Climate Effects on Oxygen Isotope Recharge Elevation Calculations from the Sierra de Los Valles and the Pajarito Plateau

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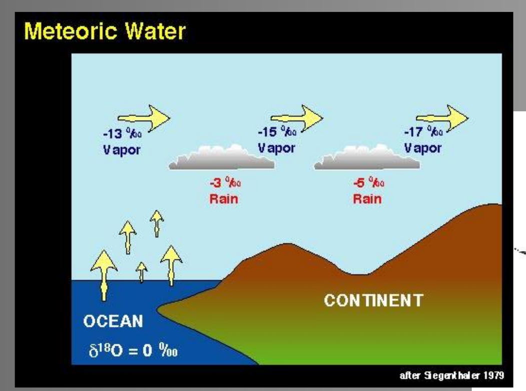
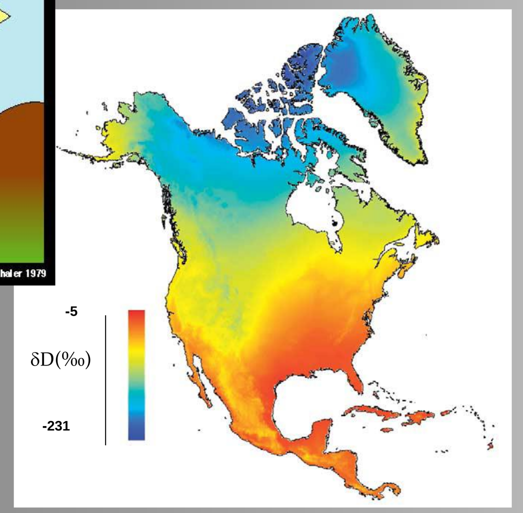
Abstract:

Recharge elevation estimates for regional aquifer groundwater beneath the Pajarito Plateau differ depending on lines of evidence considered. Hydrologic, chloride mass balance, infiltration, and precipitation considerations suggest that significant recharge derives from precipitation falling in the Sierra de Los Valles upgradient of the Pajarito Plateau. Elevations calculated from a calibration of oxygen isotopes in modern spring discharge versus recharge elevation, however, suggest significant recharge from precipitation falling on the Pajarito Plateau proper. It should be noted that the oxygen isotope technique calculates the elevation at which precipitation falls, not necessarily the elevation of actual recharge following downgradient surface flow. This fact cannot explain the observed discrepancy noted above, as it leads to overestimation of recharge elevations, whereas the oxygen isotope measurements appear to underestimate the elevation at which recharging precipitation originally fell. For simplicity sake, we refer to the elevations calculated in this manner as recharge elevations.

The slope of the modern oxygen isotope recharge relationship for the Sierra de los Valles/Pajarito Plateau is -0.3 ‰/100 m. This slope is consistent with similar relationships determined around the world, so this factor is unlikely to contribute significantly to the recharge discrepancy observed. Much of the regional aquifer beneath the Pajarito Plateau, however, is mid-Holocene in age. Could the *intercept* of the oxygen isotope – recharge relationship have been different in the past? Past higher overall $\delta^{18}O$ of regional precipitation, relative to modern regional precipitation, would lead to underestimated recharge elevations when using the modern calibration.

Past regional precipitation could have had higher $\delta^{18}O$ if temperatures were warmer (global relationship is +0.58 ‰/°C) or if a greater proportion of monsoonal precipitation was recharged (monsoonal precipitation from the Gulf of Mexico is ~ -6 ‰ while winter precipitation from the Pacific is ~ -13 ‰). Several lines of paleoclimate evidence will be presented that suggest regional precipitation during the mid-Holocene may indeed have had higher $\delta^{18}O$. These include carbon isotopic measurements of soil organic matter in the Great Plains, isotope-age relationships from groundwater in the Albuquerque basin, foraminifera abundance in the Gulf of Mexico, oxygen isotope measurements in speleothems from the Guadalupe Mountains, and tree ring records from bristlecone pines in the White Mountains of California. If $\delta^{18}O$ of regional precipitation was approximately 1 ‰ higher during the mid-Holocene, recharge elevations would be underestimated by ~ 300 m using the modern relationship. 1 ‰ heavier precipitation would correspond to a ~ 1.7 °C higher temperature or an increase in monsoonal precipitation of 15 % during the mid-Holocene. A 1‰ increase in past precipitation would be sufficient to reconcile the recharge elevation determinations, with precipitation contributing to recharge primarily being sourced in the Sierra de los Valles. These results suggest that the modern oxygen isotope–recharge relationship needs to be used with caution, taking the age of recharged waters into account.





