Direct Luminescence Chronology of the Epipaleolithic Kebaran Site of Nahal Hadera V, Israel

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We report direct luminescence ages for the culture-bearing sediments of the Kebaran site of Nahal Hadera V (NHV) in the coastal plain of Israel. Although the site contains, in addition to rich lithic deposits, plentiful mammalian bone, it has proved to be undatable using radiocarbon dating, in spite of the fact that the cultural context places the time of occupation well within the range of radiocarbon dating. In contrast, luminescence dating of the site sediments proved successful. Luminescence ages were determined using the single aliquot additive-dose (SAA) method, applied to sand-sized quartz extracts to determine past equivalent doses (De). Dose rates (R) were calculated using thick source alpha counting for the uranium (U) and thorium (Th) concentrations and x-ray fluorescence analysis for the potassium (K2O) concentration. Of the five samples collected at the site, four represent cultural and subcultural deposits and the fifth represents the geological substrate for the archaeological deposit, a quartz-rich, carbonate-cemented dune sand known as aeolianite or kurkar. The luminescence age of the kurkar is 42.7 ± 6.3 ka. Human occupation of the site occurred between 21.3 ka and 14.0 ka ago, during the Last Glacial Maximum.

INTRODUCTION

The Epipaleolithic Period in the Levant spans the time from approximately 22,500–12,500 calibrated years before present (cal yr B.P.) and is considered a bridge between the hunter-gatherer lifestyle of the Upper Paleolithic and the newly agricultural Neolithic. The Epipaleolithic is divided into three major subdivisions: Kebaran (22,500–17,500 cal yr B.P.); Geometric Kebaran (17,500–14,900 cal yr B.P.); and Natufian (14,900–12,500 cal yr B.P.). The ages of these subdivisions are based on calibrated radiocarbon chronologies of others (e.g., Bar-Yosef, 1981, 1996; Goring-Morris, 1995; Goring-Morris and Belfer-Cohen, 1998).

The Kebaran complex was named by Garrod (1954) after the layers excavated by Turville-Petre at Kebara Cave in the early 1930s (Turville-Petre, 1932). The only thorough analysis of the Kebaran complex was in the 1960s (Bar-Yosef, 1970) and was later published in detailed overviews (Bar-Yosef, 1975, 1981). Bar-Yosef’s study of Kebaran assemblages from the coastal plain, the mountainous areas in northern Israel, and the Jordan valley yielded not only a detailed definition of Kebaran lithic...
characteristics but also a subdivision of the Kebaran into four lithic facies/assemble-
blages. The Kebaran is the earliest archaeological entity of the Epipaleolithic period
and is spread over the Mediterranean zones of Israel. Kebaran sites have also been
recorded in Lebanon, Syria, and Jordan (e.g., Byrd, 1998; Garrard et al., 1988; Mu-
heisen, 1988). The Kebaran period is considered to have been a cold and dry phase
at the end of the Pleistocene (Bar-Yosef, 1996; Goring-Morris and Belfer-Cohen,
1998). Kebaran sites are usually small in area, although larger open-air sites were
explored in Jordan (e.g., Muheisen, 1988; Garrard et al., 1988).
Architectural features are rare at Kebaran sites and have been reported from the
site of Ein Gev I (Arensburg and Bar-Yosef, 1973). The site of Ohalo II on the
recently exposed floor of Lake Tiberias and dated to around 23,000 cal yr B.P. has
rounded huts (e.g., Nadel and Werker, 1989), but it seems that this site is earlier
than the Kebaran complex (e.g., Goring-Morris, 1995).
Kebaran finds, apart from rich flint assemblages, include ground stone tools
(mostly mortars and pestles) as well as faunal remains. The economy has been
reconstructed in very general terms and described as based on hunting and gather-
ing, but details are few. The dominance of mountain gazelle (Gazella gazella)
and fallow deer (Dama mesopotamica) among the game animals is clear (e.g.,
Davis, 1982; Bar-Oz and Dayan, 2002a); however, many other species also appear
in Kebaran faunal collections (e.g., Saxon et al., 1978; Bar-Oz et al., 1999).
Research of the Kebaran complex in the Mediterranean zones of Israel has been
sporadic in general and very sparse in the last two decades. At the same time, re-
search on Epipaleolithic entities is advancing, mainly due to the work of Goring-
Morris (1987, 1995) in the desert regions of Israel as well as in Jordan (e.g., Clark et
al., 1988; Henry, 1989, 1995; Byrd 1998). However “normative” Kebaran was not de-
fined in the desert of Israel and Jordan, and paralleling entities such as the Qalkhan
(contemporaneous with the early Kebaran) and the Nizzanean (late Kebaran) were
introduced (cf. Goring-Morris, 1995). The renewal of excavations at Hayonim cave
and the work at the adjacent Kebaran rockshelter of Meged touch upon the Kebaran
in the Mediterranean zones after a long gap in research (e.g., Barzilai, 2001).
Almost all of the Kebaran assemblages from the coastal plain are surface collec-
tions (Bar-Yosef, 1970) while in situ stratified sequences have been very limited.
Kebaran coastal plain sites, when excavated, provide only very small exposed sur-
faces, usually not exceeding a few square meters and sometimes only single meters
excavated as test pits (e.g., Saxon et al., 1978). Nahal Hadera V is exceptional in
this regard being a site with a deep Kebaran stratigraphy (over 1 m) and recently
re-excavated on a large scale exposing some 70 m² (Barkai and Gopher, 2001).
Kebaran sites, including Nahal Hadera V (NHV), contain plentiful faunal remains,
and one would ordinarily expect ¹⁴C dating to be the dating method of choice.
Unfortunately, the high temperature and humidity of the region’s climate, coupled
with the very porous nature of coastal open-air sediments, result in such high rates
of chemical weathering that bone collagen is too degraded for ¹⁴C dating. Only a
few Kebaran sites have ¹⁴C ages associated with them (e.g., Bar-Yosef and Vogel,
1987; Byrd, 1996; Barzilai, 2001). Faunal material from NHV, submitted to the Weiz-
mann Institute of Science Radiocarbon Laboratory, did not contain sufficient collagen for 
$^{14}$C dating (E. Boaretto, personal communication, 2001). Thus, there is a clear need for alternative means of numerical dating to be applied to Epipaleolithic archaeological deposits of the Levant.

