High-precision, heavy noble gas isotope ratios in groundwater identify past water-table depth

ALAN M. SELTZER[1], JESSICA NG[1], JUSTIN T. KULONGOSKI[2,1], WESLEY R. DANSKIN[2], RILEY GANNON[2], MARTIN STUTE[3], JEFFREY P. SEVERINGHAUS[1]

[1] Scripps Institution of Oceanography, CA 92037, USA
[2] USGS California Water Science Center, CA 92101, USA
[3] Lamont-Doherty Earth Observatory, NY 10964, USA

Over the past several decades, dissolved noble gas measurements in ancient groundwater have provided key quantitative constraints on continental surface temperature during the last glacial period [e.g. 1, 2]. Building on the noble gas groundwater paleothermometer, we have recently developed a tool for reconstructing past water-table depths from high-precision measurements of dissolved heavy noble gas isotope ratios in groundwater [3]. By measuring elemental concentrations and isotope ratios in the same samples, we demonstrate how noble gases in groundwater record both temperature and hydrological changes since the last glacial period via robust physical relationships.

The basis for this new paleohydrological tool is rooted in gravitational settling in unsaturated zone air, a well-understood physical process that results in enrichment of heavy-to-light gas ratios with depth [4]. Both a steady-state model of unsaturated-zone Kr and Xe isotopic fractionation and soil-air measurements indicate that gravitational settling accounts for nearly all fractionation of these isotope ratios in soil air relative to the well mixed atmosphere [5]. As Kr and Xe in unsaturated zone air dissolve into groundwater at the water table, the gravitational signal is 'locked in.'

Recent measurements of dissolved Kr and Xe stable isotope ratios at 5 per meg amu^{-1} precision (1σ) in 36 groundwater samples confirm the expected signal of gravitational settling. Reconstructions of water-table depth in modern groundwater samples agree with historical observations, and paleogroundwater measurements from San Diego (California, USA) indicate shallower mean water-table depths during the last glacial period, consistent with a wetter glacial climate in Southern California.

[1] Stute et al. (1995) *Science* **269** 379-383. [2] Aeschbach-Hertig et al. (2002) *GCA* **66** 797-817. [3] Seltzer et al. (2019) *EPSL* (accepted). [4] Schwander (1989) *The Environmental Record in Glaciers Ice Sheets* 53-67. [5] Seltzer et al. (2017) *WRR* **53** 2716-2732.