

EARLY BRONZE AGE CHRONOLOGY: RADIOCARBON DATES AND CHRONOLOGICAL MODELS FROM TEL YARMUTH (ISRAEL)

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ABSTRACT. Over the years, 40 radiocarbon samples (charcoal and seeds) have been measured from the site of Tel Yarmuth. These samples originate from 3 major archaeological periods: Final Early Bronze Age (henceforth EB) I, EB II, and EB IIIB-C. The samples are further on divided into 8 separate archaeological phases. Bayesian modeling analyses were performed on the data. Separate models were run with seeds and charcoals to detect a possible old-wood effect. Outliers were detected, and finally models with gaps were run to account for the lack of samples from 2 archaeological layers. The results suggest that at Tel Yarmuth the end of the EB II occurred ~2950–2880 BC, and that the EB III ended *at the latest* ~2450 BC, perhaps before 2500 BC. Although these dates are somewhat earlier than traditionally assumed, they are in close accordance with the new analysis of other ¹⁴C dates for the Early Bronze Age in the southern Levant (Regev et al., these proceedings).

INTRODUCTION

The absolute chronology of the Early Bronze Age of the southern Levant is based on comparisons between pottery types securely placed within the local pottery sequence and comparable pottery types found in Egypt in historically dated contexts (Hennessy 1967; Ben-Tor 1991; Sowada 2009). A relative chronology has thus emerged, accepted by most scholars (e.g. Ben-Tor 1992; Mazar 1990; de Miroschedji 1999, in press a). It suggests that the Final EB IB period dates to the very end of the 4th millennium BC in Egypt (van den Brink and Levy 2002), while the EB II period is more or less synchronous with the first 2 dynasties, dated ~3000–2700 BC in the consensual “high” chronology (Kitchen 1991; Shaw 2000), and the EB III period with the Old Kingdom (dynasties 3 to 6), dated about 2700–2200 (Kitchen 1991; Shaw 2000). Other chronologies exist, which lower by 1 century or more the beginning of the 1st Dynasty (e.g. Hornung et al. 2006; Jiménez Serrano 2007; Wenke 2009). A chronology based on radiocarbon dates has recently been proposed by Bronk Ramsey et al. (2010). For the first half of the 3rd millennium, the latter chronology modifies only marginally the consensual High Chronology. As for the end of the EB III, it is conventionally placed around 2350–2300 BC, i.e. during the 6th Dynasty in Egypt (Mazar 1990; de Miroschedji 1999, in press b).

The basis for this absolute chronology is thus strictly historical and depends on the validity of the reconstruction of the Egyptian king lists and reign lengths inferred from written and archaeological sources. Given the uncertainty surrounding this historical chronology, the establishment of a calibrated ¹⁴C timescale is the only way to build on an independent basis the absolute chronology of the southern Levant.

Among the major Early Bronze Age sites of the southern Levant, Tel Yarmuth ranks prominently because of its size (16 ha), the large exposures of the Early Bronze Age strata exhibiting monumental architectural remains, the length of its stratigraphic record, and its many ¹⁴C samples recovered from well-defined stratigraphic contexts. Tel Yarmuth is thus an excellent site to carry out a detailed ¹⁴C study of the Early Bronze Age with the aim of laying the ground for an absolute chronology.

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RADIOCARBON SAMPLES: PROVENANCE

The Site and Its Stratigraphy

Tel Yarmuth is located 25 km southwest of Jerusalem (Figure 1). Nineteen seasons of excavations have been conducted at the site, one under the direction of A Ben-Tor in 1970 (Ben-Tor 1975), and 18 under the direction of P de Miroschedji since 1980 (see de Miroschedji et al. 1988; de Miroschedji 1999, 2003, 2008). Altogether, 13 areas of excavations (A-N) have been opened in the Lower City (Figure 2), some subdivided into several subareas (e.g. Area Ja to Jc).

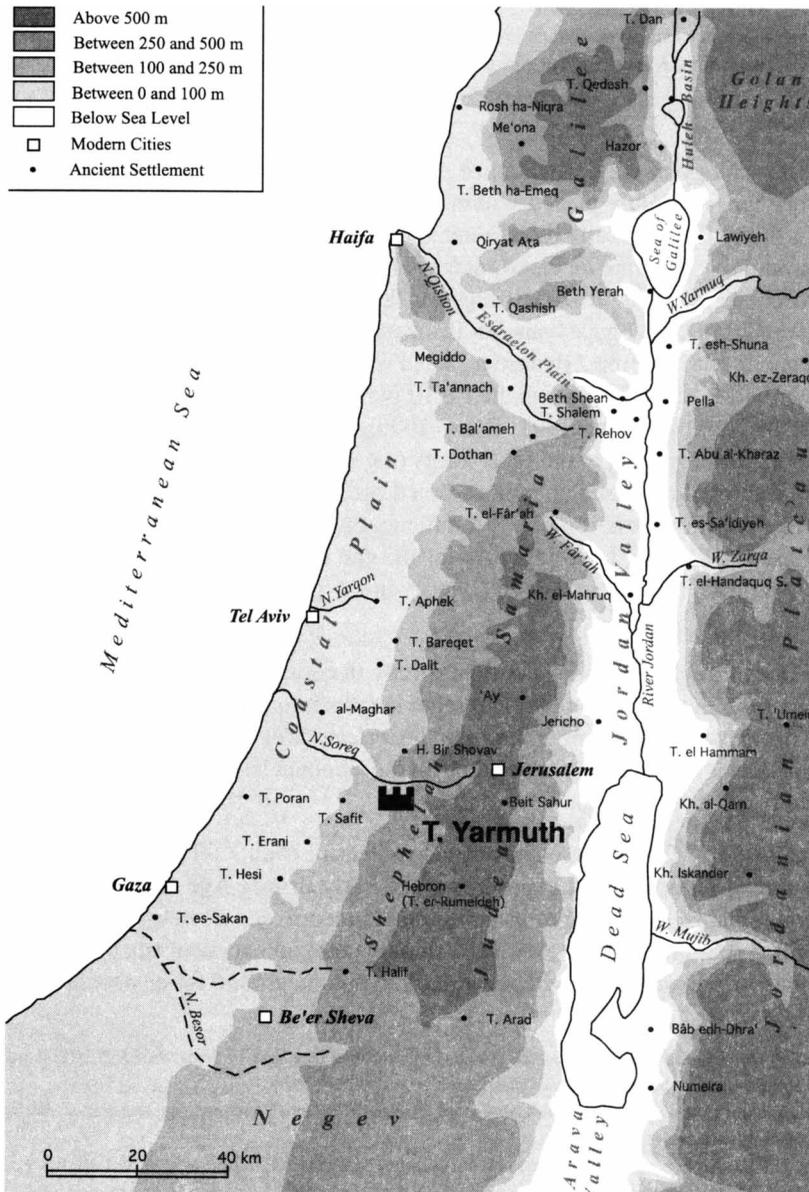


Figure 1 Map showing the location of Tel Yarmuth

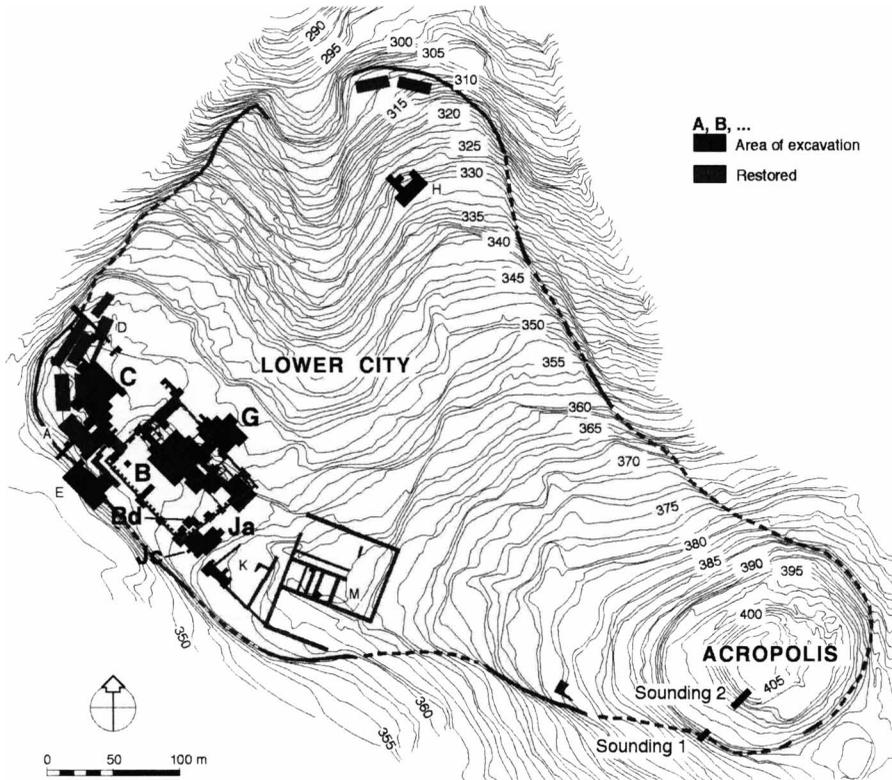


Figure 2 Plan showing the location of the excavation areas at Tel Yarmuth. The bold letters indicate the areas from which ^{14}C samples discussed in this paper originate.