SITE DESCRIPTION

Nahal Hadera V is an open air site located on the coastal plain just northwest of the city of Hadera, Israel (map ref. 140.39-43/207.83-87), about 200 m south of the Hadera stream, and approximately 1 km east of the current shoreline of the Mediterranean Sea (Figure 1). Archaeological deposits at NHV are in a sand dune lying directly on a kurkar unit (carbonate-cemented aeolian sand). The site is located on a small hilltop and slopes downwards in all directions (Figure 2). The ancient landscape was probably flatter than it is today. The site appears to have been affected by deflation (on the hilltop) and erosion (mostly on the slopes). Occupation debris and lithic and faunal finds can be seen eroding on the hill slopes. The lithic assemblage is rich in microblade technology, small cores and microbl�, and plentiful though fractured mammalian bone fragments (Bar-Oz and Dayan, 2002a, 2002b).

Nahal Hadera V contains an artifact assemblage attributed to the Kebaran cultural complex (Saxon et al., 1978; Barkai and Gopher, 2001). By Epipaleolithic standards, NHV is a large and intensively occupied site. The estimated area of the site is at least 500 m$^2$, and the thickness of its deposits is more than 1 m. Test excavation in the early 1970s revealed a sequence of six stratigraphic units of which at least two were characterized as occupation levels (Saxon et al., 1978).

During the 1997–1999 field seasons, a total of 70 m$^2$ were excavated in the central (highest) part of the site near the test excavation of the 1970s, and seven probes were placed in a lower part of the site to the south. A hutlike feature was revealed in the latest phase of the Kebaran sequence, as well as four to five superposed living floors to the south of it, indicating recurring occupation. Numerous flint and bone items were recovered using 0.25 m$^2$ excavation units, 5-cm-thick excavation levels, and screens (dry and wet) with 2.4 mm and 1 mm meshes. Groundstone tools and concentrations of flint and bone indicated activity areas. Lithic and bone assemblages were obtained from all occupational phases, including the lowermost and uppermost levels.

