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PREHISTORIC BRONZE AGE RADIOCARBON CHRONOLOGY AT POLITIKO-*TROULLIA*, CYPRUS

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ABSTRACT. Politiko-*Troullia* has generated the largest radiocarbon (^{14}C) dataset from a Prehistoric Bronze Age settlement on Cyprus. We present Bayesian modeling of 25 calibrated AMS ages, which contributes to an emerging multi-site ^{14}C chronology for Cyprus covering most of the Prehistoric Bronze Age. Our analysis places the six stratified phases of occupation at *Troullia* between about 2050 and 1850 cal BCE, in contrast to a longer estimated occupation inferred from pottery analysis. We provide a rare ^{14}C determination for the transition from Prehistoric Bronze Age 1 to 2 just after 2000 cal BCE, associated with a major architectural dislocation at Politiko-*Troullia* in response to local landscape erosion, possibly due to increased regional precipitation. We present a regional ^{14}C model for Prehistoric Bronze Age Cyprus combining the chronology for Politiko-*Troullia* with modeled ^{14}C ages from Sotira *Kaminoudhia* and Marki *Alonia*, which is bolstered by individual ages from five other settlements on Cyprus. Through the Prehistoric Bronze Age, agrarian villages on Cyprus developed the foundations for the emergence of urbanized settlement and society during the ensuing Protohistoric Bronze Age. Politiko-*Troullia*, in conjunction with other key settlements on Cyprus, provides a significant independent contribution to increasingly robust Bronze Age ^{14}C chronologies in the Eastern Mediterranean.

KEYWORDS: AMS chronology, Bayesian modeling, Cypriot Bronze Age.

INTRODUCTION

The Bronze Age of Cyprus provides a remarkable setting in which to consider the social dynamics that fueled the shift from pre-urban, modestly differentiated villages to stratified society and formal urbanized polities. The pertinent time span from the fourth to second millennia BCE on Cyprus is characterized traditionally in terms of the Chalcolithic, Early, Middle and Late Bronze Ages (also referred to as the Early, Middle and Late Cypriot Periods) (e.g., Paraskeva 2019). The culture history of these periods was originally reconstructed largely on the basis of material culture from mortuary assemblages, many excavated in the early 20th century (e.g., Gjerstad et al. 1934; Gjerstad and Westholm 1937). A more recent perspective incorporates evidence from excavated settlements and reconfigures this chronology into the Chalcolithic, Prehistoric and Protohistoric Bronze Ages (e.g., Knapp 2013: table 2). This culture history calls for the development of an independent radiocarbon-based chronology in which to chart major changes in the structure of pre-urban and early urbanized society on Cyprus (Table 1; see discussions in Stanley-Price 1979; Coleman 1992; Knapp 2013:25–28).

The Chalcolithic Period was characterized by largely self-sufficient rural agrarian communities without central places (Knapp 2013:243–262; Peltenburg 2014). Social leveling mechanisms may have actively counteracted growing inequality, thereby maintaining village and household autonomy (Peltenburg 1993). The subsequent Prehistoric Bronze Age featured a "wholesale change in the island's material culture" (Swiny 1997:185–205; see also, Steel 2004:119; Knapp 2013:263–277). This period's initial phase in the mid-third millennium BCE is signaled by the "Philia facies," an amalgam of new material culture that may

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Table 1 Bronze Age chronologies for Cyprus. Chronologies based on Manning (2013b) and Knapp (2013: table 2).

Traditional archaeological periods	Revised periods	Chronology (cal BCE)	Cypriot society
Late Cypriot IIA-IIIA	Protohistoric Bronze Age 2/3	1450–1100	Increased integration of urbanized society
Middle Cypriot III-LC I	Protohistoric Bronze Age 1	1700–1450	Coastal urban polities
Early Cypriot III-Middle Cypriot II	Prehistoric Bronze Age 2	2000–1700	Increased social differentiation; intensified metal-lurgy
Philia, Early Cypriot I-II	Prehistoric Bronze Age 1	2400–2000	Intensified agriculture
Chalcolithic	Chalcolithic	4000–2400	Agrarian village society

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reflect migration from Anatolia (e.g., Webb and Frankel 1999) or internal development on Cyprus (e.g., Knapp 2013:263–268). Over the course of the Prehistoric Bronze Age, unwalled agrarian villages implemented plow agriculture and localized metallurgical production coupled with expanding forest clearance for agricultural land and pyrotechnic fuel (Frankel 1993; Steel 2004:148; Knapp 2008:68–87; Klinge and Fall 2010; Fall et al. 2015) as local expressions of the Secondary Products Revolution (Sherratt 1981). The Prehistoric Bronze Age 2 is marked by intensified manufacture and ceremonial deposition of copper artifacts (Giardino et al. 2003; Knapp 2008:76–79) during an era of broadened social interaction in the early second millennium BCE when Cyprus received its first historical attestation (as *Alashiya*) in cuneiform texts from Alalakh and Mari in northern Syria and Upper Mesopotamia, respectively (Knapp 1996:17–20, 30). In the ensuing Protohistoric Bronze Age, copper metallurgy increased its role in signaling the stratification of Cypriot society, as rural settlements became more abundant in the mineral-rich foothills of the Troodos Mountains (Knapp 2008:74) and engaged in island-wide exchange (Frankel and Webb 2006:307; Webb 2013). Over this timespan in the later second millennium BCE, Cypriot society witnessed the coalescence of coastal urban polities with multi-tiered hierarchical settlement systems capped by fortified cities involved in international economic and diplomatic relations across the Eastern Mediterranean (Keswani 1993, 1996; Knapp 1997:53–63, 2013:348–359; Malbran-Labat 1999).

In the midst of this lengthy social trajectory, Prehistoric Bronze Age agrarian communities remained largely non-hierarchical, but experienced a suite of catalytic influences, including population growth, expanding economic exchange, increasingly gender-differentiated labor and enhanced expressions of social identity, all of which molded emergent social complexity on Cyprus (Manning 1993:48–49; Webb 2002:93–94, 2009:261–264; Bolger 2003:193; Keswani 2005:382–384; Falconer et al. 2014; Webb and Knapp 2021). While the importance of these social dynamics is increasingly clear, the Prehistoric Bronze Age chronology in which we might articulate them remains largely dependent on radiocarbon determinations from very few excavated settlements. Indeed, time remains “a contested dimension” in the study of the Eastern Mediterranean Bronze Age (Manning 2014a:23; see also Bietak and Höflmayer 2007; Manning 2007; Höflmayer 2012). In particular, Cypriot Bronze Age chronology has relied on radiocarbon-dated sequences at Sotira *Kaminoudhia*, whose two-phase occupation dates wholly to Prehistoric Bronze Age 1, and Marki *Alonia*, where eight of nine phases date to Prehistoric Bronze Age 1, with the final phase (which has two radiocarbon ages) in Prehistoric Bronze Age 2 (see Manning 2013a, 2013b, 2014b). Our study introduces Bayesian modeling of 25 calibrated AMS ages from six stratified phases of occupation at Politiko-*Troullia* that span two centuries or more, from late Prehistoric Bronze Age 1 (represented by Phases 5–3) across the first half of Prehistoric Bronze Age 2 (in Phases 2–1a). This timeframe covers an interval of increasingly clear environmental change at the Prehistoric Bronze 1–2 transition around 2000 cal BCE, as indicated by architectural displacement and abandonment of the well (due to a lower water table) at Politiko-*Troullia* between Phases 3 and 2. Jointly, the radiocarbon evidence from Sotira, Marki and *Troullia* provides a chronological framework in which the social dynamics of the Prehistoric Bronze Age on Cyprus can be articulated at higher resolution and related to environmental disjunctions on Cyprus as well as in the Eastern Mediterranean and Middle East.