$\delta^{18}O = (R_{sample}/R_{std} - 1) * 1000$

Where $R = {}^{18}O/{}^{16}O$

Units ‰

The oxygen isotopic composition of precipitation decreases with increasing elevation and with increasing distance from the oceans due to preferential rainout of the heavier isotope of oxygen (similar effects are observed in hydrogen isotopes in precipitation as well).

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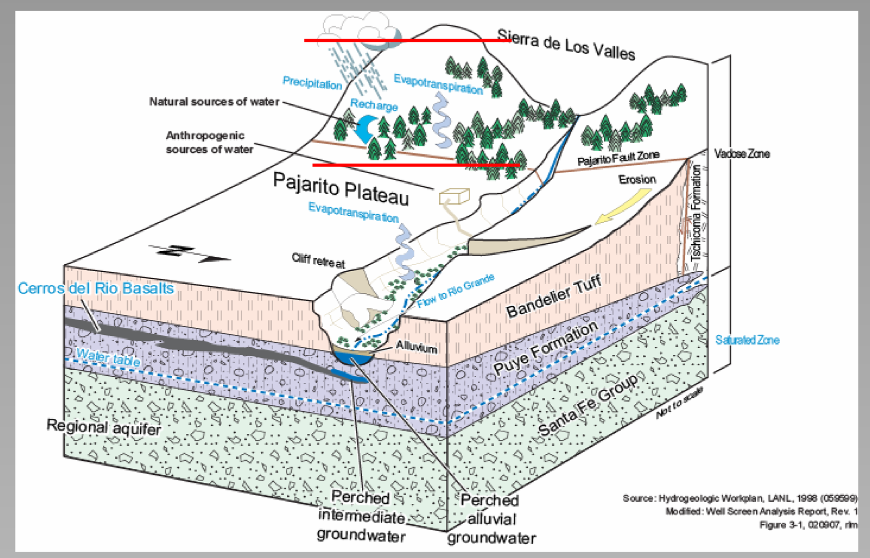
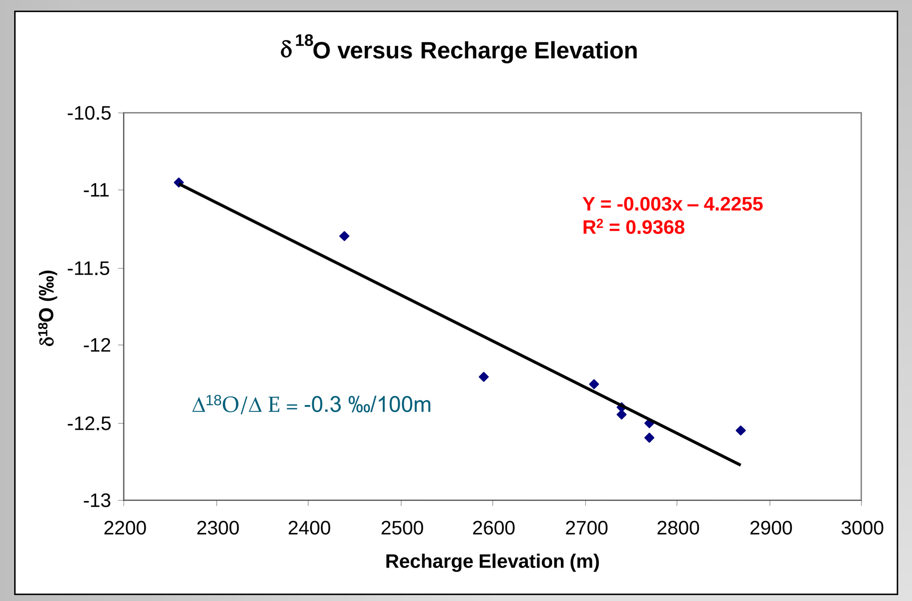
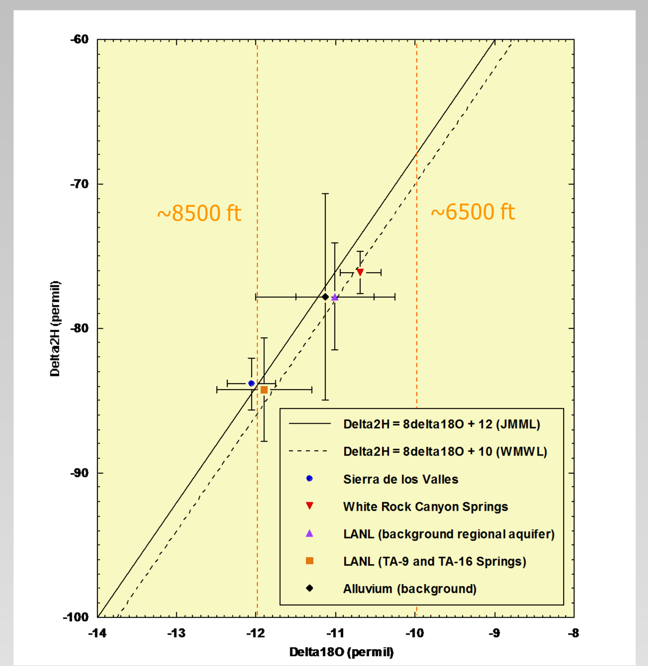


