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Paleo-environment of the Southern Levant during the Bronze and Iron Ages

The Pollen Evidence

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Introduction

The Bronze and Iron Ages[1] in the Levant were characterized by dramatic historical developments—the rise and collapse of urban societies during the Bronze Age, the emergence of territorial kingdoms during the early phases of the Iron Age and the domination of the region by great empires during the latter part of the Iron Age. These transformations and events are reflected in the archaeological record as increasing economic prosperity or decline and destruction. They are likewise represented by sharp settlement oscillations, including human movements between the Mediterranean, semi-arid and desert environments (Finkelstein 1995). These oscillations may have resulted from climate changes (e.g., years of severe drought), and/or indicate changes in human behavior, such as the transformation of subsistence patterns influenced by economic and social factors, political struggles, warfare and environmental or natural disasters (such as earthquakes and pestilence[2]). Indeed, given the long period under discussion and the absence or dearth of textual evidence, researchers are still debating the triggers behind these dynamics—historical and environmental. In this review, we present a regional climatological history of the Bronze and Iron Ages based on well-dated palynological records. In addition, this research traces evidence of human interference in natural vegetation as reflected in the pollen curves, such as olive horticulture and deforestation. Palynology is

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1. The dating of phases in the Bronze and Iron Ages follows the radiocarbon of the last two decades (for instance, Regev *et al*. 2012 for the Early Bronze Age and the transition to the Intermediate Bronze Age; Finkelstein and Piasetzky 2010; Toffolo *et al*. 2014 for the Iron Age; Martin, Finkelstein and Piasetzky 2020 for the Late Bronze Age; the latter also reflects on the much debated date of transition from Middle to Late Bronze Age – see Bietak 1991; 2013; Höflmayer 2017.
2. For the balance between these two factors, see Greener, Finkelstein and Langgut 2018.

considered a powerful tool in the reconstruction of past vegetation, climate history and human relations with the natural environment (Bryant 1989; Faegri and Iversen 1989).

The Southern Levant went through multiple climate fluctuations during the Late Holocene (Bookman [Ken Tor] *et al.* 2004; Migowski *et al.* 2006; Litt *et al.* 2012; Langgut *et al.* 2015 and references therein; Kaniewski *et al.* 2017; Laugomer 2017). The region is considered a sensitive recorder for tracing links between climate and cultural changes, due to the existence of several different vegetation zones within its relatively small territory. The question of how and to what extent environmental changes affected human activity in this area during antiquity has been a matter of debate (e.g., Rambeau 2010).

The Palynological Records

Here we summarize the results of two palynological records: The Sea of Galilee (Lake Kinneret) and the Zeʾelim (Dead Sea) profiles (Figs. 1.1b and 1.2). These studies were conducted by one of us (DL; in cooperation with Thomas Litt of the University of Bonn, Frank Neumann of the North-West University SA, and Mordechai Stein of the Israel Geological Survey) as part of a project titled "Reconstructing Ancient (Biblical) Israel: The Exact and Life Science Perspective," funded by the European Research Council (ERC). The project was directed by one of us (IF) along with Steve Weiner of the Weizmann Institute of Science from 2009 to 2014. The two palynological diagrams have already been published and discussed in detail in a series of articles (Langgut, Finkelstein and Litt 2013; Langgut *et al.* 2014; 2015; Langgut, Lev-Yadun and Finkelstein 2014; Langgut, Adams and Finkelstein 2016; Finkelstein and Langgut 2014; 2018). Here we provide a broad-scale summary of the evidence. In order to attain this broad view, our Sea of Galilee and Zeʾelim diagrams were compared to two other high resolution (consisting of pollen sample intervals separated by only a few decades) well-dated palynological records: ʿEin Feshkha (Neumann *et al.* 2007a) and Birkat Ram (Neumann *et al.* 2007b). The four records present a north–south transect of 220 km along the Southern Levant (Fig. 1.3; based on Langgut *et al.* 2015: Fig. 4). Four main pollen curves are compared: *Quercus* (oak), *Pinus halepensis* (pine), *Olea europaea* (olive)[3] and total tree pollen of the Mediterranean maquis/forest.[4]

Sea of Galilee Sediment Core

The Sea of Galilee receives its water from the Jordan River and from some shorter rivers which flow into the Rift Valley from the Galilee Mountains and the Golan Heights (Fig. 1.1a). In 2010, an 18 m core, covering almost the entire Holocene, was extracted from the northern inner part of the lake (Fig. 1.1b). Five and a half meters of this profile, corresponding to the timespan between the Early Bronze IB and the end of the Iron Age (composite depth of 458.8–1006.6 cm), were analyzed at 40-year intervals between pollen samples (Langgut, Finkelstein and Litt 2013: 154; Langgut *et al.*

3. *Olea europaea* (olive) was among the most important cultivated plants in the region since the Early Bronze Age (e.g., Zohary, Hopf and Weiss 2012). It grows today in the Southern Levantine Mediterranean climate zone primarily as a cultivated tree (Zohary 1973; Langgut *et al*. 2019). The wild olive is a minor component of the native Mediterranean *Quercus calliprinos–Pistacia palaestina* association as evident by Pleistocene and Early Holocene pollen diagrams (Horowitz 1979; Weinstein-Evron 1983; Kadosh *et al.* 2004; van Zeist and Bottema 2009; Langgut *et al.* 2011, 2019). Based on both palynological evidence (Baruch 1990; Neumann *et al.* 2007a; 2007b; van Zeist, Baruch and Bottema 2009; Litt *et al.* 2012) and archaeological finds (e.g., Zohary and Spiegel-Roy 1975; Epstein 1978; Gophna and Kislev 1979; Neef 1990; Eitam 1993), it is obvious that by the Early Bronze Age *Olea* had already been intensely cultivated in the Southern Levant. This evergreen wind-pollinated tree has a very efficient pollen dispersal system (e.g., Baruch 1993) and has a strong response to cessation and resumption of orchard cultivation (resulting in dramatic fluctuations in pollen production following abandonment or rehabilitation of olive orchards). It is therefore considered to be a reliable marker for identifying agricultural activity in antiquity (Langgut, Lev-Yadun and Finkelstein 2014).

4. This group sums up all the Mediterranean trees and large shrubs. It is dominated by evergreen and deciduous oaks while other Mediterranean trees appear in lower percentages (e.g., *Phillyrea*, *Pistacia* spp., *Pinus halepensis* and *Ceratonia siliqua*). Cultivated olives were combined within the natural elements of the Mediterranean forest (the Mediterranean arboreal pollen; grey pollen curves on Fig. 1.3), which evidently includes wild olive trees, while desert trees such as *Acacia* and *Tamarix* were excluded. In general, Mediterranean trees and shrubs require at least 350 mm of annual rainfall in order to thrive (e.g., Zohary 1973). Therefore, fluctuations in the Mediterranean arboreal pollen curve can provide information about climate, especially in the climate-sensitive areas located on the fringe of the Mediterranean zone (Finkelstein and Langgut 2014).

