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On the shore of a fluctuating lake: Environmental evidence from Ohalo II (19,500 B.P.)

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ABSTRACT

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The aim of this paper is to provide a high-resolution environmental reconstruction of the Sea of Galilee basin during a very short spell of time at the end of the Upper Pleistocene. We present a multidisciplinary study of sediments and archaeological remains exposed at the submerged and well-preserved Ohalo II prehistoric site. The Ohalo II camp includes in situ brush hut floors, hearths, and other installations, all radiometrically dated to 19,500 B.P. The remains include large quantities of charred material and animal bones. The reconstruction is based on a geoarchaeological study, accompanied by analyses of a wide variety of trees, grasses, mammals, birds, fish, and mollusc remains. The results show that the range of plant and animal species (ca. 240) is not different from that encountered today in the valley and the surrounding slopes. Water level fluctuations were the most dramatic environmental events, probably induced by climatic changes and tectonic activities at the inlet/outlet of the lake.

INTRODUCTION

The Dead Sea Rift Valley has been the focus of a large number of geological, archaeological, and environmental studies. Many works concentrated on long-term and short-term geological, climatic, and environmental

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changes by studying past and current water bodies. Pleistocene and Holocene archaeological sites along the shores of the lakes added to the growing body of data regarding dating, water level fluctuations, environments, and human adaptations. The earliest and most widely published cases are 'Ubeidiya, a ca. 1.5 my site in the southern Sea of Galilee basin (Bar-Yosef and Goren-Inbar, 1993), and Gesher Benot Ya'aqov, a 0.75 my site in the upper Jordan Valley (Goren-Inbar et al., 1992). The aim of this paper is to provide a detailed environmental reconstruction based on a variety of well-preserved finds exposed at Ohalo II, a prehistoric camp located on the Sea of Galilee shore, in situ on late Lisan deposits (Belitzky and Nadel, 2002).

The Lisan was the last large Pleistocene lake in the Dead Sea Rift Valley, and the precursor of the two smaller current lakes, the Dead Sea and the Sea of Galilee (see also this volume). The characteristics and water level fluctuations of Lake Lisan have been continuously studied (e.g., Begin et al., 1974, 1985; Stein et al., 1997; Machlus et al., 2000; Nadel et al., 2001; Stein, 2001; Bartov et al., 2002; Hazan, 2002; Marco, 2002). However, most of these works are geological in nature, and are based on a relatively broad-scale chronological framework. Details of higher resolution, in terms of dating and specific environmental conditions, were further obtained from geo-archaeological studies of prehistoric sites. These, according to their geographical and topographical locations, provided a maximum height for the lake at the time of occupation. Thus, late Upper Palaeolithic, Epipalaeolithic, and Neolithic sites, especially along the Lower Jordan Valley, show a general drop of lake level during the end of the Pleistocene (e.g., Bar-Yosef et al., 1974; Goring-Morris, 1980; Kenyon, 1981; Garfinkel, 1990; Hovers, 1990; Bar-Yosef and Gopher, 1997).

Within this framework, the Ohalo II finds include a wealth of data regarding depositional conditions before, during, and after a short human occupation, as well as floral and faunal species representing past communities living in the valley towards the end of the Last Glacial Maximum (LGM). Our work serves as a detailed source of data for reconstructing local continental climate at a time of well-documented global climatic fluctuations.

THE OHALO II PREHISTORIC CAMP

Excavations at the lakeshore camp of Ohalo II exposed a camp covering more than 2,000 m^2, of which more than 25% was excavated (Nadel et al., 1994, 1995; Nadel, 2002). The site is located on the southwestern shore, at a height of 211.5–213.5 m below sea level. The submerged site (only exposed for several non-continuous years since 1989) is excellently preserved, and the studied remains include the floors and wall bases of six oval brush huts—the oldest ever found (Nadel and Werker, 1999), six concentrations of open-air fireplaces, one grave, and small installations (Fig. 1).

Excavation methods

The remains were mapped by using a general 1 × 1 m grid, and all features were excavated in units of 0.5 × 0.5 m squares. All excavated sediment was wet-sieved (1 or 2 mm mesh) and sorted. Several samples of the wide variety of remains are relevant to past climatic and environmental conditions, and are presented in the following sections of the paper. In order to document the general setting of the camp, the pre-occupation lacustrine bedrock as well as the depositional and post-depositional processes, trenches were cut through and between the archaeological remains (Figs. 1b, 2). In total, the length of manual and tractor trenches exceeded 100 m, reaching in two points a depth of ca. 5 m.

Site description

All floors and hearths were found in situ, embedded in late Lisan deposits. A large variety of finds was discovered on the floors, around the hearths, and in all other parts of the camp. These finds included large quantities of identifiable charred seeds and fruit, thousands of animal bones, a rich flint assemblage, and smaller numbers of beads, polished bone implements, and basalt/limestone artifacts.

The site is dated by more than 40 radiocarbon assays, read by four labs. The average is about 19,500 B.P., or ca. 23,000 B.P. calibrated (Table 1). Most loci and all areas of the camp are radiometrically dated. Furthermore, the material remains from all parts are similar and belong to one culture. There were several episodes of occupation and inundations. Each occupation lasted, most probably, about one year (and definitely not only one season) as can be deduced from the plant and animal species. The overall length of site use, from the first till the last occupation, is not known but according to the combined results was probably only several tens of years, and definitely not more than 100–300 years.

The preservation of charred and uncharred plant remains used for construction, consumption, fuel, and tool production was very good in all parts of the site.

