Quaternary Science Reviews 59 (2013) 43–56

Contents lists available at SciVerse ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Last Glacial warm events on Mount Hermon: the southern extension of the Alpine karst range of the east Mediterranean

Avner Ayalon [a,*], Miryam Bar-Matthews [a], Amos Frumkin [b], Alan Matthews [c]

[a] Department of Geochemistry, Geological Survey of Israel, 30 Malchei Israel St, Jerusalem 95501, Israel
[b] Cave Research Unit, Department of Geography, The Hebrew University of Jerusalem, Jerusalem 91905, Israel
[c] Institute of Earth Sciences, Hebrew University, Jerusalem 91904, Israel

ARTICLE INFO

Article history:
Received 3 February 2012
Received in revised form
14 October 2012
Accepted 16 October 2012
Available online 29 November 2012

Keywords:
Speleothems
Paleoclimate
Hermon Mountain
Alpine Karst
Dead Sea Rift Valley
^{230}Th–U ages
$\delta^{18}O$
$\delta^{13}C$

ABSTRACT

This study focuses on warm Last Glacial episodes in the southernmost extension of the Alpine karst range of the Eastern Mediterranean (Levant) region through the study speleothems in Mizpe Shelagim Cave, located in Mt. Hermon. The Alpine karst range extends from Turkey through Syria and Lebanon, reaching its southern limit in Mt. Hermon at an elevation of more than 2000 m. Under present-day conditions, southern Mt. Hermon receives 1000–2000 mm precipitation, mostly as snow, that originates in the Eastern Mediterranean Sea. Speleothems deposition in this high altitude region was continuous during interglacials, but during the Last Glacial growth only occurred when average annual temperatures exceeded ~3 °C as inferred from the study of speleothem fluid inclusions. Warming episodes occurred at: ~65 ka, ~56 ka, 54.5 ka, ~52.5–51 ka, ~49 ka, ~42 ka, and ~36 ka and are coincident with maximum insolation at 65 °N. The main depositional period from ~56 ka to 51 ka coincides with Dansgaard–Oeschger interstadial 15 and 14, and warming in the northeastern basin of the Mediterranean Sea. Warming in the southern Alpine karst range of the Eastern Mediterranean was manifested by vegetation development, together with significant snow melting that resulted in the drainage of large amount of water to the Dead Sea Rift Valley.

1. Introduction: geographical, geological and climatological setting

Mt. Hermon is the southernmost part of the Alpine-type karst system, which extends from Turkey through Syria and Lebanon. Mt. Hermon is an intensively faulted anticlinal dome mostly built of a 900 m thick karstic Jurassic limestone (e.g. Heimann et al., 1990; Hirsch, 1996; Sneh and Weinberger, 2003). The mountain is over 55 km long and 25 km wide, rising to a maximum 2814 m asl in Syria and 2224 m at Mizpe Shelagim (Fig. 1). The region receives 1000–2000 mm annual precipitation, most of which falls during the winter between October to April, with snow fall mainly from December to March. Snow mainly accumulates during January–February, but can persist on the ground until March–June. Mean monthly temperatures at Mizpe Shelagim are ~−2 °C in January. The soil beneath the snow does not freeze under present winter conditions. The summer on Mt. Hermon is warm and dry, and average temperatures reach ~17 °C in August. Southward and eastward of Mt. Hermon, the high ridge gives way to lower elevations with an increasingly drier climate. The special geographic, climatic and ecologic setting of Mt. Hermon is reflected by the fact that it serves as the southernmost limit to some plant and bird species that are abundant in Europe (Shmida, 1980).

Precipitation is preferentially recharged into the subsurface, so relatively little surface runoff is sustained until the water is swallowed by the highly-permeable karst (Frumkin et al., 1998; Gil'ad and Bonne, 1990). Mt. Hermon recharges the main tributaries of the Jordan River, mainly through its largest springs: Dan (~250 × 10^6 m^3/year) and Hermon-Banyas (Panyas in Fig. 1) (~75 × 10^6 m^3/year) at the southwestern foot of the Hermon range (Fig. 1b: Gil'ad and Bonne, 1990; Rimmer and Salingar, 2006). Apparent residence time of water in the subsurface ranges between ~5 days (Gil'ad, 1980), up to tens of years (Wakshal, 1982). Mt. Hermon serves also as the recharge zone of the Damascus Basin to the east (Fig. 1a). Much of the dissolved load from Mt. Hermon is carried through the Jordan River towards its ultimate base level, the Dead Sea (Gur et al., 2003). A small fraction is deposited as speleothems in the mountain voids and to a larger extent as tufa in the Hula valley close to the springs (Heimann and Sass, 1989).

The carbonate bedrock, tectonic mesostructures, and abundant precipitation have favored the development of authigenic karst

* Corresponding author. Tel.: +972 2 5314297; fax: +972 2 5314330.
E-mail address: ayalon@gsi.gov.il (A. Ayalon).