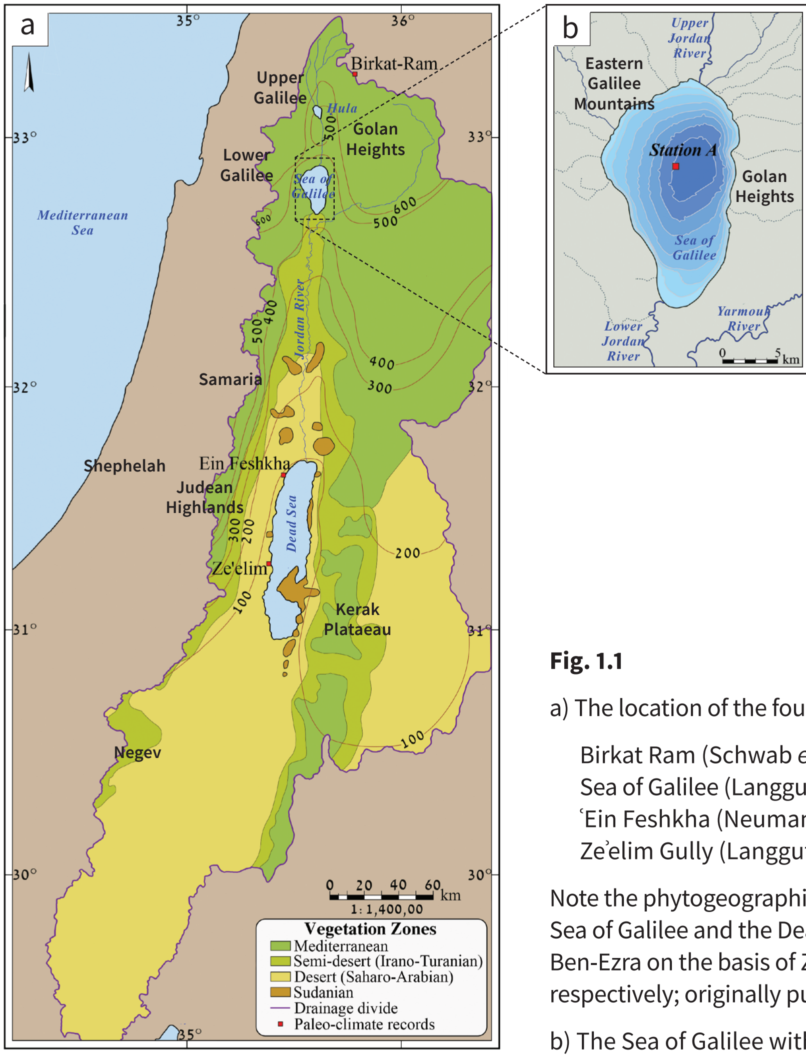

Fig. 1.1

a) The location of the four fossil pollen records discussed in this paper:

Birkat Ram (Schwab *et al*. 2004; Neumann *et al*. 2007b)
Sea of Galilee (Langgut, Finkelstein and Litt 2013; Langgut *et al*. 2015)
ʿEin Feshkha (Neumann *et al*. 2007a)
Zeʾelim Gully (Langgut *et al*. 2014)

Note the phytogeographic zones and rainfall isohyets characterizing the Sea of Galilee and the Dead Sea drainage basin (drawn by Itamar Ben-Ezra on the basis of Zohary 1962 and Srebro and Soffer 2011, respectively; originally published in Finkelstein and Langgut 2018: Fig. 1)

b) The Sea of Galilee with the coring location near Station A

2015: 220). Other sections of the profile were investigated at a lower resolution of ca. 120 years between samples (Schiebel 2013: 26 and Appendix 6; Schiebel and Litt 2018). During most of the Holocene, the Sea of Galilee stood at ca. 212 m below mean sea level (msl); yet, there were periods when the lake's level dropped to the point that the shallower southern end was exposed (Hazan *et al.* 2005). The chronological framework of the Sea of Galilee record presented here is based on an age-depth model, composed of nine radiocarbon AMS dates of short-lived organic samples (Langgut, Adams and Finkelstein 2016: Table 1). The Sea of Galilee sediment core is characterized by a relatively homogeneous lithology, with no evidence of any hiatus; thus, sediment deposition can reliably be considered continuous. This is supported by the uniformity of pollen concentration values throughout the record (Langgut, Finkelstein and Litt 2013: Fig. 2). A detailed palynological diagram of the Bronze and Iron Ages has already been presented elsewhere (Langgut *et al.* 2015: Fig. 3).

Zeʾelim (Dead Sea) Sediment Outcrop

The Zeʾelim Gully is located east of the Masada Plain (Fig. 1.2a). The Zeʾelim Ravine drains the southern part of the Judean Desert, carrying waters and sediments that originate on the eastern flank of the Judean Highlands (Fig. 1.2b). Currently, water flows through the wadi

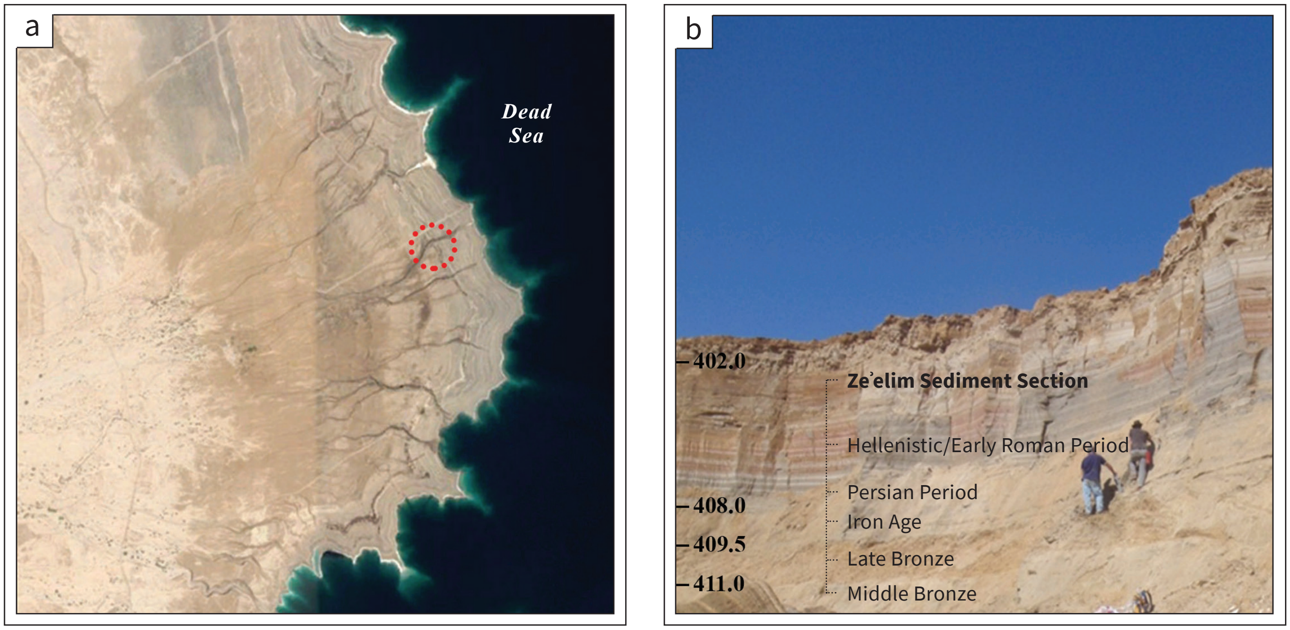

Fig. 1.2

a) Gullies of the Ze'elim fan delta cut into terraces created by the recession of the Dead Sea (Google Earth); the red circle marks the sampling location

b) The Ze'elim sediment section where we conducted our palynological and sedimentological investigations, with main archaeological periods and elevations; presented in meters below msl (photo: Dafna Langgut)

several days per year, mainly during winter months. Over the course of the Holocene, the Dead Sea has fluctuated between 370 and 430 m below msl (Frumkin and Elitzur 2002; Enzel *et al.* 2003; Bookman [Ken-Tor] *et al.* 2004; Migowski *et al.* 2006). At present the lake stands at 432 m below msl, due to the significant withdrawal of water for irrigation and drinking as well as the maintenance of evaporation ponds in the southern basin of the Dead Sea, which has occurred primarily within the past three decades. This continuous anthropogenic lake level drop (>100 cm/year) has resulted in the formation of deep gullies along the lake's shore terraces and has exposed the Holocene Ze᾿elim Formation (Bookman [Ken-Tor] *et al*. 2004) (Fig. 1.2a).