These excavations have revealed a long sequence of occupation, stretching from the Early Bronze IB (the so-called “Erani C Phase,” ~3300 BC in the conventional chronology) to the very end of the EB III (EB IIIC phase, ~2350/2300 BC in the conventional chronology), represented by large-scale public and private architecture (including 2 successive palaces, a temple, 5 areas of domestic dwellings, and a possible oil factory), powerful fortifications (2 city walls, 8 bastions, 3 city gates), and a system of urban terracing.

The stratigraphic correlations between these excavation areas are based on similarities of archaeological material, mainly pottery, and/or on the relative stratigraphic position of the strata in relation to an architectural feature encompassing different areas, such as City Wall A or Palace B1.

Contexts of the Samples

The ^{14}C samples were collected during excavation, either directly by hand when they could be easily spotted or (in the case of seeds) after flotation of sediment samples. A few additional samples (e.g. RTT-5902 to -5905) were collected *ad hoc* by E Boaretto and J Regev in 2006 after cleaning of stratigraphic sections and identification of clusters of seeds in controlled stratigraphic contexts. Although a large number of samples were collected, only 40 of them were selected for dating on the basis of the nature and quality of their archaeological context: only samples found on floors or in sealed contexts were used. The areas from which these samples originate are shown in bold letters in Figure 2 and their stratigraphic distribution is given in Table 1. Table 1 provides information on

the stratigraphic and archaeological provenience of the 40 samples, and are arranged by area, in chronological order from the most ancient to the most recent archaeological contexts.

Table 1 Stratigraphic distribution of the ¹⁴C samples of Tel Yarmuth. A vertical line between 2 numbers indicates that the samples were in direct superposition, a horizontal line that they come from the same layer. The numbers within a box correspond to samples retrieved from the same stratigraphic context, although not always in close proximity.

Period	Area - Stratum						
	C-9 to C-6	Jc-Phase 3	Bd-2	Ja-3	G-3	B-2	B-1
C EB III B A						5295 5296	2964 2965 2966 2967 2968 3495 5293 5294 (2963) (2969)
				5286 5283 — 5285	3505 3506 3508		
			3493				
	Hiatus corresponding to Strata C-5 to C-3 (early part of EB III)						
EB II	C-6	3502	5288 5289 — 5290				
	C-7	3496 5292 — 3497	3501				
	C-8	5903 5902	3498	3503 — 3500 3504 — 5291			
EB IB Final	C-9	5904 — 5905	3499				

Area C (15 Samples)

Located in the west corner of the city, Area C covered 950 m² and revealed 9 strata (C-9 to C-1, from bottom to top). Stratum C-9, exposed in small probes only, consists of a thin layer (~0.20 m) with occupation surfaces resting directly on bedrock and no associated architecture. The archaeological material is ascribed to the very end of the EB I period (Late EB IB). Sporadic finds of sherds dating to the EB IB [Erani C Phase] attest to an earlier occupation of the site but they were not found in clear stratigraphic context and have not yielded datable ¹⁴C samples. This stratum yielded 2 samples of seeds (RTT-5904 and -5905). Stratum C-8 was also excavated in small soundings only and dates to the very beginning of the EB II. It belongs to an apparently unfortified settlement with some significant architectural remains. Seven samples originate from this stratum (RTA-3498, -3500, -3503, -3504; RTT-5291, -5902, -5903). The latter 3 samples were collected just beneath the foundation of City Wall A). One other sample (RTA-3499) comes from a context that may belong either to Stratum C-9 or C-8. The following strata C-7 and C-6 date to the traditional EB II period. Stratum C-7 is contemporaneous with the construction and early use of City Wall A. It has yielded 4 samples (RTA-3496, -3497, -3501; RTT-5292). Only 1 sample (RTA-3502) comes from Stratum C-6. The uppermost strata, C-5 to C-1, all belong to the EB IIIA-B and have not yielded any samples appropriate for ¹⁴C dating.

Subarea Jc (3 Samples)

Subarea Jc corresponds to the part of Area J located outside (i.e. southwest) of City Wall A, which marks the limit of the first EB II settlement. A deep probe was excavated there through a fill intentionally deposited between City Wall A and City Wall B. This fill is ascribed to the second phase of the fortification system dated to a later part of the EB II (see de Miroschedji et al. 1988). The 3 samples (RTT-5288 to -5290) originate from layers of ashy sediments sealed by plastered surfaces in the upper part of the fill. The pottery assemblage suggests that they are contemporaneous with Stratum C-6 within the settlement.

Subarea Bd (1 Sample)

Subarea Bd is located along the southeast side of the main courtyard of Palace B1 and covers an area of 150 m². Three strata were identified (Bd-3 to Bd-1), all dated to the EB III period. Stratum Bd-1 corresponds to Palace B1 (Stratum B-1), while Stratum Bd-2 (from which sample RTA 3493 was obtained) is contemporaneous with strata B-3 or B-4.

Area G (4 Samples)

Area G is situated to the southeast of Area C and extends along part of the northeastern side of Palace B1. It was excavated over 500 m² and revealed 6 strata (G-6 to G-1) partly synchronous with those of Area B. Three samples (RTA-3505, -3506, -3508) originate from Stratum G-3, which is the extension of Stratum B-3 to the northeast of Area B. Stratum G-3 is represented by a series of domestic dwellings in which complete vessels were found *in situ* on floors. In its southwestern part, this stratum was violently destroyed, together with strata B-3, J-3, and K-2, prior to the construction of Palace B2. A fourth sample (RTA-3507) from Stratum G-2 unexpectedly provided a “very old” date (see Table 1) and had to be discarded.

Subarea Ja (5 Samples)

Subarea Ja occupies a low terrace alongside the southeastern wall of Palace B1 and is limited to the southwest by the line of City Wall A. Partial excavations revealed 4 strata, J-1 to J-4 (from top to bottom). Strata J-1 and J-2 correspond, respectively, to strata B-1 and B-2. Stratum J-3 is coeval with Stratum B-3 and was also violently destroyed. Five samples (RTT-5283 to -5287) were retrieved from the destruction layer among vessels crushed on the floor under the fallen roof. Two of these samples (RTT-5284 and -5287), however, unexpectedly provided a post-bomb (i.e. modern) date and were clearly intrusive.

Area B (12 Samples)

The extent of Area B is defined by the limits of Palace B1. The stratigraphic sequence comprises 6 strata, B-1 to B-6, from top to bottom (de Miroschedji et al. 1988:31–3). Extensive excavations were carried out only for strata B-1 (= Palace B1), B-2 (= Palace B2), and B-3. The latter is equivalent to strata G-3 and J-3. Stratum B-2 corresponds to the first palace erected on the leveled ruins of a violently destroyed area. Since this palace was razed to the ground to be replaced by Palace B1, few floors were preserved. Two samples of seeds (RTT-5295, -5296) were nevertheless collected from a sound context (L.2632) sealed by a floor of the overlying Stratum B-1. The latter stratum yielded 8 samples (6 charcoals, 2 seeds) all retrieved from floors of Palace B-1, together with a large amount of complete vessels. Two additional samples from this stratum deserve a special note: RTT-2969 is a fragment of charcoal from a wooden post resting on a stone base in Locus 89. This sample provided a date much earlier than that of the other samples, presumably because of the “old wood

effect.” The possibility of an “old wood effect” should also be considered in the case of sample RTT-2963 since it consisted of charcoal from a wooden plank inserted into a threshold.

Chronological Ordering of the Samples

The ^{14}C samples can be arranged chronologically on the basis of the stratigraphic information described above (see Table 1). They document a continuous sequence from the Late EB IB to the end(?) of the EB II, and then from the second half or second third of the EB III until the end of the EB III. The current hypothesis is that the latest Early Bronze Age strata at Yarmuth (i.e. strata B-1, G-2, J-1, and K-1) immediately precede the late 3rd millennium abandonment of the site and date indeed from the very end of EB III period since no pottery later than the one found in these strata has been reported from any southern Levantine sites (for details see de Miroschedji 2000:319, 340). Hence, the sequence spanned by the ^{14}C dates incorporates a hiatus corresponding to strata C-5 to C-3 in Area C, i.e. to the first third or first half of the EB III period, a phase labeled “EB IIIA.” The length of this hiatus is impossible to estimate precisely; it could be 1 or 2 centuries.