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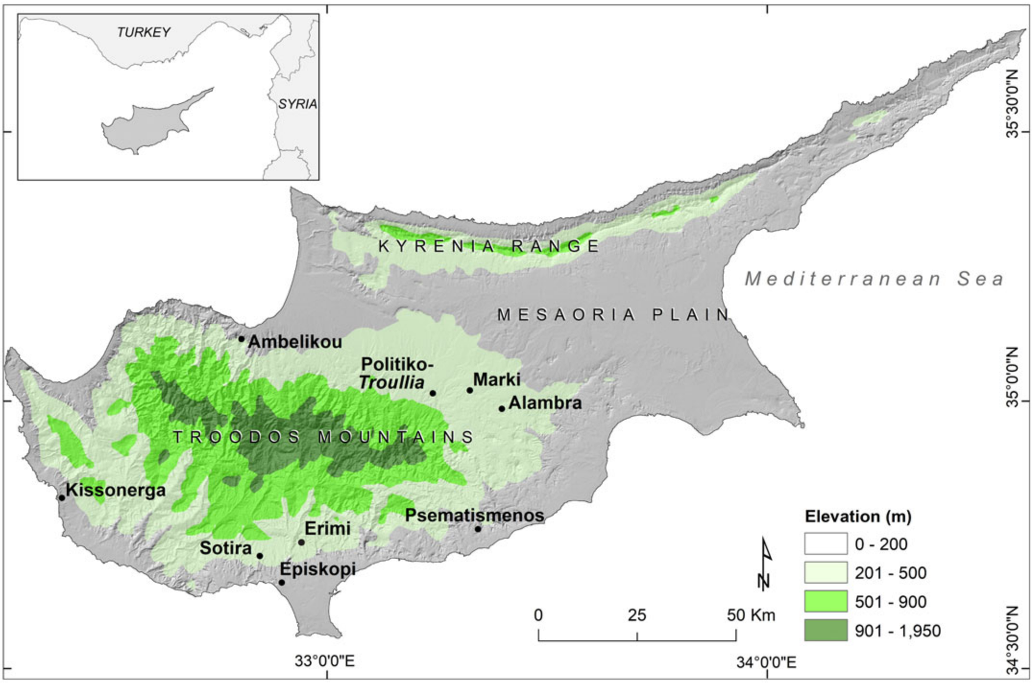

Figure 1 Map of Cyprus in the northeastern Mediterranean, showing archaeological sites that provide radiocarbon ages for the Prehistoric Bronze Age of Cyprus.

ARCHAEOLOGICAL SETTING: POLITIKO-*TROULLIA*

Field Investigations

Politiko-*Troullia* lies in the foothills of the Troodos Mountains at the interface between the fertile Mesaoria Plain to the north and the mineral-rich pillow lavas to the southwest (Figure 1), which provide readily accessible eroded exposures of the copper-bearing Troodos ophiolite (Knapp and Kassianidou 2008). Village remains lie buried in alluvial and colluvial sediments on a terrace between the Pediaios River to the east and Kamaras Creek to the west (Fall et al. 2008). Perennial springs, today less than one km to the south of Politiko-*Troullia* (and probably adjacent to *Troullia* West during the Bronze Age), provided a readily accessible water source for the village's inhabitants, with streamflow that eroded the banks of Kamaras Creek and the structures along the western edge of the village of *Troullia* (Figure 2)

The local archaeological landscape includes material culture (primarily potsherds and ground stone) spread over about 20 ha across the fields of *Troullia* and the adjacent slopes of Politiko-*Koloiokremmos*. Surface ceramic evidence (especially Red Polished Ware sherds), with associated patterns of buried architecture revealed by soil resistivity, define the main component of Bronze Age village structures covering at least 2 ha on Politiko-*Troullia*, in Fields 1 and 2 (Falconer et al. 2005). Immediately to the south, widespread Red Polished sherds and ground stone artifacts are associated with extensive agricultural terracing on the slopes of *Koloiokremmos* (see Figure 2, Fields 3 and 4). In concert, this evidence reflects

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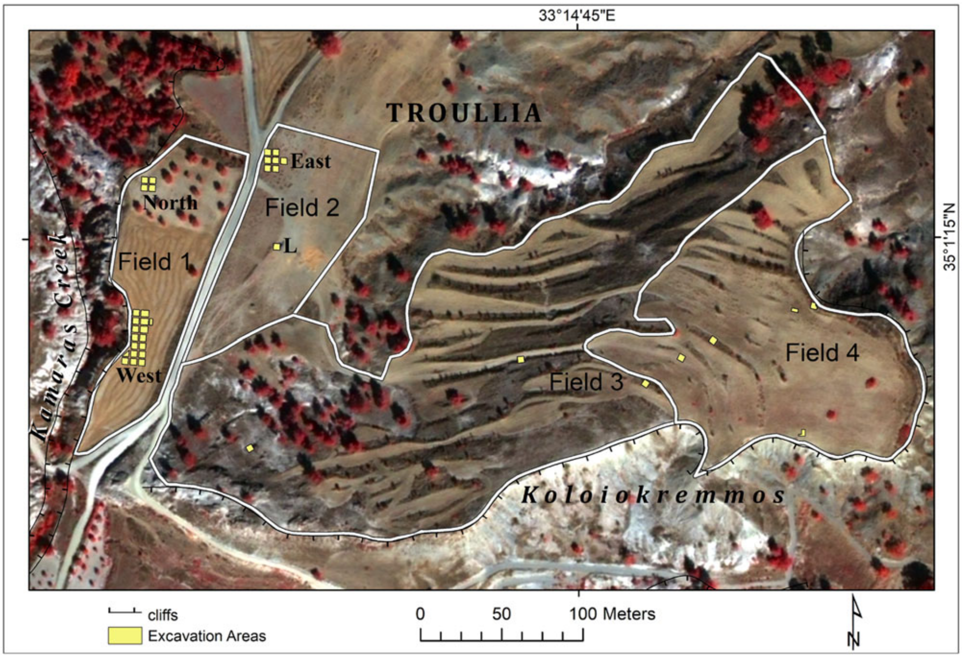