Within the framework of an ERC project, a sediment outcrop was extracted from the Ze᾿elim Gully exposure. Several 50 cm long sediment wall-profiles were collected and sampled for pollen analysis at ca. 5 cm intervals (Langgut *et al.* 2014); each sample represents a few decades. This sediment outcrop is located near the section previously studied by Neumann *et al.* (2007a), who analyzed the pollen record at a lower and irregular resolution. The proximity to this older profile enabled us to perform a stratigraphic and chronological correlation (Langgut *et al*. 2014; Kagan *et al.* 2015). The chronology of the entire integrated sediment sequence is based on 11 radiocarbon AMS dates of short-lived organic material and on the identification of a seismic event dated to the 8th century BCE (Kagan *et al.* 2011). The Ze᾿elim compiled profile covers the time interval of ca. 2500–500 BCE—from the beginning of the Intermediate Bronze Age to the end of the Iron Age. The different sediment facies characterizing this sedimentological section accumulated in two depositional environments: shore environment (coarse-sand units, beach ridges, aragonite crusts and ripple marks) and lacustrine environment (laminated-detritus, laminated aragonite and detritus). The former is indicative of low Dead Sea lake levels, while the latter depositional environment represents an increase in lake levels. Detailed descriptions of the stratigraphy, sedimentology and radiocarbon chronology of the

Zeʾelim sediment outcrop are given elsewhere (Langgut *et al.* 2014 and Kagan *et al.* 2015).

The Southern Levant: Current Climate and Vegetation

The Southern Levant features two main climate gradients. The first is a dramatic transformation from a sub-humid Mediterranean climate (>800 mm of mean annual precipitation) in the north to hyper-arid climate in the southern Negev Desert (<50 mm of mean annual rainfall) (Fig. 1.1a). This steep precipitation gradient occurs over a distance of less than 300 km (north to south). The second gradient runs from west to east, from the Mediterranean coast toward the Dead Sea Rift Valley. It is formed by an orographic obstacle—the central ridge— which creates a rain-shadow desert: The west side of the ridge is characterized by typical Mediterranean climate, while on the east it features a rapid transition to the aridity of the Judean Desert. This entire gradient occurs over a distance of less than 100 km. As a result, the Southern Levant is composed of three main phytogeographical zones (Zohary 1962; 1973) (Fig. 1.1a):

1. The Mediterranean region includes the coast and its adjacent mountainous areas (Galilee, Carmel Ridge, Samaria and Judea). It receives more than 400 mm rainfall annually and is generally influenced by the Mediterranean climatic system together with some regional orographic phenomena. This vegetation zone features Mediterranean maquis/forest with typical evergreen trees such as *Quercus callipprinos, Olea europaea* and *Pinus halepensis* and some deciduous trees (e.g., *Quercus boissieri, Q. ithaburensis* and *Pistacia palaestina*). In the understory of forests and in open fields, dwarf-shrubs as well as many herbaceous species are common. The Israeli Coastal Plain is occupied by a mix of Mediterranean and desert plants due to its sandy soil and saline environment. This sandy strip is dominated by different species of Poaceae, Chenopodiaceae, *Artemisia monosperma* and *Ephedra.*

2. The Irano-Turanian phytogeographic region covers the area from the Coastal Plain near Gaza to the Negev Highlands and the southern edge of the Judean Highlands and then continues northward via the Central Jordan Valley to the Sea of Galilee. This is an almost treeless landscape with semi-arid vegetation, often described as steppe. Different species of Poaceae and Chenopodiaceae are the main vegetal components here, as well as *Artemisia herba-alba.* The annual rainfall is 200–400 mm on average and is due mainly to western Mediterranean depressions. The region is also characterized by relatively broad seasonal and daily temperature ranges.

3. The Saharo-Arabian region occupies most of the Negev Desert, which lies within the world desert belt (30° latitude). The vegetation is typified by relatively low species diversity and is dominated by many members of the Chenopodiaceae, *Zygophyllum dumosum*, grasses and *Tamarix* spp. This region has a typical desert climate: the mean annual rainfall does not exceed 200 mm and is typically lower than 100 mm. Seasonal and daily temperature ranges are broad. It is influenced by southern and southeastern synoptic systems, which are widespread in the spring and autumn, as well as by the western Mediterranean depressions, which mainly influence the northern part of the Negev Desert. Within this desert plant phytogeographic region, patches of Sudanian phytochorion with tropical elements occur along the shores of the Dead Sea, in the Arabah Valley and in the Central Jordan Valley (up to about 80 km north of the Dead Sea). Some of the tropical plants are linked to freshwater springs or wadi beds; they include *Acacia*, *Ziziphus spina-christi* and *Salvadora persica* (Zohary 1962; Shmida and Or 1983; Al-Eisawi 1996).

Vegetation Changes, Climate Fluctuations and Settlement History during the Bronze and Iron Ages

Though this book is devoted to the period between the Late Bronze II–III and the Iron IIA, in what follows we review the pollen evidence for the climate of the Levant over a longer period. We believe that a long-term perspective better illuminates the specific demographic, economic and territorio-political processes associated with the rise of ancient Israel (see also Chapter 17).

