# Variability of ($^{234}U$ / $^{238}U$) in surface water: A study in the Mono Basin, California, USA


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## Main findings

- **Groundwater springs in Mono Basin, California have uranium (U) concentrations about 10 times higher than creek waters, contributing to 70% of U in the lake water despite delivering only 15% of annual inflow.**
- **U has a residence time in lake water of around 15,000 years, similar to Li, Na, and Cl but longer than alkaline earth elements.**
- **$\delta^{234}U$ in Mono Lake water is 180‰, matching modern tufa deposits, while higher values (~ 250‰) in modern creeks and springs reflect the dry environment and stronger physical weathering in the basin.**

## What do uranium isotopic compositions reveal?

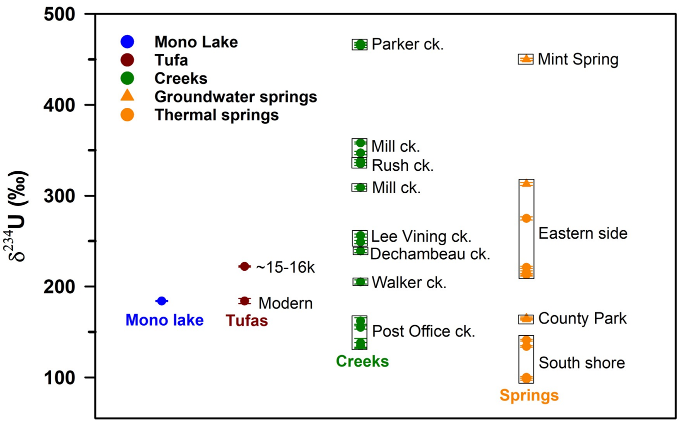


**Figure 2.** U isotopic compositions of water samples and tufa carbonates. Modern tufas have $\delta^{234}U$ values similar to Mono Lake water (183‰), while deglacial tufas have higher values (220‰). Creek waters show a wide range of $\delta^{234}U$ values (135‰ to 467‰), while spring waters range from 98‰ to 450‰.

### Today's Mono Lake water

- The $\delta^{234}U$ mean value of Mono Lake water is 183±1‰, which updates the previously reported 140±10‰ (Anderson et al., 1982).

### Tufa carbonates

- Modern: $\delta^{234}U$ mean value of 184‰ is in line with the lake water's value, indicating that authigenic lake carbonates reflect the $\delta^{234}U$ value of the precipitating water.
- Last deglacial wet period (~16 ka ago): $\delta^{234}U$ values were about 50‰ higher than current lake water values, suggesting intense physical weathering or greater runoff from the eastern Sierra Nevada creeks.

### Creeks from the Sierra Nevada

- Relatively high $\delta^{234}U$ values result from physical weathering and uplifting of the Sierra Nevada.
- Physical weathering can release excessive $^{234}U$ into creeks flowing through glacial moraines due to damaged lattice sites or direct alpha-recoil out of mineral grains.
- The Sierra Nevada's active uplift, with a rate of 1 to 2 mms/yr, exposes fault surfaces with fresh minerals and accelerates erosion (Millar, 2012).

### Hot springs from south shore

- Low $\delta^{234}U$ values ranging from 100-140‰, originate from the Mono Craters volcanic chain. This is likely because volcanic activity, such as the Panum Crater eruption between 1325 A.D. and 1365 A.D., reset the $^{234}U/^{238}U$ ratio in the rocks to a secular equilibrium state (Sieh and Bursik, 1986).

## Sample locations in the Mono Basin

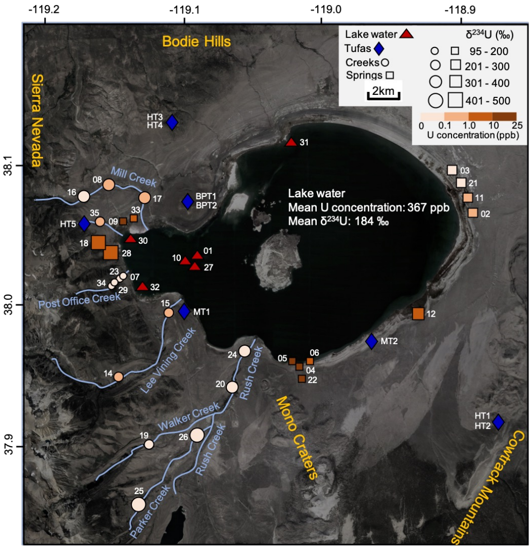


**Figure 1.** Sampling sites and their U compositions. The map displays $\delta^{234}U$ values in creeks and springs, ranging from 95 to 500‰, represented by circles and squares. Additionally, the symbols are color-coded to show U concentrations, which vary from approximately 0.004 to 25 ppb.