The conceptual model for LANL has natural recharge derived from precipitation in the Sierra de los Valles, with actual infiltration occurring in the mountain front or in wet canyon bottoms.



Evidence for Recharge in the Sierra de los Valles

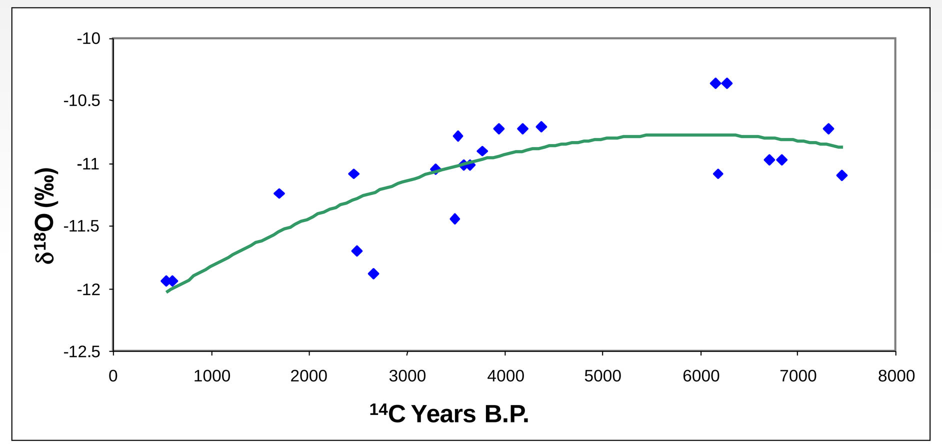
- Water budget and chloride mass balance
- Inverse modeling using head and streamflow data
- Precipitation and infiltration data for **natural** recharge (as opposed to recharge from outfalls)



The relationship between $\delta^{18}O$ of spring discharge and recharge elevation for **modern** waters suggests that much of the regional aquifer water and discharge from the White Rock Canyon springs was derived from precipitation that fell at the elevation of the Pajarito Plateau proper (i.e. not in the Sierra de los Valles mountain front to the west).

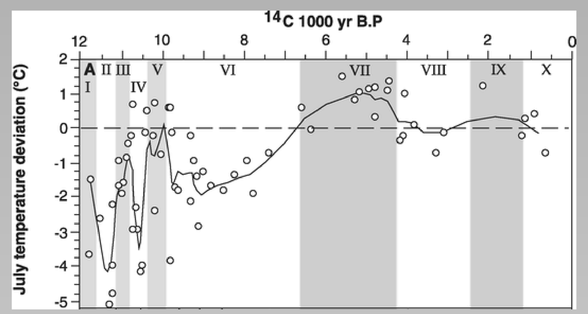
Is There an Alternative Explanation for Isotope Data?

- Isotope – elevation relationship is based on modern waters
- Might curve have been different when waters were recharged?
- Holocene climate change? Much of the regional aquifer groundwater was recharged in the mid-Holocene (see figure to right)

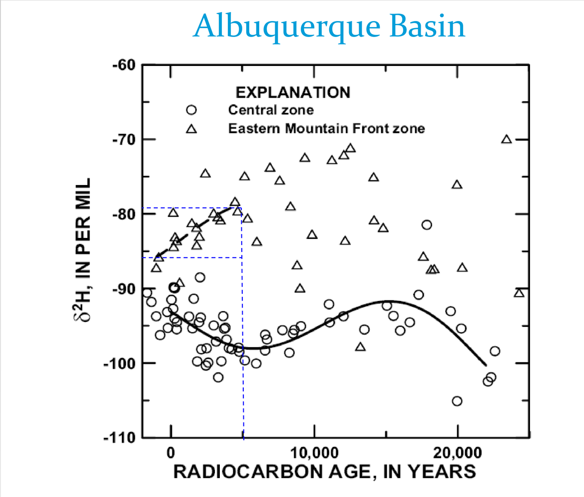


What could make $\delta^{18}O$ and δD heavier during mid Holocene?

