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Vegetation and climate changes in the South Eastern Mediterranean during the Last Glacial-Interglacial cycle (86 ka): new marine pollen record

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ABSTRACT

The Eastern Mediterranean, located at the meeting between the Mediterranean vegetation of the Eurasian continent and the desert vegetation of the Saharan-Arabian desert belt, is ideal for tracking changes in regional vegetation as function of climate changes. Reconstruction of these changes in the South Eastern Mediterranean during the last 86 ka is based on a palynological record, from deep-sea core 9509, taken by R/V *Marion Dufresne*, off the southern Israeli coast. The chronological framework is based on the correlation of $\delta^{18}O$ records of planktonic foraminifera with the high resolution, well-dated U-Th speleothem record from the Soreq Cave, Israel and the occurrence of sapropel layers. Several cycles of humid/dry periods were documented during the last 86 ka. The record starts with the moderate humid and warm sapropel S3 marking the end of Marine Isotope Stage (MIS) 5. The climate during the Last Glacial period (75.5–16.2 ka) was cold and dry, with low Arboreal Pollen (AP) levels, and high values of semi-desert and desert vegetation (e.g. *Artemisia* - sagebrush). The driest and coldest period during the last 86 ka corresponds to MIS 2 (27.1–16.2 ka), characterized by the lowest tree cover along the sequence and the dominance of steppe vegetation. Some slightly more humid fluctuations were identified during the period of 56.3 and 43.5 ka with its peak between 56.0 and 54.4 ka. The most pronounced climate change started at the beginning of the Deglaciation (16.2–10 ka) and continued throughout the Holocene (last 10 ka), notwithstanding some short fluctuations. High AP levels were dominated by *Quercus calliprinos* (evergreen oak), suggesting that the Mediterranean forest was more extensive in the area and the climate was wet.

Sapropels S3 and S1 were clearly recognized here by the high concentrations and good state of preservation of pollen because of the development of anoxia in the bottom water that may be related to more extensive Nile discharge coinciding with high insolation values at 65° N and enhanced westerlies activity. Another wet and warm event is the Bölling-Allerød (14.6–12.3 ka). Cold and dry spells identified by low AP and high steppe elements correspond with Heinrich Events H2–H6, the Last Glacial Maximum, Younger Dryas and the 8.2 ka event. Similar pattern of vegetation trends was observed also in Lake Zeribar Western Iran, Tenaghi Philippon North East Greece and the Alborán Sea. There is a clear general difference between the South East Mediterranean and western and central Mediterranean because of W-E climatic moisture gradient reflected in the dominance of Mediterranean maquis, lower tree population and higher steppe vegetation in the South East Mediterranean.

1. Introduction

Pollen records from the Eastern Mediterranean Sea serve as direct indications for the paleovegetation and paleoclimate of the Levant and nearby area, and yet a relatively detailed pollen resolution from the South Eastern Mediterranean is still scarce. During the last ~90 ka the region experienced large climatic fluctuations (e.g. Horowitz, 1979; Bar-Matthews et al., 1997, 2003; Frumkin et al., 1999; Almogi-Labin et al., 2004, 2009), that must have affected the vegetation (e.g. Rossignol-Strick, 1993). There are increasing numbers of high resolution paleoclimate studies on the Levant both on the marine and land realm (e.g. Robinson et al., 2006; Almogi-Labin et al., 2009; Box et al., 2011, and references therein), showing that the paleoclimate and paleohydrology in the South East Mediterranean region responded to glacial-interglacial cyclicity and that the long-term trend is often punctuated by

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several shorter climatic events such as the Last Glacial Maximum (LGM), Heinrich Events, the Bölling-Allerød phase, the Younger Dryas (YD) episode and the 8.2 ka event.

Previous palynological marine records from the Levant were studied by Cheddadi and Rossignol-Strick (1995a,b). They documented the paleoclimate of the area during the last 250 ka, based on three marine pollen records (MD 84 642, MD 84 629, MD 84 627), located at the distal part of the Nile Cone (Fig. 1b). During the interglacial period, the abundance of tree pollen reached its maximum, indicating an optimum Mediterranean climate of great humidity, including some summer rainfall. During glacial maxima pollen of steppe and semi-desert plants were abundant and low for trees, suggesting more arid, continental and probably colder climate. Short-lived climatic events were not identified in these records due to relatively low sampling resolution. Moreover, Rossignol (1963, 1969) examined Pleistocene and Holocene cores from the Israeli coast and found only minor fluctuations along the sequences because of low resolution and interpreted them as slight oscillations in humidity. Horowitz (1974, 1979) studied two cores from Haifa Bay, covering the last 6 ka and suggested that during the early part of this period tree cover was more extensive in the area than at present, and therefore the climate was probably wetter whereas during the last 3 ka arboreal vegetation decreased, pointing to dryness. From the Levantine coastal plain only limited palynological records are available, indicating an existence of marshes at the beginning of the Holocene and a notable expansion of oak maquis suggesting a relatively wet early Holocene (Galili and Weinstein-Evron, 1985; Kadosh et al., 2004).