RADIOCARBON SAMPLES: PREPARATION AND ANALYSIS

The 40 samples of charcoal and short-lived charred materials from Tel Yarmuth were dated at the Weizmann Institute Kimmel Center for Archaeological Sciences in Rehovot, Israel. The acid-base-acid protocol was used to remove contamination as described in Yizhaq et al. (2005). For the small samples like charred seeds, Fourier transform infrared (FTIR) analysis was performed after pretreatment in order to verify the absence of clay in the residual material (Yizhaq et al. 2005). After pretreatment, the ^{14}C concentrations were measured either by liquid scintillation counting (LSC) or by accelerator mass spectrometry (AMS) depending from the size of the sample after pretreatment. The data regarding the sample, context, type, and age are given in Table 2 in stratigraphic order.

Table 2 Results and details of the context of all the samples measured from Tel Yarmuth. The samples are listed in stratigraphic order. Short-lived material samples are marked with an asterisk after the sample number. Note the following abbreviations in the column “Archaeological context”: Sq. = square; Str. = Stratum; L = Locus; B = Basket.

Lab code	Age	Calibrated $\pm 1 \sigma$ yr BC	Calibrated $\pm 2 \sigma$ yr BC	Archaeological context
RTT-5904*	4455 \pm 60	3331 (32.4%) 3215 3186 (7.4%) 3156 3127 (28.4%) 3023	3346 (86.4%) 3006 2990 (9.0%) 2930	Area C, Sq. Q13; Stratum C-9; L1038-2; field nr TY134; layer above bedrock (same as RTT-5905); seeds
RTT-5905*	4345 \pm 60	3078 (2.1%) 3073 3024 (66.1%) 2900	3322 (2.4%) 3272 3266 (2.5%) 3236 3171 (0.4%) 3162 3116 (90.1%) 2877	Area C, Sq. Q13; Stratum C-9; L1038-2; field nr TY141; layer above bedrock (same as RTT-5904); seeds
RTA-3499	4370 \pm 90	3309 (1.2%) 3301 3282 (0.9%) 3277 3265 (4.7%) 3240 3105 (61.5%) 2892	3354 (95.1%) 2872 2799 (0.2%) 2794 2783 (0.1%) 2781	Area C, Sq. P15; Stratum C-9 or C-8; L392-1+2; B9293b; charcoal
RTT-5902*	4420 \pm 60	3311 (3.4%) 3295 3285 (2.2%) 3275 3265 (6.9%) 3239 3106 (55.7%) 2923	3336 (25.7%) 3210 3193 (6.4%) 3151 3139 (63.3%) 2911	Area C, Sq. R12; Stratum C-8; base of L1055; field nr TY 118; seeds
RTT-5903*	4330 \pm 55	3014 (68.2%) 2897	3264 (1.0%) 3246 3101 (94.4%) 2874	Area C, Sq. R12; Stratum C-8; L1052 (floor at the junction of L1052A and B); field nr TY 119; seeds
RTA-3498	4385 \pm 55	3090 (16.1%) 3047 3033 (52.1%) 2917	3327 (11.3%) 3231 3225 (0.5%) 3219 3176 (1.4%) 3160 3121 (82.3%) 2896	Area C, Sq. Q13; Stratum C-8; L1038-1+floor a; B9281b (just above RTT-5904 and -5905); charcoal

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Lab code	Age	Calibrated $\pm 1 \sigma$ yr BC	Calibrated $\pm 2 \sigma$ yr BC	Archaeological context
RTA-3504	4330 \pm 45	3011 (22.2%) 2977 2971 (11.0%) 2949 2944 (35.0%) 2898	3090 (6.7%) 3051 3031 (88.7%) 2882	Area C, Sq. N18 Stratum C-8 ; L925; B9403; charcoal
RTT-5291*	4300 \pm 40	3007 (9.1%) 2989 2931 (59.1%) 2883	3024 (95.4%) 2876	Area C, Sq. O17; Stratum C-8 ; L922-1; B9363; seeds, <i>Scorpiurus</i> sp.
RTA-3503	4390 \pm 50	3089 (15.8%) 3051 3031 (52.4%) 2920	3325 (10.4%) 3234 3173 (1.0%) 3161 3118 (83.9%) 2901	Area C, Sq. N18; Stratum C-8 ; L910-2; B9389; charcoal
RTA-3500	4360 \pm 60	3084 (6.8%) 3066 3028 (61.4%) 2905	3324 (7.4%) 3235 3173 (0.7%) 3161 3117 (87.3%) 2883	Area C, Sq. N17; Stratum C-8 ; L913; B9214; charcoal
RTT-5292*	4380 \pm 40	3079 (4.5%) 3071 3025 (63.7%) 2921	3264 (1.6%) 3247 3101 (93.8%) 2902	Area C, Sq. R13; Stratum C-7 ; L609-surface e; B9222b; seeds, <i>Lolium</i> sp.
RTA-3497	4325 \pm 50	3011 (21.1%) 2977 2971 (11.1%) 2949 2944 (36.1%) 2895	3091 (8.2%) 3043 3038 (87.2%) 2879	Area C, Sq. Q14; Stratum C-7 ; L1030-floor c=L1051; B9279b; charcoal
RTA-3496	4365 \pm 50	3079 (3.7%) 3071 3025 (64.5%) 2911	3310 (0.7%) 3297 3284 (0.4%) 3276 3265 (2.4%) 3240 3106 (92.0%) 2889	Area C, Sq. Q13-14; Stratum C-7 ; L1030-floor a; B9227b; charcoal
RTA-3501	4425 \pm 55	3311 (3.8%) 3295 3286 (2.6%) 3275 3265 (7.5%) 3239 3106 (54.3%) 2927	3335 (26.7%) 3211 3192 (6.3%) 3152 3137 (62.4%) 2916	Area C, Sq. N17; Stratum C-7 ; L657-3+floor c; charcoal
RTA-3502	4470 \pm 90	3339 (32.3%) 3206 3196 (26.2%) 3082 3069 (9.7%) 3026	3370 (95.4%) 2910	Area C, Sq. O17; Stratum C-6A ; L922-1+Tr.931-2; B9383; charcoal
RTT-5289*	4410 \pm 40	3095 (43.1%) 3006 2991 (25.1%) 2930	3325 (13.1%) 3234 3173 (1.2%) 3161 3118 (81.1%) 2914	Area Jc, Sq. H42; Phase Jc-3 ; L2821; B17567 (same as RTT-5290); seeds, <i>Lolium</i> sp.
RTT-5290*	4360 \pm 40	3016 (68.2%) 2916	3091 (95.4%) 2900	Area Jc, Sq. H42; Phase Jc-3 ; L2821; B17567 (same as RTT-5289); seeds, cereals
RTT-5288*	4340 \pm 40	3011 (24.0%) 2978 2971 (13.8%) 2949 2944 (30.4%) 2905	3087 (5.6%) 3061 3030 (89.8%) 2890	Area Jc, Sq. H42; Phase Jc-3 ; L2819-1 (layer of black ashy earth sealed by plastered surface); B17551; seeds, Lens
RTA-3493	4300 \pm 55	3011 (15.9%) 2977 2971 (1.9%) 2966 2961 (4.8%) 2949 2944 (45.6%) 2880	3091 (89.7%) 2862 2807 (5.0%) 2758 2718 (0.7%) 2708	Area Bd, Sq. L39; Stratum Bd-2 (corresponding to Str. J-4); L1805-1; B14039; charcoal
RTA-3505	4135 \pm 50	2870 (19.7%) 2800 2760 (48.5%) 2620	2880 (95.4%) 2570	Area G, Sq. AB33; Stratum G-3 ; L1298-floor a; B12276; charcoal
RTA-3506	4100 \pm 50	2855 (15.7%) 2812 2747 (6.9%) 2725 2697 (45.6%) 2577	2873 (90.6%) 2566 2524 (4.8%) 2496	Area G, Sq. X31; Stratum G-3 ; L1279-1; B12321; charcoal
RT-3508	4342 \pm 50	3013 (68.2%) 2905	3096 (95.4%) 2885	Area G, Sq. X31; Stratum G-3 ; paved threshold between L1234 and L1219; B12510; charcoal
RTT-5283*	4150 \pm 70	2873 (12.8%) 2834 2818 (51.2%) 2662 2649 (4.2%) 2635	2896 (93.9%) 2569 2516 (1.5%) 2500	Area Ja, Sq. K41-42; Stratum J-3 ; L2104 (black ashes on floor 2104-a); B17561; seeds
RTT-5285*	4240 \pm 70	2919 (29.5%) 2850 2813 (26.6%) 2741 2729 (10.5%) 2694 2687 (1.5%) 2680	3021 (95.4%) 2620	Area Ja, Sq. K44; Stratum J-3 ; L2137-2 + floor b; B17583; seeds