CRITERIA FOR OPTICAL DATING

In order for optical dating (Huntley et al., 1985) to be successful at a given site, several criteria must be met. First, the sediments of interest must contain sufficient quantities of the mineral chosen for analysis. Typically this is either quartz or feldspar, although other minerals such as calcite or zircon have been studied. Second, the mineral grains must have been exposed to the equivalent of at least several hours of full spectrum sunlight during deposition (Godfrey-Smith et al., 1988), after which they should have been completely buried and have remained in total dark-
Figure 1. Location of Nahal Hadera V along the eastern Mediterranean coastline, shaded relief. Extending southeast from Haifa is the Carmel mountain range.
Figure 2. Plan (top) and section, showing locations of optical dating samples. Dash-dotted line (—·—) marks the boundaries of excavation. Hatched area in plan marks the extent of a dark brown soil with concentrated flint and bone. Contour lines are in meters above sea level. Stepped solid line and thin arrows in plan refer to the profile along which samples are shown. The heavy numbered arrows in plan correspond to sample numbers shown in profile. Vertical double dashed lines in the profile mark the turns. Hatched base in the profile indicates excavation to kurkar.
ness until sampling. Finally, the last exposure to light, which is the event being optically dated, should have taken place within the time range appropriate for the dating method. Depending on the concentration of the common radioisotopes in the sample, its burial depth, average moisture content, and the selected mineral’s saturation response to large radiation doses, this is usually no more than a few hundred thousand years ago.

For this study, we chose to work with the quartz grains. Previous studies (Godfrey-Smith et al., 1988, Godfrey-Smith, 1991, 1994) demonstrated that quartz has an extremely favorable response to bleaching by natural sunlight. In addition, the extreme degree of insolation in the region means that the clock-resetting criterion necessary for optimal dating results is fulfilled. A recent study (Godfrey-Smith and Shalev, 2002) verified that sediments of the coastal plain of the eastern Mediterranean are rich in quartz mineral grains, and that these have favorable luminescence properties, which include an excellent dose response sensitivity, making them well suited to a chronological application. Although the upper limits for the optical dating of quartz are typically lower than the limits for feldspar, the postulated <40,000 year-age of the site all but guaranteed a successful outcome.

**Nomenclatures in Radiocarbon and Luminescence Dating**

In the previous discussion, we used calibrated years B.P. for dendrochronologically calibrated radiocarbon ages. By definition, this terminology is restricted to radiocarbon dates, and we deliberately avoid using it for luminescence dates (and, indeed, for numerical ages obtained by any other method). In luminescence dating, the notation ka is typically used for numerical ages equal to or greater than 1000 years (1 ka = 1000 years). We have chosen to retain this convention in our presentation of luminescence ages. The validity of this approach is made obvious when one considers that luminescence ages of, say, 65 ka are common in the literature, but an age of 65,000 cal yr B.P. cannot occur because of the limitations of both the radiocarbon dating method and existing calibration curves. In spite of the deliberate notational differences, a luminescence age of 20 ka and a radiocarbon age of 20,000 cal yr B.P. both refer to the secular time scale and are equivalent to 20,000 calendar years ago.

**SAMPLE DESCRIPTIONS**

The samples collected for optical dating are mapped in Figure 2 with respect to the 1997-1999 excavation.

NHV1. Unit I16D, 221 cm b.d. (below datum). Kurkar aeolianite fragment, 12 × 17 × 5 cm, immediately below contact with overlying soft sediments. The natural surface of the site at sample locations 1 and 2 is 120 cm below datum. Because the sample was in contact with overlying sediments that were different than the kurkar, separate dosimetry samples for gamma dose rate measurements were also collected. These are NHV1A (subkurkar) and NHV1B (superkurkar, 0–3 cm above the upper surface of the kurkar, in overlying brown sediment).
NIHV2. Unit I15B, 210 cm b.d., soft brown sediment from the north wall of unit I15, 13 cm from its east wall, and 11 cm above its contact with the kurkar. This is a subcultural phase located below the earliest occupation of the site and above the kurkar.

NIHV3. Unit G14B, 190 cm b.d., sampled from its east wall. Living floor plus subliving floor sediments. Since the living floor is 175–185 cm b.d., and the sediment sample was centered at 190 cm, one half to a third of the sediment collected is in the subunit below the living floor.

NIHV4. Unit G10B, 238 cm b.d., sampled from the unit’s east wall. The living floor here is at 205–212 cm b.d. The kurkar’s upper surface is not exposed at this location, although it is found at a much lower elevation.

NIHV5. Unit J18C, 164 cm b.d., sampled from south to north, 21 cm east of boundary with unit I, about 30 cm below surface. This sample constitutes the fill of a housepit feature, a very dense concentration of flint artifacts and bone fragments in dark brown to black sediment.