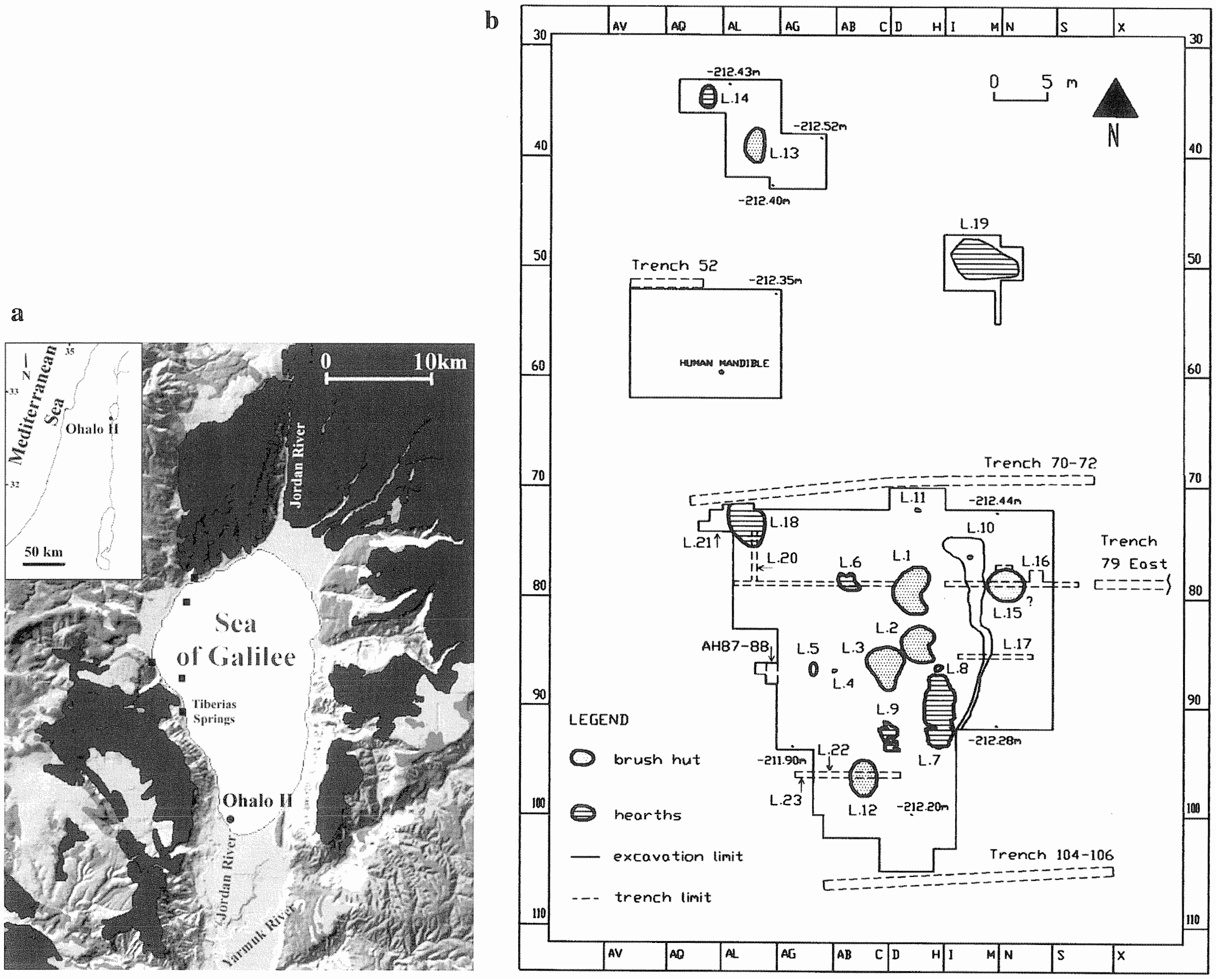

Fig. 1. Location map (a) and plan of the Ohalo II camp, central area of excavation (b). Note location of two key sections at AH87/88 and AJ79.

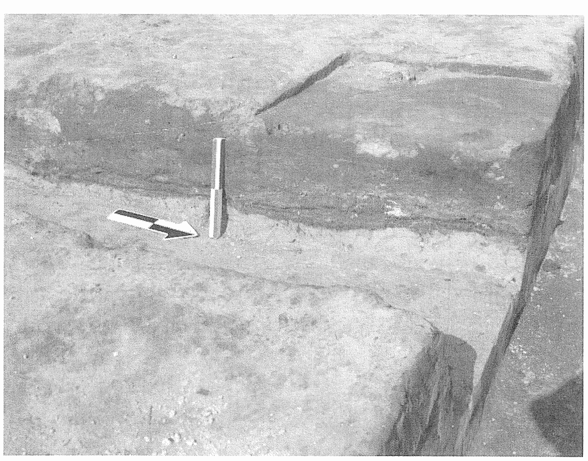

Fig. 2. Section through the floor of hut 12, showing the dark anthropogenic layer on top of fine lacustrine sediments.

The range of in situ finds provided an opportunity to study in detail daily life in a Late Pleistocene camp of fisher-hunter-gatherers, an aspect that will not be discussed here (see Nadel, 2002, for details). Here, we reconstruct the environment by using sedimentological, floral, and faunal evidence. The sedimentological sequence reflects the immediate environment: lake levels and the depositional conditions of lacustrine and shore sediments. The variety of floral remains represents plant communities on the shore and in the lake basin in general. The mammal, bird, fish, and mollusc species attest, again, to the variety of ecological niches in the area. These are presented in this order, and show, both independently and in a combined manner, the environment in the valley during a short spell of time at the end of the LGM.

Table 1
Carbon-14 dates (uncalibrated) from Ohalo II, central and south areas of excavation

Lab #	Area/Locus	Material	^{14}C age ± 1σ (yr) B.P.	δ^{13}C (‰)
RT-1625	Central, Loc. 1	Charcoal	21,050 ± 330	–21.8
RT-1616	Central, Loc. 1	Charcoal	19,590 ± 150	–13.4
RT-1617	Central, Loc. 1	Charcoal	18,700 ± 180	–23.2
RT-1623	Central, Loc. 1	Charcoal	18,210 ± 240	–21.0
RT-1619	Central, Loc. 2	Charcoal	19,860 ± 190	–20.2
RT-1297	Central, Loc. 2	Charcoal	17,500 ± 200	–22.7
RT-1618	Central, Loc. 2	Charcoal	19,220 ± 180	–20.6
RT-1251	Central, Loc. 3	Charcoal	19,000 ± 190	–22.0
RT-1248	Central, Loc. 3	Charcoal	19,800 ± 360	–22.0
RT-1342	Central, Loc. 3	Charcoal	19,500 ± 170	–21.5
RT-1252	Central, Loc. 3	Charcoal	18,900 ± 400	–20.2
RT-1250	Central, Loc. 3	Charcoal	19,250 ± 400	–24.4
Pta-5387	Central, Loc. 3	Charcoal	20,100 ± 440	–17.9
RT-1343	Central, Loc. 3	Charcoal	18,600 ± 220	–19.5
OxA-2565	Central, Loc. 3	Wild barley seed	19,310 ± 190	–24.4
OxA-2566	Central, Loc. 3	Wild barley seed	19,110 ± 390	–24.6
Pta-5374	Central, Loc. 3	Charcoal	19,400 ± 220	–19.2
RT-1244	Central, Loc. 3	Charcoal	18,360 ± 230	–21.5
Pta-5386	Central, Loc. 3	Charcoal	19,600 ± 400	–23.6
RT-1246	Central, Loc. 4	Charcoal	15,550 ± 130	–20.9
OxA-2564	Central, Loc. 4	Wild barley seed	18,680 ± 180	–24.5
RT-1358	Central, Loc. 4	Charcoal	18,760 ± 180	–20.8
RT-1620	Central, Loc. 6	Charcoal	20,830 ± 180	–19.7
RT-1621	Central, Loc. 7	Charcoal	20,070 ± 270	–21.5
RT-1622	Central, Loc. 8	Charcoal	20,190 ± 170	–18.4
RT-1624	Central, Loc. 10	Charcoal	20,840 ± 290	–20.6
RTA-3275	Central, post-occupation	Stem of reed	15,430 ± 110	–28.0
RT-3537	South	Charcoal	21,250 ± 275	–13.0
RT-3539	South	Charcoal	19,940 ± 210	–22.3
RTA-3538	South, AI65c	Charcoal	19,490 ± 150	–11.9
RTA-3540	South, ZA36	Charcoal	20,270 ± 180	–25.2
RTA-3541	South, L66c	Charcoal	19,910 ± 170	–25.1
RTA-3276	South, post-occupation	Plant material	12,830 ± 80	–26.6

