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Dansgaard-Oeschger events and their reflection in speleothems (Hans Oeschger Medal Lecture)

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Speleothems in karstic cave environments form by passage of meteoric water through the overlying soils, where the water dissolves CO_2 to form carbonic acid, which in turn dissolves the host-rock carbonate. Degassing of the carbonate supersaturated meteoric water leads to the formation of calcite speleothems, which therefore can be considered as the end product in the much larger sea-atmosphere-land cycle. Their stable isotopic and geochemical composition reflect the environmental conditions above the cave, which in turn depend on larger scale parameters such as isotopic composition of the rainfall source, atmospheric storm patterns, ocean-land heat transfer.

In this talk I specifically address the potential of using speleothems to look at short term climatic events: the Dansgaard-Oeschger (D-O) events; rapid climate changes first observed in Greenland ice cores by Hans Oeschger with Willi Dansgaard and suggested to occur during the last glacial period. Many researches now show that D-O events are globally synchronous and can be identified in the marine and terrestrial climate records. Given, the ability to accurately date speleothems and to perform high-resolution studies of stable isotopes, trace elements and various other proxies (e.g., fluid inclusions, 'clumped isotopes' thermometry), it has become clear that speleothems enable us to better date the exact timing of D-O events and to understand the climatic response on land in different parts of the world to their occurrence, i.e., to address specific questions on the marine-atmosphere interaction, sea surface temperature, rainfall generation and their influence on human habitation and dispersal. Since the stable isotopic signal in speleothems primarily is a function of temperature and isotopic composition of rainfall, short time climatic events can be registered in fast growing speleothems. Indeed recent studies clearly demonstrate that D-O events are registered in speleothems, for example, vegetation changes in Western Europe show good correlation with D-O events[1]; changes in the monsoon intensity during glacials are recorded in Chinese speleothems[2]; the response of the Indian Ocean hydrological cycle to temperature changes in Greenland ice cores are recorded in speleothems from Oman[3]. D-O events are also registered in the mid-latitude, Eastern Mediterranean (EM) speleothems and marine cores[4,5,6]. Of special interest are the responses to D-O 15 and 14. The multiple proxy speleothems record from the southern extension of the high altitude Alpine karst in Mount Hermon[7], shows that from $\sim$56 ka to 51 ka several major pulses of wet and warm episodes occurred. This is expressed by vegetation development, and significant snow melting that drained a large amount of water to the Dead Sea Rift Valley. Speleothems from the Middle-East and Arabia demonstrate that during these D-O wet pulses, the African monsoon and westerly storm/rainfall systems intensified, resulting in the 'greening' of the Sahara. A major question that is currently under investigation using speleothems is the recent Modern Human migration out of Africa at 60-50 ka into the Levant and Europe: is this migration is related to D-O 15 and 14?

So called "D-O events" are also found in mid-Holocene speleothems from Soreq Cave, central Israel[8]. High-resolution ($\sim$3 to 20 years) speleothems records reveal a $\sim$1500 years cyclicity pattern similar to Bond cycles. Superimposed on these cycles are rapid climate changes (RCC) resembling the structure of D-O events, The characteristic "dogtooth" shaped isotopic changes indicate rather fast ($\sim$50-100 years) trends of increase in rainfall (up to $\sim$30%) and vegetation development, followed by gradual aridification over a longer period of $\sim$100-500 years. This climate oscillation is also expressed in the archeological cultural record. It is not clear yet what cause these RCC, and it is possible that of all potential climate forcing mechanisms, the most probable was solar variability, but this needs to be further investigated.

[1]Genty et al., 2003 *Nature*, 833-837; [2]Wamg et al., *Nature,* 2008, 1090-1093; [3]Burns et al., 2003, *Science,* 301, 1365-1367; [4]Almogi-Labin et al., 2009 *Quat. Sci. Rev* 28, 2882-2896; [5]Bar-Matthews et al., 1998 *EPSL* 166, 85-95;

[6]Bar-Matthews et al., 2003 *GCA*, 67, 3181-3199;[7]Ayalon et al., 2013 *Quat.Sci. Rev.,* 59, 43-56. [8]Bar-Matthews and Ayalon, 2011 *The Holocene* 21, 163-171;