Figure 2 Quickbird satellite false color composite image (October 2003) of Politiko-*Troullia* showing fields investigated by survey and excavation, agricultural terraces, topographic features, and Kamaras Creek to the west of Field 1 (see Fall et al. 2008: fig. 8). Excavation units indicated by yellow squares. This study incorporates evidence from excavation areas in *Troullia* West, North and East in Fields 1 and 2.

intensive premodern management of the local landscape, including agricultural and copper ore processing (Fall et al. 2012; Galletti et al. 2013; Ridder et al. 2017). Spatial analyses of these agrarian features, and rich excavated evidence of seeds, charcoal and animal bones document a mixed Bronze Age subsistence regime of grape and olive arboriculture, sheep/goat and cattle husbandry, plus hunting of wild deer and feral pigs by villagers living on the verge of oak and pine woodlands (Klinge and Fall 2010; Falconer and Fall 2013; Fall et al. 2015; Ridder et al. 2017; Metzger et al. 2021; Pilaar Birch et al. 2022).

Politiko-*Troullia* was excavated in a series of field seasons between 2004 and 2015. The site was gridded into 5 × 5 m areas, each consisting of 4 × 4 m excavation units separated by one-meter balks, arrayed primarily in three portions of the site: *Troullia* East, North and West (see Figure 2). Additional single areas were excavated in Area L (near *Troullia* East) and in a series of soundings on Politiko-*Koloiokremmos*. All of the areas in *Troullia* East, North and West, each designated by a letter, were positioned on the basis of buried architecture indicated by subsurface sensing or eroded wall exposures along Kamaras Creek. The most extensive excavations at Politiko-*Troullia* involved a matrix of areas in *Troullia* West (totaling 360 m^2), which were situated where soil resistivity revealed lengthy patterns of buried stone wall alignments (Falconer et al. 2005). The excavation areas of *Troullia* East (totaling 142 m^2) were positioned over a particularly clear soil resistivity image of a subsurface multi-room compound. Excavations in *Troullia* North (totaling 81 m^2) were positioned near buried stone walls exposed by erosion along the site's edges.

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The Settlement of Politiko-*Troullia*

The architecture of Politiko-*Troullia* is comprised of six stratified phases of construction and reconstruction (Falconer et al. 2012, 2014; Falconer and Fall 2013, 2014). The full stratigraphic sequence (Phases 5–1a, from earliest to latest) is represented in sediments more than three meters deep in Politiko-*Troullia* West. Excavations in Politiko-*Troullia* East and North revealed architecture and associated deposits from Phases 2 and 1b. Our correlation of phases between these fields is based on the Politiko-*Troullia* radiocarbon chronology presented here. The major structures in *Troullia* West include two large rectangular open courtyards, bounded by a 2-m-wide alley on the south, which provided villagers access to the waters of Kamaras Creek in antiquity (Falconer and Fall 2013: figs. 7, 8, 2014: figs. 3, 4). The more southerly courtyard provided abundant evidence for communal activities, including feasting on Mesopotamian fallow deer (*Dama dama mesopotamica*), textile production, gaming stones and display of plank figures (including the largest stone plank figure excavated on Cyprus) (Falconer et al. 2014). The earliest phase in *Troullia* West (Phase 5) includes the lowermost sediments in the alley, which are stratified below the alley walls and represent the earliest archaeological sediments at Politiko-*Troullia*. In subsequent Phase 4, the courtyards were constructed with adjoining rooms on their west, all situated just upslope from Kamaras Creek. The Phase 3 village retained this architectural plan, with modifications of some walls and doorways. A well in *Troullia* West provided intramural access to drinking water during phases 5–3 via stone steps leading down to the water table, which would have been linked with the streamflow of Kamaras Creek.

During Phases 2, 1b and 1a, the architecture in *Troullia* West, including the walls defining its courtyards and adjoining rooms, was shifted upslope one meter or more to the east. The latest habitation of the village in Phase 1a is represented by a two-room mudbrick structure and adjacent burned area at the northern edge of *Troullia* West. As part of the architectural relocation of the last three phases, the well in *Troullia* West was abandoned and capped with compacted limestone plaster. Numerous eroded stone walls from phases 4–1a are exposed in cross-section along the modern east bank of Kamaras Creek. This stratified architectural sequence suggests that the occupational history of Politiko-*Troullia*, including its comprehensive repositioning between phases 3 and 2, was linked to the geomorphological dynamics of its local landscape.

Excavation of *Troullia* East revealed a compound buried in sediments 0.75 m deep, which was occupied in a single stratigraphic phase. *Troullia* East features two roofed rooms, which were surrounded by smaller outbuildings (Fall et al. 2008; Falconer and Fall 2013: fig. 6). An exterior workspace with a pit furnace, dense charcoal deposition, copper tongs, a limestone mold, copper slag and ore attest to a household scale metallurgical workshop (Fall et al. 2008; Falconer and Fall 2013), in keeping with Politiko-*Troullia*'s proximity to local near-surface ore sources. Excavations of a multi-room structure in the upper phase of *Troullia* North revealed a copper workshop similar to that found in *Troullia* East, with an external *terra cotta* oven and copper slag, as well as *tuyere* fragments. These excavations also exposed stone wall foundations and floor deposits in a stratified lower phase of this compound.

MATERIALS AND METHODS

During the excavation of Politiko-*Troullia*, all excavated sediments (other than those processed by water flotation) were dry-sieved through 0.5-cm wire mesh to ensure maximum recovery of smaller sized ceramics, bones, metal and stone artifacts. Sediments with visible burned organic

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content were processed using non-mechanized water flotation to recover plant macrofossils. Each flotation sample was assigned a unique spatial identifier that includes the excavation area, a locus number (pertaining to a three-dimensional feature), and a bag number. We emphasized sampling of relatively shallow localized deposits in or on burned surfaces (e.g., small pits, postholes, thin occupational debris on surfaces). This strategy targets short-term depositional events and minimizes the potential for chronological mixing, leading to the recovery of well-preserved seeds and few degraded remains. All recovered plant remains 0.25 mm or larger were sorted under a binocular microscope at 6 to 40× magnification and identified using Fall's personal reference collection, comparison with published literature (and scanning electron microscopy of charcoal pieces) following established methods of floral recovery and analysis (Falconer and Fall 2006:38–43, 2019:13–14; Klinge and Fall 2010; Fall et al. 2015, 2019; Porson et al. 2021).