Several Eastern Mediterranean marine palynological studies in higher resolution focused on the paleoclimate conditions during the formation of sapropel layers (e.g. Rossignol-Strick et al., 1982; Rossignol-Strick and Paterne, 1999; Kotthoff et al., 2008a). Sapropels are dark-colored marine sediments, thicker than 1 cm, with a high content (>2%) of organic matter (Kidd et al., 1978). Sapropel deposition is most common in the Eastern Mediterranean, related to deep-water stagnation. Increased riverine runoff caused a reduction of surface-water salinity, thus weakening deep-water formation. At the same time, it may have provided an enhanced nutrient supply (e.g. Rohling, 1994; Kotthoff et al., 2011). A particularly important contribution to the formation of sapropels is the discharge of the River Nile to the Levantine Basin (e.g. Rossignol-Strick et al., 1982; Rossignol-Strick, 1985; Fontugne et al., 1994; Rohling, 1994; Calvert and Fontugne, 2001; Scrivner et al., 2004).

This study discusses the palynological sequence of the last 86 ka in a higher resolution as compared with previous marine pollen records from the South Eastern Levantine Basin. Pollen was extracted from core 9509, taken from the distal part of the Nile Cone (Fig. 1b). The importance of this marine palynological record is: 1. The time frame is well constrained and is based on the comparison of the $\delta^{18}O$ of the planktonic foraminifera *Globigerinoides ruber* with the accurately dated, high resolution isotopic record of Soreq Cave speleothems (Almogi-Labin et al., 2009); 2. Core 9509 was already subjected to a high resolution study of sediment characteristics including index color parameters, Total Organic Carbon (TOC) and Sea Surface Temperatures (SST) based on alkenones (Almogi-Labin et al., 2009) as well as the identification of

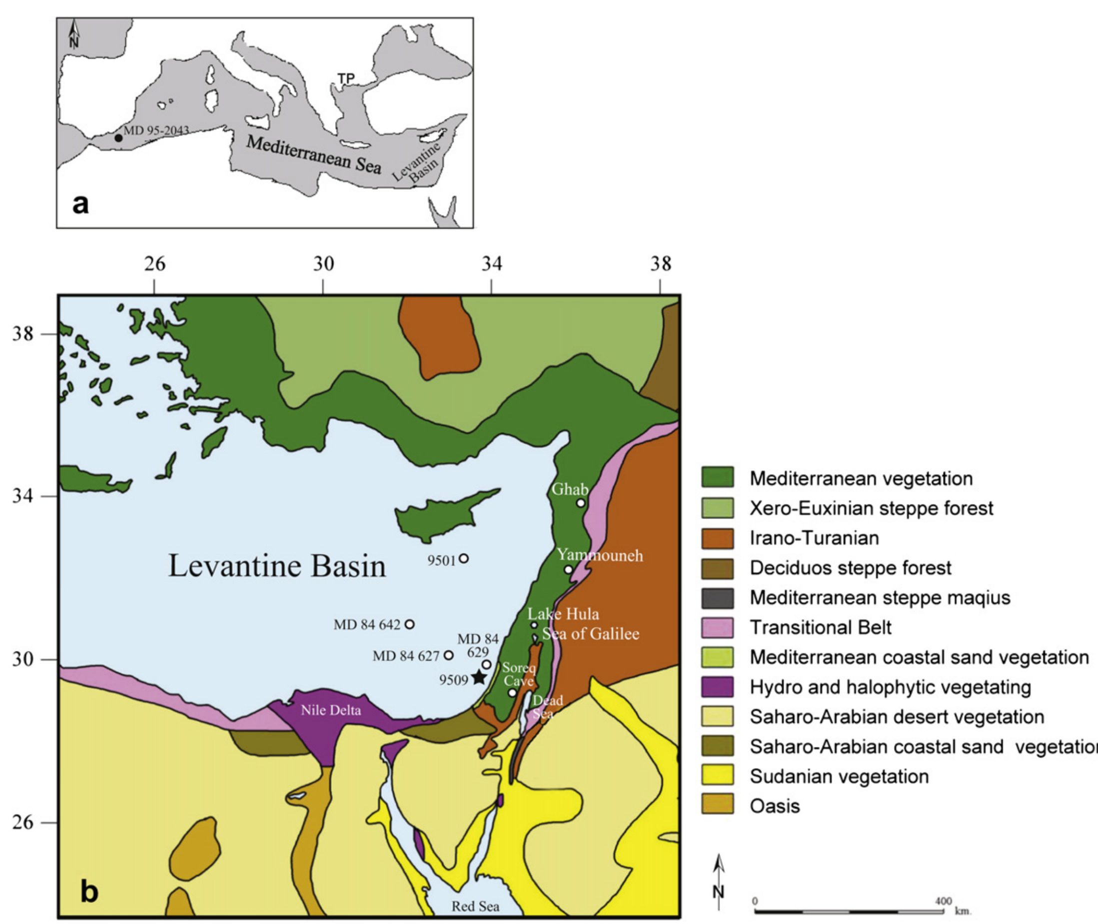

Fig. 1. a. Map showing the Mediterranean Sea with the location of the Levantine Basin. b. Eastern Mediterranean vegetation map (modified after Zohary, 1973) together with the location of marine core 9509 and other sites mentioned in the text.