METHODS

Sample Preparation and Analysis

The bulk sediment was treated with HCl and H2O2 to remove carbonates and organics, and dry sieved to obtain fine sand size grains in the narrow range of 90–125 μm. Most nonquartz minerals were removed using two heavy liquid separations which removed grains with densities <2.60 and >2.70 g cm⁻³, and magnetic separation. The remaining quartz-dominated grains were treated with concentrated HF, which dissolved the remaining nonquartz minerals and removed the outer 20 μm layer of the quartz grains themselves. The purified quartz extract was re-sieved through a 90 μm screen to remove fragments of grains broken during treatment.

Dosimetry

Potassium concentrations were determined by x-ray fluorescence at the Geochemistry Centre, St. Mary’s University, Halifax. A 5% error in the measured K₂O value is included in the dose rate calculation. Uranium (U) and thorium (Th) concentrations were measured using thick-source alpha counting of samples crushed to a fine powder, which had rested for >1 month after crushing before being measured (Table I). The great advantage of alpha counting over more precise determinations of U and Th (for example, INAA and DNA) is that it determines the true activity of each radioisotope chain in its entirety, and thus naturally compensates for any disequilibria which may be present in the sediment. Thus, although the equivalent U and Th concentrations (Table II) are not of high precision, the actual dose rate variation due to all dosimetry variables, excluding moisture content, is <3%. Inclusion of the moisture content error increases the error in the dose rate to <5%. No moisture content measurements were done; instead, an assumed value of 0.06 ± 0.05 (6% water, as a percentage of dry sediment weight) was used, which reflects both Holocene seasonal winter/summer variations and a probable higher...
moisture content during the late Quaternary. The coarse, highly porous, and well-drained nature of the sediments makes it unlikely that average yearly moisture contents could have fluctuated outside the moisture content’s assumed error (±0.05).

Dₐ Determinations

Single aliquot additive dose (SAA) analysis was used to determine the past Dₐ (Duller, 1994). For each sample, 15 aliquots were prepared by depositing 10–15 mg of quartz extract in a monolayer on 0.98 cm Al disks. All aliquots were preheated at 230°C for 300 s and stimulated with a narrow band of green photons for 0.5 s. Detection was through a stack of ultraviolet-transmitting Schott U340 glass filters. In order to prevent charge re-trapping in the 100°C TL trap and avoid second-order effects, all optical stimulations were performed at 120°C.

During each additive dose analysis, an aliquot was given six irradiations in the range of 10–150 Gy. For sample NHV5, the initial set of measurements yielded a significantly lower Dₐ than expected; thus a second set of 10 aliquots was analyzed.

<table>
<thead>
<tr>
<th>Table II. Alpha-equivalent U and Th concentrations.a</th>
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<tbody>
<tr>
<td>Nahal Hadera V Sample</td>
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<tr>
<td>NHV 1: kurkar cemented dune</td>
</tr>
<tr>
<td>NHV 2: immediately above kurkar</td>
</tr>
<tr>
<td>NHV 3: living floor + subfloor</td>
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<tr>
<td>NHV 4: immediately below living floor</td>
</tr>
<tr>
<td>NHV 5: housepit feature</td>
</tr>
</tbody>
</table>

*aBased on the following conversion factors: Th ppm = Th counts/0.0372; U ppm = Total – Th counts/0.128.
with added doses of 10–100 Gy only. The average $D_a$'s obtained in the two runs were statistically identical.

A preheat calibration was performed on each aliquot independently of all other aliquots, after the aliquot’s additive dose run, with eight preheat shine cycles identical to those used in the additive dose run. This procedure was tested on a quartz extract from an African sediment that was completely bleached with natural light and re-irradiated with 4.4 Gy. It yielded a mean $D_a = 4.46 \pm 0.30$ Gy ($\sigma_D = \pm 0.09$ Gy, $n = 10$). The validity of the SAA method for dating quartz-rich sediments within the Epipaleolithic time frame was verified in an earlier study (Ivester et al., 2001). A past $D_a$ was obtained for each aliquot by extrapolation of a least squares fit of the preheat-corrected dose response growth curve, with inverse weighting with respect to intensity. The additive dose growth curves were only slightly sub-linear; quadratic fits were made to the data using a published least squares routine (Noggle, 1993). Typical growth curves and $D_a$ extrapolations for NHV1 and NHV5 demonstrate the maximum and minimum degrees of sublinearity shown by quartz of this site and are presented in Figure 3.