Twenty seed samples and five charcoal samples were selected from well-defined contexts in the six phases at Politiko-*Troullia* for AMS analysis by the University of Arizona Accelerator Mass Spectrometry Laboratory and the University of Georgia Center for Applied Isotope Studies (Table 2). Our most abundant seed taxon is *Olea*, and all five charcoal samples represent *Pinus* wood, which reflects the fact that pine is the most abundant taxon in our charcoal assemblage. Among our 25 samples, 20 come from small, well-defined burned sediments in earthen surfaces, shallow pits or postholes, or occupational debris built up ≤ 10 cm deep immediately on top of surfaces. The remaining five samples come from localized fill deposits associated with surfaces. All seed and charcoal samples were prepared for analysis at both AMS labs following an acid/alkali/acid pretreatment protocol. Uncalibrated ages are given in radiocarbon years before 1950 (years BP), using the ^{14}C half-life of 5568 years. The error for each uncalibrated date is quoted as one standard deviation and reflects both statistical and experimental errors. The dates have been corrected for isotope fractionation using $\delta^{13}C$ values.

The occupational chronology for Politiko-*Troullia* is based on AMS ^{14}C ages for these excavated carbonized plant remains, which have been calibrated using OxCal 4.4.4 (Bronk Ramsey 2009a) and the IntCal20 atmospheric curve (Reimer et al. 2020; van der Plicht et al. 2020). The analytical tools in OxCal 4.4.4 were used for Bayesian modeling of the calibrated dates. Bayesian analysis permits probabilistic modeling of calibrated ^{14}C determinations using prior stratigraphic information and can accommodate the non-normally distributed probabilities of calibrated ^{14}C ages (Bronk Ramsey 2009a). Agreement values (A, A_{model}) can be used to assess the reliability of the individual calibrated ages in Bayesian models and the quality of overall models. Values of A calculate the likelihood of overlap of the non-modeled distribution for each calibrated age with its posterior Bayesian modeled distribution. Values of $A > 60$ approximate values of $p < 0.05$ for a χ^2 significance test (Manning 2013a:496, fig. A5). We use values of $A_{model} > 60$ to identify statistically robust Bayesian models, and we treat calibrated ages with $A \leq 60$ as statistical outliers, which we exclude from our Bayesian modeling (Bronk Ramsey 2009b). The radiocarbon ages from Politiko-*Troullia* were organized for modeling according to stratigraphic phases using the "Phase" function in Oxcal, in which each phase consists of a group of unordered events. Although the sediments within each phase are stratified, we did not construct a more complex model since it would be difficult to match individual sediment layers within any given phase across all of the excavation areas at Politiko-*Troullia*.

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Table 2 AMS radiocarbon ages for unmodeled and modeled calibrated seed and charcoal samples from Politiko-*Troullia*, Cyprus. Uncalibrated ^{14}C ages are indicated in BP with their 1σ uncertainty. Calibration based on OxCal 4.4.4 (Bronk Ramsey 2009a, 2017) using the IntCal20 atmospheric curve (Reimer et al. 2020). Stratigraphic phases at Politiko-*Troullia* run from Phase 5 (the earliest, basal stratum) to Phase 1a (the latest occupation). Samples are tabulated by phase and ordered chronologically according to conventional ^{14}C age within each phase. Phase; Location (*Troullia* North, East, West); Excavation sample (Unit, Locus and Bag, e.g., A.012.41 = Unit A, Locus 012, Bag 41); Archaeological context; Species and plant part dated shown. *Outlier, A ≤ 60.

#	Lab number	^{14}C age BP	Unmodeled 2σ range cal BCE	Unmodeled median cal BCE	Modeled 2σ range cal BCE	Modeled median cal BCE	Phase; location; excavation sample; context	Species, plant part
25	UGAMS-55320	3480±25	1884-1700	1808	1929–1771	1867	1a; West; N.018.64; occupational debris	*Pisum* seed
24	AA-109808	3522±27	1931–1751	1833	1936–1785	1881	1a; West; N.005.97; surface	*Cerealia* seed fragments
23	AA-101939	3562±44	2031–1751	1909	1976–1901	1945	1b; East; A.012.41; occupational debris	*Pinus* sp. charcoal
22	AA-109807	3591±24	2026–1884	1944	1976–1906	1946	1b; West; M.034.108; surface	*Triticum*/*Hordeum* spikelet
21	AA-94182	3600±37	2125–1785	1958	1977–1907	1947	1b; East; B.013.56; surface	*Pinus* sp. charcoal
20	UGAMS-51988	3600±21	2026–1891	1955	1977–1911	1948	1b; North; AA.035.116; posthole	*Cerealia* seed fragments
19	UGAMS-55317	3600±25	2027–1890	1956	1977–1910	1948	1b; West; R.007.80; fill debris	*Olea* seeds (2)
18	AA-106612	3609±26	2033–1891	1967	1978–1910	1949	1b; West; J.019.73; surface	*Pinus* sp. charcoal
17	UGAMS-55316	3620±25	2113–1896	1979	1980–1911	1950	1b; East; E.012.22; occupational debris	*Olea* seeds (2)
16	AA-101940	3661±44	2195–1902	2039	1982–1911	1951	1b; East; AF.006.18; occupational debris	*Pinus* sp. charcoal
15	AA-106613	3652±26	2136–1942	2022	2003–1947	1973	2; North; AA.047.164; pit	*Pinus* sp. charcoal
14	AA-94183	3665±38	2194–1936	2045	2004–1947	1973	2; West; W.006.67; fill debris	*Olea* seed
13	AA-109809	3583±24	2024-1831	1934	2006–1946	1970	2; West; O.069.262; occupational debris	*Pistacia* seed fragments
12	AA-101943	3622±44	2136–1883	1986	2006–1946	1971	2; West; U.024.154; fill debris	Seeds
11	AA-94184	3630±38	2134–1891	1995	2006–1946	1972	2; West; W.008.76; occupational debris	*Olea* seed
10	AA-101942	3632±45	2137–1889	1999	2006–1946	1972	2; West; W.016.179; occupational debris	*Olea* seed

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Table 2 (*Continued*)