GEOARCHAEOLOGY

Stratigraphy

The most complete stratigraphic section is found in the western part of the site, where three depositional units are distinguished (Fig. 3): upper, middle, and lower. The central part of the site is devoid of the upper cover sediment, while the eastern sector of the site is the most disturbed area. For example, in square L79, the upper contact of the archaeological layer shows a "slope break" in the form of lakeward dipping and is partially truncated, while the lower contact exhibits displaced micro-faults, several centimeters wide (Fig. 4), which were suggested to manifest a secondary tectonic deformation (Belitzky and Nadel, 2002). Lacustrine deposits here overlie the cultural layer with inclined lakeward bedding. Hence, the section in AH87/88 (Fig. 3), in the western part of the site, is used as a locality for reference stratigraphy. The section consists of the following units from top to bottom:

Unit 1 (Upper)

Lacustrine clay, pale olive (5Y 6/3–5/3) with red yellow (7.5YR 6/8) rootlets and subhorizontal, flat bedding represented by several-mm-thick laminae. Angular unconformity separates this unit from lower

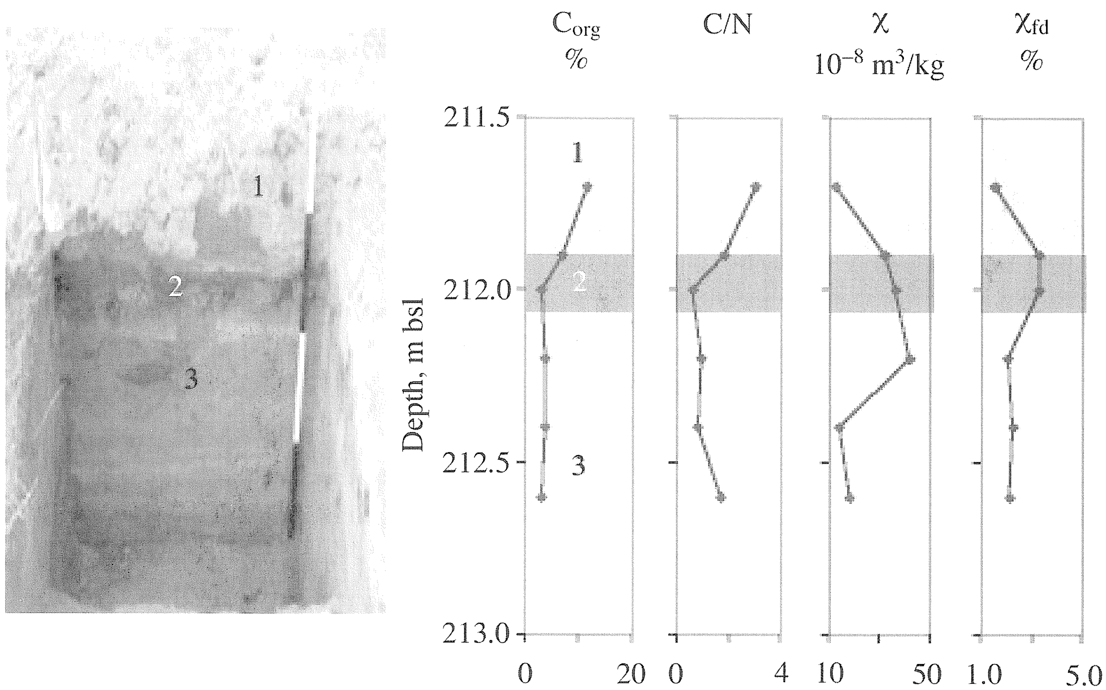

Fig. 3. Stratigraphic section in square AH87/88 and its analytical characteristics. Key sedimentary units: 1—post-occupational lacustrine deposits; 2—pararendzina soil with mole holes; 3—pre-occupational lake deposits. *Unit 2* is shaded on graphs.

Fig. 4. Section through Loci 10–15, at the eastern side of the site (L/M79, looking south, width of section in photo: 75 cm). Note the upper contact of the archaeological layer with a "slope break" lakeward dipping and partial truncation. The lower contact exhibits displaced micro-faults several centimeters wide. The unconformities are probably related to plastic deformations of water-saturated sediments, or to a secondary tectonic event.

deposits, testifying to an erosional gap. The deposition of the unit apparently followed a drastic lake level rise of climate-induced and/or tectonic origin (Belitzky and Nadel, 2002).

Unit 2 (Middle)

In square AH87/88, the dark-colored horizon is comprised of strongly bioturbated sandy clay, 30 cm thick, with indistinct wavy lamination, tiny charred particles, and few artifacts (Fig. 3). This grades into massive, loose yellow (2.5Y 7/4) sandy horizon, with striking biological activity features in the form of black subvertical root tubes, ca. 20 cm deep with lateral bifurcations, and rodent burrows. Taking into account the diagnostic soil morphological features of biological activity, we may recognize here an incipient sandy pararendzina soil.

Unit 3 (Lower)

The unit comprises a series of sand/clay bands, ca. 20–30 cm thick, occasionally with several-mm-thick ripple marks (disconnected lenses of yellow sand), which, at ca. 213 m below msl depth, grade to a laminated, rhythmically built (varved), calcareous greenish mud (Fig. 5). The latter is similar in structure and bedding to Lake Lisan rhythmites in the Dead Sea area (Begin et al., 1985; Reid and Frostick, 1993), where they indicate high lake stands (Stein et al., 1997; Stein, 2001).

Sedimentology

The analytical characterization of deposits from AH87/88 (Fig. 3) shows that the clay of *Unit 1* is organic-rich with 3.93% TOC (Total Organic Carbon),