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Lab code	Age	Calibrated $\pm 1 \sigma$ yr BC	Calibrated $\pm 2 \sigma$ yr BC	Archaeological context
RTT-5286*	3795 \pm 40	2290 (54.8%) 2195 2172 (13.4%) 2145	2434 (0.8%) 2422 2404 (2.1%) 2379 2349 (89.3%) 2130 2087 (3.2%) 2049	Area Ja, Sq. K41-42; Stratum J-3 ; L2137-1+2 (ashy earth); B17611; seeds, cereals
RTT-5295*	4135 \pm 40	2864 (13.4%) 2830 2822 (5.8%) 2807 2759 (16.8%) 2717 2711 (32.2%) 2628	2875 (89.7%) 2617 2611 (5.7%) 2581	Area Ba, Sq. Q26; Stratum B-2 ; L2632; B17159 (beneath RTT 5293 and RT 5294 of L89; same as RTT 5296); seeds, cereals
RTT-5296*	4250 \pm 40	2911 (55.1%) 2870 2802 (13.1%) 2778	2926 (62.7%) 2849 2814 (25.8%) 2740 2730 (6.4%) 2693 2687 (0.5%) 2679	Area Ba, Sq. Q26; Stratum B-2 ; L2632; B17151+B17159+B17169 (beneath RTT 5293 of L89; same as RTT 5295); seeds, cereals
RT-2969	4420 \pm 25	3261 (1.7%) 3257 3097 (65.4%) 3012 2948 (1.1%) 2945	3310 (1.1%) 3297 3284 (0.7%) 3276 3266 (6.1%) 3240 3106 (87.5%) 2923	Area Ba, Sq. Q26; Stratum B-1 ; Palace B1, L89-floor a (above RTT 5295 and 5296 from L2632); B13431. Fragment of a wooden post; probable old wood effect; charcoal
RT-2966	4215 \pm 65	2903 (22.7%) 2850 2813 (30.7%) 2742 2729 (12.9%) 2694 2687 (2.0%) 2680	2924 (93.2%) 2617 2611 (2.2%) 2581	Area Ba, Sq. Q28; Stratum B-1 ; Palace B1, L1619; B13333; charcoal
RTT-5293*	4210 \pm 40	2892 (23.3%) 2860 2809 (36.4%) 2756 2720 (8.5%) 2704	2905 (31.6%) 2835 2816 (63.8%) 2668	Area Ba, Sq. Q26; Stratum B-1 ; Palace B1, L89- floor a (seeds on floor); B17150 (same as RTT 5294); seeds, cereals
RTT-5294*	4180 \pm 40	2880 (14.4%) 2851 2813 (37.3%) 2743 2727 (15.6%) 2695 2683 (0.9%) 2681	2891 (22.1%) 2831 2821 (73.3%) 2631	Area Ba, Sq. Q26; Stratum B-1 ; Palace B1, L89 (seeds on floor); B17168 (same as RTT 5293); seeds, cereals
RT-2963	4115 \pm 35	2860 (20.3%) 2810 2750 (9.4%) 2720 2700 (38.5%) 2580	2880 (24.5%) 2800 2780 (70.9%) 2570	Area Bb, Sq. T37; Stratum B-1 ; Palace B1, L2018 floor; B15053 or B15059? Charcoal from plank on threshold: possible old wood effect; charcoal
RT-2964	4105 \pm 50	2860 (16.3%) 2810 2750 (7.4%) 2720 2700 (44.5%) 2570	2880 (91.4%) 2560 2530 (4.0%) 2490	Area Bb, Sq. S 38; Stratum B-1 ; Palace B1, L2025 floor; B15112; charcoal
RT-3495	4100 \pm 23	2840 (14.4%) 2810 2670 (53.8%) 2570	2860 (22.0%) 2800 2750 (6.9%) 2720 2700 (66.5%) 2570	Area Bb, Sq. T40; Stratum B-1 ; Palace B1, L1970; B15666. Sample taken from layer of debris on the floor; charcoal
RT-2967	4035 \pm 95	2853 (7.9%) 2813 2745 (3.1%) 2726 2696 (57.1%) 2466	2878 (94.6%) 2339 2322 (0.8%) 2309	Area Bb, Sq. S36-37; Stratum B-1 ; Palace B1, L2012-1; B15174; charcoal
RT-2968	3980 \pm 40	2569 (40.4%) 2517 2500 (27.8%) 2467	2618 (0.7%) 2610 2581 (90.3%) 2400 2382 (4.4%) 2347	Area Ba, Sq. R 25; Palace B1, Stratum B-1 ; L80-1 to 3 + floor a; B13071; charcoal
RT-2965	3565 \pm 40	2009 (2.3%) 2002 1977 (62.5%) 1879 1839 (3.4%) 1830	2026 (76.5%) 1865 1849 (18.9%) 1773	Area Ba, Sq. R29; Stratum B-1 ; Palace B1, L1647-1+floor a; B13341; Palace B1; charcoal
RTA-3507	45,150 \pm 550			Area G, Stratum G-2 ; L1418-floor c; B12490; charcoal
RTT-5284*	131.3 \pm 05 pMC	modern		Area Ja; Stratum J-3 ; L2104; B17575; Thymelaeaceae
RTT-5287*	110.0 \pm 03 pMC	modern		Area Ja; Stratum J-3 ; L 2819; B17550; <i>Pisum</i>

^{14}C ages are reported in conventional ^{14}C yr BP (AD 1950) in accordance with international convention (Stuiver and Polach 1977). Thus, all calculated ^{14}C ages have been corrected for fractionation as to refer the results to be equivalent with the standard $\delta^{13}\text{C}$ value of -25‰ . All the samples have $\delta^{13}\text{C}$ values between -22‰ and -27‰ . The only exception is sample RTT-3507 ($\delta^{13}\text{C} = -29.0\text{‰}$). All ^{14}C ages were calibrated using OxCal v 4.1.6 (Bronk Ramsey 2009a) and the IntCal09 data (Reimer et al. 2009) calibration curve. Analysis and modeling of the dates based on archaeological information was performed using the Bayesian method and the mathematical tools as given in OxCal v 4.1.6.

Two of the samples, RTT-5284 and RTT-5287, both originating from Subarea Ja, were found to be modern (intrusive), and 1 sample, RTA-3507, provided an age of $45,150 \pm 550$ yr uncalibrated. This sample was probably a piece of asphalt used in antiquity (Aufderheide et al. 2004). After removal of these 3 samples, 37 dates were used for building a chronology for Tel Yarmuth: 3 samples (2 seeds, 1 charcoal) originate from "Late EB IB" contexts, 15 samples (7 seeds, 8 charcoals) from EB II contexts, 7 samples (3 seeds, 4 charcoals) from EB IIIB contexts, and 12 samples (4 seeds, 8 charcoals) from EB IIIC contexts (Table 2).

MODELING

Various Bayesian models were applied in order to determine the most reliable dates of transition between the archaeological layers. Four types of models were applied: Simple model, Detailed model, a model with an imposed gap, and a model with gap with *terminus post quem* (henceforth TPQ) of 2900 ± 10 yr BC for the beginning of the gap. Each of these models was again separated into models of seeds only and charcoal only in order to evaluate the possible old-wood effect. Outliers identified after the modeling were excluded and the model was run without the outliers. In case an end of a previous phase is given by a short-lived sample that is an outlier, while the beginning of the following phase is given by charcoal sample, we preferred to remove the charcoal because of the possibility of the old-wood effect.

As a general rule, any single date that had an agreement of less than 60% was considered an outlier. However, some samples close to the 60% cut-off will be just above or below the 60% cut-off when a model is run a few times. If more than 1 sample was identified as an outlier, the removal was done stepwise, namely the one with the lowest agreement was removed first. The model was run again after removal of each outlier, to verify if the removal of the sample(s) would cause a change in the agreement of the rest of the samples.

The models are built using phases or sequences, following the archaeological information. If a model was built using phases, the samples within each phase were ordered from oldest to youngest. This does not indicate that the samples were necessarily found in that order in the archaeological layers. If the model was built using sequences, the samples are ordered according to archaeological stratigraphic order. OxCal v 4.1.6 (Bronk Ramsey 2009a) software was used to calculate the transitions.

Structure of the Models

Simple models: The data were separated according to their association to Final EB I, EB II, or EB III cultural materials. In the Simple model, the dates were ordered as phases, since it was not possible to know the exact stratigraphic order of the samples within each period. Inside the phases, dates were ordered from old to young independent of the stratigraphy. The Final EB I to EB II transition is "contiguous," implying that as the previous period ended, the following started (see OxCal v 4.1). The EB II to EB IIIB transition is "sequential" due to the gap in the ^{14}C data. This model should pro-

vide the transition between the Final EB I and EB II and the end range for EB II and beginning range for EB IIIB.

