South to north flow in Lake Bonneville: evidence from carbonate mineralogy and geochemistry

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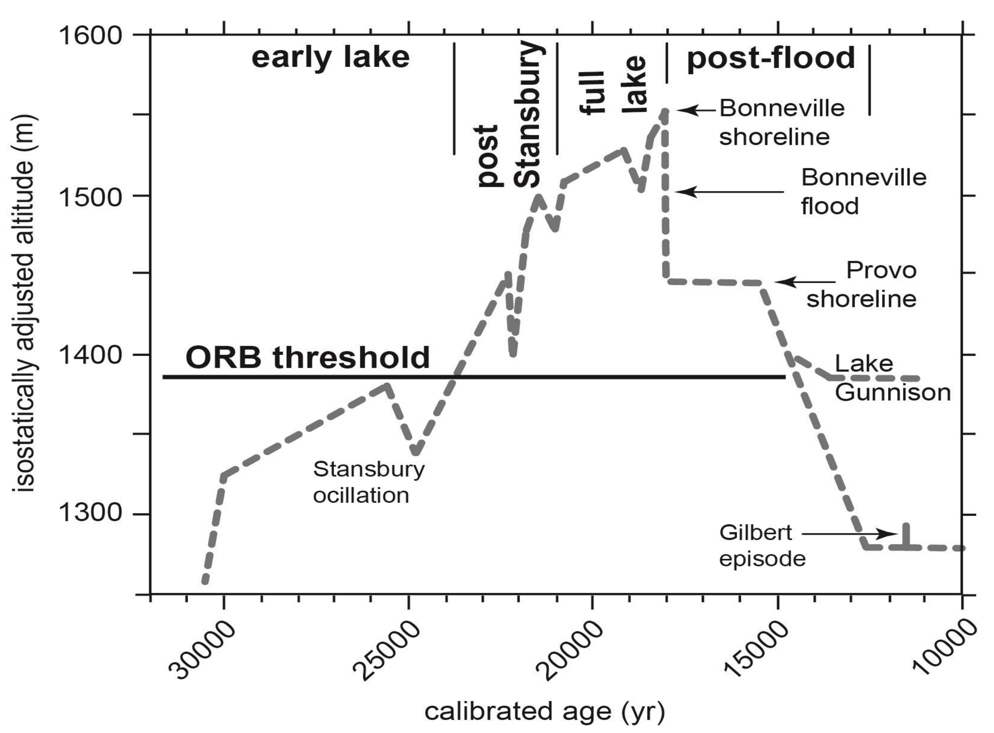
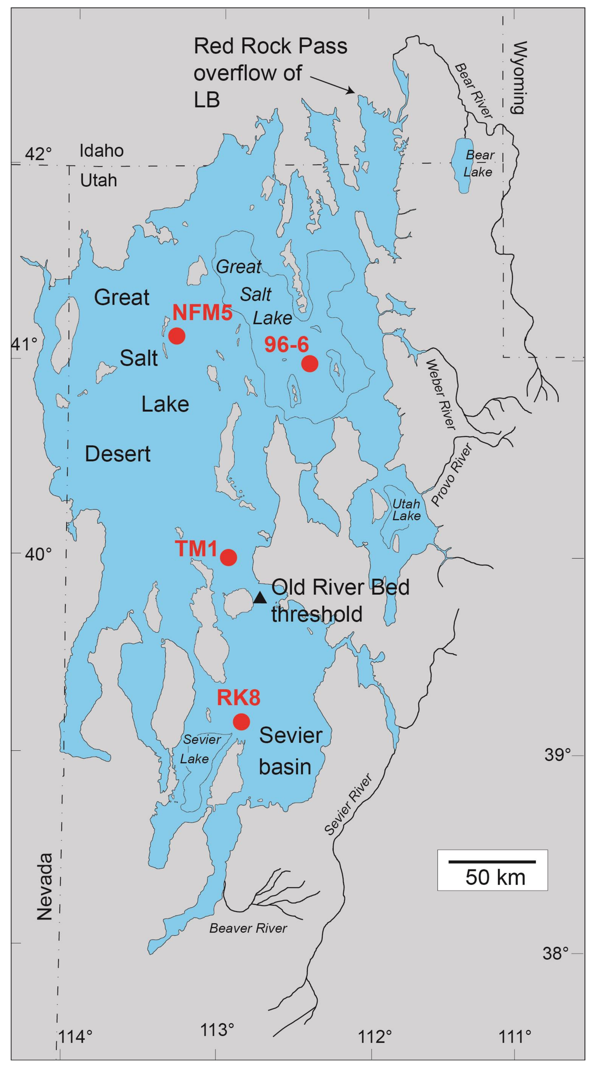
Goals and Significance of the Study