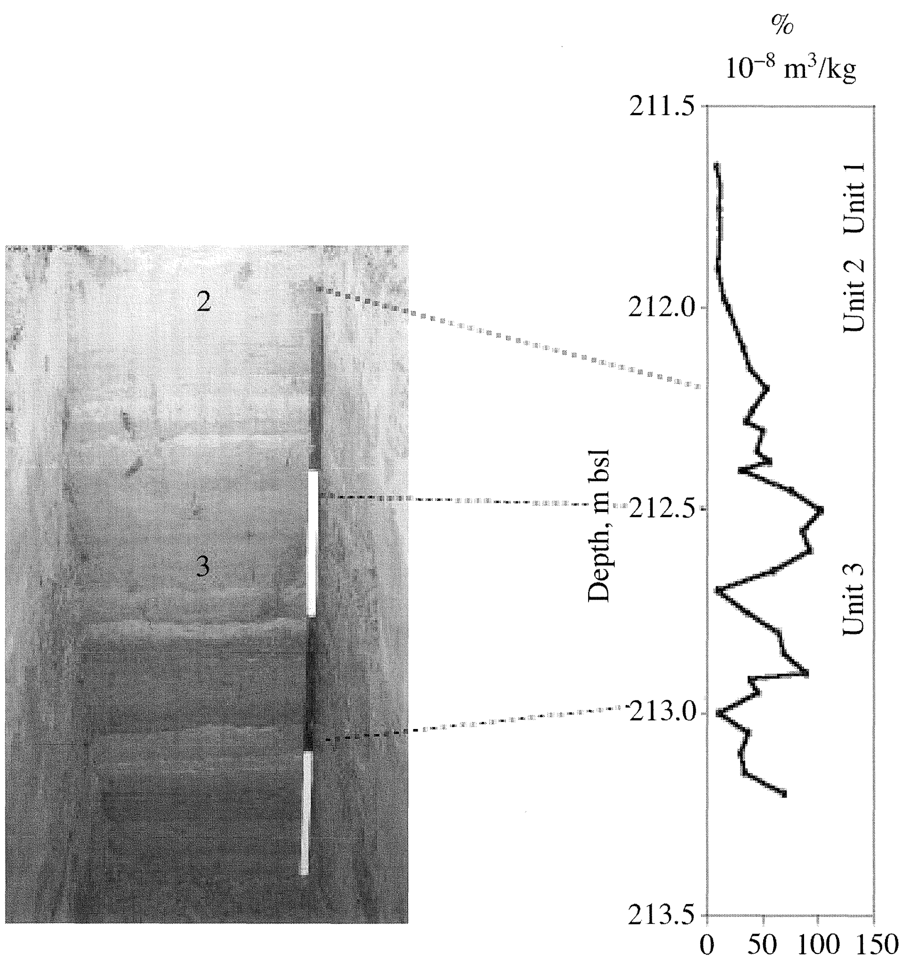

Fig. 5. Pre-occupational Lake Lisan deposits in section AJ79 and its magnetic susceptibility curve. Key sedimentary units as in Fig. 4 (*Unit 1* is truncated). Note alternating laminae at the bottom of section grading upward into sandy beds with ripple marks and bioturbation. Peaks on magnetic susceptibility curve are correlated with sandy laminae in the section.

15.3 C/N ratio (the highest in the section), and maximal in the section value of electrical conductivity (20.00 dS/m). The high electrical conductivity value is a good measure of high-level salinity of the deposits. This seems to derive from the accumulation of water-soluble salts, primarily chloride of sodium Na^+ and, to a lesser extent, sulfate of calcium Ca^{++} and magnesium Mg^{++} (Table 2). In the archaeologically related dark-colored *Unit 2*, the amount of soluble salts is as high as in *Unit 1*, while TOC decreases to 1.4%, C/N ratio drops from 9.3 to 3.2, indicating stronger mineralization of organic materials under subaerial conditions as compared with microbiologically produced, poorly mineralized TOC in anoxic lake sediments of *Unit 1* (Table 2). Below, the deposits of *Unit 3* show a substantial drop in salinity to 6.6–9.16 dS/m EC, gradual decrease in TOC, and increase in C/N ratio (Fig. 3), as compared to *Unit 2*. This indicates that salinity here was much lower, or nonexistent. It appears that salinity values rose in the top two units after occupation, though the date and duration of the process were not established.

Magnetic susceptibility measurements along the section show the minimal magnetic susceptibility χ_{lf} and frequency-dependent susceptibility χ_{fd} values in *Unit 1*, while the organic-rich A horizon of a pararendzina soil or a regosol shows a three times higher value of χ_{lf} (Fig. 3). Significantly, the frequency-dependent susceptibility χ_{fd} in the soil surface horizon of *Unit 2* shows a slight increase, which coincides with low C/N, as is characteristic for soils, and hence it may have resulted from the higher concentration of ultra-fine magnetic minerals produced in biologically active soils (Maher and Taylor, 1988).

In section AJ79 (Fig. 5), in contrast to section AH87/88, soil morphological features in *Unit 2* are less pronounced. In square AJ79 we were able to analyze the fluctuations of magnetic susceptibility along the section. The complex character of magnetic susceptibility values in section AJ79 (in relation to depth) is presented (Fig. 5). Here the archaeological soil clearly has low susceptibility, while the lacustrine deposits of *Unit 3* have a much higher susceptibility and demonstrate several peaks. Analysis shows that the magnetic peaks are correlated with the lithology of the pre-occupational lacustrine deposits. For example, maximal susceptibility (up to 90–100 $\times 10^{-8}$ m^3kg^{-1}) is found in sand laminae and minimal values in organic-rich or calcareous clay laminae. As will be shown later, coarse-grained laminae comprise sand-sized grains of detrital, basalt-derived material, which explains the magnetic susceptibility increase in these beds.

Studies of sediments in petrographic thin sections by light and SEM microscope show that *Unit 1* is massive, comprised of silty clay alternating with dark, organic-rich clay (Fig. 6). The organic-rich laminae are usually disturbed and bioturbated, suggesting high primary productivity (also supported by high TOC value, C/N ratio, and anoxic conditions). EDS analyses detected the presence of scattered crystals of halite NaCl ca. 20 μm in size, as well as pyrite framboids.

Unit 2, being archaeologically diverse and, as mentioned above, with occasionally morphological bioturbation soil features, shows abundant and well-

Table 2
Electrical conductivity (EC), ion concentrations on the saturated extract, and sodium adsorption ratio (SAR) for section AH87/88

Unit/depth m bsl	Saturation (%)	EC ($dS\ m^{-1}$)	K^+ ($mmol\ l^{-1}$)	Na^+ ($mmol\ l^{-1}$)	Ca^{2+} + Mg^{2+} ($mmol\ l^{-1}$)	Cl^- ($mmol\ l^{-1}$)	SO_4^{2-} ($mmol\ l^{-1}$)	SAR (%)
Unit 1 (Upper) 211.7	76.0	19.90	2.63	105.9	121.5	195.3	55.3	13.59
Unit 2 (Middle) 211.9	50.3	20.00	3.40	118.8	111.9	198.8	55.1	15.88
Unit 2 (Middle) 212.0	49.2	14.30	2.91	72.9	85.8	126.0	52.4	11.13
Unit 2 (Middle) 212.2	52.8	10.25	1.91	45.8	69.3	82.3	51.5	7.78
Unit 3 (Lower) 212.4	71.1	9.16	1.91	37.6	64.9	63.0	49.7	6.60
Unit 3 (Lower) 212.6	66.5	6.60	1.63	26.7	47.7	50.8	34.3	5.47

preserved organic remains in thin sections. The abundance and type of organic remains in the dark archaeological layer vary in different loci of the occupation area. The plant remains are sometimes black due to charring, sometimes dark brown with a preserved cell structures. However, these organic horizons with ash and debris of human activities also contain pedogenic neoformations in the form of complex gypsum nodules stained by ferric oxides and humus. SEM and microprobe analysis allowed us to detect the existence of well-defined crystals of prismatic, euhedral gypsum, partly covered with ferric coatings and iron sulfide FeS_2 framboids (Fig. 7). Large size, prismatic form, and occurrence basically in nodules all suggest the secondary origin of gypsum, possibly from groundwater-controlled precipitation (Magee, 1991). In *Unit 3* rounded peds, or ooids, comprised of calcite aggregates (no aragonite, according to FTIR), ca. 100–200 mm in size, are mixed with strongly weathered, sub-rounded grains of olivine, epidote, feldspar, and opaque ore minerals, 150–250 μm in size (Fig. 8a). Occasionally the mineral grains are replaced by dark-brown/reddish clay pseudomorphs, indicating strong post-depositional weathering. The presence of basalt rock clasts (Fig. 8b) alongside sand-sized grains of olivine, feldspar, and ore minerals, identified in thin sections, accord well with magnetic enhancement in pre-occupational lacustrine deposits vs. the soil and archaeological layer.