Detailed models: In this model, the data are separated according to the detailed stratigraphic sequence of the site. Several samples from layers C-8, C-7, C-6A, and Jc-3 had additional information about their inner ordering within the layer indicating which samples were found one above the other. Accordingly, for these layers the samples were ordered as sequences, while the samples that had no additional indication of their relative placement in the strata were placed in the sequence according to their ^{14}C age. Where no information on the relative placement was available, the samples were ordered in phases, also from oldest to youngest, even though this does not affect the modeling. The transitions between phases or sequences are contiguous, except in the case of the EB II-EB IIIB boundary, where it is sequential due to the absence of datable ^{14}C samples from strata C-5, C-4, C-3, covering the EB IIIA period.

Models with a gap: The length of the EB IIIA period at Tel Yarmuth lacking ^{14}C dates was estimated to be between 100 to 200 yr. Therefore, separate models were run by inserting a gap of 150 ± 50 yr between the EB II and EB IIIB layers. These models have the same structure as the Simple and the Detailed models described above.

Models with a gap and a *terminus post quem* (TPQ): A *terminus post quem* was inserted before the 150 ± 50 yr gap. This was done in order to determine whether it would be possible to stabilize the end of the EB II period around 2900 BC.

RESULTS

In Figures 3, 4, 6, and 7, all the models are shown with all the dates, including the outliers. Outliers are identified by the code [P] and a question mark after the sample number and they are plotted in dark gray only (e.g. samples RTT-5291 and RT-2969 in Figure 3). Even though they are seen in the plot, they do not affect the model. The general agreement of the model is given on top of the multiplot, written as [Amodel:xxx] (e.g. in the Simple model Figure 3 the general agreement is 123). After each ^{14}C date, the sample number appears first, and nearby is given the amount of agreement [A:xxx] of each individual date within the model (e.g. in Figure 3 sample RTT-5904 has an A value of 95). The light gray single plots describe the whole span of possible dates as determined by the calibration combined with laboratory error. The probability distributions marked with dark gray define the modeled results.

EB I-II and EB II-III Transitions According to the Simple and Detailed Models

The Simple model has 2 outliers (RTT-5291, RT-2969). The agreement of the model was 94 before their removal and 123 after (Table 3). As a result, the EB II end and EB IIIB begin dates were lowered by about 30 yr. According to the Simple model, the EB I-II transition took place between 3030–2970 BC and the EB II ended by 3000–2930 BC (Figure 3). The EB IIIB began between 2960–2910 BC. These dates are significantly higher than the conventionally accepted dates (see above). If only seed samples are used, the EB I-II lower limit of the transition becomes younger by 20 yr. The EB II ends between 2980–2910 BC, and EB IIIB starts between 2950–2850 BC, up to 60 yr later than when charcoal samples are also used.

In the Detailed model, the major transitions turn out to be very similar to the Simple model, but they are more spread by few decades (Figure 4, Table 3). The EB I-II transition range is 3050–2980 BC, being up to 20 yr older than in the Simple model. The EB II ends 2960–2910 BC, which is a date up to 40 yr younger than in the Simple model. The EB IIIB begins also ~30 yr later (2930–2880 BC).

Table 3 Modeled ranges for EB I-II transition, EB II end, and EB IIIB begin ranges in all the models. The transition limit is given in relation to the ±1 σ.

Name of the model	EB I-II	EB II end	EB IIIB begin	Dates	Outliers removed	Agreement
Simple with outliers	3030–2990	3010–2960	2990–2940	37	—	94
Simple	3030–2970	3000–2930	2960–2910	35	5291, 2969	123
Simple seeds	3030–2950	2980–2910	2950–2850	16	5291	90
Simple charcoal	3040–2970	3010–2940	2970–2910	21	2969	119
Simple with gap 150 ± 50 yr	3030–2980	3010–2950	2840–2770	33	5291, 2969, 3508, 3493, 5296	110
Simple seeds with gap	3040–2970	3010–2940	2830–2750	14	5291, 5296	83
Simple charcoal with gap	3040–2960	3000–2920	2820–2720	18	2969, 3508, 3493	112
Simple with gap 150 ± 50 yr	3010–2930	2920–2890	2770–2720	33	2969, 3508, 3493, 5285	87
TPQ 2900 ± 10 BC						
Simple seeds with gap 150 ± 50 yr	3020–2930	2920–2880	2760–2700	14	5296, 5293	74
TPQ 2900 ± 10 BC						
Simple charcoal with gap 150 ± 50 yr	3050–2940	2920–2880	2760–2700	18	2969, 3508, 3493	104
TPQ 2900 ± 10 BC						
Detailed	3050–2980	2960–2910	2930–2880	32	5291, 3508, 5286, 5296, 2969	122
Detailed seeds	3040–2950	2950–2890	2920–2860	14	5286, 5296	125
Detailed charcoal	3060–2980	2970–2910	2940–2880	19	3508, 2969	110
Detailed with gap 150 ± 50 yr	3050–2980	2970–2910	2810–2740	30	5291, 3508, 5286, 5296, 2969, 3493, 5293	106
Detailed with gap 150 ± 50 yr	3050–2980	2920–2880	2760–2710	28	5291, 3508, 5286, 5296, 2969, 3493, 5293, 2966, 5294	125
TPQ 2900 ± 10 BC						

Since the Detailed model comprises 8 separate phases, it is very efficient in pinpointing outliers. Out of the 37 samples, 5 are below 60% agreement, and were accordingly removed from the final model. The samples RTT-5286 and -2969 are clear outliers, and cannot be placed in the model in the given stratigraphic position. As pointed out by the excavator (see above), the sample RT-2969 has very probably a significant old-wood effect since it is a fragment of charcoal from a wooden post resting on a stone base. The seed sample RTT-5286 from Stratum Ja-3 is probably intrusive. It should be noted that out of the 5 samples dated from this area, 2 were found modern, indicating some clear disturbance in this vicinity. The seed sample RTT-5291 found under City Wall A in Area C is somewhat surprisingly young. Sample RT-3508 from Stratum G-3 is likely affected by an old-wood effect, and sample RTT-5296 from Stratum B-2 is not a striking outlier, although it may be an intrusion from the overlying layer.

The “Final EB I”-II transition in all 6 Simple and Detailed models (Simple, Simple seeds only, Simple charcoal only, Detailed, Detailed seeds only, and Detailed charcoal only) is more or less the same: it starts between 3060–3030 BC and ends between 2980–2950 BC (see Figure 5, black bars, and Table 4). The 30-yr variability in ranges is probably due to a minor old-wood effect since it corresponds to the differences between the “seeds only” and the “charcoal only” models. In the same 6 models, the “EB II end” ranges have slightly greater variance, from 3010–2950 to 2940–2890 BC (Figure 5, white bars). In this transition as well, the “charcoal only” results are older by 20–60 yr. Similar discrepancies between short-lived material and samples with a possible old-wood effect are apparent in the dates for the beginning of EB IIIB: 2970–2920 BC and 2910–2850 BC (Figure 5, gray bars).