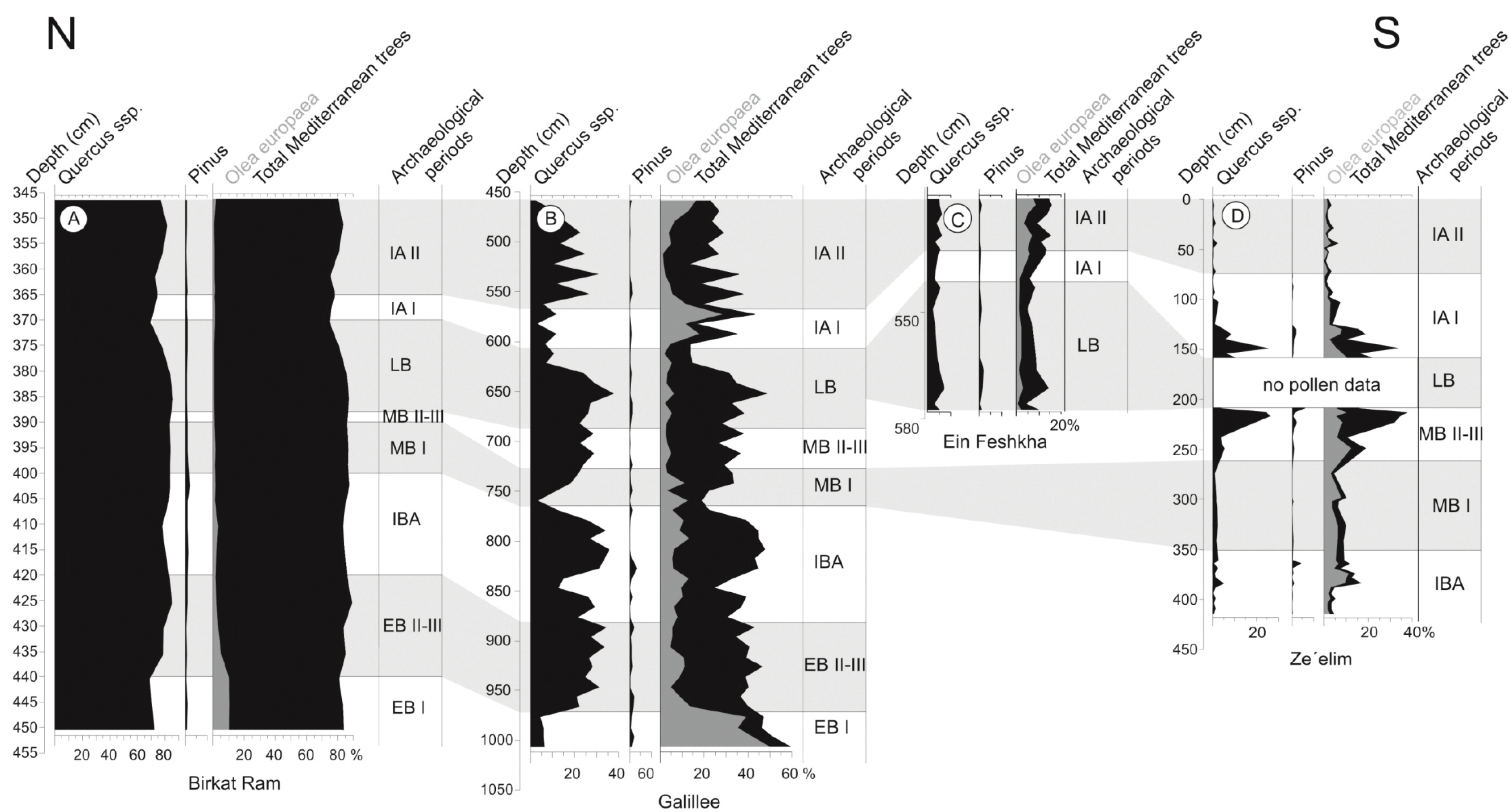

Fig. 1.3: A north–south palynological transect of 220 km along the Southern Levant during the Bronze and Iron Ages (published in Langgut *et al*. 2015: Fig. 4). The transect is composed of the pollen records from Birkat Ram, Sea of Galilee, ʿEin Feshkha and the Zeʾelim Gully (references in Fig. 1.1a). Four main pollen curves are given: *Quercus* (oak), *Pinus halepensis* (pine), *Olea europaea* (olive) and total tree pollen of the Mediterranean maquis/forest. Within this north–south palynological transect, decreasing percentages of the total Mediterranean trees indicate the shrinkage of the Mediterranean maquis/forest and the shifting of the semi-arid boundaries to the north and west due to less available moisture (Fig. 1.1a); increasing values of the Mediterranean pollen tree indicate the opposite. The pollen records from the Sea of Galilee and the Dead Sea are sensitive to the conditions in both the Mediterranean area and the Irano-Turanian vegetation belt, as the two lakes collect wind-driven pollen from these two adjacent zones. In addition to air borne pollen, they receive fluvially transported pollen from large sectors of the Southern Levant—primarily via the Jordan River, but also via local streams. Therefore, the southern pollen records (Sea of Galilee, ʿEin Feshkha and Zeʾelim; Fig. 1.3b–d) are more sensitive recorders of climate fluctuations than the northernmost pollen record from Birkat Ram (Fig. 1.3a), which is located in an area that receives more than 1,000 mm of annual rainfall (Srebro and Sofer 2011). EB = Early Bronze Age; IB = Intermediate Bronze Age; MB = Middle Bronze Age; LB = Late Bronze Age; IA = Iron Age

The Early Bronze I (ca. 3600–3000 BCE)

Two palynological diagrams are available for this period (Fig. 1.3a,b)—Birkat Ram and the Sea of Galilee (the latter begins in ca. 3150 BCE, corresponding to the later phase of the period). The Mediterranean arboreal pollen curve, including olive trees, appears at its highest percentages, indicating that the Early Bronze I was the most humid phase of the Bronze and Iron Ages. Relatively wet climate conditions are similarly evident from the Sorek Cave isotopic record (Bar-Matthews and Ayalon 2011: Fig. 6) as well as from the Jezreel Valley geoarchaeological data (Rosen 2006: 468–469; Adams *et al.* 2014). Wet climate conditions in the Early Bronze I may have facilitated the initial phase of the wave of settlement in the Negev Highlands (for the chronology, see Avner and Carmi 2001; Sebbane *et al.* 1993). The picture is similar in the semi-arid regions of Transjordan, which feature more Early Bronze I than Early Bronze II–III sites (Philip 2008: 189; Bradbury *et al.* 2014: 211–214).

The Early Bronze I also features the highest frequencies of olive trees (at Birkat Ram ca. 10% and in the area of the Sea of Galilee up to 50% of the total pollen sum), representing the development of a specialized economy focused on olive orchards and their secondary products (Neumann *et al.* 2007b; Langgut *et al.* 2015; Langgut, Adams and Finkelstein 2016). In the En-Gedi palynological record (mainly representing the situation in the Judean Highlands; Litt *et al.* 2012), high olive percentages were also documented, indicating that during the Early Bronze I large scale olive horticulture activity took place in the entire Mediterranean zone of the Southern Levant. Archaeobotanical evidence from excavations indicates that olive wood was exploited at a remarkably high level in this specific period (Benzaquen, Finkelstein and Langgut 2019, and see also the review of evidence in Genz 2003). As olive yields benefit more from an even pattern of rainy days over a long period of time than from rains that fall in sudden torrents (as is the situation today in the region), the high arboreal and olive pollen frequencies may reflect a different rain regime (Langgut, Adams and Finkelstein 2016). A similar suggestion was raised by Rosen (1991: 197) based on her study in the Lachish area.

Olive grows best in its original natural habitat in hilly Mediterranean zones; it is no wonder then, that this period is characterized by large-scale settlement expansion into the hill country on both sides of the Jordan (Finkelstein and Gophna 1993; Finkelstein *et al.* 2006; Bradbury *et al.* 2014; Langgut, Adams and Finkelstein 2016: Table 2). Many of the new highland settlements were located in the orchard niches of western Samaria (for the situation in the early 20th century CE, see distribution map of olive orchards in Palestine, 1935, available in Finkelstein and Langgut 2018: Fig. 4). Considering the intensity of olive growth in this period as indicated in the pollen records, olives and their oil must have been produced in quantities beyond local consumption as a “cash crop” (Langgut, Adams and Finkelstein 2016). Evidence from the southern Coastal Plain and the Nile Delta attest to strong trade relations with Egypt; secondary products of the highlands’ olive horticulture activity must have played a major role in this network (e.g., Finkelstein and Gophna 1993; Braun 2002). Indeed, commercial contacts during the Early Bronze I are evident from material culture items found in both the Levant and Egypt (Braun 2002; de Miroschedji 2002; Sowada 2009). Egyptian demand for Southern Levantine goods during the Early Bronze IB (Naqada IIB–IIIC1; 3500–3000 BCE) must have accelerated the expansion of the settlement system into the hill country, intensified production in the olive orchards, encouraged the development of Egyptian marketing stations along the southern Coastal Plain (in Naqada IIIC1) and stimulated the growth of social and political complexity in the Southern Levant (Finkelstein and Gophna 1993; de Miroschedji 2002; 2009; Regev *et al.* 2014; Langgut, Adams and Finkelstein 2016).