Secular changes in the mineralogy and chemistry of fine-grained carbonate sediment formed in the surface waters of lakes are sensitive to changes in lake hydrology. This study tests the utility of Sr-isotope ratios and formation of aragonite as indicators of direction of flow and mixing of water masses in Lake Bonneville.

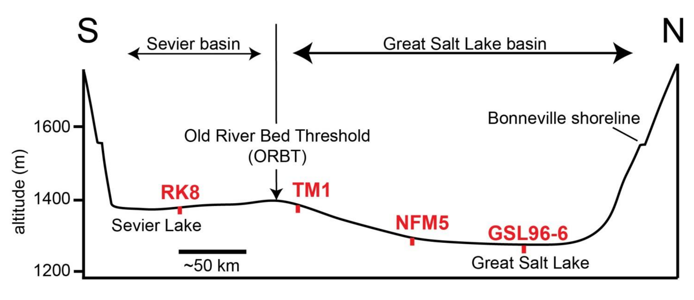
Geologic Setting

Pluvial Lake Bonneville formed at the end of the Pleistocene Epoch. At its largest, it consisted of a number of subbasins. The two dominant basins were the large and deep Great Salt Lake basin in the north and the smaller and shallower Sevier basin in the south.





Transgression began ~30,000 calibrated years B.P. The northern and southern lakes joined when lake level rose above the Old River Bed threshold at ~24 ka. Continued transgression to the Bonneville shoreline was punctuated by at least three significant oscillations. The Bonneville flood at 18 ka catastrophically dropped lake level to the Provo shoreline, where it remained until ~15 ka. The lake then regressed over a period of ~2 kyr to levels similar to the Great Salt Lake.



schematic south-to-north through the Sevier and Great Salt Lake basins

Samples and Lake Phases

Samples were analyzed from four cores of offshore marl from the Great Salt Lake and Sevier basins. Two cores are located in the center of the northern basin, one core in the center of the southern basin, and one on the north side of the threshold that separates the two basins.

Four lake phases are defined by this study. The early lake phase occurred prior to 18 ka when lake elevation was below the Old River Bed threshold. The post-Stansbury and full lake phases occurred between 24 and 18 ka. The full lake phase is defined geochemically by the Sr-isotope ratios. In the Sevier basin, full lake is defined by consistent ratios of ~0.7115. In the Great Salt Lake basin, full lake is defined by significant shifts to values below 0.7115. The post-flood phase occurred after the Bonneville flood at 18 ka.