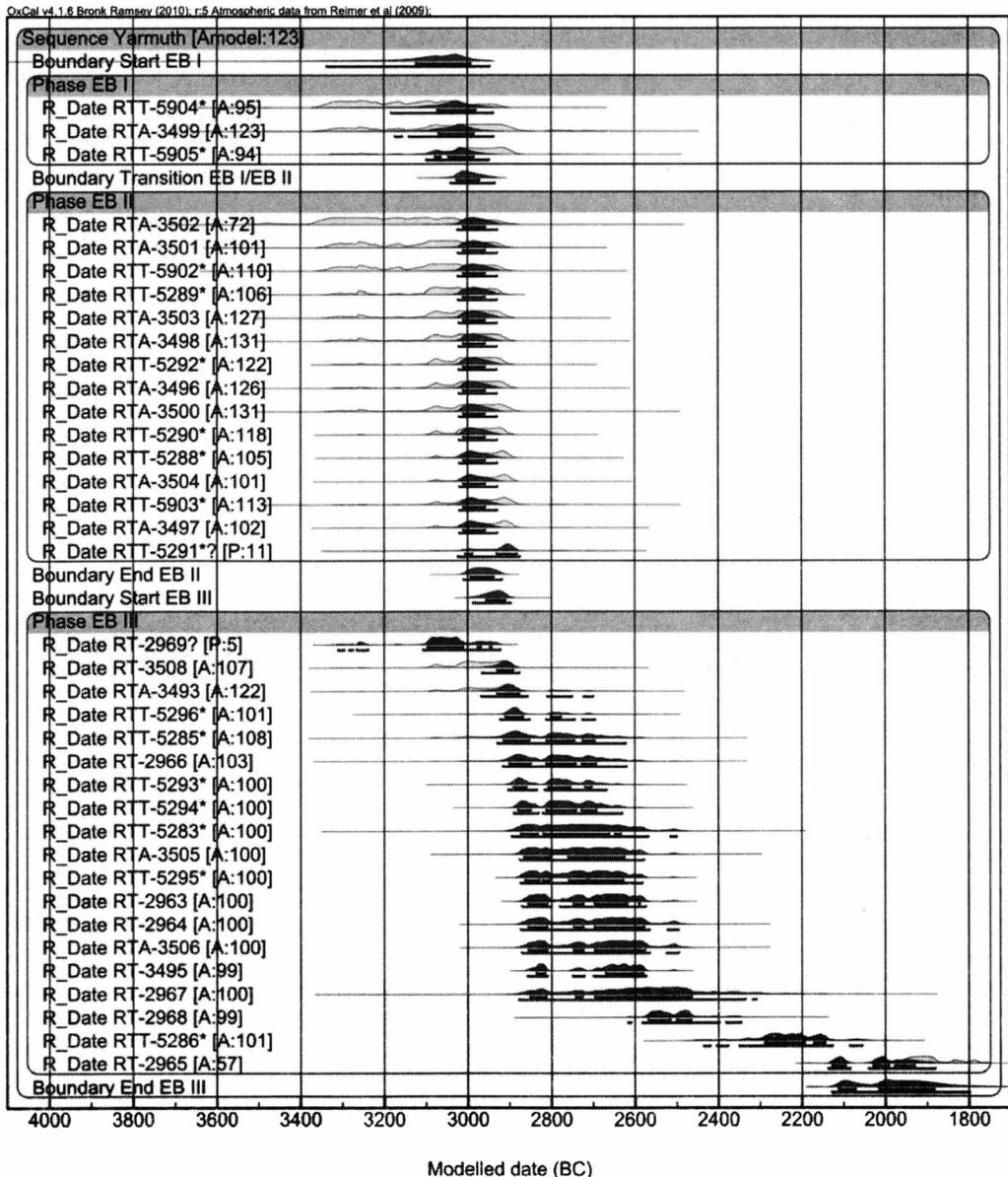


Figure 3 The Simple model: Simple “Final EB I,” EB II, EB III transitions, using seeds and charcoal samples together. Two outliers are marked with a “P” and excluded from the analysis.

Even when the latest date of 2890 BC for the end of EB II is taken as the actual end of the period, the dates remain older than currently accepted by ~200 yr. Furthermore, the beginning of EB IIIB starts before 2850 BC, leaving a short duration of 40 yr for the EB IIIA period (instead of the 100–200 yr accepted conventionally). If a longer EB IIIA period is more likely, the EB II period could have ended as early as 3010 BC based on our results, leaving 160 yr of duration for the EB IIIA period. It is important to stress that in any combination these dates are older than expected, and allow a short duration for the EB IIIA period. For this reason, it was decided to test the insertion of a gap of 150 ± 50 yr to the model between the end of EB II and the beginning of EB IIIB.

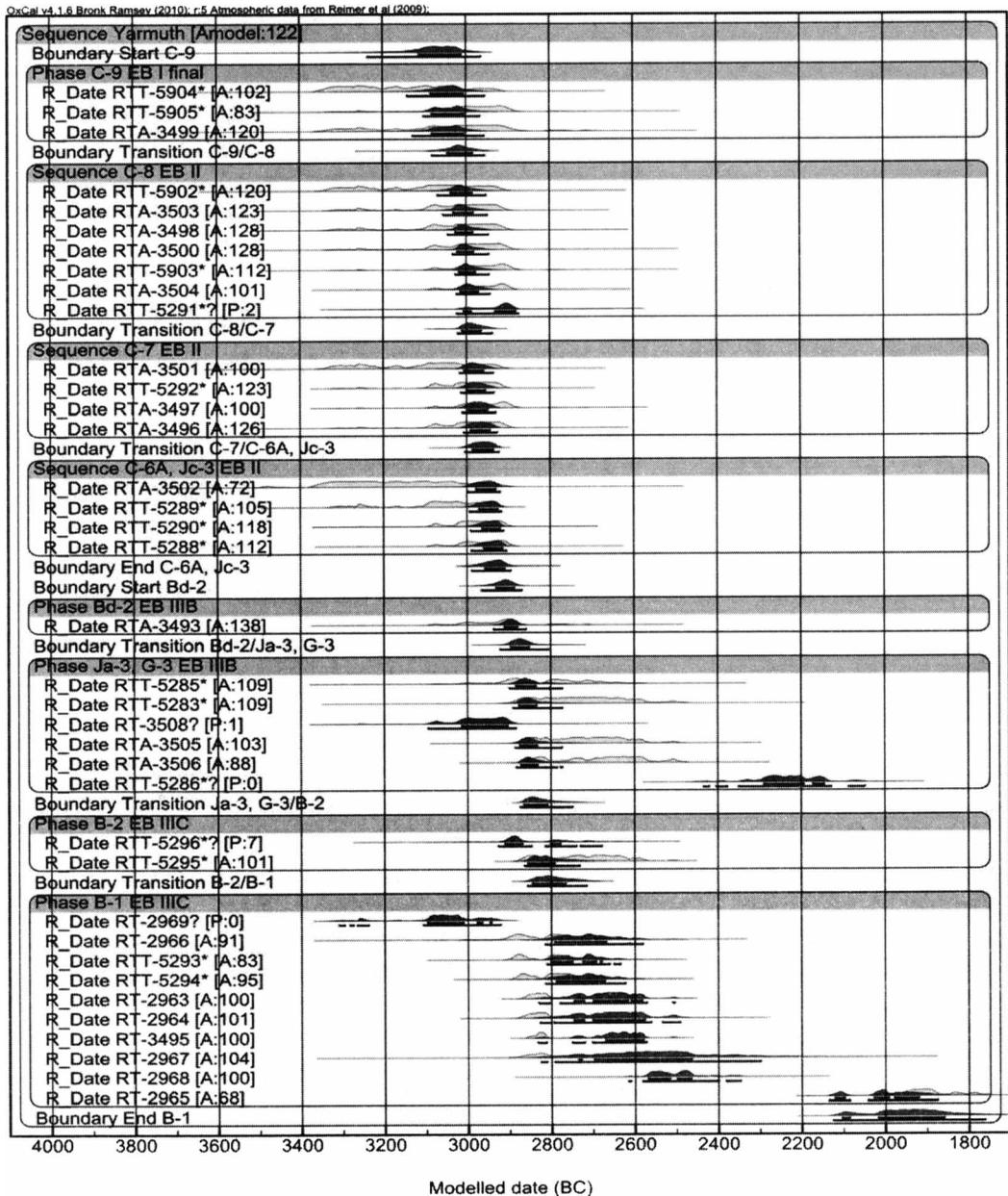


Figure 4 The “Detailed” model

Models with Inserted Gap and TPQ

The insertion of the 150 ± 50 yr gap after the end of the EB II period in the Simple model shifted the end of that period upward by only 10–20 yr (3010–2950 BC) compared to the original Simple model (3000–2930 BC). In contrast, the beginning of the EB IIIB period was shifted downward by as much as 120–140 yr, to 2840–2770 BC (Figure 5 and Table 4). This model has 5 outliers (compared to 2 outliers in the Simple model), from which 4 out of the 5 appear as outliers also in the Detailed model

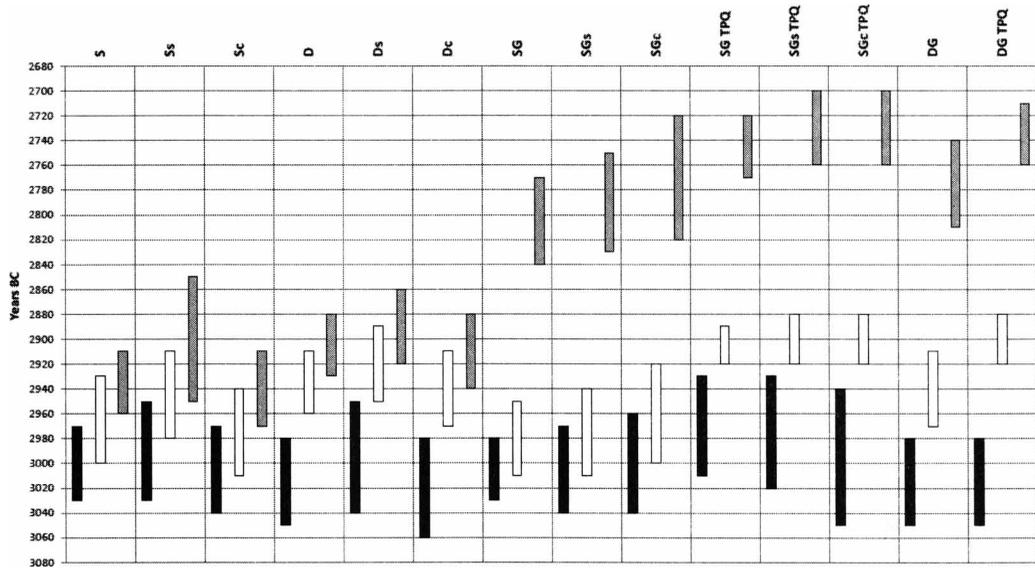


Figure 5 A summary of transition dates according to the various models. S: Simple model. s: Seeds samples only. c: Charcoal samples only. D: Detailed model. G: Gap included. TPQ: Terminus post quem. Black bars: EB I-II transition. White bars: End of EB II. Grey bars: Beginning of EB III B.

without the gap. Interestingly, the “Simple model of charcoal only with gap” yielded younger transitions than the “Simple model of seeds only with gap” model. This further supports that the old-wood effect at Tel Yarmuth is a minor one in general. When the same gap of 150 ± 50 yr was inserted in the Detailed model, the beginning of EB III B moved further downward to 2810–2740 BC, but retained nevertheless the 120–140 yr difference from its original model (Figure 6). Also in this case, the number of outliers increases from 5 to 7 outliers in the “Detailed model with gap.”