## Uranium budget from isotopic compositions

**Table 1.** The contribution of U from springs is estimated to be ~51,276 g/yr, which is ~2.3 times higher than that from creeks. The residence time of U is calculated to be ~15.7 ka.

**Mono Lake mean volume (between 2009 and 2017): $3.10\times10^{12}$ (l)**
**Total creeks flow: $1.75\times10^{11}$ (l/yr)***
**Total springs flow: $4.5\times10^{10}$ (l/yr); the ratio of groundwater and thermal springs: ~36:1.***
**Mono Lake mean U concentration: 375.6 (μg/l)**
**$\delta^{234}Ui$ weighted mean: 258‰; Calculated $\delta^{234}U$ value in Mono Lake water: 247‰****
**U Residence Time: approx. 15,700 (yrs)**

| Location | U concentration (μg/l) | $\delta^{234}U$ value (‰) | Runoff (%) | Flow (l/yr) | U flux (g/yr) |
|---|---|---|---|---|---|
| **Creeks** | | | | | |
| Rush Creek | 0.06 | 338 | 41 | $7.18\times10^{10}$ | 4,100 |
| Lee Vining Creek | 0.22 | 249 | 33 | $5.78\times10^{10}$ | 12,658 |
| Mill Creek | 0.15 | 347 | 15 | $2.63\times10^{10}$ | 3,880 |
| Parker Creek | 0.08 | 467 | 6 | $1.05\times10^{10}$ | 850 |
| Walker Creek | 0.04 | 205 | 4 | $7.00\times10^{9}$ | 250 |
| Post Office Creek | 0.02 | 155 | 0.5 | $8.75\times10^{8}$ | 17 |
| Dechambeau Creek | 0.70 | 239 | 0.5 | $8.75\times10^{8}$ | 614 |
| **Weighted mean** | **0.13** | **290** | **100** | $\mathbf{1.75\times10^{11}}$ | **22,369** |
| **Groundwater springs** | | | | | |
| Mint Spring*** | 3.04 | 450 | | | |
| Simmons Spring | 1.17 | 313 | | | |
| County Park | 1.05 | 165 | | | |
| County Park**** | 13.32 | 164 | | | |
| **Median** | **1.17** | **239** | | | |
| **Weighted mean** | | | **97** | $\mathbf{4.38\times10^{10}}$ | **51,276** |
| **Thermal springs** | | | | | |
| Spring in eastern side | 0.31 | 221 | | | |
| Spring in eastern side | 0.05 | 213 | | | |
| Spring in eastern side | 0.19 | 275 | | | |
| Harrier Flat Spring | 0.02 | 215 | | | |
| Spring in South Shore**** | 19.81 | 100 | | | |
| Spring in South Shore**** | 21.80 | 134 | | | |
| Spring in South Shore**** | 8.94 | 141 | | | |
| Spring in South Shore**** | 22.48 | 98 | | | |
| **Median (exclude spring in South Shore)** | **0.12** | **177** | | | |
| **Weighted mean** | | | **3** | $\mathbf{1.22\times10^{9}}$ | **145** |
| **In total** | **0.28** | **258** | | | **73,791** |

*Average estimated flows are used from Blevins et al. (1984) and Tomascak et al. (2003).
**The calculated Mono Lake water δ234U value is based on $\delta^{234}Um = (\delta^{234}Ui) \times e^{(-\lambda_{234}t)}$
***We used the weighted mean values of U concentration and δ234U of sample 15-09-18 and 18-06-28.
****The concentrations of springs in County Park and South Shore are overall higher than normal springs, and all of them are not count for calculation.

- Lee Vining Creek contributes around 57% of U of creek water, while Rush Creek and Mill Creek each contribute approximately 18%. The remaining creeks contribute less than 5% altogether.
- Groundwater springs are the largest source of uranium in Mono Lake, accounting for approximately 70% of the total annual uranium input. Thermal springs, on the other hand, make a negligible contribution.
- Residence time of U in Mono Lake is estimated to be around 15.7 ka (-2 ka/+3 ka) based on its fluxes from creeks and springs, assuming lake water maintains steady state with respect to U. This time is similar to other conservative elements like Li, Na, and Cl, but longer than alkaline earth elements.
- Mono Lake's high alkalinity causes calcium carbonates to precipitate quickly and promotes the carbonate complexation of actinide elements, resulting in U's longer residence times in the water (Simpson et al., 1982).


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