0277-3791/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.quascirev.2012.10.047

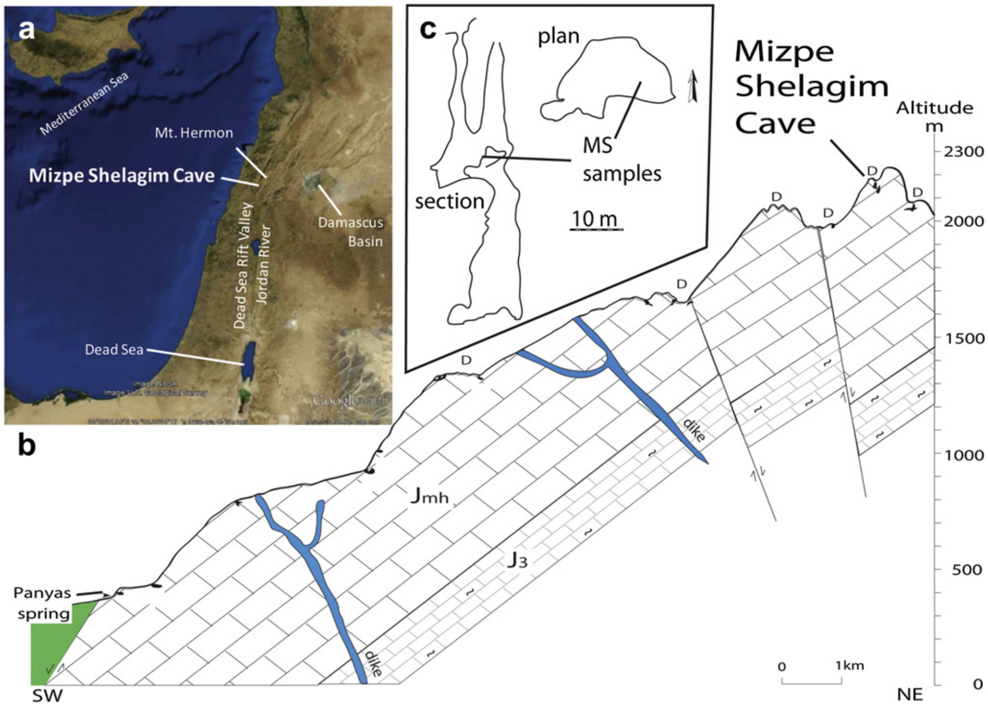

Fig. 1. Location and setting of study site. (a) Google map of the study site and the region; (b) Mizpe Shelagim Cave on a geological section of south-western Mt. Hermon (after Frumkin et al., 1998). Jmh is middle-Jurassic Hermon Formation (Sneh and Weinberger 2003), underlain by Jurassic J3 Formation. D indicates a doline (closed karst depression), (c) East-west section of Mizpe-Shelagim Cave, with sampled speleothems location.

features in Mt. Hermon, particularly in the vicinity of Mizpe Shelagim (Frumkin et al., 1998). Several generations of karstification are observed, including ancient hydrothermal paleokarst. Terra rossa soil, often originating from weathered basaltic dykes or magmatic plugs (Singer, 1978), covers the bottom of the depressions. Ponors (swallets), often located at the soil–rock contact, typically drain the depressions into the vadose zone.

A few tens of caves are known in the southern Hermon ridge (Frumkin et al., 1998). Some caves act as intermittent drains to snow melt and rainwater, and others are relict features without active ephemeral streams. The active drains dominantly demonstrate dissolution features associated with aggressive water activity, whereas active speleothems are especially abundant in relict caves which do not act as active sinks today.

Mizpe Shelagim (MS) Cave is one of the largest caves on Mt. Hermon (Fig. 1) and it is the deepest (52 m) known cave in the high part of the mountain. The cave is 2180 m asl, in the Alpine karst region of Mt. Hermon, west of Mizpe Shelagim peak and just north and above a steep slope scarp, descending 200 m to the bottom of Emeq Bole'an (="ponor valley") (Fig. 1b). MS cave is below the present-day snow line.

The cave is intensively decorated with speleothems, often concealing its original morphology. It contains several types of calcite dripstones, such as flowstone, stalactites and stalagmites, as well as a variety of helictites, 'cave corals', 'cave pearls', and subaqueous 'dogtooth spar'. Subaqueous deposits are formed in terminal pools at the lowermost part of the cave. The cave air temperature (7 °C) reflects the mean annual temperature. The surface above the cave is dominated by sparse C3 flora belonging to the subalpine tragacanthic belt that is typical of semi-arid alpine regions of the east Mediterranean (Auerbach and Shmida, 1993). It is characterized by sparse, cushion-like shrubs, short herbaceous species, and geophytes. MS Cave is located ~300 m above the uppermost xeromontane open forest belt.

The cave had no human-size entrance before being truncated by construction work, and received only seepage flows through narrow fissures. Therefore, it was well isolated from direct atmospheric influence throughout its history. This isolation prevented evaporation and rapid loss of CO_2. The cave comprises a central chamber in which speleothems were sampled, and two vertical shafts above and below the chamber (Fig. 1c).

The wide variety of speleothem' types and evidence for high activity suggest that MS cave is capable of providing a unique high-resolution record of the Eastern Mediterranean Alpine Karst region. Understanding the paleoclimate of the South Alpine region, the relationships with northern Hemisphere climate and the Eastern Mediterranean climate are the main goals of this study. Special emphasis is given to the paleo hydrological activity in the cave area, and its potential relationship to paleo discharge of rivers and springs running into the Dead Sea Rift valley, mainly during the Last Glacial when the precursor lake of the Dead Sea, Lake Lisan, was in its higher stands.

2. Materials and methods

2.1. Sampling of speleothems, cave water and precipitation (rain and snow)

Rainfall and snow were collected ~500 m below the cave at 1650 m asl at the "Lower Cable" site in Mt. Hermon (coordinates 222306E/301520N). During most of the winter months, snow covers the site. Oxygen ($\delta^{18}O$) and hydrogen (δD) isotopic compositions of the precipitation (mainly snow) was obtained by collecting monthly samples (from October to May) during eight wet seasons between 2001 and 2009. The precipitation was allowed to accumulated in plastic buckets with a 1 cm thick oil layer to prevent evaporation, and then transferred to sealed plastic bottles and its quantities measured. The time periods for which precipitation was collected,