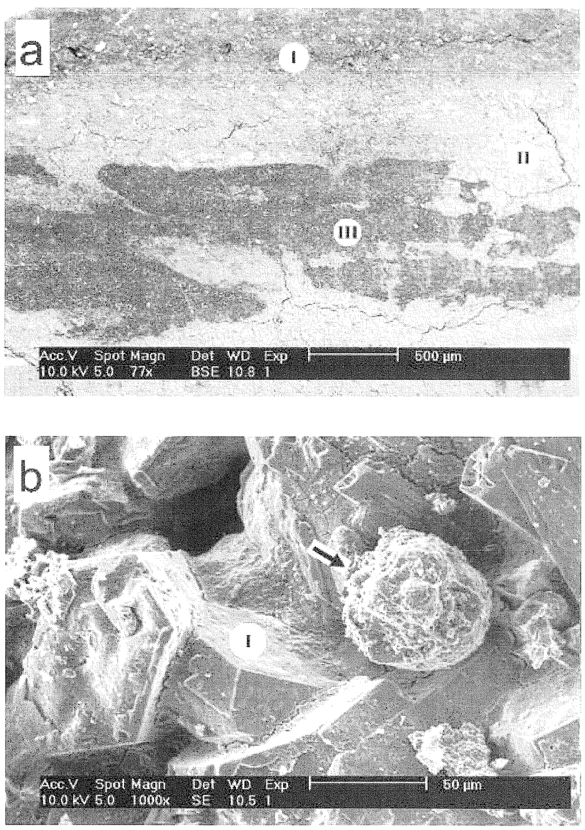

Fig. 6. SEM photomicrograph of sedimentary features in section AH87/88. (a) BSE image of post-occupational clay marl consisting of dark silty-clay laminae (I) alternating with light-colored laminae (II) and organic-rich, dark-colored clay, with microfaults and possibly biogenic turbations (III); (b) SE image of large gypsum crystals (I) in a nodule with iron sulfide framboid (arrow).

Site formation processes

Site formation at Ohalo II was primarily controlled by pronounced lacustrine fluctuations and related changes around the lake. The pre-occupational lacustrine deposits demonstrate changing conditions of deposition from varved, calcareous marls to ooid-rich basalt-derived sand and marl bands, deposited in shallow water at the lake margin. Since the magnetic susceptibility curve shows at least four depositional cycles, we assume that the water level was intermittently falling towards the time of occupation. The rate of deposition seems to have eventually increased, compared with an earlier period of varve deposition, assumed to accumulate at a rate of 0.9 mm/yr (Marco, 2002).

Early Epipalaeolithic occupational deposits demonstrate remarkable spatial variability and a multiphase history of anthropogenic accumulation. Bioturbated sandy soils on higher landforms, probably dunes, associated with hydromorphic marshy soils in low geomorphic positions, formed penecontemporaneously with human occupation. Abandonment of the site is believed to have followed a drastic lake level rise of climate-induced and/or tectonic origin (Belitzky and Nadel, 2002).

Post-occupational lacustrine deposits lie unconformably upon the archaeological horizons, indicating an erosional gap of unknown duration. They consist of calcareous, laminated lake marls, and are interpreted as relatively deep-water facies. There was a strong diagenesis of mineral and organic materials. We hold that these sediments originated in periodically anoxic conditions, conducive to reductive diagenesis of ferromagnetic grains, and minimal clastic influx of coarse basalt-derived inflow into the lake.

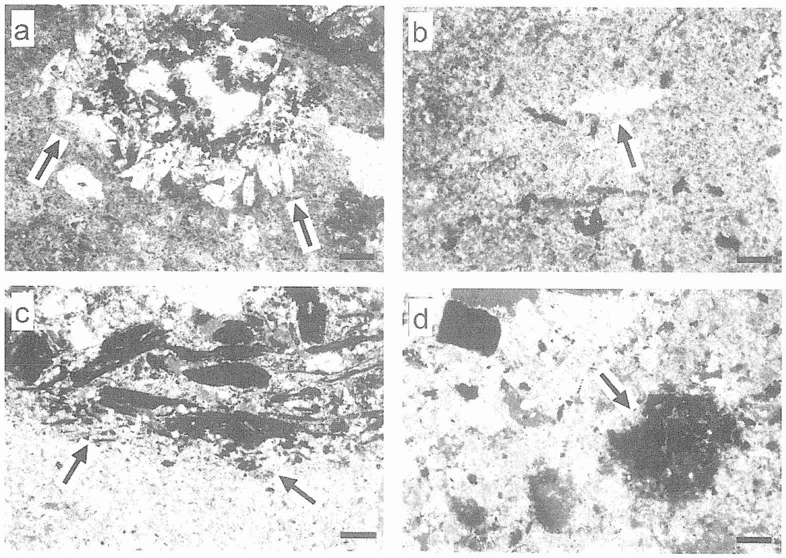

Fig. 7. Photomicrograph of micromorphological features; plane-polarized light (PPL); cross-polarized light (XPL); scale bars = 200 μm. (a) Gypsum nodule (arrows) on root pseudomorph, note occasional staining by opaque iron oxide and sulfide (PPL). (b) Lenticular gypsum crystal (arrow) in Lisan marl (XPL). (c) Layer of charred/unheated elongated grass remains on a floor in hut 1 lying on Lake Lisan deposit (XPL). (d) Degraded charcoal (arrow) in a calcareous ash-rich matrix in a fireplace in Locus 9; note chip of fish bone in upper left corner (XPL).

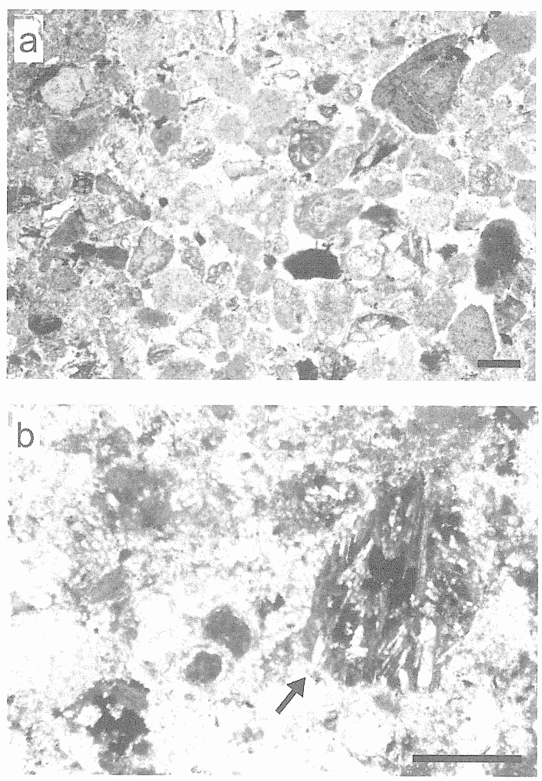

Fig. 8. Photomicrographs of upper portion of pre-occupational Lake Lisan deposits in thin sections; plane-polarized light (PPL); cross-polarized light (XPL); scale bars = 200 μm. (a) Well-sorted fabric of rounded ca. 250 μm clayey ooid-like aggregates mixed with weathered olivine, plagioclase, epidote sand-sized grains (PPL). (b) Basalt aggregate (arrow) embedded in calcareous clay matrix with fragments of shells (XPL).