The insertion of the 150 ± 50 yr gap into the various models resulted in a slight shortening of the EB II period, which is difficult to reconcile with current historical and archaeological reconstructions that ascribe for this period a much longer duration. In order to prevent an excessive shortening, it was decided to place a constraint for the end of the EB II period. Since the end of the EB II did not occur later than 2900 ± 10 BC in both the Simple and the Detailed models, it was decided to select this date as the most suitable *terminus post quem* (TPQ). As a result, in the Simple models with gap and TPQ, all periods shifted downwards by 20–70 yr. The beginning of the EB III B period shifts accordingly to 2770–2720 BC in both the Simple and the Detailed models, irrespective of the type of sample, seeds or charcoal. Interestingly, the number of outliers in the Simple model with gap and TPQ is lower than in the Simple model with gap without TPQ (4 outliers instead of 5). On the other hand, in the Detailed model with gap and TPQ (Figure 7), 9 samples turn out to be outliers, compared to 7 outliers in the Detailed model with gap without TPQ.

Transitions between Individual Archaeological Strata at Site According to Detailed Models

When the Detailed models with seeds only or with charcoal only are run, the results for the boundaries are very similar. This implies that the old-wood effect is very small, if any. It is important to note that the sequence of archaeological phases in the 2 models is different. In the sequence of charcoal only, the Stratum B-2 is absent, while in the sequence of seeds only, the Stratum Bd-2 is absent (see Table 4). Therefore given the similarity of the boundaries between the 2 models, even with

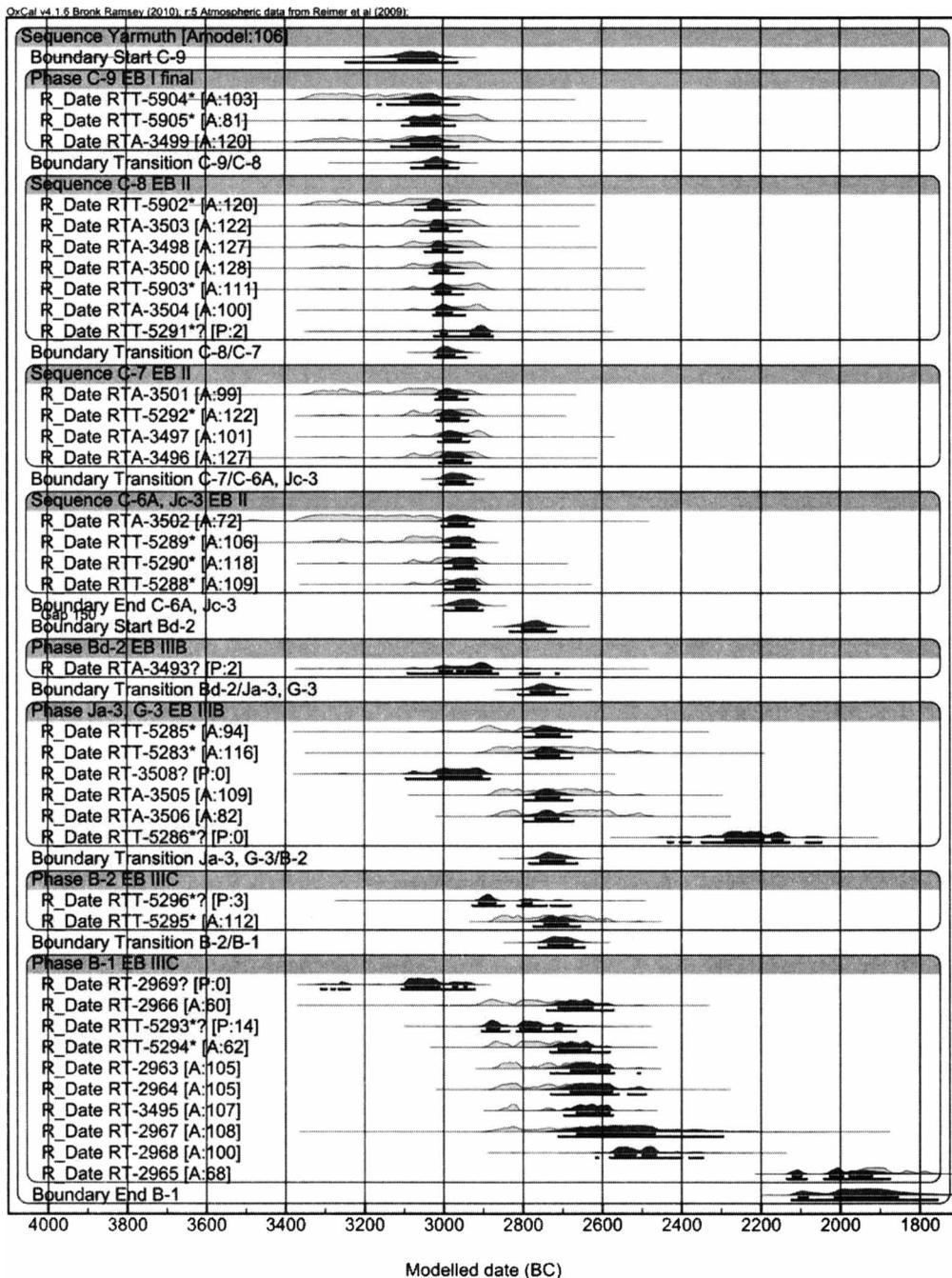


Figure 6 Detailed model with inserted gap of 150 ± 50 yr

some differences in the strata, it was decided to build the final model using all the samples together, covering more phases. The models with gap and gap with TPQ were built using the same set of data. The ranges of the transitions as they appear in the various models are summarized in Table 4.

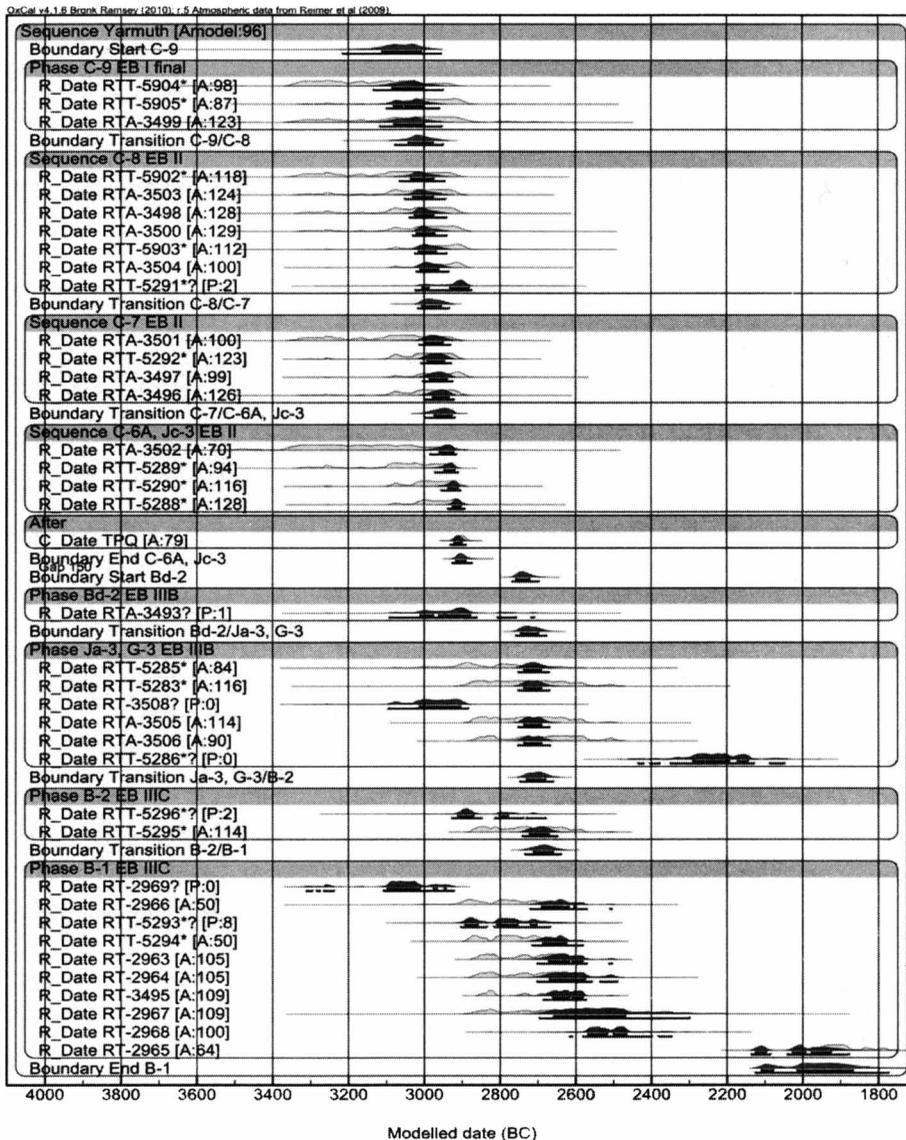


Figure 7 Detailed model with a gap of 150 ± 50 yr and a *terminus post quem* of 2900 ± 10 BC