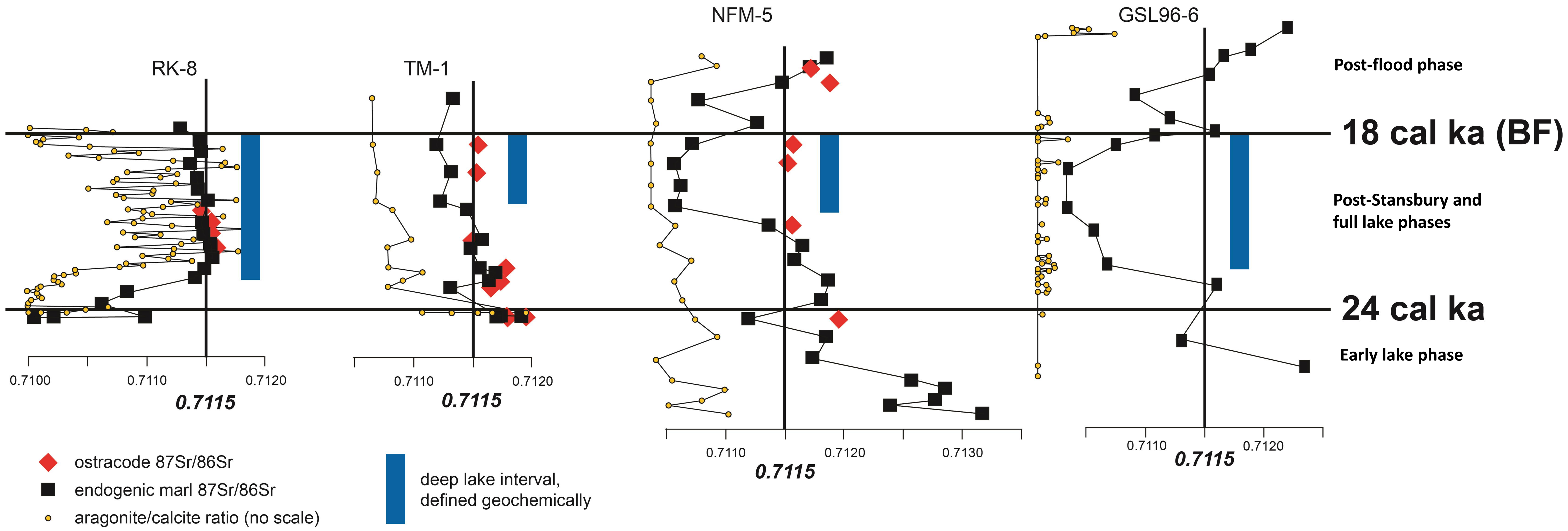
	$^{87}Sr/^{86}Sr$ ratio of endogenic carbonate				Aragonite to Calcite ratio			
	RK8	TM1	NFM5	GSL96-6	RK8	TM1	NFM5	GSL96-6
post-flood	0.71129	0.71134	0.71141	0.71156	low	insufficient data	low	low to moderate
full lake	0.71148	0.71125	0.71061	0.71067	high	low	mostly absent	mostly absent
Post-Stansbury	0.71073	0.71162	0.71165	0.71159	low to moderate	high to moderate	low to moderate	mostly absent
early lake	0.71041		0.71231	0.71182	low to moderate		low to moderate	mostly absent

Results

RK-8 and NMF-5 show opposite trends in A:C and Sr-isotopes during each lake phase. During the early lake and post-Stansbury phases, values are low in RK-8 and moderate to high in NFM-5. During the full lake phase, values are moderate in RK-8 and low in NMF-5. During the post-flood phase, values in RK-8 decrease and those in NFM-5 increase.

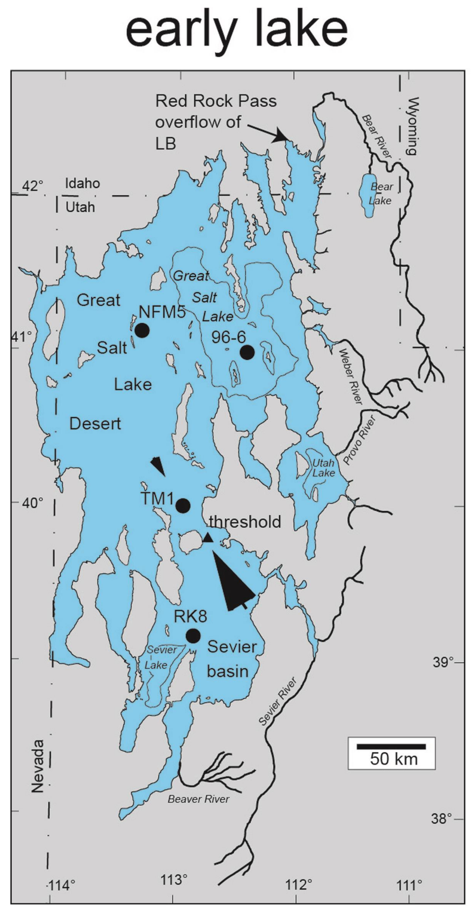
The values of A:C and Sr-isotope ratios in TM-1 are generally intermediate between those of RK-8 and NMF-5, although the shapes of the curves are similar to those of NFM-5. Similarly, the shape of the Sr-isotope curve in GSL96-6 is similar in that in NFM-5, although values are slightly different. In contrast to the other cores, GSL96-6 has little aragonite during any lake phase, except for minor spikes during the post-Stansbury and full-lake phases.