Analogues of gypsum concretions in association with amorphous ferric precipitates and pyrite in decayed root channels at Ohalo II may be found in saline sulfidic soils in tidal areas (Stoops et al., 1978; Rabenhorst and James, 1992). It is still unclear, however, whether gypsum as an evaporative mineral, commonly occurring in the southern Lisan Formation (Stein, 2001), precipitated from evaporation of sulfate-bearing lake water or from rising saline groundwater.

THE CHARRED SEEDS: RECONSTRUCTING THE PALEO-ECOLOGY

Current ecology and landscape

The leading vegetation community today in the area of the sites, is a park-like forest of *Ziziphus spina-christi,* characteristic to the southern part of the Upper Jordan Valley and both adjacent low slopes. It is often associated with, or in some areas replaced by, members of batha communities. The vegetation gradually changes, upwards to the hills, into *Quercus ithaburensis–Styrax officinalis* association, an open deciduous oak forest. Higher up on the hills it changes again, into *Quercus calliprinos–Pistacia palaestina* association, the typical evergreen oak forests and maquis of the Levant, which covers most of the mountain slopes west and east of the Upper Jordan Valley.

Unlike other oak species in Israel, *Q. ithaburensis* has some noteworthy characters:

a. it forms an open forest;
b. it does so both on plains and on lower mountain slopes, with preference to deep alluvial soils;
c. it does not endure humidity in summer; and
d. it is sensitive to low temperatures (Zohary, 1962, pp. 92–102).

The paleoecology of Ohalo II

The large assemblage of seeds/fruit identified at Ohalo II (ca. 90,000) includes species from several habitats. The remains of *Quercus ithaburensis, Styrax officinalis*, and *Pistacia atlantica* appear to have belonged to an open park forest. Grasses and herbaceous species, such as *Aegilops peregrina*, *Anthemis pseudocotula*, *Avena sterilis*, *Hordeum bulbosum*, *Hordeum spontaneum*, and *Triticum dicoccoides*, commonly grow among the trees of this park forest. All were found at Ohalo II.

Several desert, Irano–Turanian (continental) species, such as *Anabasis articulata*, *Atriplex leucoclada*, *Nitraria schoberi,* and *Suaeda palaestina/fruticosa* were found. These represent the dry conditions that prevailed in the nearby surroundings. The finds of *Nitraria schoberi* (an extinct species in Israel), together with *Anabasis* and *Atriplex,* suggest the presence of a saline habitat near the site.

Additional habitats are the lake, with plants like *Chara* spp. and *Potamogeton pectinatus*, and the river bank with *Arundo/Phragmites*, *Scirpus litoralis*, *Vitis vinifera*, etc. (Table 3) (Kislev et al., 1992).

The phytogeographical data presented here shed light on the climate at the time of occupation. It is therefore suggested that the *Quercus ithaburensis–Styrax officinalis* association migrated several km southwards, towards Ohalo II, in comparison to the situation today (Kislev and Simchoni, 2002).

Table 3
Reconstructed habitats around Ohalo II according to identified seeds/fruit

Park forest			Saline	Lake	River bank
Trees	Grasses	Herbaceous			
Pistacia atlantica	*Aegilops peregrina*	*Anthemis pseudocotula*	*Anabasis articulata*	*Chara* spp.	*Arundo/ Phragmites*
Quercus ithaburensis	*Avena sterilis*		*Atriplex leucoclada*	*Potamogeton pectinatus*	*Scirpus litoralis*
Styrax officinalis	*Hordeum bulbosum*	*Nitraria schoberi*		*Vitis vinifera*	
	Hordeum spontaneum		*Suaeda palaestina/ fruticosa*		
	Triticum dicoccoides				

THE CHARRED WOOD REMAINS

The large quantities of charred remains include many fragments of wood tissues. Two assemblages of charred wood were analyzed, totaling 113 specimens (Tables 4, 5). All identified tree species grow today in the Sea of Galilee basin and surrounding slopes. Thus, it appears that the Ohalo II people were commonly using wood of tamarisk, oak, willow, and pistachio growing on the shore and on the nearby hillsides. The relative frequencies of the identified specimens do not reflect their relative importance at the site or their abundance in nature. This is due to the fact that many fragments of one burnt branch could bias any studied sample.

Table 4
Identified charred plant remains (wood and stems) retrieved from in situ loci and the surface of the site, identified by Liphschitz (Liphschitz and Nadel, 1997)

Species	Loci	Surface	Total
Tamarix (X5)	47	13	60
Tamarix (X4)	4		4
Pistacia atlantica	14	2	16
Quercus ithaburensis	1	2	3
Populus euphratica	5	3	8
Fraxinus syriaca	2		2
Rhamnus palestina	1		1
Atriplex halimus	5	1	6
Phoenix dactylifera		1	1
Total	79	22	101

Table 5
Identified charred plant remains from the in situ wall of hut 1 (after Nadel and Werker, 1999)

Species	Part	N
Salix	branch	3
Tamarix	branch	1
Quercus ithaburensis	branch	1
Quercus	branch	1
Atriplex / Seidlizia	stem	3
Prosopis?	branch	2
Monocotyledon	straw	1
Total		12

FAUNAL REMAINS

Thousands of animal bones were found in each brush hut and around most open-air hearths. This section does not attempt to provide a full description of the faunal assemblages and their distribution patterns in the camp. It does present, however, several preliminary samples of identified mammals, micromammals, birds, fish, and molluscs in order to illustrate the immediate environment and hence climatic conditions in the valley.

The sample of 2,749 identified mammal bones (Table 6) is dominated by gazelle (74.9%), which is still found in many parts of the Mediterranean open park forest and grasslands (Rabinovich, 2002). The other nine species include fallow deer, fox, hare, and wild boar. All species are common in Mediterranean habitats, though some became extinct in recent centuries, probably because of man.

Five species of micromammals (animals weighing less than 3 kg when alive) were identified, of which the common field vole (*Microtus guentheri*) is the most abundant (Belmaker, 2002). Tristram's jird (*Meriones tristrami*), the European hedgehog (*Erinaceus europeaus*), the black rat (*Rattus rattus*), and the house mouse (*Mus macedonicus*) are also present (Table 7). These species are all found today in the Mediterranean region and in grassland habitats in particular (Tchernov, 1988).

