H12R-0895 - Triple Oxygen Isotopes in Pedogenic Carbonates Reveal the Varied Role of Evaporation in Western US Drylands

Monday, 12 December 2022

10:00 - 13:30

McCormick Place - Poster Hall, Hall A (South, Level 3)

Abstract

Pedogenic carbonate is ubiquitous in dryland critical zones but our understanding of the processes driving its formation is incomplete. We do not understand the relative importance of abiotic vs. biotic processes (evaporation vs. transpiration, respiration) that drive carbonate formation. This uncertainty has persisted in part because traditional oxygen isotope measurements of carbonate ($\delta^{18}O$) cannot discern evaporation from variation in the $\delta^{18}O$ of water that recharges soils. Here, we develop the use of triple oxygen isotopes (^{16}O, ^{17}O, ^{18}O) in carbonates to address this longstanding ambiguity. The measurement of the excess ^{17}O compared to reference meteoric waters ($\Delta'^{17}O$) is an emerging technique that can identify evaporation. As a first application to soils, we measure $\Delta'^{17}O$ of pedogenic carbonates and meteoric waters at three well-studied sites in the Western US: the Mojave National Preserve, Jornada Basin LTER, and Reynolds Creek CZO. We expected the most evaporative signatures at the hyper-arid site, Mojave. We expected variability in evaporation at the two arid sites, Jornada and Reynolds, which receive similar amounts of yearly precipitation but differ in their precipitation regime (summer monsoon vs. winter rain/snow) and in their mean annual temperatures. The $\Delta'^{17}O$ of meteoric waters at all sites overlaps (14 to 44 per meg, n = 6). At Mojave and Jornada, the reconstructed soil water values ($\Delta'^{17}O_{rsw}$) are similar (based on carbonate $\Delta'^{17}O$ values, using carbonate-water fractionation factor = 0.5250); they range from -40 to -9 per meg (n = 3 samples) and -39 to -16 per meg (n = 7), respectively. At Reynolds, the $\Delta'^{17}O_{rsw}$ values range from -6 to 12 per meg (n = 5). From these $\Delta'^{17}O_{rsw}$ values, the Mojave and Jornada pedogenic carbonates formed during high soil water evaporation. The Reynolds pedogenic carbonates formed during lower soil water evaporation. Our next steps will include coupling these $\Delta'^{17}O$-based insights on soil evaporation with other approaches (e.g. clumped-isotope based growth temperatures, monitoring of soil temperature, moisture, and CO_2, and existing estimates of evaporation and transpiration) to further constrain the timing and mechanisms of carbonate formation. Our initial results show promise for using $\Delta'^{17}O$ to understand when evaporation drives carbonate formation in drylands.

Full Abstract

Soil carbonate is commonly found in deserts. Its formation can alter soil porosity and chemistry, affecting plant growth and carbon storage. Despite its prevalence, we do not fully understand how soil carbonates forms and specifically, the relative roles of evaporation and transpiration. Stable isotopes of oxygen are used to study soil carbonates because they record information about soil water, but traditional oxygen isotope approaches cannot uniquely detect evaporation. We develop an approach to identify evaporation using three stable isotopes of oxygen (^{16}O, ^{17}O, ^{18}O). We measure triple oxygen isotope abundances in soil carbonates from three sites: the Mojave Desert (California), Reynolds Creek (Idaho), and Jornada (New Mexico). We expected the importance of evaporation to vary based on environmental differences including rainfall amounts and distribution. The Mojave and Jornada carbonates have similar triple oxygen isotope compositions that suggest moderate soil water evaporation. In contrast, the Reynolds carbonates have triple oxygen isotope compositions that suggest a minor role for evaporation in soil carbonate formation. We will compare these isotopederived perspectives to independent estimates of evaporation and transpiration. By building a tool to identify where evaporation drives soil carbonate formation, this work will improve our understanding of how this widespread mineral forms.

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