Isotopic composition of groundwater in the southern Great Basin (USA) from late Miocene to the present: results from a pilot fluid-inclusion study

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Isotopic composition of paleogroundwater and paleoprecipitation can be derived from analyses of aqueous fluid inclusions trapped in hydrogenic minerals. Such mineral deposits are known in the southern Great Basin and can be used for characterization of the isotope paleohydrogeology of this currently arid region.

Previous studies

First results from the southern Great Basin were reported by Winograd et al. (1985), who determined δD values of inclusion water in Plio-Pleistocene calcite veins (fossil spring feeders) emplaced in clastic deposits of the Amargosa Desert and Furnace Creek (Death Valley), Late Pleistocene phreatic deposits from Devils Hole cave in Ash Meadows, and Holocene flowstone from Trout Springs cave in the Spring Mountains. The authors reported a unidirectional decline of δD from values between -50 and -70 ‰ to values ranging from -85 to -105 ‰ between the Pleistocene and today. The decline was explained by the uplift of the Sierra Nevada, and the Transverse Ranges, which purportedly resulted in a progressively increasing rainout of the Pacific-derived precipitation.

Fig. 1. Calcite veins in fanglomerate of the Pliocene Funeral Formation in Furnace Creek wash, Death Valley, California, USA, offset by a low-angle fault.

Samples

In order to improve the record, we re-sampled the most important sites studied by Winograd and co-authors: calcite deposits at Furnace Creek (Fig. 1), Devils Hole, and Amargosa desert. In addition, we acquired data from a 17 to 20 ka-old stalagmite from Pinnacle Cave (southern Spring Mountains), and from ca. 12.9 Ma-old hydrothermal calcite and fluorite from the Diamond Queen (fluorspar) and Sterling (gold) Mines at Bare Mountain (Nevada).

Dating

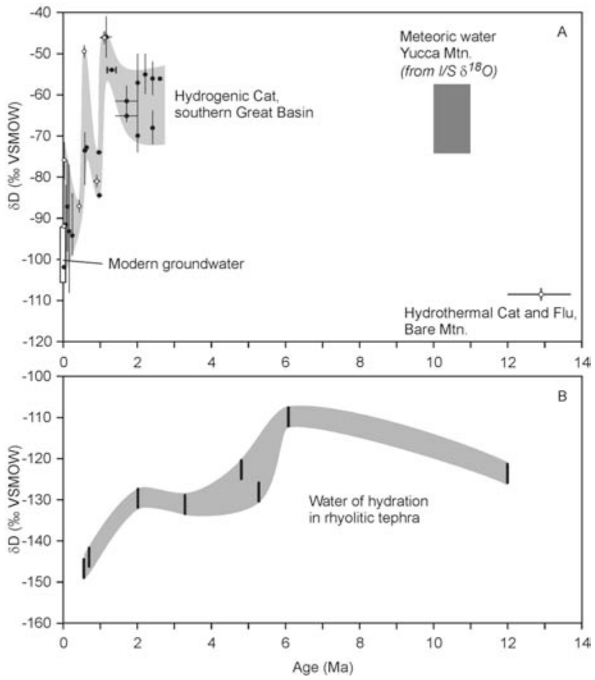
Whenever possible, samples were dated by the U-series disequilibrium method. Where material was too old for U-series dating, ages were estimated from growth rates obtained on the younger parts of these samples. Ages of hydrothermal calcite and fluorite from Bare Mountain were constrained by the published ^{40}Ar-^{39}Ar dates of the associated hydrothermal minerals.

Method

The δD values of fluid inclusion water were measured on an analytical line at Innsbruck University. Water was released by heated crushing (Dublyansky and Spötl, 2009).

Results

The new data suggests that between ca. 11 Ma and 1.8 Ma meteoric precipitation in the



ig. 2. Evolution of δD values in groundwater and recipitation in southern Great Basin, USA, etween late Miocene and the present. A - Fluid nclusion data: black circles - Winograd et al. 1985), white circles - this study. Field for δD of the 0-11 Ma-old meteoric water at Yucca Mountain vas calculated from $\delta^{18}O$ of illite/smectite using lata from Feng and others (1999). B - δD of water f hydration in rhyolitic tephra (based on data of Iulch et al. 2008).

area had characteristically higher δD values as compared to modern values (Fig. 2A). The transition to the lower values of the late Holocene was not continuous, but associated with high-amplitude (30-40 ‰) oscillations.

Surprisingly, water from the late Miocene massive hydrothermal fluorite and scalenohedral calcite sampled in the Bare Mountain mines show remarkably constant values of -108±2 ‰ (n = 6), similar to modern precipitation.

The fluid inclusion isotope data show similarities with the δD values obtained from the water of hydration in tephra of different age studied by Mulch et al. (2008). Hydration of glass occurs within the first ca. 1000 years following tephra deposition; these δD values, thus, reflect the integrated isotopic composition of local precipitation at the depositional site.

Discussion

Models relating the decline of δD values of precipitation in the southern Great Basin to the uplift of the Sierra Nevada appear no longer plausible. The Sierra formed a high topographic barrier already in the Late Cretaceous or early Cenozoic (Henry, 2009). The large-amplitude (30-40 ‰) fluctuations in the post-Pliocene part of our data may be explained by different pathways of moisture supply. In one scenario moisture from the Pacific Ocean crosses the Sierra Nevada (resulting in low δD values due to orographic rainout effects). An alternative scenario involves moisture transport from the Gulf of Mexico, skirting the Sierra Nevada from the south (little rainout, higher δD values). The specific climatic forcing responsible for the switch, though, remains to be identified.

Presently, there is no reliable fluid inclusion data for the period 2.5 to 12.5 Ma, but the search for hydrogenic deposits formed during this period of time is underway.

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