UPLAND OLIVE DOMESTICATION IN THE CHALCOLITHIC PERIOD: NEW ^{14}C DETERMINATIONS FROM EL-KHAWARIJ (AJLUN), JORDAN

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ABSTRACT. New radiocarbon results on olive stones from el-Khawarij date olive cultivation at this site, in the Jordanian highlands, to the last 2 centuries of the 5th millennium cal BC. This period also sees the emergence of olive cultivation at Teleilat Ghassul, by the Dead Sea. The 10 new AMS dates were deliberately obtained from carbonized olive stones in order to date the exploitation of olives at el-Khawarij, a late prehistoric settlement believed to have been reliant on olive production. The results reveal a much longer span of occupation than hitherto suspected, including 2 dates that may fall later than 3900 cal BC (particularly OZI221, 3950–3530 cal BC). These later dates are in line with dates from other upland sites in the region, and may strengthen suggestions that Chalcolithic settlement persisted for longer in better watered upland areas (Lovell 2002). Further, an early date from a sample in a rock-cut installation in Area A suggests a much earlier date for occupation at the site, implying that upland olive exploitation may have commenced before 4700–4450 cal BC.

INTRODUCTION

The Wadi Rayyan Archaeological Project (WRAP) was designed to investigate the phenomena of olive domestication and highland settlement in the late Chalcolithic. The project has focused upon excavation of el-Khawarij, a site in the Wadi Rayyan (Figure 1) attributed to the Chalcolithic period (about 4500–3600 cal BC). Excavations at el-Khawarij have revealed an upland Chalcolithic settlement with stone-built broadroom architecture that makes use of protruding bedrock for floors and working surfaces (Lovell et al. 2006, 2007). The ceramics and other finds suggest a late or "classic" Chalcolithic date, with some suggestions of items that might be considered "Terminal Chalcolithic," i.e. transitional to the Early Bronze Age (EBA) (Lovell et al. 2006:58). It had been previously argued (Lovell 2002) that a change in climatic conditions may have provided additional motivation for Chalcolithic communities to move to higher altitudes during the Late Chalcolithic–Early Bronze Age transition, and that development of olive cultivation (Meadows 2005: Appendix F), optimally carried out above 300 m asl, assisted this move.

The earliest dates for the earliest phase of the Early Bronze Age, EBI, fall between 3650 to 3350 cal BC (Bronk Ramsey et al. 2002:83–4; Gibbs et al. 2009; cf. Carmi and Segal 2004). While lowland sites (~300 m asl and below) had been producing radiocarbon determinations that argued for an end date for the Chalcolithic period of 3900/3800 cal BC (Bourke et al. 2004), younger dates derived from charcoal [3800–3500 cal BC] from the highland Golan Chalcolithic site, Rasm Harbush, assumed to have been reliant on olive, were known (Carmi and Segal 1998), as were a handful of dates from Chalcolithic sites in the Negev (see Burton and Levy 2001:1232). ^{14}C dates on olive stones taken from a pit postdating the Early Chalcolithic phases at Tell es-Shuna (North) (OxA-4641 and -4642; Figure 4) appear to confirm early 4th millennium cal BC activity in association with olive, although no well-stratified Late Chalcolithic deposits have been found there (Bronk Ramsey et al. 2002:83–4).