DISCUSSION

The 37 dates of Tel Yarmuth provide a good framework for the chronology of the Final EB I, the EB II, and the EB III periods in Israel. The Bayesian modeling applied to the Tel Yarmuth data set using the different approaches as explained above, identified from a minimum of 2 to a maximum of 9 outliers. By increasing the level of detail and constrains in the model, the number of outliers grows. The data indicate that at Tel Yarmuth the old-wood effect is not very significant, being between 20–60 yr in Simple models and ~ 20 yr in the Detailed models. The actual effect is probably due to a few specific samples that are clearly defined as outliers (especially RT-2969, RT-3508).

Table 4 Transition dates according to the different Detailed models.

Boundary (phase)	Seeds and charcoal, 37 samples (5) A = 122		Seeds only, 16 samples (3) A = 125		Charcoal only, 21 samples (2) A = 110		Seeds and charcoal with 150 ± 50 gap, 37 samples (7) A = 106		Seeds and charcoal with a gap of 150 ± 50 TPQ, 37 samples (9), A = 125	
	±1 σ	±2 σ	±1 σ	±2 σ	±1 σ	±2 σ	±1 σ	±2 σ	±1 σ	±2 σ
EB I final-EBIIe C-9/C-8	3120-3010	3240-2960	3040-2950	3080-2930	3060-2980	3110-2950	3050-2980	3090-2960	3050-2980	3080-2950
EBIIe/IIIm C-8/C-7	3020-2960	3030-2930	3010-2940	3040-2920	3020-2960	3080-2920	3020-2970	3030-2940	3010-2960	3020-2930
EB IIIm/II L C-7/C-6A, Ic-3	2990-2930	3010-2920	2980-2920	3010-2910	3000-2930	3020-2910	3000-2940	3010-2920	2980-2930	3000-2920
EB IIL end C-6A, Ic-3	2960-2910	2990-2890	2950-2890	2990-2870	2970-2910	3000-2880	2970-2910	3000-2900	2920-2880	2930-2860
EB IIIB start Bd-2 start	2930-2880	2970-2870	No Bd	No Bd	2940-2880	2980-2780	2810-2740	2840-2710	2760-2710	2770-2680
EB IIIB/EB IIIB Bd-2/Ia-3, G-3	2900-2850	2930-2800	2920-2860	2940-2790	2900-2770	2920-2690	2780-2720	2820-2680	2740-2680	2760-2650
EB IIIB/EB IIIC Ja-3, G-3/B-2	2870-2800	2880-2740	2890-2810	2900-2740	No B-2	No B-2	2760-2690	2790-2660	2720-2650	2740-2630
EB IIIC/EB IIIC B-2/B-1	2850-2760	2860-2710	2880-2760	2880-2710	2810-2690	2850-2650	2740-2670	2770-2640	2690-2630	2720-2600

Based on all the different modeling performed, the models that best represent the archaeological stratigraphy and ^{14}C dates are

1. Detailed model (seeds and charcoal samples combined);
2. Detailed model with gap;
3. Detailed model with gap and TPQ.

The Detailed model, divided into 8 separate sequential layers, is built following the stratigraphy, and the boundaries are determined only by the ^{14}C dates. This model has the largest amount of data (32 samples) and a total of 5 outliers. In this model, the boundary between “Final EB I” and EB II falls around 3000 BC. The expected gap in the ^{14}C data (EB IIIA strata) is accounted for by the use of a sequential boundary between EB II and EB IIIB and the time range between the 2 boundaries is at most 170 yr (maximum length individually for EB II is 140 yr and for EB IIIA 80 yr; see Table 4), and most probably around 50–60 yr (EB II ends roughly 2930 BC and EB IIIB begins before 2880 BC). This is a completely different scenario for the EB II, which is traditionally given duration of about 300–400 yr, as well as the EB IIIA, allocated traditionally as 100–200 yr (e.g. de Miroschedji 2000:340).

Relying on historical and archaeological considerations, the 50-yr duration for EB IIIA is considered too short. The addition of a gap of 150 ± 50 yr in the Detailed model increased the EB IIIA duration to a maximum duration of 230 yr. But 2 more samples were turned into outliers (RTT-3493 charcoal, RTT-5293 short-lived), and the beginning of EB IIIB moved to between 2810–2740 BC.

In the Detailed model with gap, the end of EB II remains high and an attempt was made to stabilize it around 2900 BC by inserting a TPQ for the beginning of EB IIIA. This created 2 additional outliers (total 9 outliers), but lowered the beginning of EB IIIB to 2760–2710 BC. These boundaries are closer to the conventional dates, and they leave a reasonably long duration for the EB IIIA and EB II. This identification of 2 more samples as outliers, with no contextual or archaeological explanation raises the question about the other contexts used in the model. Based on the comparison of the various models, and the raw ^{14}C data in this study, it is not straightforward to select the Detailed with gap and TPQ model instead of the Detailed model.

Among the 15 ^{14}C measurements (charcoal and seeds) made on samples from the EB II at Tel Yarmuth, none has a calibrated 1σ range later than 2870 BC. On the other hand, the EB IIIB dates mostly do not start before 2900 BC (except 3 charcoal samples RT-2969, RT-3508, RTA-3493). Thus, the end of the EB II at Tel Yarmuth can be quite confidently established around 2900 BC, some 200 yr earlier than conventionally thought. It is important to note that the end of EB II seems to have taken place precisely when a deep slope exists in the calibration curve, occurring between 2910–2890 BC (corresponding to 4350–4200 uncalibrated). The fact that the measurements are neatly divided on the opposite sides of this slope further adds to the reliability of the date of the transition. The “EB IIIB begin” date can be slightly more flexible, but seems to have taken place in the course of the 29th century, or even during the 28th century. The latter date would imply that some of the ^{14}C samples are either not *in situ* or residual (RTT--5293, -5294) or there is a substantial old-wood effect (RTA-3493, RT-2966).

The end of the EB III in Tel Yarmuth is documented by a series of dates associated with the latest known pottery assemblage of EB IIIC as represented in Palace B1. The samples were gathered on plastered floors and are understood to form a uniform group of dates close to the time of abandonment of the site. All of the dates of this phase end before 2470 BC (except sample RT-2965 that is clearly intrusive). Actually most of the date ranges end before 2580 BC, and if the dates are really

to be seen as an homogeneous group, the sample RT-2968 could be interpreted as secondary use of the ruins after the abandonment Tel Yarmuth. In this case, the end of EB IIIC could be even much earlier.

A lesson learnt from this study is that secure archaeological context is crucial for the accuracy of the model and reliability of the results. Detailed stratigraphy enables effectively to find out the archaeological outliers, like RTT-5286, which appears as an outlier only in the Detailed model. A case like this might bring attention to the context as open to intrusive samples.

The new chronological framework for the “Final EBI”- EB II, and EB III in Tel Yarmuth, taking in consideration the Detailed model and Detailed model with gap and TPQ, can be presented as below:

Transition “Final EB IB” to EB II: 3050 to 2980 BC	
End of EB II (= transition EB II-EB IIIA): 2950–2900 BC, most probably around 2900 BC	
Scenario 1	Scenario 2
Very short EB IIIA (max 70 yr)	EBIIIA of 150 yr duration
Beginning of EB IIIB: 2930–2880 BC	Beginning of EB IIIB: 2760–2710 BC
End of EB IIIC: before mid-25th century BC	End of EB IIIC: before mid-25th century BC

CONCLUSION

Based on the modeling of the 37 ¹⁴C dates from Tel Yarmuth, spanning the Early Bronze Age I, II, and III, a new chronology for this period has been proposed. The EB II has been shortened and its end is raised to about 2950–2900 BC. The EB III ends at the latest around 2450 BC, although according to the models an earlier date could be supported. The new ¹⁴C-based chronology of Tel Yarmuth, covering a major part of the EB period, represents a backbone for the EBA chronology in southern Levant.

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