value of -5.81‰) (Xiao et al., 1994). This indicates that the lithium in the deep lithium-rich brine of the western Qaidam Basin originates from the dissolution of lithium in the lithium-rich protolith and deep fluid.

Conclusion

There is a distinct lithium-isotope fractionation from

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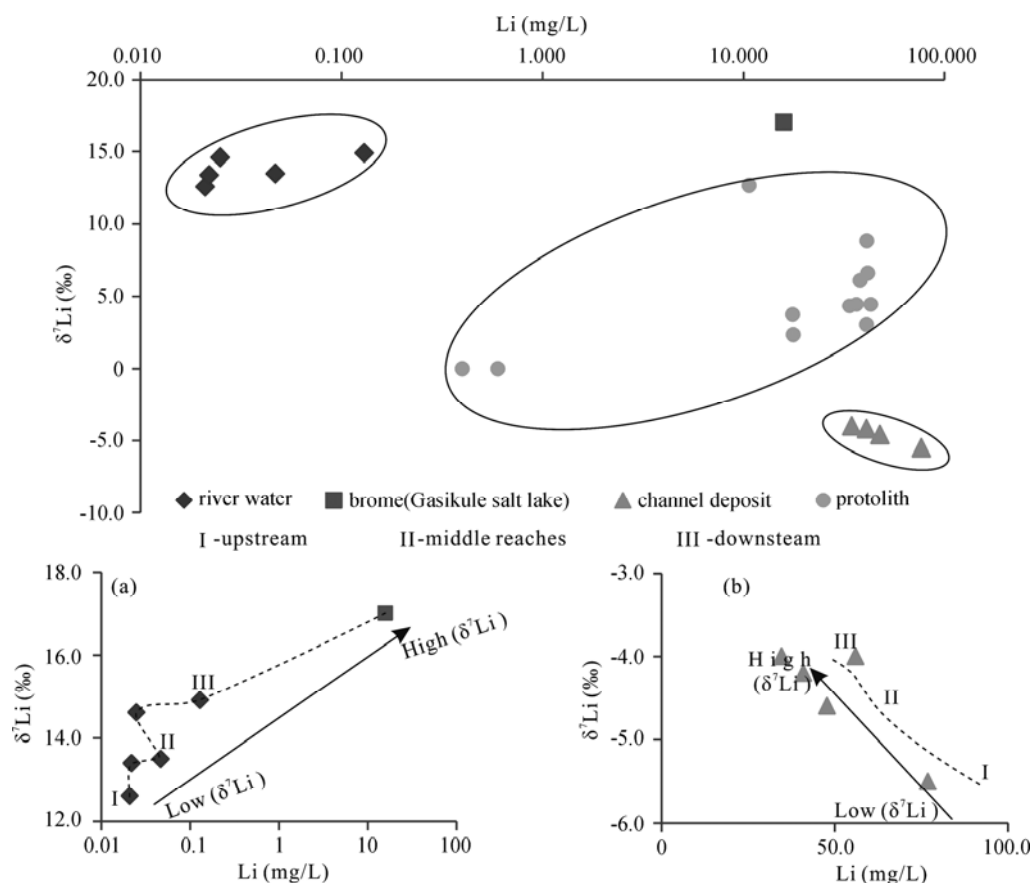


Fig. 1. Lithium isotopes and lithium concentrations in different media in western Qaidam Basin. (a), Lithium isotopes and lithium concentrations in water at different locations between the source and the deposit; (b), Lithium isotopes and lithium concentrations in the channel sediments at different locations between the source and the deposit.

source to deposit in the brine of the western Qaidam Basin, and the value of $\delta^7\text{Li}$ decreased in the order of river, protolith and channel deposit. The lithium in the deep brine originates from the dissolution of lithium in the lithium-rich protolith and deep fluid.

Acknowledgments

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Appendix 1 Data of lithium isotope and Li concentrations in rivers, channel sediments, protoliths and Salt Lake in the western Qaidam Basin

Number	Sample	Li	$\delta^7\text{Li}$ (‰)	Number	Lithology of original rock	Li (ppm)	$\delta^7\text{Li}$ (‰)
R1	River water	0.021 (mg/L)	12.6	Q1	Granite	43.0	4.4
R2	River water	0.022 (mg/L)	13.4	Q3	Granite	41.0	3.0
R3	River water	0.047 (mg/L)	13.5	Q4	Granodiorite	41.6	6.6
R4	River water	0.025 (mg/L)	14.6	Q23	Diorite	17.7	2.3
R5	River water	0.130 (mg/L)	14.9	AL3	Andesite	33.8	4.3
L1	Brine of Gasikule Lake	15.90 (mg/L)	17.0	Q18	Hornfels	17.6	3.7
N16	Deep brine	241.59 (mg/L)	4.7	Q11	Marble	0.4	/
H2	Channel deposit	34.7 (ppm)	-4.0	AL5	Phyllite	41.2	8.8
H3	Channel deposit	41.0 (ppm)	-4.2	AL6	Mica schist	36.5	4.4
H4	Channel deposit	47.8 (ppm)	-4.6	Q14	Limestone	0.6	/
H5	Channel deposit	76.9 (ppm)	-5.5	Q15	Sandstone	38.1	6.1
HL1	Lakebed deposit	48.7 (ppm)	4.4	Q17	Sandstone	10.7	12.7