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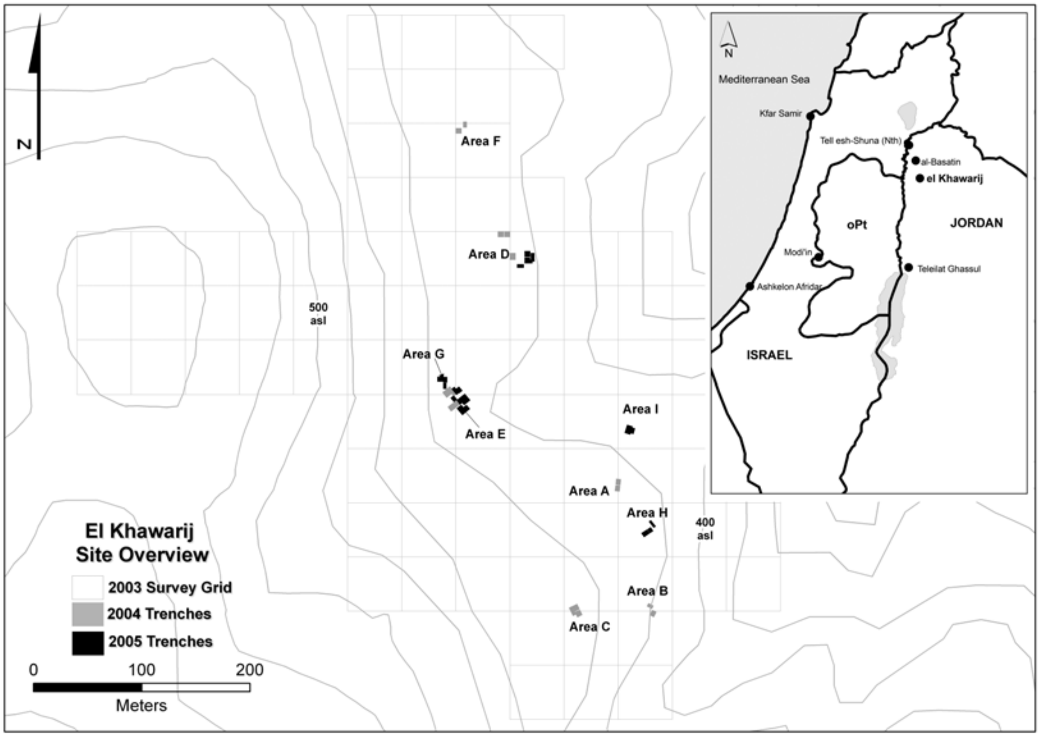

Figure 1 Plan of el-Khawarij as excavated by Area with location map

METHOD

Following the first season of excavation at el-Khawarij (Lovell et al. 2006), 10 ^{14}C samples were selected to confirm the Late Chalcolithic date of olive exploitation. Nine of the 10 samples were from bulk samples taken for archaeobotanical flotation, whose light fractions were sorted under low-power microscopy. The tenth, OZI225, was collected by hand during the excavation.

The extensive evidence of bioturbation and the reoccupation of the site in the Middle Bronze Age meant that it could not be assumed that all plant remains from apparently undisturbed Chalcolithic layers were of the same date. Dating single olive stones would help to identify any much older or more recent material, and provide a date range for olive exploitation in the Late Chalcolithic.

The samples were processed and measured by accelerator mass spectrometry (AMS) at the Australian Nuclear Science and Technology Organisation (ANSTO). The charred olive stones were pretreated using the acid-alkali-acid method. Initially, the olive stones were washed with deionized water to remove soil, then treated with 2M HCl at 60 °C for 2 hr after which the olive stones were washed repeatedly with 0.1 to 0.5% NaOH at 60 °C for 2 hr until the solution was clear (varied between 5 to 13 washes, depending on sample). This was followed by a final 2M HCl wash for 2 hr, then washed with Milli-Q™ water and dried at 60 °C. The pretreated material was combusted to CO_2 at 900 °C in sealed Vycor™ tubes containing CuO and Ag wire. The CO_2 was converted to graphite by reduction over Fe catalyst at 600 °C using an excess of H_2 (Hua et al. 2001). The resulting graphite target was pressed into aluminium cathodes and analyzed at the AMS facility at ANSTO. The δ^{13}C of the graphite was determined using an elemental analyzer with an isotope ratio mass spectrometer (Fink et al. 2004).

RESULTS

The results (Table 1) are given as conventional ^{14}C ages (Stuiver and Polach 1977). The calibrated date ranges are 95% confidence intervals, calculated by the maximum intercept method (Stuiver and Reimer 1986), using the IntCal04 data set (Reimer et al. 2004) and the program OxCal 4.0.5 (Bronk Ramsey 1995, 1998, 2001, 2009). Figure 2 shows the calibration of these results by the probability method (Stuiver and Reimer 1993).