The Early Bronze II (ca. 3000–2900 BCE)

The high olive pollen frequencies that characterize the Early Bronze I were followed by a dramatic decline in olive pollen percentages during the transition to the Early Bronze II, as is evident in the Birkat Ram and especially the Sea of Galilee pollen records (from a peak of more than 50% to a low of only 5% of the total pollen sum; Fig. 1.3a–b). Decreased olive pollen frequencies around

2900 BCE were also documented in the Lake Ḥula record (van Zeist, Baruch and Bottema 2009: Fig. 5).

A slight reduction in the arboreal vegetation was recorded in the Early Bronze II (from a range of 46.1–59.5% to 36.5–40.4% in the Sea of Galilee record for example), which might signal a minor shrinkage of the natural Mediterranean forest/maquis. Still, relatively humid climate conditions continued to prevail in the region, as is also evident by the Sorek Cave isotopic record (Bar-Matthews and Ayalon 2011: Fig. 6; Laugomer 2017). Reconstruction of the Dead Sea levels shows high stands during the Early Bronze II (lake levels reached 385 m below msl—Migowski *et al.* 2006: Fig. 3), indicating wet climate conditions not only in the area of the lake, but also in the northern parts of its drainage basin (for the drainage basin of the two lakes, see Fig. 1.1a). Continued wet climate conditions were especially significant for the marginal regions of the Southern Levant in the south and east. In the Early Bronze II, the wave of settlement in the Negev Highlands peaked (Cohen 1999) and the town at Arad in the Beersheba Valley reached its zenith, probably becoming a gateway community for southern trade (Finkelstein 1991; Finkelstein *et al.* 2018 and references therein).[5]

The Early Bronze I/II transition ca. 3000 BCE witnessed significant change in the organization of society and the distribution of settlements in the Southern Levant, which seems to be unrelated to climate conditions, but rather to territorio-political or economic circumstances (Langgut *et al.* 2015; Langgut, Adams and Finkelstein 2016; Laugomer 2017). The decline in olive pollen (Fig. 1.3a–b) was also probably linked to changes in geopolitical (rather than climatic) conditions in the region. Based on the archaeological evidence, overland transportation between the Southern Levant and Egypt had waned, while maritime links between Egypt and the northern Levant were intensified (Marcus 2002). This explains the decline in settlement activity across northern Sinai, which served as the overland route between Egypt and the Levant. Botanical and archaeological data from the northern Levant corroborates this picture (Langgut, Adams and Finkelstein 2016 and references therein). In general, the Southern and Northern Levant olive pollen curves show a “mirror image” throughout the Bronze and Iron Ages, reflecting shifts in balance between the two regions from which olive oil was exported, mainly to Egypt (Fig. 1.4).

The Early Bronze III (ca. 2900–2500 BCE)

Based on the Sea of Galilee pollen record, the Early Bronze III is also characterized by relatively high arboreal percentages (reaching up to 46.2%), indicating the continuity of relatively wet climate conditions. The minor increase in oak pollen documented in the Birkat Ram and Sea of Galilee records signals a slight expansion of the natural Mediterranean forest/maquis (Fig. 1.3a). The Sorek Cave isotopic record also indicates humid climate conditions in the region, with estimated annual rainfall above 520 mm (the mean annual rainfall today; Bar-Matthews and Ayalon 2004 2011), though a slight gradual decline was documented over the course of this period.[6] The *Olea* pollen values retain their low frequencies. Still, in the Sea of Galilee record slightly higher olive pollen percentages were recorded in the early phase of this period (ca. 2900–2650 BCE) in comparison to the later phase (ca. 2650–2500 BCE), reaching maximum of olive pollen values of 11.3% versus 5.4% (of the total pollen sum) respectively. This means that neither the decline in the number of sites in the central hill country nor the southward expansion of urban settlement in the lowlands were climate-related (Langgut, Adams and Finkelstein 2016: Table 2). New radiocarbon dates and other lines of evidence from the copper mining districts in the Arabah, the Negev Highlands and Arad also reveal activity in the arid regions during the Early Bronze III, contra previous theories (Ben Yosef *et al.* 2016;

5. In addition to the Mediterranean climate system, precipitation in these regions is influenced by the Red Sea Trough.

6. The differences between the pollen and the isotopic records lay only within the fluctuations of the general trends, since both records point to relatively humid climate conditions. The slight discrepancies may derive from differences in sampling resolution (the Sorek Cave record was sampled at a higher resolution), and/or differences within the dating methods (^{14}C versus Uranium-Thorium). They may also be related to the slower response of the vegetation in comparison to the more sensitive isotopic proxy.

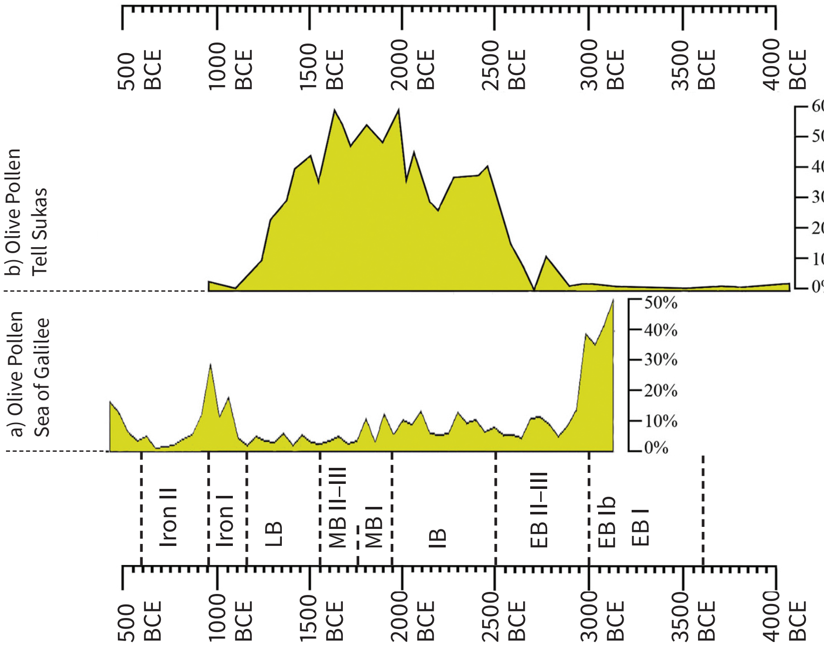

Fig. 1.4: Olive cultivation: Southern Levant (Sea of Galilee; Langgut *et al.* 2015; Langgut, Adams and Finkelstein 2016) versus Northern Levant (Syrian coast near Tell Sukas; Sorrel and Mathis 2016). This figure illustrates the mirror-image relationship between the Sea of Galilee and Syrian olive pollen records: the Sea of Galilee olive pollen percentages retained their low values from the Early Bronze II until the end of the Late Bronze Age, while at the beginning of the Iron I, around 1100 BCE, they increased dramatically. The exact opposite trend can be seen in the northern olive record. In both Levantine records—south and north—periods of high olive distribution point to export-aimed production, while periods of relatively low olive percentages indicate cultivation primarily meant for local consumption (after Langgut, Adams and Finkelstein 2016: Fig. 4)

Finkelstein *et al.* 2018). While the wet climate conditions which are reconstructed for this period may have facilitated activity in the arid lands of the Southern Levant, it seems that other factors were more influential, first and foremost the demand for copper in Egypt (Finkelstein *et al.* 2018).