The assemblage of identified bird bones (N = 1,353, as of 2002) is the largest for any archaeological site in Israel. It includes 19 families, 48 genera, and 83 species (Simmons and Nadel, 1998; Simmons, 2002). The

Table 6
A sample of identified mammal bones

Species	NISP	%
Sus scrofa	19	0.7
Cervidae	14	0.5
Cervus elaphus	11	0.4
Dama mesopotamica	413	15.0
Bos primigenius	4	0.1
Gazella gazella	2,058	74.9
Capra aegagrus	4	0.1
Vulpes vulpes	118	4.3
Hyaena hyaena	2	0.1
Felis silvestris	18	0.7
Carnivore sp.	12	0.4
Lepus capensis	76	2.8
Total	2,749	100.0

Table 7
NISP of micromammal species retrieved from in situ loci and the surface of the site

Provenance/ species	*Microtus guentheri*	*Meriones tristrami*	*Mus macedonicus*	*Rattus rattus*	*Erinaceus europeaus*	indet.	Total
Loci	174	43	15	4	21	139	396
Surface	26	13	1	2	3	13	58
Total	200	56	16	6	24	152	454

Table 8
Bird bones from Ohalo II by families and species (sample does not include finds from last season of excavations)

Family	Species	N
Podicipidae	*Podiceps auritus*	93
	Podiceps cristatus	114
	Podiceps grisegena	30
	Podiceps nigricollis	15
	Tachybaptus ruficollis	3
Pelecanidae	*Pelecanus onocratalus*	1
Phalocrocoracidae	*Phalocrocorax aristotelis*	1
	Phalocrocorax pygmaeus	2
	Phalocrocorax carbo	1
Ardeidae	*Ardea cinerea*	3
	Ardea purpurea	1
	Ardeola ralloides	1
	Egretta garzetta	4
	Egretta ibis	1
Threskiornithidae	*Platalea leucorodia*	2
	Plegadis falinellus	2
Anatidae	*Cygnus bewickii*	8
	Cygnus cygnus	5
	Anser albifrons	2
	Anser anser	16
	Anser fabalis	21
	Tadorna tadorna	4
	Alpochen aegyptiacus	3
	Anas acuta	6
	Anas capensis	1
	Anas clypetea	9
	Anas crecca	2
	Anas penelope	1
	Anas platyrhynchos	11
	Anas querquedula	11
	Anas strepera	1
	Aythya fuligula	4
	Aythya marila	1
	Netta rufina	1
	Mergus merganser	1
	Mergus serrator	2
	Melanitta fusca	1
	Bucephala clangula	1

Family	Species	N
Accipitiridae	*Milvus migrans*	4
	Haliaeetus albicilla	4
	Circus aeruginosis	6
	Circus cyaneus	13
	Accipter nisus	13
	Accipter gentilis	15
	Melierax metabates	1
	Buteo rufins	5
	Buteo buteo	19
	Aquila rapax	2
Falconidae	*Falco tinnunculus*	4
	Falco columbarius	8
	Falco biarmicus	2
	Falco cherrug	2
Phasianidae	*Alectoris chukar*	8
	Ammoperdix heyi	2
	Coturnix coturnix	37
Rallidae	*Fulica atra*	23
	Porphyrio porphyrio	1
Otididae	*Tetrax tetrax*	15
	Otis tarda	1
Recurvirostridae	*Himantopus himantopus*	1
	Recurviostra avosetta	1
Charadriidae	*Vanellus vanellus*	1
Scolopacidae	*Numenius phaeopus*	1
	Numenius arquata	4
	Arenaria interpres	1
Laridae	*Larus minutus*	1
	Larus sabini	1
	Larus argentatus	7
	Larus ridibundus	1
Strigidae	*Bubo bubo*	5
Corvidae	*Corvus corone*	2
	Corvus monedula	3
	Corvus frugilegus	3
Total		603

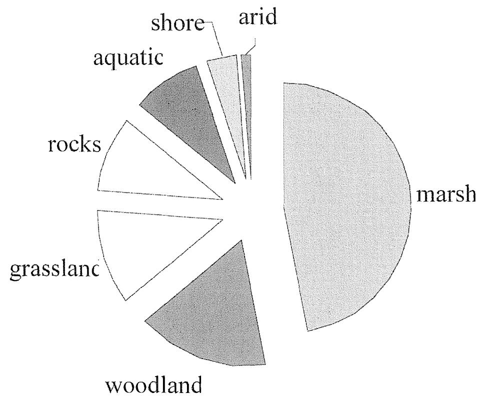

Fig. 9. The major nesting habitats of birds by NISP (N = 487).

assemblage is dominated (>33% of NISP (number of identified specimens)) by *Podiceps cristatus*, the great crested grebe of the Family Podicipidae (Table 8). At certain loci, e.g., the Locus 13 brush hut, *P. cristatus* accounts for greater than 90% of the NISP, indicating the value of this species to the Ohalo II people. It should be noted that many species are represented by very few bones.

Birds nesting in marsh and aquatic habitats comprise more than half of the species found at the site (Fig. 9); woodland and grassland habitats are also common, while birds nesting in arid environments comprise only ca. 1% of the sample. The bird species reflect the proximity of the site to the lake and indicate that habitats surrounding the Kinneret today were present in the same area 23,000 years ago.

The assemblage of identified bird bones (N = 1,352) is the largest for any archaeological site in Israel. It includes 19 families, 48 genera, and 83 species (Simmons and Nadel, 1998; Simmons, 2002). The sample presented here (N = 487) is dominated by *Podiceps cristatus*, the Great Crested Grebe of the Podicipidae family.

Birds nesting in marsh or aquatic habitats comprise more than half of the species found at the site (Fig. 9), wood and grass habitats are also common, while birds nesting in arid environments comprise ca. 1% of the sample. The bird species reflect the presence of water bodies (lake, marsh) near the site, and indicate that habitats surrounding the Kinneret today were present in the same area 23,000 years ago.

Fish remains are the most abundant at the site. The sample from hut 1 alone includes more than 20,000 specimens. There are two families present, namely the Cyprinidae and Cichlidae. The first live in fresh water while the latter can tolerate low-salinity waters. Fish of these two families are common today in the lake and the nearby streams.

Table 9
Freshwater molluscs from Ohalo II and their presence in different aquatic biotopes

Species	Spring	Brook	River	Lake	Lagoon	Marsh
Theodoxus michonii	+	+			(+)	(+)
Theodoxus jordanii			+	+	(+)	
Valvata saulcyi	+	+	+	+	+	+
Heleobia contempta	+	+				
Heleobia longiscata	+	+				
Islamia gaillardoti	+	+				
Falsipyrgula barroisi			+	+		
Bithynia phialensis	+	+	+	+	+	+
Melanoides tuberculatus	+	+	+	+	+	+
Melanopsis buccinoidea	+	+			(+)	(+)
Melanopsis costata			+	+	(+)	
Melanopsis "saulcyi"					(+)	
Radix virginea				+	+	
Radix natalensis		+				+
Radix tenera		+				+
Unio terminalis			+	+	+	
Corbicula fluminalis		+	+	+	+	+

Table 9
Freshwater molluscs from Ohalo II and their presence in different aquatic biotopes

Species	Spring	Brook	River	Lake	Lagoon	Marsh
Theodoxus michonii	+	+			(+)	(+)
Theodoxus jordanii			+	+	(+)	
Valvata saulcyi	+	+	+	+	+	+
Heleobia contempta	+	+				
Heleobia longiscata	+	+				
Islamia gaillardoti	+	+				
Falsipyrgula barroisi			+	+		
Bithynia phialensis	+	+	+	+	+	+
Melanoides tuberculatus	+	+	+	+	+	+
Melanopsis buccinoidea	+	+			(+)	(+)
Melanopsis costata			+	+	(+)	
Melanopsis "saulcyi"					(+)	
Radix virginea				+	+	
Radix natalensis		+				+
Radix tenera		+				+
Unio terminalis			+	+	+	
Corbicula fluminalis		+	+	+	+	+

INLAND MOLLUSCS (PRELIMINARY REMARKS)

Freshwater molluscs

Seventeen taxa of freshwater molluscs were found during excavations: 15 gastropods and 2 bivalves (Table 9).