Table 1 ^{14}C results, el-Khawarij, 2004 season of excavations (Lovell et al. 2006). Each sample consisted of a single carbonized olive stone (*Olea europaea*).

Lab code	Sample	$\delta^{13}C$ (‰)	^{14}C age (BP)	Calibrated date range (95% confidence)
OZI216	040364, Area C1 [1215]	–26.0	5250 ± 60	4250–3950 cal BC
OZI217	040560, Area E3 [1155]	–22.1	5220 ± 50	4230–3950 cal BC
OZI219	040600, Area C2 [1225]	–23.3	5100 ± 60	4040–3710 cal BC
OZI220	040888, Area E4 [1307]	–22.1	5310 ± 60	4330–3970 cal BC
OZI221	040933, Area E6 [1309]	–23.5	4930 ± 80	3950–3530 cal BC
OZI222	040974A, Area E6 [1314], below floor	–22.0	5370 ± 70	4350–3990 cal BC
OZI223	040974B, Area E6 [1314], below floor	–23.2	5240 ± 70	4260–3940 cal BC
OZI224	040975, Area E6 [1312], above floor	–20.6	5310 ± 60	4330–3970 cal BC
OZI225	040977, Area E6 [1311], above floor	–22.1	5200 ± 60	4230–3810 cal BC
OZI226	040134, Area A1 [1063]	–21.9	5715 ± 50	4700–4450 cal BC

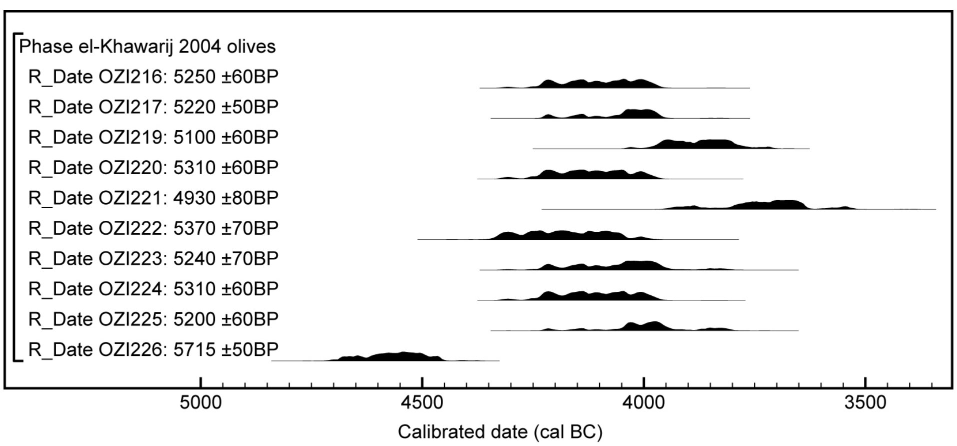

Figure 2 Calibration of ^{14}C results by the probability method (Stuiver and Reimer 1993)

The results obtained are largely consistent with initial expectations, with no evidence of carbonized plant remains from later periods infiltrating into Chalcolithic layers. The only Area A sample, OZI226, was somewhat older than expected and is clearly earlier than samples from areas C and E, but it came from a context stratigraphically predating the buildings in this area (and thus the main phase of occupation). The date of OZI226 implies that the rock-cut feature filled by context [1063] went out of use after 4700–4450 cal BC, and this feature probably predates the later 5th millennium cal BC start of the Late Chalcolithic occupation. The function of these rock-cut features is difficult to determine, but clearly olive processing is one possibility. It is not possible to say whether a single olive stone is from a wild or cultivated tree, so OZI226 does not prove that olives were cultivated as early as the mid-5th millennium cal BC.

OZI221, apparently the most recent sample, came from the latest intact layer of Chalcolithic occupation in Area E. The calibrated dates of the other samples are all similar to each other, and place the main phase of olive exploitation at about the end of the 5th millennium cal BC.