Sr-isotope values of marl and ostracodes are similar during the full-lake phase in RK-8 and in the post-Stansbury phase in TM-1 and NMF-5. However, the values of marl and ostracodes diverge during the full-lake phase in TM-1 and NMF-5. The $^{87}Sr/^{86}Sr$ ratio of the ostracodes in NFM-5 is similar to those of the marl and ostracodes in RK-8 during this lake phase.



Discussion and Conclusions

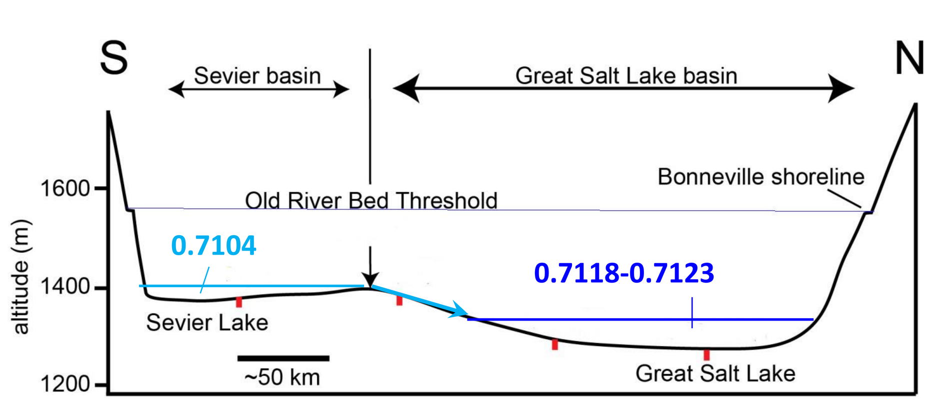
early lake



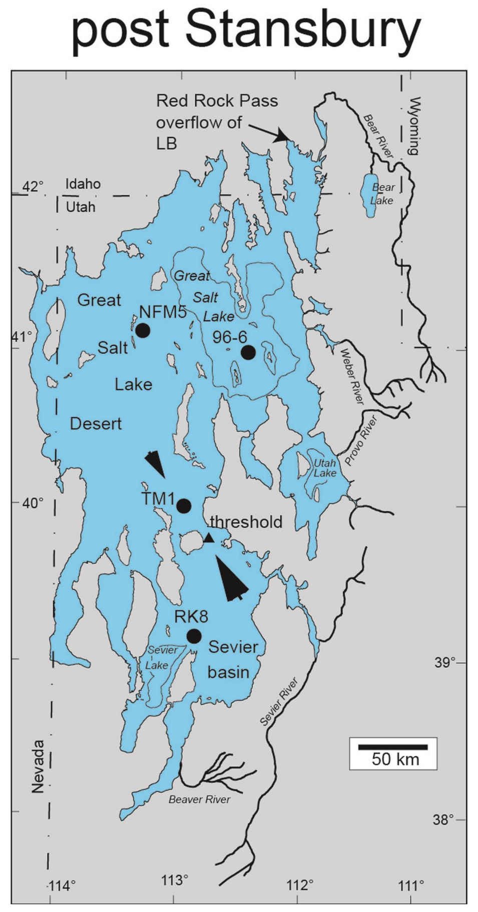
The small lake in the shallow Sevier basin overflowed through the river channel at the Old River Bed threshold into the Great Salt Lake basin.

Sevier lake water was dominated by the Sevier ($^{87}Sr/^{86}Sr$ = 0.7086) River, with minor discharge from radiogenic hot springs at higher elevations. Conditions and water chemistry produced variable and low to moderate amounts of aragonite.

Water in the Great Salt Lake basin was dominated by the Bear River ($^{87}Sr/^{86}Sr$ = 0.7155), which included discharge from radiogenic hot springs at low elevations. Outflow from the Sevier basin had a stronger influence on areas proximal to the outflow, like NFM-5.