The Intermediate Bronze Age (ca. 2500–1950 BCE)

At both Birkat Ram and the Sea of Galilee, this period shows no major change in the distribution of the Mediterranean arboreal vegetation (Figs. 1.3a–b). Therefore, it seems that the crisis in the urban system, which started at the end of the Early Bronze Age (ca. 2500 BCE; Regev *et al.* 2012) and lasted through the entire Intermediate Bronze Age, was not a result of climate change. Yet, two short events pointing to drier conditions were recorded: at ca. 2350 BCE (based on the Sea of Galilee record) and at the end of the Intermediate Bronze/beginning of the Middle Bronze I (Sea of Galilee and Zeʾelim; Fig. 1.3b,d; Langgut *et al.* 2015). These dry events were also documented by the declining level of the Dead Sea (Kagan *et al.* 2015). The latter dry event was also identified in the new pollen record from Tel Dan (Kaniewski *et al.* 2017). The Intermediate Bronze Age features evidence for strong settlement activity in the Negev Highlands (Cohen 1999; Dunseth *et al*. 2017), which was related to the copper industry in the Arabah Valley south of the Dead Sea (Ben-Yosef *et al.* 2016; Finkelstein *et al.* 2018). The humid climate conditions did not stimulate dry farming in the region but could have supported pastoral nomadic activity (Rosen 2017; Dunseth, Finkelstein and Shahack-Gross 2018). The cessation of activity in the region during the middle of the Intermediate Bronze Age, ~2300–2200 BCE, is probably related to diminishing demand for copper as a result of the decline of the Old Kingdom in Egypt (Finkelstein *et al.*, 2018).

The Intermediate Bronze Age is a period traditionally associated with a more pastoral mode of subsistence in the Southern Levant. However, the northern pollen records (Birkat Ram and the Sea of Galilee) indicate that no major shift took place in human exploitation of the environment, that is, olives were probably still cultivated to the same extent as during the previous period—the Early Bronze II–III.[7]

More arid conditions at the end of the Intermediate Bronze Age are also evident in the lithology of the Zeʾelim section, which points to accumulation of sediments in a shore environment (sands and a thin beach ridge were deposited from ca. 2000 to 1800 BCE; Langgut *et al.* 2014; Kagan *et al.* 2015). Drier climate conditions were also documented in: 1) other Southern Levant pollen records (Litt *et al.* 2012; Kaniewski *et al.* 2017); 2) declining level of the Dead Sea (from 380 m below msl to 400 m below msl; yet, the drop began slightly earlier ca. 2200/2100 BCE and lasted about 200–300 years) (Migowski *et al.* 2006; Kagan *et al.* 2015); 3) isotopic composition of tamarisk wood from the Mount Sedom Cave (southern Dead Sea), which points to a prolonged drought (of more than 100 years) at the end of the Intermediate Bronze Age (Frumkin 2009); as well as the Sorek Cave speleothems isotopic record, which indicates a decrease in precipitation during ~2200–1900 BCE (Bar-Matthews and Ayalon 2004, 2011; Laugomer 2017). The magnitude and duration of the event (within each respective profile) is more or less similar; these observations suggest a regional event rather than a localized one. Indeed, this dry episode was also identified in isotopic records from northern parts of the eastern Mediterranean (Finné *et al.* 2017; Kaniewski *et al*. 2018).

The Middle Bronze I (ca. 1950–1750 BCE)

During the Middle Bronze I, olive tree percentages appear at the same magnitude as in the Intermediate Bronze Age in both records (Sea of Galilee and Zeʾelim), representing olive production likely sufficient only for local consumption. From the beginning of the period until about 1800 BCE, Mediterranean tree values remain low. It seems that the dry period that began at the end of the Intermediate Bronze Age lasted about two centuries (ca. 2100–1800 BCE). Based on other paleoclimate records already mentioned, this event may have lasted slightly longer—about 300–400 years, between 2200–1800 BCE (Langgut *et al.* 2015; Laugomer 2017). Can this dry event be associated with the much discussed 4.2 BP event, suggested by Weiss *et al.* (1993; Weiss 2012; 2017) as the region-wide "mega-drought" that brought about the collapse of the Akkadian Empire (see critique in, e.g., Wanner *et al.* 2008; Finné *et al.* 2011)? The answer is that climatic proxies of the Southern Levant cannot be easily projected onto Mesopotamia, at the very least because the latter is influenced by parameters other than just the Mediterranean climate system (Finkelstein and Langgut 2014 and references therein).

The ca. 2100–1800 BCE dry phase may explain changes in settlement patterns in the entire Levant and beyond, from the Beersheba Valley in the south (Fig. 1.5) to the upper Euphrates in the north. These include withdrawal of permanent settlement activity from semi-arid zones in southern Canaan and a demographic low in steppe zones in the north, such as the Beqaa Valley of Lebanon and the Jezirah. These were the result of the shift in the 400 mm rainfall isohyet (marking the boundary between the Mediterranean and Irano-Turanian vegetation zones), to the north and to the west. For this reason, significant numbers of people may have moved to "greener" parts of the Levant (Finkelstein and Langgut 2014). This dry phase in the Levant could have been one of the reasons for the beginning of Asiatic settlement in the northeastern Nile Delta during the 19th century BCE (*ibid*.).

The Middle Bronze II–III (ca. 1750–1550 BCE)

Based on the three pollen records available for the Middle Bronze II–III (Birkat Ram, Sea of Galilee and Zeʾelim; Fig. 1.3), wetter climate conditions, which are recognized by the increasing percentages in Mediterranean trees around 1800 BCE, prevailed throughout this period

7. Since *Olea* pollen production has a strong response to cessation of cultivation (a dramatic decrease in pollen production was documented in deserted orchards after several decades of abandonment—Langgut, Lev-Yadun and Finkelstein 2014), the olive pollen that was identified during the Intermediate Bronze Age represents well-maintained orchards.

(Langgut *et al.* 2015), in comparison to the previous period. During this timespan the Zeʾelim sediments accumulated in a lacustrine environment, representing an increase in Dead Sea levels and more humid conditions (as opposed to the beginning of Middle Bronze I, when sediments accumulated in a shore environment; Langgut *et al.* 2014; Kagan *et al.* 2015). Indeed, according to the reconstruction of the Dead Sea levels, it was in the Middle Bronze II–III, that the lake reached its highest level during the last four millennia—up to 370 m bmsl (Migowski *et al.* 2006; Kushnir and Stein 2010).

The archaeological evidence points to an increase in settlement activity in the central highlands during the Middle Bronze II–III (Finkelstein 1995; Ofer 1994). Along the coast, the wetter climate conditions of the Middle Bronze II–III that followed the dry phase seem to have enabled the settlement system to recover and re-expand southward into the Naḥal Besor area and the Beersheba Valley (e.g., Finkelstein *et al.*, 2018). Settlement of Asiatics in the Nile Delta continued and intensified—this time mainly for economic reasons (Finkelstein and Langgut 2014).

The Late Bronze Age (ca. 1550–1150 BCE)

According to the northern pollen diagrams (Birkat Ram and Sea of Galilee; Figs. 1.3a, b) during the beginning of the period, the Mediterranean arboreal pollen percentages remain relatively high, representing continuity of a well-developed Mediterranean forest/maquis. The ʿEin Feshkha record begins in the middle of the Late Bronze Age; it exhibits high values for arboreal pollen, which decline toward the end of the period, reflecting drier climate conditions (Fig. 1.3c). No pollen data for the Late Bronze Age is available from the Zeʾelim record (Fig. 1.3d) due to sedimentary erosion and unfavorable conditions for pollen preservation in sandy sediments (Langgut *et al.* 2014; 2015).

During the 14th century BCE, ca. 1350 BCE, high frequencies of Mediterranean pollen trees were recorded in the Sea of Galilee pollen diagram, which most likely indicate relatively wet climate conditions (Fig. 1.3b); this is consistent with the fact that the Amarna tablets, dated to ca. 1360–1330/35 BCE, do not mention droughts or famine in the region. Yet, the values of olive pollen remain in their low frequencies, indicating a limited spread of olive horticulture (Figs. 1.3a–c). The En-Gedi palynological record (Litt *et al.* 2012) is consistent with this picture.