**DISCUSSION OF LUMINESCENCE AGES**

As expected, the sediments at NHV contain plentiful quartz sand. Because of the high geological maturity of the sediments, the relative proportion of feldspar minerals is extremely low. This is reflected by the very low potassium contents: Uranium and thorium concentrations in the archaeological sediments (U 1.2–1.7 ppm, Th 2.5–2.9 ppm) are about one third of typical concentrations of most clastic sediments, and they are very low (U 0.7, Th 0.5 ppm) in the carbonate-rich kurkar. Cosmic dose rates were estimated on the basis of present depths below surface and ranged from 0.18 to 0.2 Gy/ka. Beta dose rates were calculated based on each
Table III. Past doses, dose rates, and ages for Nahal Hadera V.a,b

<table>
<thead>
<tr>
<th>Nahal Hadera V Sample</th>
<th>Past dose De (Gy)</th>
<th>Dose rate R (Gy/ka)</th>
<th>Age (ka)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHV 1 kurkar cemented dune</td>
<td>27.40 ± 0.23</td>
<td>0.69 ± 0.09</td>
<td>21.3 ± 1.3</td>
</tr>
<tr>
<td>NHV 2 immediately above kurkar</td>
<td>23.65 ± 0.20</td>
<td>1.24 ± 0.07</td>
<td>18.3 ± 2.3</td>
</tr>
<tr>
<td>NHV 3 living floor + subfloor</td>
<td>22.76 ± 2.46</td>
<td>1.11 ± 0.07</td>
<td>21.3 ± 2.3</td>
</tr>
<tr>
<td>NHV 4 immediately below living floor</td>
<td>24.97 ± 2.95</td>
<td>1.23 ± 0.07</td>
<td>20.3 ± 2.2</td>
</tr>
<tr>
<td>NHV 5 housepit feature</td>
<td>14.00 ± 1.95</td>
<td>0.99 ± 0.06</td>
<td>14.0 ± 2.1</td>
</tr>
</tbody>
</table>

*aDose rate for 21.3 ka–present.

bDose rate since kurkar formation until 21.3 ka ago, for depth 1.05 m b.s. See text for details.

The sediment of NHV5 was exceptionally rich in flint flakes. Based on estimates of total flint debitage recoveries from the adjacent 0.5 x 0.5 m subunits, the composition of this unit is 10% flint by weight. Because flint is radioisotope-depleted in comparison to the sediment matrix, it acts as an inert diluant for the γ dose rate. Because the flakes collected with the matrix during sampling were deliberately excluded from crushing for alpha counting, the γ dose rate for NHV5 was reduced to 0.9 self R, to correct for radioisotope dilution by the flint.

Mean past doses, dose rates, and ages are shown in Table III. Ages for the archaeological sediments ranged from 21.3 ± 2.3 to 18.3 ± 2.2 ka for the main deposit, and 14.0 ± 2.1 ka for intrusive sediments in the Kebaran housepit feature. The ages of greatest interest are NHV3 and NHV4. NHV3 was taken directly below an artifact (flint) and bone-rich layer (locus 175) at 175–185 cm b.d. NHV4 was taken below another artifact and bone-rich living floor to the south (locus 100) at 202–215 cm b.d. Thus, the lower living floor (locus 100) is securely dated between 21.3 ± 2.3 and 18.3 ± 2.2 ka. Locus 175, the upper living floor, postdates 18.3 ka but is defi-
nately earlier than the fill of the house pit feature (sample NHV5) dated at 14.0 ± 2.1 ka. Ongoing analyses of more tightly defined (in a vertical sense) samples of the upper living floor and horizons immediately above it are expected to resolve the ages with more precision.

Results of the single aliquot Ds determinations are shown in Figure 4. Some variation in the Ds’s is observed. This is an expected consequence of variations in natural sedimentation rates. Based on the depths below the living floor of NHV3 and NHV4, and the 2 ka difference in their ages, we estimate an average depositional rate at the site of 10 cm/ka. Therefore, a finite, 6-cm-thick vertical slice (the thickness of the sampling container) of the archaeological sediments should contain a mixture of quartz grains that were last exposed to light at least 600 years apart. Additional disturbance due to faunal and floral bioturbation would be expected to widen this range by transporting older grains from lower horizons upward and younger grains downward.