#	Lab number	^{14}C age BP	Unmodeled 2σ range cal BCE	Unmodeled median cal BCE	Modeled 2σ range cal BCE	Modeled median cal BCE	Phase; location; excavation sample; context	Species, plant part
9	AA-94185*	3688±38	2199–1955	2080	2199–1955	2080	2; West: X.016.95; fill debris	*Olea* seed
8	AA-104834	3636±29	2132–1900	1998	2020–1960	1990	3; West; T.051.318; pit	*Olea* seed
7	AA-104835*	3686±29	2196–1972	2082	2196–1971	2082	3; West; T.046.300; pit	*Olea* seed
6	UGAMS-55319	3610±25	2033–1892	1968	2031–1974	2011	4; West; O.103.380; fill debris	*Pinus* sp. seed
5	AA-109794	3624±23	2114–1900	1984	2032–1976	2011	4; West; T.014.130; occupational debris	*Olea* seed
4	UGAMS-49350	3640±25	2133–1929	2002	2035–1974	2012	4; West; T.046.294; pit	*Hordeum vulgare* seeds (3)
3	UGAMS-55318	3640±25	2133–1929	2002	2035–1974	2012	4; West; T.025.200; occupational debris	*Olea* seeds (2)
2	AA-101941	3650±44	2141–1897	2023	2036–1972	2012	4; West; T.019.176; occupational debris	Wild seeds
1	AA-109795	3686±26	2194–1976	2083	2118–1980	2040	5; West; W.039.300; occupational debris	*Olea* seed

RESULTS

Our Bayesian modeling analyzes the 25 calibrated radiocarbon ages from Politiko-*Troullia* in six contiguous phases of occupation, beginning with Phase 5 and ending with Phase 1a. These ages are reported in radiocarbon years BP (Before Present, with the present defined as 1950 CE) following international convention (Stuiver and Polach 1977). Our preferred Bayesian analysis (Model 1) is structured primarily by the stratigraphy of Politiko-*Troullia* West and also incorporates the four ages from *Troullia* East in Phase 1b and the date from the upper phase in *Troullia North* in Phase 1b, while the age from the lower phase in *Troullia* North is included in Phase 2. The dates from *Troullia* East and North are positioned in Model 1 according to their fit with the radiocarbon chronology for *Troullia* West. Model 1 excludes two seed ages, one from Phase 3 (AA-94185) and one from Phase 2 (AA-104835). Following the analytical methods described above, we treat these two ages as statistical outliers based on their values of $A \leq 60$.

Model 1 ($A_{model} = 153.7$) estimates the occupation of Politiko-*Troullia* between approximately the mid-21st and mid-19th centuries cal BCE, from the starting boundary for Phase 5 (1σ range: 2097–2021 cal BCE; median = 2056 cal BCE) to the ending boundary for Phase 1a (1σ range: 1882-1800 cal BCE; median = 1839 cal BCE) (Figure 3; Supplementary Table 1). The intervals between modeled boundary medians suggest that phases 5-1b each lasted 20–30 years (Table 3). A longer occupation for Phase 1a is estimated based on the two ages in the uppermost stratum in *Troullia* West, which includes a burned area possibly marking the abandonment of Politiko-*Troullia*. Separate models for *Troullia* West and *Troullia* East produce very similar results (Table 4). For example, the model for Politiko-*Troullia* West alone (Model 2; $A_{model} = 146.5$) generates start and end boundaries, median and A_{model} values very similar to those of Model 1 (Supplementary Figure 1; Supplementary Table 2). Boundary medians differ by less than 10 years between Models 1 and 2. The precision of the posterior estimates in these two models remains similar. The model for *Troullia* East (Model 3; $A_{model} = 104.0$), based on fewer ages, generates a lower value for A_{model} and broader start and end boundary intervals, but still accords with the time frame estimated by Model 1 (Supplementary Figure 2; Supplementary Table 3). Independent modeling of the two ages from Troullia *North* in Phases 1a and 1b nearly replicates the results for these two ages in Model 1. As a further consideration, the charcoal ages from Politiko-*Troullia* do not indicate a significant "old wood" effect of inbuilt age (Dee and Bronk Ramsey 2014) on the Bayesian modeling of Politiko-*Troullia*. All five charcoal ages are compatible with the seed ages in Models 1 and 2, they do not skew these models early, and they have individual values of $A > 60$. Modeling of all 25 dates from Politiko-*Troullia* using the Charcoal Outlier Model in OxCal (Model 4; see Bronze Ramsey 2009b; Dee and Bronk Ramsey 2014) produces results ($A_{model} = 154.0$) nearly identical to those of Models 1 and 2 (Supplementary Figure 3; Supplementary Table 4). The Outlier Model posterior values are 0 for all five charcoal ages, indicating that wood-age offsets are negligible.

DISCUSSION

A set of main inferences arise from the coordination of stratigraphic and chronological evidence for the occupation of Politiko-*Troullia*. Our initial assessment of the pottery wares and forms surveyed on *Troullia* West (Falconer et al. 2005) and excavated from *Troullia* East (Fall et al. 2008) suggested an occupation through most of the Prehistoric Bronze Age and possibly into the Protohistoric Bronze Age (i.e., from the Early through Middle Cypriot periods, and possibly into Late Cypriot). The settlement's ceramic assemblage is

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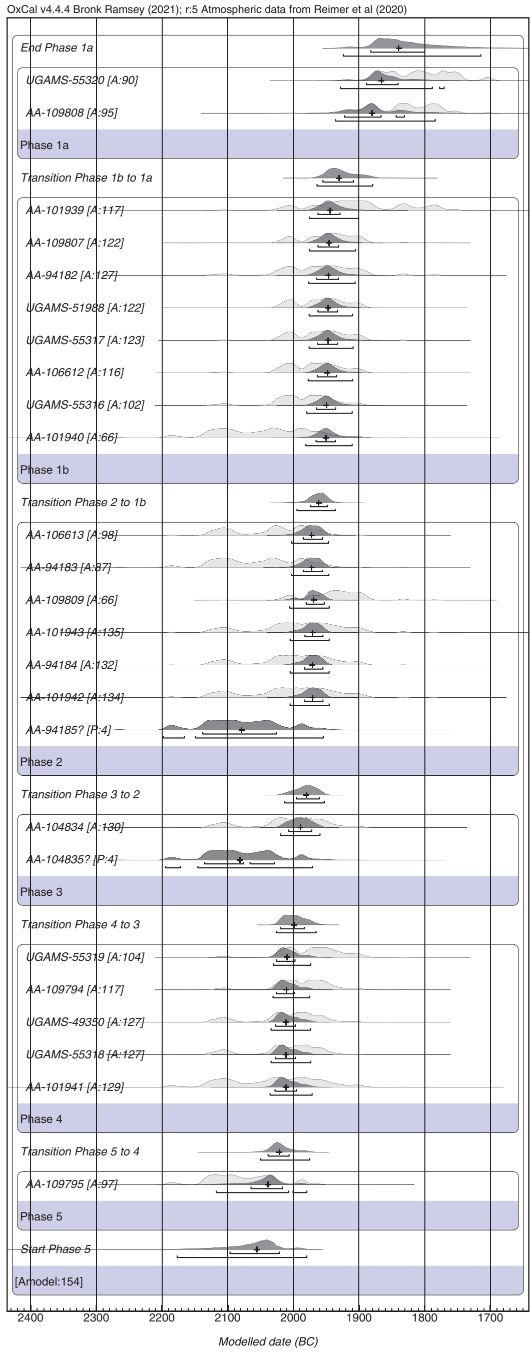

Figure 3 Model 1: Bayesian sequencing of calibrated radiocarbon ages for 25 seed and charcoal samples from Politiko-*Troullia*, Cyprus; $A_{model} = 153.7$. Light gray curves indicate single-sample calibration distributions; dark curves indicate modeled calibration distributions. Calibrations and Bayesian modeling based on OxCal 4.4.4 (Bronk Ramsey 2009a) using the IntCal20 atmospheric curve (Reimer et al. 2020; van der Plicht et al. 2020). Two ages (AA-94185, AA-104835) are excluded as statistical outliers based on $A \leq 60$.