The Late Bronze Age was marked by a dramatic decrease in settlement activity in the hill country of the Galilee, Samaria and Judea (Bunimovitz 1994; Ofer 1994; Finkelstein 1995). The relatively high percentages of the arboreal pollen indicate that in much of the period the settlement crisis was man-induced rather than a result of a climate change.

According to all four pollen records, the most striking feature in the Bronze and Iron Age pollen transect appeared at the end of the Late Bronze Age. This phase is characterized by extremely low arboreal vegetation percentages (for both Mediterranean trees and olive trees) in the Sea of Galilee and ʿEin Feshkha, while in the less-sensitive Birkat Ram record only a slight reduction in arboreal pollen was documented. Based on the En-Gedi (Litt *et al.* 2012) and Sea of Galilee pollen records, the beginning of decline in Mediterranean elements can be dated to the mid-13th century BCE. The dryness is also made evident by a dramatic drop in the Dead Sea levels (Kagan *et al.* 2015). Litt *et al.* (2012) report that around 1300 BCE a thick sand unit accumulated in the En-Gedi core while Neumann *et al.* (2007a) describe a sedimentological unconformity in the ʿEin Feshkha record at about the same time. In the Zeʾelim Gully, a beach ridge was deposited in a shore environment around 1200 BCE (Langgut *et al.* 2014; Kagan *et al.* 2015). The occurrence of a shore depositional environment in these western Dead Sea margin sites represents a drop in the Dead Sea lake levels that was most likely the result of reduced precipitation, primarily in the area of the northern sources of the Dead Sea drainage basin. Low settlement activity at that time indicates that the shrinkage of the Mediterranean forest was most likely the result of climate rather than man-induced change (Langgut *et al.* 2015).

Severe dryness during the end of the Late Bronze Age and into the Iron I transition was identified in three other high-resolution palynological profiles from nearby regions: the northern Syrian coast (Kaniewski *et al.* 2010), Cyprus (Kaniewski *et al.* 2013) and the Nile Delta (Bernhardt, Horton and Stanly 2012). A dry event is also observable in eastern Mediterranean isotopic records

Fig. 1.5: Southern line of urban centers during the Early Bronze III, Middle Bronze I and Middle Bronze II–III (based on Finkelstein and Langgut 2014: Fig. 4)

(e.g., Finné *et al.* 2017). This data suggests that the dry spell at the end of the Late Bronze Age took place across a vast geographical area (Langgut, Finkelstein and Litt 2013; Kaniewski *et al.* 2015 and references therein; Langgut *et al.* 2015).

Harsh long-term droughts may have been the prime mover, then, for the collapse in the eastern Mediterranean basin during the "crisis years" at the end of the Bronze Age (Carpenter 1966; Weiss 1982; Neumann and Parpola 1987; Alpert and Neumann 1989; Ward and Joukowsky 1992; Issar 1998). Destruction layers at Levantine sites seem to indicate that the crisis in the eastern Mediterranean took place from the mid-13th century until the end of the 12th century BCE—during the same time interval when drier climate conditions were prevalent in the region. In the Levant, the crisis years are represented by the destruction of urban centers, shrinkage of other major sites, hoarding activities and changes in settlement patterns. Textual evidence from several places in the Ancient Near East attests to drought and famine starting in the mid-13th century BCE and continuing until the second half of the 12th century BCE (Astour 1965; Klengel 1974: 170–174; Naʾaman 1994: 243–245; Zaccagnini 1995; Singer 1999: 715–719; 2000; 2009: 99; Cohen 2021).

The Iron I (ca. 1150–950 BCE)

All four pollen records for the Iron I show an increase in oak, total Mediterranean trees and olive pollen percentages. In the Birkat Ram record, where only two samples fall within the Iron I, a minor increase of Mediterranean tree pollen is visible in the transition from the previous period (Fig. 1.3a). In the Sea of Galilee record, a significant *Olea* pollen peak is notable; a similar peak appears in the ʿEin Feshkha and Zeʾelim pollen diagrams, together with a rise in oak pollen (Fig. 1.3b,d). As a result of the increase in moisture following the severe dryness at the end of the Late Bronze Age, both the Mediterranean forest/maquis and olive orchards expanded (Langgut *et al.* 2015). This is also evident in the En-Gedi pollen record starting from ca. 1000 BCE (Litt *et al.* 2012).

The improved climate conditions during the Iron I enabled the recovery of settlement activity. This is demonstrated by the revival of the urban system in the northern valleys (Finkelstein 2003) and in the settlement wave which took place in the highlands, including areas which are amenable to olive cultivation (Gal 1992; Finkelstein 1995; Frankel *et al.* 2001; Zertal 2004, 2007). The growth of settlement activity in the highlands is the backdrop for the rise of Ancient Israel and other Iron Age groups—the Arameans, Ammonites and Moabites (Finkelstein 1995; Joffe 2002). Especially noteworthy are settlement developments on the margin of the settled lands: the spread of activity in the Beersheba Valley (Herzog 1994), the rise of an early Moabite territorial polity south of the Arnon River (Finkelstein and Lipschits 2011) and the appearance of Iron I sites on the Edomite Plateau (Finkelstein 1992). Wetter climate conditions than what we see in the arid region today could have helped the daily subsistence economy, which was probably based on dry farming and herding. Copper mining in the Wadi Faynan area (for Khirbet en-Naḥas, see Levy *et al.* 2004; 2008) would have likely been made easier by increased water flow in the ravines that run from the Edomite Plateau to the Arabah. An exception to this picture may be observed in the Judean Highlands, where settlement activity during the Iron I remained sparse. This highlights the fact that demographic expansion during the Iron I must have also been influenced by factors other than climate; the harsh rocky terrain of the region demanded considerable effort to clear land for agriculture and this could have deterred settlement activity in a period when more hospitable areas were still sparsely settled (Finkelstein and Langgut 2018).

The peak in olive pollen is notable mostly in the Sea of Galilee record, starting in the very late 12th century and climaxing during the first half of the 10th century BCE. This is the highest representation of olives since the Early Bronze I. What could have caused this development?

The collapse of urban centers in northern Canaan at the end of the Late Bronze Age was followed by slow settlement recovery. In the Late Iron I, between the late 11th and the middle of the 10th centuries BCE (Toffolo *et al.* 2014), some of these places—in the valleys and Lower Galilee—grew to become prosperous urban centers; this process may be interpreted as a revival of the Late Bronze city-state system (Finkelstein 2003). The main centers were Tel Megiddo, Tel Yoqneʿam, Tel Keisan, Tel Kinrot and Tel Rekhesh. Most of these sites feature olive-oil presses and strong evidence of olive cultivation in the botanical assemblages (Finkelstein and Langgut 2018).[8] It can therefore be assumed that the

8. Evacuations at Megiddo have revealed olive presses dating to the Late Bronze III and Iron I (Frankel 2006) Yoqneʿam's "Oil Maker's House" dates to the late Iron I (Zarzecki-Peleg 2005). In addition, Megiddo's Iron I strata have produced an exceptionally high percentage of olive charcoal remains (Benzaquen, Finkelstein and Langgut 2019). Olives were also cultivated in the Beth-Shean Valley. The largest percentages of olive charcoal and olive pits were documented at Tel Reḥov from the Iron IIA (Liphschitz 2020). At Tel Beth-Shean the Iron IB features high frequencies of olive charcoal remains (Baruch 2006; Liphschitz 2020: Table 52.4). At Tel Kinrot an olive-oil press was found in Area U, where olive cultivation played a significant role in the economy. In Tel Rekhesh, an extraordinary number of five Iron I oil presses were discovered (Onozuka 2012). It seems, then, that the areas around both Tel Kinrot and Tel Rekhesh included significant territory devoted to olive orchards. The proximity of these two sites to the Sea of Galilee may account for the exceptional percentage of olive pollen recorded in the sediment core extracted from the lake. This is especially true for Tel Kinrot, located relatively close to the place where the Sea of Galilee sediment core was extracted (Finkelstein and Langgut 2018).

regions near the Sea of Galilee, as well as other areas in the north such as the Jezreel Valley, were devoted to intense olive horticulture. Olive oil was likewise produced in the Shephelah during this timeframe (Bunimovitz and Lederman 2009). The overall production in the region seems to have been beyond the needs of the local population. As for export, the primary venue for Southern Levantine olive oil during the Iron I seems to have been Egypt (Finkelstein and Langgut 2018).