Although these samples were selected to provide a date range for olive exploitation rather than to provide a tight chronology for the archaeological deposits, the ^{14}C results do not suggest that the samples were significantly older than the deposits in which the olives were found. The 2 results from 1 context, OZI222 and OZI223, are statistically consistent with a single ^{14}C date (T' = 1.7, T'(5%) = 3.8, ν = 1; Ward and Wilson 1978), as they should be if the 2 samples provide good dates for their deposition in this context. OZI224, OZI225, and OZI221, from stratigraphically later contexts in Area E6, may all be more recent than OZI222 and OZI223, as the relative dates of the contexts implies.

Indeed, it is possible that all 10 ^{14}C samples are close in date to the contexts in which they were found. A simple Bayesian model of the results, in which the relative dates of the samples are constrained by their stratigraphic positions, has good overall agreement (A_{model} = 81.3; Figure 3; Lovell 2009). This supports the interpretation that the dates of the olive stones may provide a realistic chronology for the Late Chalcolithic buildings, although the relatively low individual index of agreement for OZI221 (A = 49.0) suggests that this result does not fit very comfortably with the other 8, and it is arguable that the latest deposits may be under-represented by the ^{14}C samples.

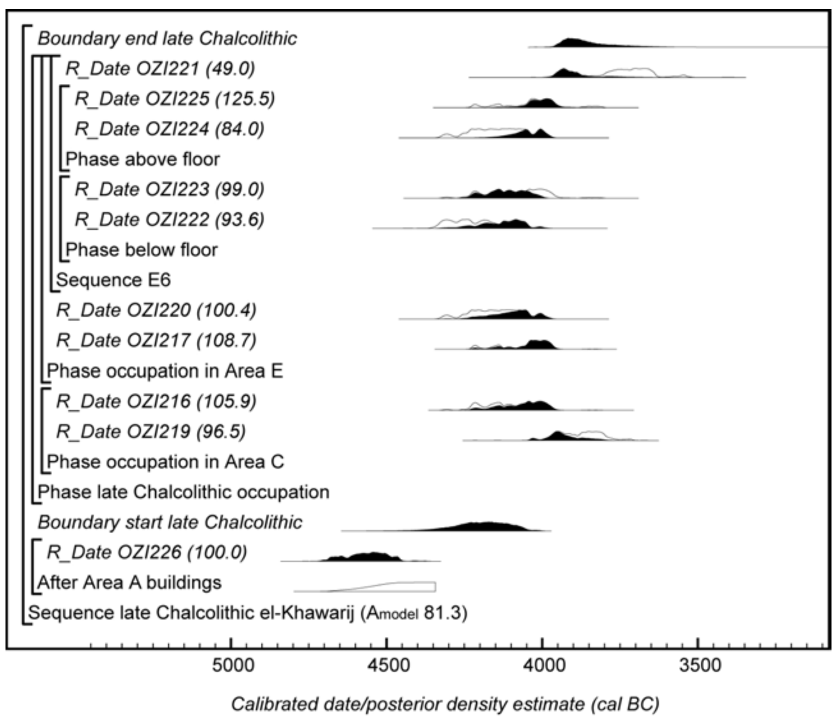

Figure 3 A Bayesian model of the el-Khawarij ^{14}C results, in which stratigraphic relationships are used to infer relative dates of samples. The model structure, shown by the square brackets and OxCal v 4 keywords, defines these relationships precisely. The satisfactory overall index of agreement (A_{model} > 60) shows that the results are consistent with the model structure. Where 2 distributions are visible for the same ^{14}C result, that in outline was obtained by calibration (Stuiver and Reimer 1993), while the solid distribution is a *posterior density estimate* of the date of the sample, which would change if more samples were dated or if the model structure was changed.

Although this model may provide a better idea of the site's chronology than simple inspection of the calibrated dates (Figure 2), we cannot demonstrate that the olive stones date their contexts; however, we anticipate that further ^{14}C dating at el Khawarij will focus on plant remains that appear to have been charred *in situ*.

DISCUSSION

As only single carbonized olive stones were selected, the ^{14}C results should date olive exploitation at el-Khawarij, irrespective of the precise dates of the stratigraphic sequence. This is a more satisfactory situation than generally prevails in Levantine archaeology, where site chronologies are often based on ^{14}C measurements from bulk samples of unidentified wood charcoal.