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Table 3 AMS age ranges (cal BCE) for six stratified phases at Politiko-*Troullia*, Cyprus based on phase boundary medians produced by Bayesian modeling of 25 radiocarbon ages (see Figure 3). Calibration and modeling based on OxCal 4.4.4 (Bronk Ramsey 2009a, 2017) using the IntCal20 atmospheric curve (Reimer et al. 2020).

Phase	AMS age range (cal BCE)
1a	1931–1839
1b	1962–1931
2	1981–1962
3	2000–1981
4	2022–2000
5	2056–2022

dominated by Red Polished Ware, which constitutes 85–92% of the polished, painted and slipped ware sherds from each phase. White Painted and Black Polished sherds occur at frequencies up to 10%, while Red Slipped, Drab Polished and Brown Polished sherd frequencies are less than 4% in each phase. Initial ware-based analysis of the site's stratified pottery suggested a potentially lengthy occupation (i.e., ~500 years) from Middle Cypriot I to Late Cypriot I (Fall et al. 2008). The ceramic-based chronology for these time periods in Cyprus stretches more than 500 years between 2000 and 1450 cal BCE (e.g., Knapp 2013: table 2).

Our radiocarbon-based chronology for Politiko-*Troullia* now documents a more focused, roughly two-century occupation consisting of a series of relatively brief stratigraphic phases occurring between about 2050 and 1850 cal BCE. The most pronounced stratigraphic and chronological disjunction at Politiko-*Troullia* West is marked by the shift from the more downslope positioning of architecture and the use of the village's well in the earlier phases (5–3) to the more upslope architecture and abandonment of the well in the later phases (2–1a). This shift appears to have been a response to downcutting along Kamaras Creek that would have eroded the settlement's western edge and lowered the water table feeding the village well. The timing of this event, marked by the boundary between Phases 3 and 2, is estimated slightly after 2000 cal BCE (1σ range: 1997–1962 cal BCE; median = 1981 cal BCE), which may correlate with climate changes involving increased precipitation and decreased temperature hypothesized at about 2000 cal BCE for the nearby Southern Levant (Soto-Berelov et al. 2015). This juncture, marked by geomorphological change at Politiko-*Troullia*, corresponds roughly with the chronological transition between Prehistoric Bronze Age 1 and 2. The majority of the ages from Politiko-*Troullia* then provide the most substantial stratified radiocarbon sequence for Prehistoric Bronze Age 2 habitation on Cyprus.

Other models of stratified radiocarbon evidence for the Prehistoric Bronze Age come from Sotira *Kaminoudhia* and Marki *Alonia*. Excavation of Area A at Sotira revealed two architectural phases of adjoining, largely rectilinear domestic structures associated with long, narrow alleyways (Rapp and Swiny 2003:5–7). Ten charcoal ages from these two phases (Swiny et al. 2003:503–505) provide the basis for Bayesian modeling of the occupation at Sotira *Kaminoudhia* in the 24th and 23rd centuries cal BCE, with the end of Phase II modeled at about 2200 cal BCE (Figure 4; Supplementary Table 5; $A_{model} = 124.0$; see also Manning 2013b: fig. 10, 2014b: fig. 5), squarely within Prehistoric

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Table 4 Summary of results from Bayesian modeling of AMS ages from Politiko-*Troullia*, Cyprus. Calibration and modeling based on OxCal 4.4.4 (Bronk Ramsey 2009a, 2017) using the IntCal20 atmospheric curve (Reimer et al. 2020).

Model	Ages	Phases	A_{model}	Modeled 1σ start boundary (cal BCE)	Modeled 1σ end boundary (cal BCE)	Modeled start & end medians (cal BCE)
1. *Troullia* West, East & North	25	6	153.7	2097–2021	1882–1800	2056 & 1839
2. *Troullia* West	19	6	146.5	2099–2020	1883–1807	2054 & 1843
3. *Troullia* East	4	1	104.0	2053–1955	1994–1874	2018 & 1925
4. *Troullia* West, East & North; OxCal Charcoal Outlier Model	25	6	154.0	2101–2022	1881–1791	2057 & 1839

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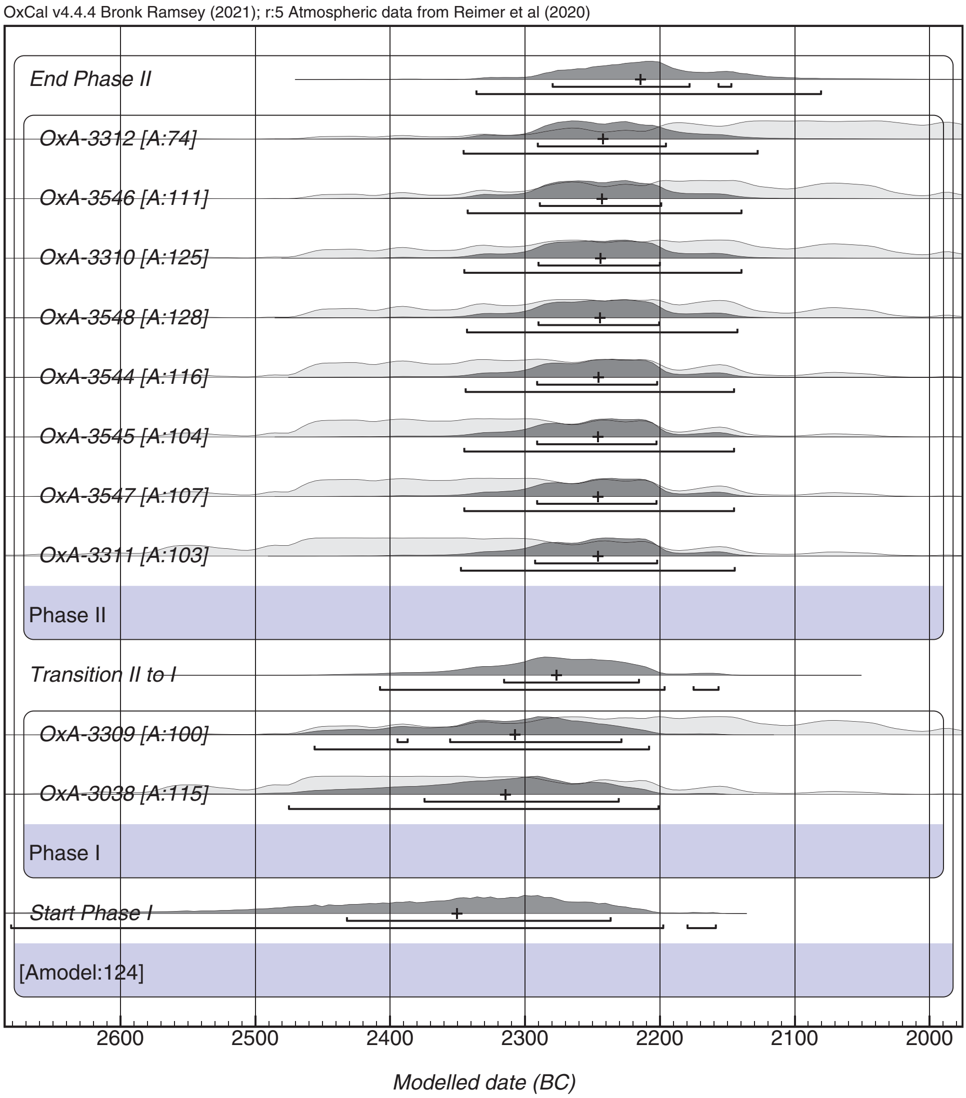

