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Variation of Palaeoclimate in the Eastern Mediterranean Region – As Derived from Speleothems in Various Climate Regimes in Israel

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New insight in the climatic variability of the Eastern Mediterranean (EM) region have been gained by studying the $\delta^{18}O$, $\delta^{13}C$ and U-Th ages of four karst sites in Israel representing an almost complete spectrum of present-day climate variability in the region. An important objective of this work is to compare the responses of different caves to climatic events in Israel and to regional and global events. The conditions at the chosen cave sites are given in Table 1. Our previous studies on the Soreq cave speleothems using U-Th dating shows that they were continuously deposited during the last 180 Ky (Bar-Matthews et al., 1997, 1999, 2000; Kaufman et al, 1998). The δ^{18} O record mimics that of the planktonic foraminifera G.ruber from the EM Sea, but with an offset by an almost constant difference of -5.5 permil. The average annual temperature in the Soreq cave area is also the sea surface temperature of the EM Sea (the source of the rain in the Soreq cave area - Ayalon et al., 1998) during the winter when rainfall occurs. Thus, the -5.5 permil difference is most probably due to the rainout effect during precipitation.

The fact that the offset is almost constant over the last 180 Ky indicates that the source for the rain in the Soreq cave area was always the EM Sea and similarly temperature changes occurred on the EM surface and on the land. Thus the $\delta^{18}O$ variations of the speleothems are directly related to variation in the $\delta^{18}O$ value of the sea surface. This establishes a connection between the marine and the terrestrial record, and allows the accurate ages of the Soreq cave speleothems to date the EM marine record.

New U-Th dating of the Pekiin cave shows that as in the Soreq cave, speleothem deposition was continuous throughout the last 180 Ky. Moreover, the $\delta^{18}O$-$\delta^{13}C$ profiles of the speleothems from Pekiin cave speleothems are similar to those of Soreq cave, indicating that the rainfall above the Pekiin cave also originated from the EM Sea. Since it is anticipated that a temperature difference existed in the past between the Soreq and Pekiin caves, as for the present-day (Table 1), similar speleothems $\delta^{18}O$ values means that the $\delta^{18}O$ values of the rainfall above the two caves was different. This difference in rainfall $\delta^{13}C$ values is attributed to the higher elevation of the Pekiin cave causing more efficient rainout. Thus two different controls of isotopic composition (temperature, and elevation difference) apparently cancel each other out causing speleothems in two different climatic regions to have similar $\delta^{18}O$ values.

Mitzpe Shlagim and Ma'ale Ephraim caves are located in extreme climatic conditions (Table. 1) and hiatuses are common. Moreover, the speleothem $\delta^{18}O$ records differ from those of Soreq and Pekiin caves presumably because under these more extreme climatic conditions it is the local developed $\delta^{18}O$ signal that dominates. This emphasises that an exact time framework is necessary for reconstructing the palaeoclimate in extreme climatic conditions. In Mitzpe Shlagim cave no speleothems were dated between 40 to 15 Ky, suggesting the speleothem growth ceased in this interval due to freezing and deposition restarted ~15,000 years ago.

The most arid conditions exist in the vicinity of Ma'ale Epharaim cave, which is located near the desert boundary. Several hiatuses occur in the speleothem growth, which are evident both from the dating and the petrography of the speleothems. The hiatuses most probably reflect periods when the amount of rainfall in the area was too low for water to enter the cave. Periods of deposition most probably reflect a shrinking of the desert area relative to present-day. The last major intensive deposition period occurred ~55 Ky and ended ~40 Ky and this was recognised in Soreq and Pekiin caves to reflect a wet period during the last glacial.

Cave Location	elevation (m a.s.l)	distance from sea (km)	mean annual rainfall (mm)	mean annual temperature (°C)
1. Soreq	400	40	550	18
2. Pekiin	900	25	900	16
3. Mitzpe Shlagim	2,000	50	>1000	7
4. Ma'ale Ephraim	200	65	200	23

Table 1: Cave site information:

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