Figure 4 shows the published ^{14}C dates from sites in the southern Levant on samples of olive stones or olive pulp, which have no intrinsic age (although we cannot be certain that these samples were all single organisms). Measurements on olive wood are omitted, as the olive is a very long-lived tree, and without detailed information about the maturity of the wood dated, it is possible that such ^{14}C results are misleading.

The apparent range of dates obtained at Kfar Samir is surprising, particularly as these samples should have been well-stratified within installations 6 and 7, and functionally related to their contexts (Galili et al. 1997). Even the latest results apparently predate those from el Khawarij, but at Kfar Samir we appear to be dealing with the exploitation of wild olives (Kislev 1994–95). At Shuna, olive may have been cultivated (Neef 1990), but perhaps not as early as OxA-5395 would suggest. Early-Middle Chalcolithic olives at Teleilat Ghassul have the same variation in size as those at Kfar Samir (Meadows 2005: Appendix F), and were presumably collected from the wild. They have not been dated directly, but other short-lived plant remains from these strata date to the early-mid 5th millennium cal BC (Bourke et al. 2004). The status of olives at Afridar and al-Basatin is unknown.

The narrow spread of olive-stone dimensions suggests that olives from el-Khawarij are consistent with other cultivated olives, such as those from Late Chalcolithic Teleilat Ghassul (Meadows 2005: Appendix F). It is thus not surprising that whereas the earliest date from el-Khawarij (OZI226) is earlier than published dates on olive from Teleilat Ghassul (OZG248 to 252), the other dates are broadly consistent with them (Bourke et al. 2004:318). OZI226 corresponds well with ceramic data from this area of el-Khawarij (Lovell et al. 2007:116, Figure 12.2) suggesting that there was earlier settlement on the site, as yet unexcavated, which may yet show that exploitation of olive here predated any proposed olive cultivation in the lowlands. Other recent assays on olive stones from Modi'in, in the Shephelah, Israel, where 1200 carbonized olive stones were recovered in a single cache, present consistent dates with the el-Khawarij dates (van den Brink 2010). The 2 ^{14}C dates on olive stones from coastal Ashqelon, Afridar–Area E (Carmi and Segal 2004) are also consistent and provide additional support for Chalcolithic olive exploitation.

To further elucidate the development of olive cultivation in the region, we require more well-sampled and suitably stratified ^{14}C dates, which are tied to well-articulated sequences. Galili et al. (1997) produced ^{14}C dates from the submerged, coastal site of Kfar Samir on what are considered to be wild olive stones (Kislev 1994–95), which apparently cover much of the period 5500–4500 cal BC. Bourke has suggested that domesticated olive came late to the north Jordan Valley, but spread into the foothills and eastern uplands rapidly (Bourke 2008:121; cf. Lovell 2002), on the basis that olive stones from Ghassul (Bourke et al. 2004) and Pella provide dates in the early phases of the Chalcolithic (with many more olive stones derived from earlier phases which are, as yet, undated) and the fact that the clearest evidence for the actual domestication of olive comes from Ghassul (S