The geological substrate underlying the archaeological deposit is a quartz-rich, carbonate-cemented aeolianite or kurkar. Its luminescence age is 42.7 ± 6.3 ka. We emphasize that, in the absence of empirical evidence, the modern depth below surface (1.05 m) was used in the dose rate calculation, a variable which relates to the cosmic dose rate via the equation

\[
c = 0.21 \exp(-0.07 \times 2d + 0.0005 \times 4d^2),
\]

where \( c \) = cosmic dose rate and \( d \) = depth below surface in meters (Prescott and Hutton, 1988).

Though this depth is likely to be correct, on average, for the post-21.3 ka period, we do not know how closely it approximates the average depth prior to that time. Because the kurkar is a friable material unlikely to sustain a stable geomorphic surface for >20 ka, we believe that an average depth < 1 m is unlikely. It is possible, however, that the kurkar aggraded rapidly to a much greater height and eroded quickly during the last glacial maximum. Thus, at 1.05 m average depth, \( c \) is 0.182 Gy/ka. However, if the average depth was 5 m, \( c \) would be reduced to 0.110 Gy/ka, and the kurkar’s age would increase to 45.6 ka. If the pre-21.3 ka average depth was 10 m, the age would increase to 48 ka. Because of the uncertainties in the kurkar’s ancient depth below surface and the resulting potential for age differences, it is best to accept 42.7 ka as a minimum age for the kurkar. We stress that such large depth-related age changes are atypical in most clastic-rich sediments, in which self dose rates are >2 Gy/ka and the cosmic dose rate is, therefore, a much smaller fraction of the total \( R \). The depth variations are significant to the age estimate of NHV1 because radioisotope-poor carbonates and quartz dominate this sediment, and therefore its self β and γ dose rates are very low. They would be equally significant in other quartz-dominated, very mature sediments (Ivester et al., 2001).

In any event, we suggest that the kurkar is cognate with the Dor Kurkar exposed at the Givat Olga section, which has yielded an average age of 54 ± 9 ka based on IRSL dating of potassium feldspar grains (Frechen et al., 2002). Individual IRSL
Figure 4. Scattergrams of single aliquot De versus that aliquot's natural luminescence per unit mass. Samples all points were included in the mean De.

Natural Luminescence (counts / 0.5g mg)

De (Gy)

De (Gy)
ages for this kurkar at the Givat Olga and the Netanya South sections range from
32 to >80 ka (Frechen et al., 2002).

CONCLUSION

We have obtained the first direct luminescence ages for a Kebaran period arch-

aeological site, Nahal Hadera V. These ages suggest that human occupation of
the site occurred between 21.3 and 14.0 ka. This time range places the site’s oc-

cupation within marine oxygen isotope stage 2, the Last Glacial Maximum (Martin-

son et al., 1987). During this stage, sea levels worldwide were 60–120 m lower than
they are today because of the mass of oceanic water bound within continental ice
sheets. Hence, the coastline of the Mediterranean Sea, now within 1 km of the site,
would have been several kilometers further west.

The direct luminescence dates for NHV bracket specific living floors between
20.3 and 18.3 ka and can be compared with ^14C ages for other Kebaran sites. The
available Kebaran ^14C ages include series or single determinations made in the last
three decades from several sites in Israel and Jordan. These include Rakefet Cave,
Nahal Oren, Ein Gev (Arensburg and Bar-Yosef, 1973), Kharaneh (Muheisen, 1988),
Wadi el-Jilat 6 (Garrard and Byrd, 1992), and Meged rockshelter (Barzilai, 2001).
Additional ^14C ages from Jordan are reported in Byrd (1998:67–69) and include
dates from the following Kabaran sites: Uwaynid 14 and 18, Wadi Hammeh 26, 31,
50, 51, and 52; Tor el Tareeq and Madanagh and Tabaqat el-Buna. When calibrated,
these ages range from 21,700 cal yr B.P. (not including one earlier date from Meged
rockshelter) to 16,800 cal yr B.P. The NHV dates we have obtained thus far are in
accordance with the middle to late part of this range. The results of the lithic
analysis of NHV assemblages support this conclusion.

Direct luminescence dating of sand has great potential for developing a numer-
cical chronology for coastal plain Epipaleolithic sites in the Levant and should be-
come a routine procedure.

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dation.

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