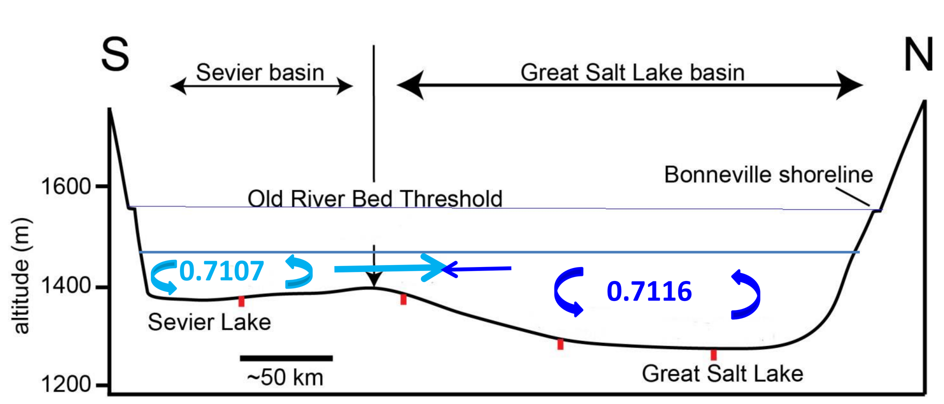


post Stansbury

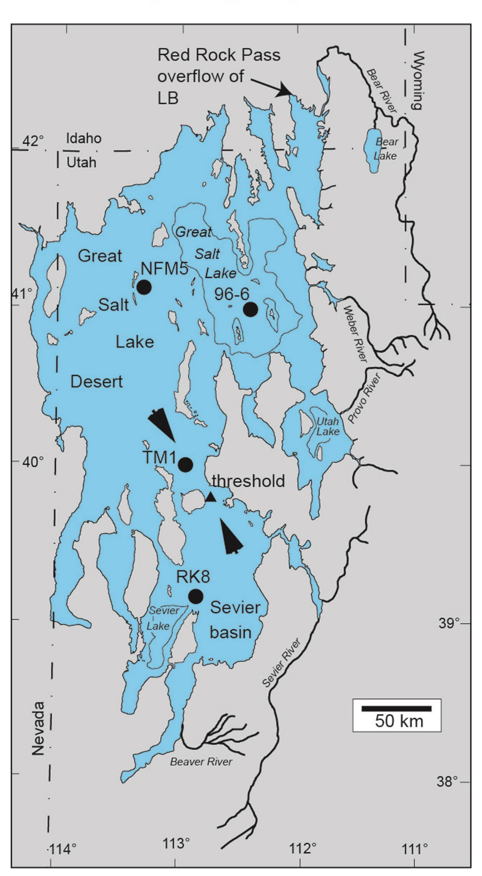


The lakes in the Sevier and Great Salt Lake basins were joined as a single lake. However, the differences in $^{87}Sr/^{86}Sr$ ratios show that water in the two basins was not well mixed. The presence of similar amounts of aragonite in RK-8, TM-1, and NMF-5 suggest that flow from the Sevier basin continued during this phase of lake transgression.

Similarity in Sr-isotope ratios in ostracodes and marl indicate that water in the Great Salt Lake basin was vertically well mixed. No ostracode data were obtained for the Sevier basin, but it is likely this shallow lake was also vertically well mixed.