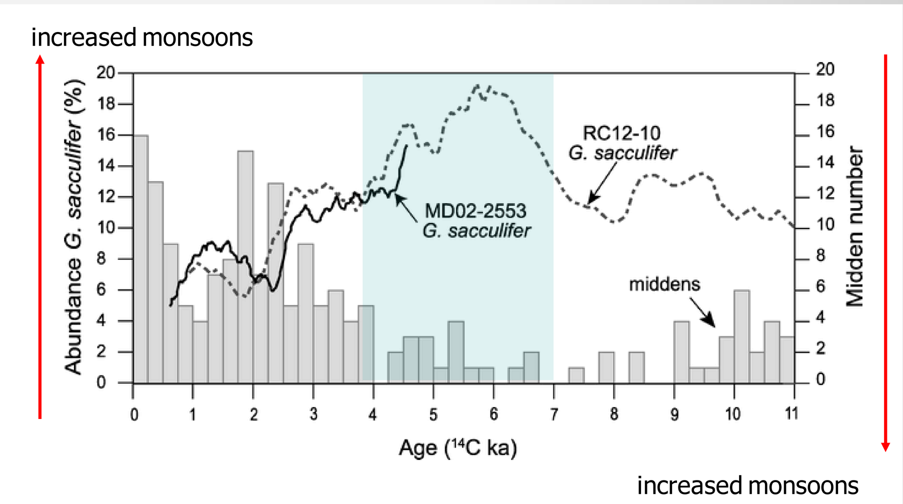
- Warmer – positive relationship between temperature and $\delta^{18}O$ and δD – e.g. for continental settings: 0.58 ‰/°C for $\delta^{18}O$
- Increased summer (monsoonal precipitation) **and** infiltration; summer $\delta^{18}O$ of ~ -6 ‰ (Gulf source); winter $\delta^{18}O$ ~ -13 ‰ (Pacific Source)



Warmer temperatures estimated from ~ 4-7 ka buried soils (based on relationship between $\delta^{13}C$ of modern soil organic matter and July temperature in Great Plains). Nordt et al. 2007

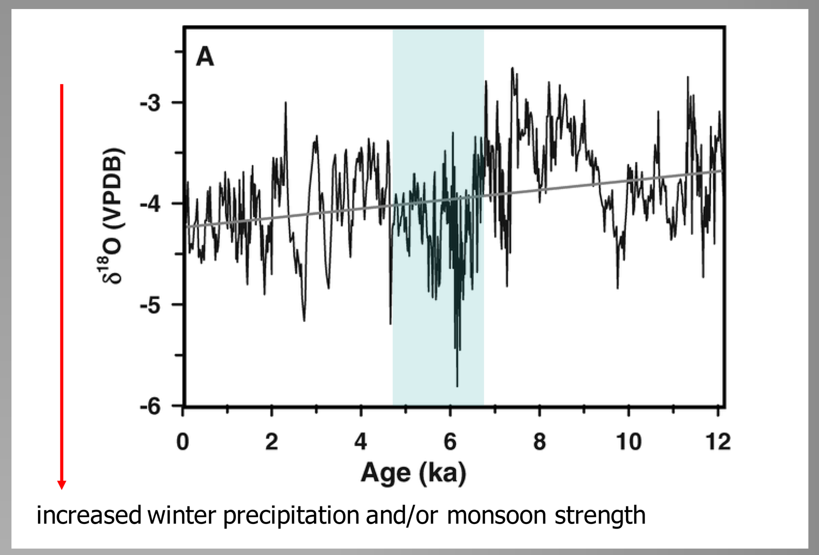


~7 ‰ decrease in δD (~0.9 ‰ decrease in $\delta^{18}O$) over last 5000 years for waters in the Eastern Mountain Front zone of the Albuquerque basin; corresponds to an ~ 1.5°C temperature decrease if entirely temperature change. Plummer et al., 2004.