The Iron II (ca. 950–586 BCE)

During the Iron IIA (ca. 950–780 BCE), pollen from Mediterranean trees maintained relatively high ratios, reflecting a developed Mediterranean forest/maquis and relatively wet climate conditions, while the Iron IIB (ca. 780–680 BCE) and the Iron IIC (ca. 680–586 BCE) were characterized by a slight reduction in Mediterranean trees as evident in all three northern pollen records (Birkat Ram, Sea of Galilee and ʿEin Feshkha; Fig. 1.3a–c). The slight decline in arboreal percentages may represent moderate climate conditions but may also have been the result of anthropogenic activity such as tree clearing, spread of agriculture and grazing activities (Langgut *et al.* 2014; 2015). Indeed, a surge in human activity that had started in the Iron I, and increased in the Late Iron IIA, reached its zenith during the Iron IIB–IIC. The picture is less clear in the southernmost record (Zeʾelim; Fig. 1.3d): Mediterranean arboreal pollen appears in relatively low values starting from the end of the Iron I and continuing through the entire Iron II; at the same time, the lithology of this sequence has shown that sediments were deposited in a lake environment, and therefore represent relatively high Dead Sea lake levels (ca. 408 m below msl) (Langgut *et al.* 2014; 2015).

The almost total disappearance of olive pollen from both the Sea of Galilee and Zeʾelim records ca. 700 BCE may be the outcome of the depopulation that resulted from the deportations by Assyria and the ensuing abandonment of olive orchards (Finkelstein and Langgut 2018). Archaeological data indicates strong olive-oil industries in the Shephelah of Judah, highlands around Samaria and the western Galilee in the Iron IIB–IIC (Finkelstein, Gadot and Langgut 2021). Yet, as pollen in the Southern Levant is transported mainly by westerly and northwesterly winds, and because of the barrier formed by the mountains of the Lower Galilee and Judea, pollen from these regions is not represented in the record extracted from the Dead Sea Rift Valley.

With the rise of territorial kingdoms and the later domination of the region by empires, climate was only one factor in shaping settlement processes, even in the marginal areas of the Southern Levant (Greener, Finkelstein and Langgut 2018). The transformation of the Kingdom of Judah, beginning in the late 8th century BCE, from a typical mixed Mediterranean subsistence agriculture to a high-risk/high-gain specialized, region-based economy, with viticulture in the highlands and olive oil industry in the Shephelah, was an outcome of the incorporation of Judah as a vassal into the Assyrian global economy (Finkelstein, Gadot and Langgut 2021).

Summary

This review presents the role of climate fluctuations in shaping south Levantine human history ca. 3600–600 BCE (the Bronze and Iron Ages) as evidenced in four palynological archives. Three of the four show similar vegetation fluctuations (Sea of Galilee, ʿEin Feshkha and Zeʾelim), indicating that at least during the Bronze and Iron Ages different regions of the Southern Levant were characterized by similar climate patterns. The Birkat Ram record does not point to any dramatic vegetation and climate fluctuations because of its northern location within an area that receives more than 1,000 mm of annual rainfall, which makes it a less sensitive climate recorder.

The climate history of the Southern Levant during the Bronze and Iron Ages, as derived from the high-resolution pollen diagrams, can be summarized as follows: The wettest period was identified during the Early Bronze I (ca. 3600–3000 BCE). Though a reduction in the arboreal pollen percentages was documented during the Early Bronze II–III (ca. 3000–2500 BCE), the region was still typified by humid climate conditions. The Intermediate Bronze Age (ca. 2500–1950 BCE) was also characterized by relatively wet climate conditions. From ca. 2000 BCE and through the beginning of the Middle Bronze I, drier climate conditions were prevalent, while the Middle Bronze II–III (ca. 1750–1550 BCE) was characterized by wetter climate. During the early phases of the Late Bronze Age humid conditions continued. The driest conditions during the entire Bronze and Iron Age timespan were recorded toward the end of this period, starting ca. 1250 BCE and continuing until the end of the 12th century BCE. An increase in arboreal percentages was documented between ca. 1100–750 BCE, which therefore covers most of the Iron I (ca. 1150–950) and the Iron IIA (ca. 950–780 BCE), representing humid conditions after the severe dryness. During the Iron IIB (ca. 780–680 BCE) and IIC (ca. 680–586 BCE), the region experienced moderate climate. These climatic trends were evaluated with regard to the regional archaeological picture of the Bronze and Iron Ages. Based on this study, it is clear that climate is only one of the factors that influenced settlement processes and economic trends in antiquity.

Two relatively profound dry periods were identified based on the significant decrease in oaks and total Mediterranean arboreal pollen during the Bronze and Iron Ages. The more severe event occurred at the end of the Late Bronze Age (ca. 1250 BCE) and lasted until the end of the 12th century BCE. This arid phase is characterized by the lowest arboreal percentages in the Bronze and Iron Ages. The dry climate conditions at the end of the Late Bronze Age seem to correspond to references in Ancient Near Eastern texts to a period of droughts and famine and thus political instability, which is also reflected in the archaeological record by the destruction of cities. All this contributes to a better understanding of the “crisis years” in the eastern Mediterranean at the end of the Bronze Age.

The second dry episode was dated to ca. 2100–1800 BCE, and may be associated with the mega drought suggested by Weiss (2017 and references therein) between 2200–1800 BCE (also known as the 4.2 BP event). This dry phase resulted in a shift of the border between the Mediterranean and Irano-Turanian vegetation zones to the north and west. Permanent settlements withdrew from the margins of southern Canaan. It is assumed that while these settlements were abandoned as a result of water stress, other sites, located in the greener parts of the region, became more populated. This is mostly true for sites which were located near marshes and/or springs; these sources buffered the fluctuations in precipitation and water supply. Sites like Tel Dan and Tel Aphek had a permanent source of water for irrigation—a key for food supply and human health. The migration of people from the semi-arid regions may have created competition for resources and tensions between groups.

The migration of 1.5 million people from rural farming areas to the peripheries of urban centers was witnessed in modern Syria during the three-year drought from 2007 to 2010. Social conflicts and demographic disturbances were among the main factors behind the onset of the subsequent Syrian civil war (e.g., Kelley *et al.* 2015). Overuse of groundwater in the years prior to the drought dramatically increased Syria’s vulnerability. When the severe drought began in 2007, the agricultural system in the northeastern “breadbasket” region, which typically produced over two-thirds of the country’s crop yields, collapsed. In contrast, almost no contemporaneous reduction of crop yield was documented in southeastern Turkey, on the other side of the border, which had likewise suffered from decreased rainfall. The difference between the two countries stems from the fact that in Turkey the government practiced a much more organized and targeted economy, which could successfully handle the environmental deterioration. This means that the sociopolitical structure of a given region should also be taken into consideration when evaluating the impact of severe droughts on ancient societies.

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