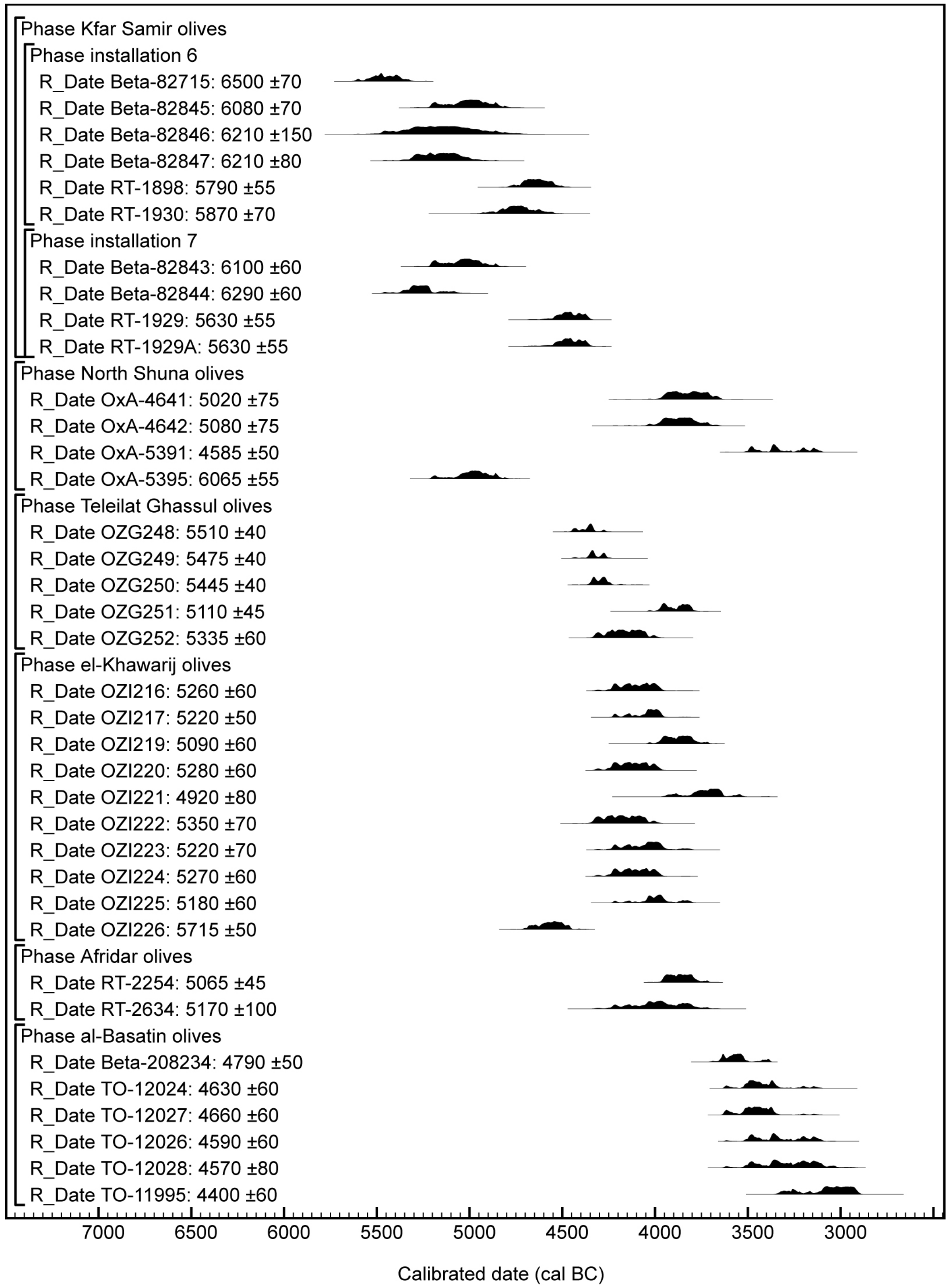

Figure 4 Calibration by the probability method (Stuiver and Reimer 1993) of ^{14}C measurements on olive stones sites in the southern Levant (Kfar Samir: Galili et al. 1997; Shuna: Bronk Ramsey et al. 2002; Teleilat Ghassul: Bourke et al. 2004; el-Khawarij: this paper; Afridar: Carmi and Segal 2004; el-Basatin: Gibbs et al. 2009).

Bourke, personal communication; Meadows 2005: Appendix F). Further work on larger populations of "early" olive stones from sites at higher altitudes will be necessary to confirm the spread of domesticated olive.

CONCLUSIONS

OZI226 confirms Early Chalcolithic occupation at the site, and is likely to provide a reasonable date for the first late prehistoric occupation. While OZI221 apparently overlaps with the other 8 dates, it still remains possible that this sample points to a later phase of occupation of the site. Excavations in 2005 (Lovell et al. 2007) and more recently in 2008 sampled later deposits in both Area E and in nearby Area G, many of which contained good short-lived samples for dating purposes. These will provide a closer terminal date for the end of occupation at el-Khawarij.

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