Interpretation of the data is extremely difficult because of bio-fouling by recent molluscs living in the Sea of Galilee. Species like *Unio terminalis* and *Corbicula fluminalis* live always buried in the sediment, while *Melanoides tuberculatus* hides in the sediment during daytime. However, under adverse conditions (receding of the lake level) all species may dig deep into the sediment (20–30 cm and more) and contaminate much older layers. This explains the finds of complete, recent specimens of the mussel *Corbicula* or snails like *Melanoides* and *Falsipyrgula* still with the operculum in situ, mixed with what seems to be true fossil material.

A large variety of habitats seems to have existed near the site of Ohalo II, according to the recovered species. Especially interesting is the presence of *Melanopsis "saulcyi"*, which is a hybrid between *Melanopsis buccinoidea* (a spring-brook dweller) and *Melanopsis costata* (a lake-river dweller). Today the *"saulcyi"* form is characteristic of the lagoons of Biq'at Bet Zayda, in the northeast corner of the Sea of Galilee. These lagoons often have a much higher Cl^- content during summertime, and are also well known for the presence of a number of salt-loving plants.

None of the freshwater molluscs are of any economic value, although *Theodoxus* and *Melanopsis* can be easily transformed into shell-beads. *Unio* and *Corbicula* are in principle edible species. However, of *Unio* only very few fragments of valves have been encountered, while most of the *Corbicula* shells probably fall into the category of recent intruders.

Terrestrial snails

Only four species of terrestrial snails have been identified so far (Table 10). *Xeropicta vestalis joppensis* and *Helix engaddensis* are neither indicative of a certain biotope, nor of the amount of rainfall. Both species are

Table 10
Terrestrial snails from Ohalo II and their presence in different habitats

Species	Plain	Hills
Xeropicta vestalis joppensis	+	+
Metafruticicola fourousi		+
Levantina spiriplana caesareana		+
Helix engaddensis	+	+

encountered today in areas with an annual rainfall ranging between 100 and 1000 mm.

Metafruticicola fourousi is characteristic of woodland in hilly areas, while the *Levantina spiriplana caesareana* is only encountered among rocks in the hills. Both are currently confined to areas characterized by Mediterranean climate and vegetation. Both *Levantina* and *Helix* are edible species and might have been collected by the inhabitants of Ohalo II for that purpose.

DISCUSSION

The Ohalo II camp was occupied several times, for at least a year each time. In between, there were short-term inundations and the site was abandoned. The final abandonment, it appears, was more dramatic, and the water level rose high enough to submerge the site in deep water and begin the deposition of fine sediments; these sealed the site and protected the archaeological remains for millennia (Belitzky and Nadel, 2002; Tsatskin and Nadel, 2003). It is possible that the last water level rise was the result of an earthquake affecting the entrance/exit of the lake.

Our geoarchaeological study shows a pre-occupational sequence beginning with varved, calcareous marls and changing to basalt-derived sand deposited at the lake margin. As the magnetic susceptibility curve shows at least four depositional cycles, we assume that towards the time of occupation the water level was intermittently falling. The anthropogenic camp deposits are found on bioturbated sandy soils, located topographically slightly higher than marshy soils. The later post-occupational lacustrine deposits lie unconformably upon the archaeological horizons. These calcareous, laminated lake marls probably represent a relatively deep-water facies.

Various geological works provided evidence for water level fluctuations during the later phase of the Upper Pleistocene in the Sea of Galilee basin (e.g., Stein et al., 1997; Machlus et al., 2000; Stein, 2001; Bartov et al., 2002; Hazan, 2002). Recently, additional evidence was exposed on the southern shore of the lake at heights of 213–215 m below msl. These include a concentration of tree trunks ca. 1.5 km south of Ohalo II, and several locations with organic matter embedded in fine lacustrine layers (all radiocarbon dated between 21,000 and 16,000 B.P., Nadel et al., 2001). The finds probably reflect locations of shores, and immediate (ensuing) water level risings. In addition, various prehistoric and historic archaeological sites around the lake attest to water level fluctuations, and to the continuous presence of people along the shores (Nun, 1991; Nadel, 1993).

Environmental changes in the upper/central Jordan Valley are also manifest in the palynological records obtained from cores in Lake Hula (Weinstein-Evron, 1993) and the Sea of Galilee (Baruch and Bottema, 1991). Both provide important data and show fluctuations through time, but the possibility of dating each and every one of the observed events, and correlating them with documented water level fluctuations, is tentative at best (Nadel et al., 2001). Similar problems are encountered in other informative and important environmental reconstructions, such as those based on geological sequences and speleothems (Goldberg, 1994; Bar-Mathews et al., 1999).

Returning to our finds, one of the most striking characteristics of the Ohalo II floral and faunal assemblages is the similarity to extant species lists. More than 100 plant taxa were identified, and only two do not grow in the Sea of Galilee basin today. There is no faunal turnover in the many preserved families or genera (ca. 100 species of birds, mammals, and molluscs).

Comparisons of several of the above families or genera (especially of flora) to other more-or-less contemporaneous sites are rendered impossible, as similar remains were not preserved or not published in detail. However, the mammals in the size range of deer to hare were commonly hunted in many sites and their bones were preserved and studied. A recent study has clearly shown that during the Epipalaeolithic, from the Kebaran through the Late Natufian, there was no major change in the range of hunted mammals (Bar-Oz et al., 1999). Thus, the Ohalo II faunal and floral assemblages are more detailed than others, but are not surprising in terms of showing very little evidence for extinction/introduction of species during the end of the last Ice Age or in the preceding seven millennia.

All identified plant and animal species point to one conclusion: There was no dramatic climatic or environmental change since the last Ice Age until today, in terms of species diversity richness in the Sea of Galilee basin.

One can suggest that the southern Levant in general, and the Jordan Valley in particular, did not witness the dramatic climatic fluctuations so well documented on a global scale. In the central and upper Jordan Valley, local fauna and flora species were not driven to extinction. This is not to say that there were no changes, on a local scale, in distribution patterns and relative frequencies. Most probably, there were shifts of plant communities up and down the slopes surrounding the Jordan Valley, and also on a north–south axis. Thus, there was no apparent environmental stress dictating changes in subsistence patterns. People in the valley enjoyed this situation and some groups did not move much—they had water and a large variety of plant and animal food resources on the lakeshore and in the immediate surroundings.

Indeed, it appears that the most dramatic environmental events in the Jordan Valley were lake water level changes, and accordingly, changes in lake size. These were the result of certain fluctuations in precipitation within the drainage system, and evaporation in the lake area. When water level changes were swift, they were probably induced by earthquakes and tectonic events at the inlet and/or outlet of the lake.

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