Figure 4 Bayesian sequencing of calibrated radiocarbon ages for 10 charcoal samples from Sotira *Kaminoudhia*, Cyprus; $A_{model} = 124.0$. Light gray curves indicate single-sample calibration distributions; dark curves indicate modeled calibration distributions. Calibrations and Bayesian modeling based on OxCal 4.4.4 (Bronk Ramsey 2009a) using the IntCal20 atmospheric curve (Reimer et al. 2020; van der Plicht et al. 2020).

Bronze Age 1 (i.e., Philia/Early Cypriot I and II in more traditional terms). Sotira's charcoal ages produce relatively large confidence intervals for individual modeled dates, start and end boundaries, and suggest that each of Sotira's two phases might cover decades or stretch up to a century (see also Manning 2013b: fig. 1, table 1).

The settlement at Marki *Alonia* was characterized by shifting configurations of domestic compounds, most with two or more rooms and an adjoining walled courtyard. These

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households were periodically occupied and abandoned in varying combinations through a series of temporal episodes labeled Phases A–I (Philia/Early Cypriot to Middle Cypriot II traditionally) (Frankel and Webb 2006: 35–41; Webb 2009). The evidence from each phase includes deposition related to its construction (e.g., "Phase A") and its occupation (e.g., "Phase A-1"). Marki *Alonia* provides a total of 21 AMS ages, including 19 dates for seed samples and two ages for charcoal samples (Frankel and Webb 2006: table 3.3a), which are modeled in nine phases (Figure 5; Supplementary Table 6; $A_{model} = 154.3$). This evidence includes five dates from levelling fill from "Source γ" whose stratigraphic placement is equivocal. Three of the Source γ ages (OZB 161–163) are the earliest from Marki *Alonia* and in previous analyses are modeled in a separate phase prior to Phase A, while two of the Source γ ages (OZA-279U, OZB-160) have been modeled with Phase F (following Manning 2013b:5–6, fig. 3; Peltenburg et al. 2013). The best documented sequence at Marki in Phases A-H is based on 12 ages that are modeled between about 2200 and 2050 cal BCE (Manning 2013b: figs. 7, 11, table 1). The two charcoal dates from Phase I have large standard deviations, are "quite distinct from the majority of the Marki Sequence" (Manning 2013b:6) and are modeled in the 19th and 18th centuries cal BCE (see also Manning 2013b: fig. 7).

The remaining radiocarbon determinations for the Prehistoric Bronze Age on Cyprus include 14 ages for charcoal samples from five other sites: Alambra *Mouttes* (4 dates) (Coleman et al. 1996: table 29), Ambelikou *Aletri* (2) (Håkansson 1981:402), Episkopi *Phaneromeni* (3) (Fishman et al. 1977:189), Erimi-*Laonin tou Porokou* (4; excluding 3 outliers) (Scirè Calabrisotto and Fedi 2017; Scirè Calabrisotto et al. 2012), and Psematismenos *Trelloukkas* (1) (Manning and Sewell 2006:68). The calibrated ages for these samples range from late Prehistoric Bronze Age 1 through Prehistoric Bronze Age 2, between the mid-23rd century and the mid-18th century BCE, with the lone exception of a single age (Beta-82995) from Alambra *Mouttes*, which dates around 2500 cal BCE. Due to the susceptibility of charcoal ages to the effects of inbuilt age (e.g., see discussion of "old wood" problems with the ages from Erimi [Scirè Calabrisotto et al. 2017:1927]), these dates (and those from Sotira *Kaminoudhia*) are best viewed as supplying *terminus post quem* information.

A schematic depiction of the modeled radiocarbon sequences for Politiko-*Troullia*, Marki *Alonia* and Sotira *Kaminoudhia*, and individual calibrated dates from five other sites (Figure 6) facilitates comparative inferences of Prehistoric Bronze Age chronology on Cyprus. In light of the potential for inbuilt age effects noted above, the charcoal ages from Sotira Area A most clearly indicate the end of its habitation about 2200 cal BCE, after two stratigraphic phases jointly covering a century or more. At Marki, following the disjunct set of dates from early Source γ, the stratigraphically-defined sequence in Phases A–H models this settlement's best-attested occupation through about three centuries in the latter half of Prehistoric Bronze Age 1. The two distinct charcoal ages from Phase I then mark the latest evidence from Marki early in Prehistoric Bronze Age 2. The individual charcoal ages from Alambra, Ambelikou, Episkopi, Erimi and Psematismenos sporadically populate the timespan from late Prehistoric Bronze Age 1 into Prehistoric Bronze Age 2.