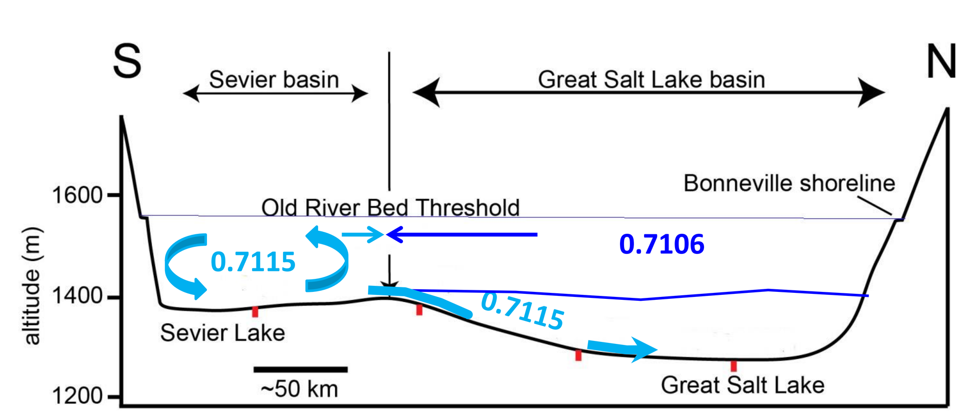
full lake



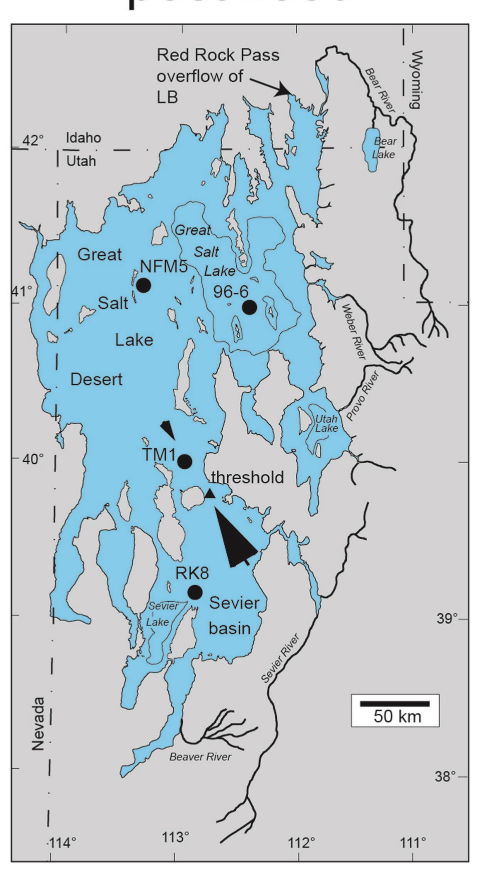
The $^{87}Sr/^{86}Sr$ ratios in the Sevier basin increased as the lake received greater discharge from radiogenic springs. Those in the Great Salt Lake basin decreased as low radiogenic waters from the upper Bear River dominated the inflow.

Surface flow from Sevier basin ceased, indicated by low A:C and $^{87}Sr/^{86}Sr$ ratios in TM-1. However, the spikes of aragonite in GSL96-6 might reflect times when south-to-north flow did occurred, possibly associated with lake oscillations.

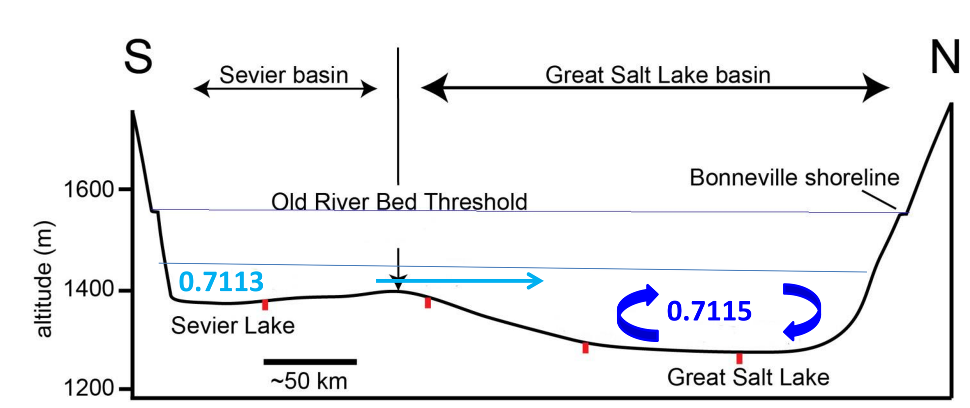
The lake in the Great Salt Lake basin stopped overturning and was not vertically well mixed. The similar $^{87}Sr/^{86}Sr$ ratios of the ostracodes to those in the Sevier basin indicate that water from the Sevier basin formed the bottom water in the Great Salt Lake basin.



post flood



Following the Bonneville flood, values in A:C and Sr-isotopes show a trend toward the values they had prior to the full-lake phase. This suggests that south-to-north flow resumed.



Conclusions

The distinct A:C and Sr-isotope ratios of the Sevier basin provide a fingerprint of water from this basin that can be used to track hydrology of Lake Bonneville. South-to-north surface flow from the Sevier basin into the Great Salt Lake basin occurred during the early-lake, post-Stansbury, and post-flood phases. However, during the full-lake phase, there was no surface flow between the basins. Bottom flow, apparently driven by density currents from south to north, continued to occur throughout the full-lake phase.

Acknowledgments

Grants from California State University Northridge supported this work. Jessica Olsen, CSUN undergraduate, prepared samples for Sr-isotope analyses. Gary Hemming, Queens College and adjunct research scientist at Lamont-Doherty Earth Observatory performed the Sr-isotope analyses at Lamont.