ITCZ migration during the Holocene recorded in speleothems from Southern Oman (Arabian Peninsula)

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However, one monitor of monsoon variation is the oxygen isotope ratios of stalagmite measured in caves where cave drip water accurately reflects the oxygen isotope ratios of monsoon precipitation, such as stalagmites from Qunf Cave (17°10 N, 54°18 E; 650 meters above sea level) in Southern Oman (Fleitmann *et al.* 1999).

Presently, the area sits at the northern limit of the summer migration of the ITCZ and the associated Indian Ocean monsoon rainfall belt. Annual precipitation in this region is highly seasonal, more than 80% of total annual precipitation (400-500 mm yr^{-1}) falls during the summer monsoon months (July to September) when dense clouds and mists cover the region. The clouds are unable to rise higher than 1500 m because of a temperature inversion created by the convergence between the hot dry northwesterly winds and the low-level southwest monsoon winds. As a result, monsoon precipitation occurs as fine drizzle, seldom exceeding more than 5 mm d^{-1} (unlike the heavy rains normally associated with strong convectional monsoonal rainfall).

The $\delta^{18}O$-profile (Fig. 1) of stalagmite Q5 shows three distinct features. First, a rapid increase in monsoon precipitation between 10.3 and 9.8 kyr BP is indicated by a sharp decrease in $\delta^{18}O$ from -0.8‰ to ~-2‰. Second, an interval of generally high monsoon precipitation lasting from 9.8 to 5.5 kyr BP with $\delta^{18}O$ values averaging -2‰. Third, a long-term gradual decrease in monsoon precipitation staring at around 7 kyr BP is indicated by a slow shift in $\delta^{18}O$ from -2.2‰ at 7 kyr BP to ~0.9‰ (slightly more negative than $\delta^{18}O$ values of modern stalagmites) at 2.7 kyr BP. Furthermore, the early to mid-Holocene period of generally high monsoon precipitation is interrupted by three distinct intervals of reduced precipitation, occurring at around 9.2-9.1, 8.5-8.1 and 6.3-6.2 kyr BP.

The question arises, what circulation pattern controlled the amount of monsoon precipitation in Southern Oman over the course of the Holocene? As mentioned before, convective cloud development is prevented by the temperature inversion over Southern Oman, where the height of this temperature inversion is dynamically linked to the mean latitudinal summer position of the ITCZ and to the southwest monsoon pattern over Southern Arabia. A northward shift of the ITCZ into the Arabian Peninsula, as indicated by lacustrine sediments (McClure, 1976) and stalagmites (Burns *et al.*, 2001, Neff *et al.*, 2001), would lift the height of the temperature inversion, leading to stronger convective cloud development and higher monsoonal rainfall over Southern Oman. Due to the amount effect, $\delta^{18}O$ values of precipitation become more negative (depleted). Hence, the Q5 $\delta^{18}O$ record can be regarded as a record of the amount of Indian Ocean monsoon precipitation, where the latitudinal summer position of the ITCZ over the Arabian Peninsula plays a dominant role.

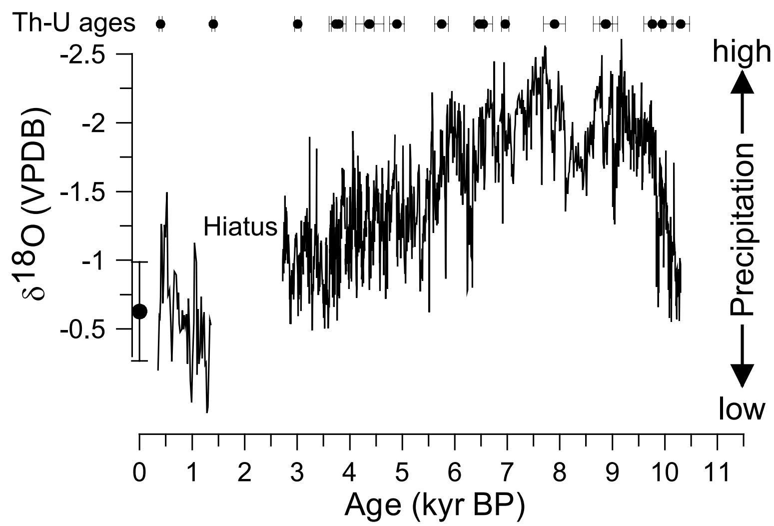

Figure 1. Stalagmite Q5 oxygen isotope record from Southern Oman. Black dots above are U-Th-ages. Black dot with vertical error bar shows the $\delta^{18}O$ range of modern stalagmites (101 stable isotope measurements, ~50 years).

References

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