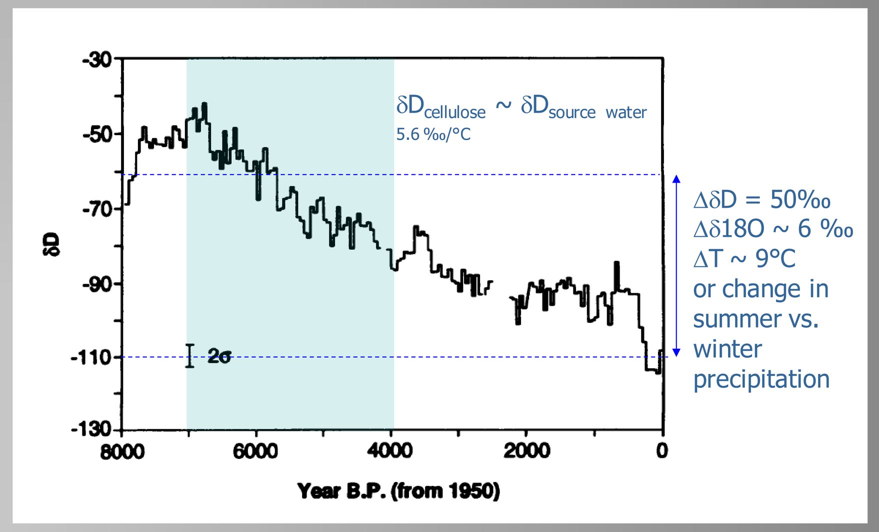
Poore et al., 2005

Increase in the southwest monsoon from ~4-7 ka as indicated by the abundance of *Globigerinoides sacculifer* in Gulf of Mexico sediment cores and from packrat midden abundance. Poore et al., 2005.

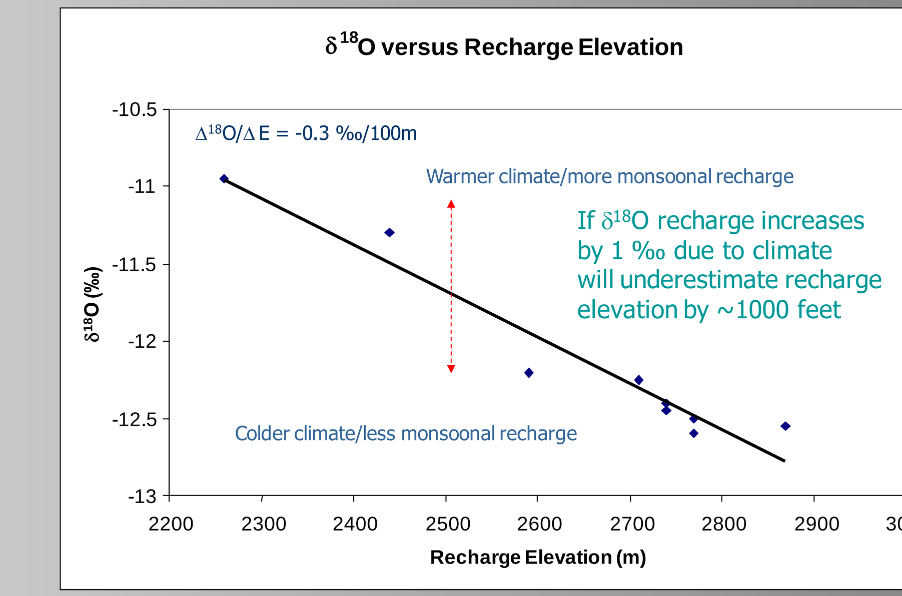


After Asmerom et al. 2007

Increase in monsoonal precipitation (lower $\delta^{18}O$ from amount effect) from 4-7 ka as indicated by $\delta^{18}O$ of a speleothem from the Guadalupe Mountains. Asmerom et al., 2007.



Warmer temperatures or isotopically heavier precipitation from ~ 4-7 ka based on reconstructions from bristlecone pines in the White Mountains of California. Feng and Epstein, 1994.



1 ‰ = 1.7 °C; or 15% increase in proportion of monsoonal recharge

An increase in $\delta^{18}O$ of precipitation of 1 ‰ would be sufficient to resolve the discrepancy between oxygen isotope data and our conceptual model. 1 ‰ = 1.7 °C; or 15% increase in proportion of monsoonal recharge (or some combination thereof).

Conclusions:

- The timing of recharge during the Holocene may be an important variable in determining recharge elevations for waters underlying the Pajarito Plateau
- Isotope/recharge elevation curve may have to be shifted as a function of age of recharge

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