Combined Bayesian modeling of the stratified AMS ages from Sotira *Kaminoudhia*, Marki *Alonia* and Politiko-*Troullia* (Figure 7) now leads to a set of interrelated inferences with fundamental implications for the framework of Cypriot Bronze Age chronology and the

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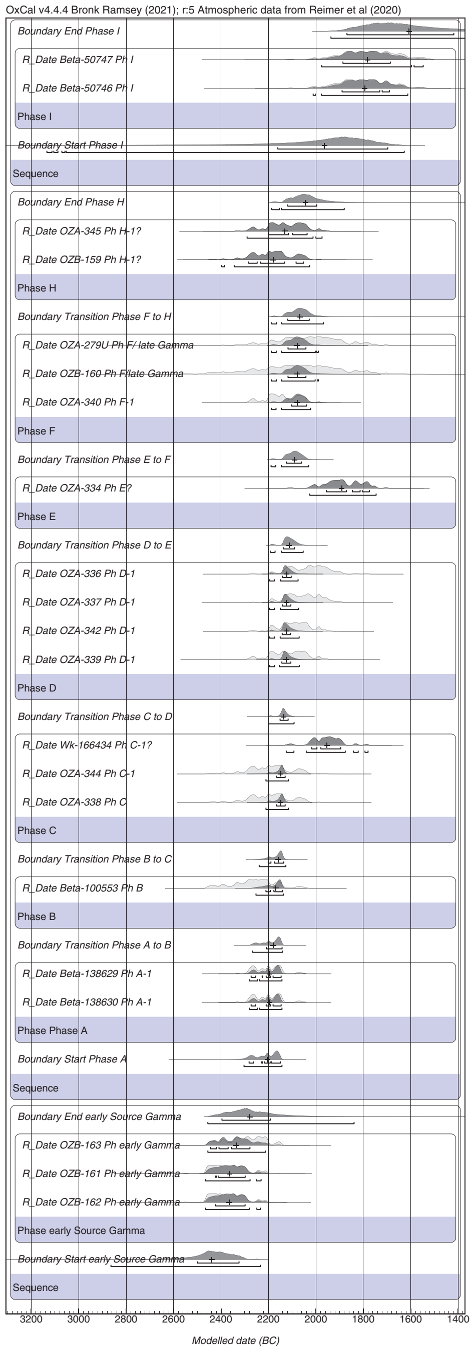

Figure 5 Bayesian sequencing of calibrated radiocarbon ages for 21 seed and charcoal samples from Marki *Alonia*, Cyprus; $A_{model} = 154.7$. Light gray curves indicate single-sample calibration distributions; dark curves indicate modeled calibration distributions. Calibrations and Bayesian modeling based on OxCal 4.4.4 (Bronk Ramsey 2009a) using the IntCal20 atmospheric curve (Reimer et al. 2020; van der Plicht et al. 2020). Two samples (OZA-334 and Wk-166434) are excluded as statistical outliers based on $A \leq 60$ and two samples (OZA-345 and OZB-159) are excluded following Manning 2013b, Models 7–10.

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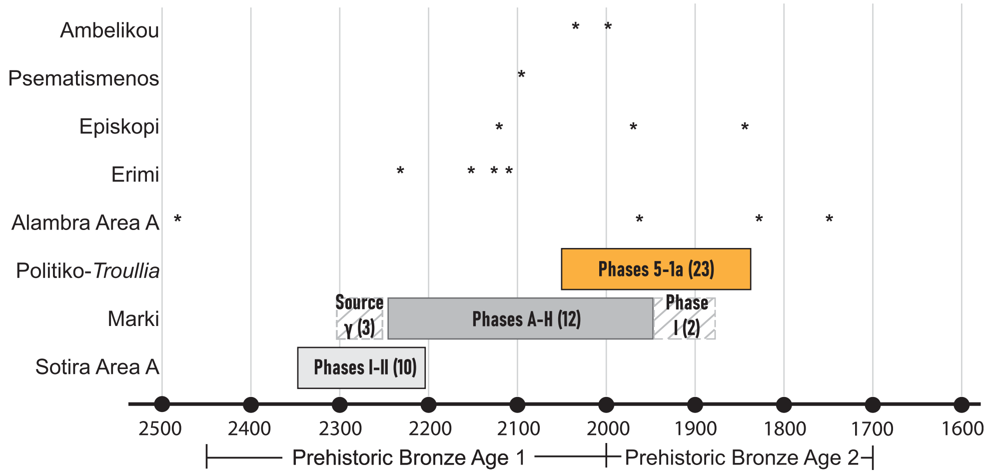

Figure 6 Schematic comparison of calibrated radiocarbon evidence from Prehistoric Bronze Age settlements on Cyprus. Bars depict Bayesian modeled sequences for calibrated radiocarbon ages from Politiko-*Troullia*, Sotira *Kaminoudhia* and Marki *Alonia* depicted according to modeled boundary medians (number of modeled ages for each sequence indicated in parentheses). Modeling of *Troullia* excludes two dates from Phases 3 and 2 that are statistical outliers. Marki excludes four ages: two from Phase H-1 and two statistical outliers (see Manning 2013b: table 1, figs. 7, 10). Radiocarbon ages from Alambra, Ambelikou, Episkopi, Erimi, and Psematismenos are plotted as individual unmodeled calibrated dates.

social and environmental changes that frame its temporal structure. Bayesian modeling of the charcoal ages from Sotira *Kaminoudhia* places its two phases of occupation prior to about 2200 cal BCE, thereby positioning it early in Prehistoric Bronze Age 1, even if the potential effects of inbuilt age are considered (see Knapp 2008: table 2, 2013: table 2; Manning 2014b:215). The radiocarbon evidence from Marki *Alonia* Phases A-1 through H-1 situates this settlement's best attested sequence between about 2200 and 2050 cal BCE, in the latter portion of Prehistoric Bronze Age 1. Three dates from early Source γ could reflect the Philia Facies in roughly the 24th century cal BCE, while two ages from Phase I suggest a disjunct final phase for the Marki sequence ending around 1800 cal BCE. Politiko-*Troullia* now provides a high-resolution Prehistoric Bronze Age chronology supported by Bayesian modeling of 25 stratified radiocarbon ages over roughly 200 years, from the 21st century cal BCE across the Prehistoric Bronze Age 1/2 transition, and through most of the 19th century cal BCE to the mid-Prehistoric Bronze Age 2. The major architectural shift at Politiko-*Troullia* at about 2000 cal BCE was a response to accentuated local erosion, especially stream downcutting near Politiko-*Troullia* at a time of decreased temperature and increased precipitation in the eastern Mediterranean at the beginning of the Middle Bronze Age in the Southern Levant (e.g., Soto-Berelov et al. 2015). The interval for the Prehistoric Bronze Age 2, in turn, approximates the timing of Levantine Middle Bronze Age reurbanization (Höflmayer et al. 2016; Falconer and Fall 2017; Fall et al. 2021). These major inferences derive from the modeling and articulation of stratified radiocarbon sequences from excavated Prehistoric Bronze Age settlements that illuminate major junctures of social and environmental change and thereby refine the radiocarbon-based chronology for Prehistoric Bronze Age Cyprus.

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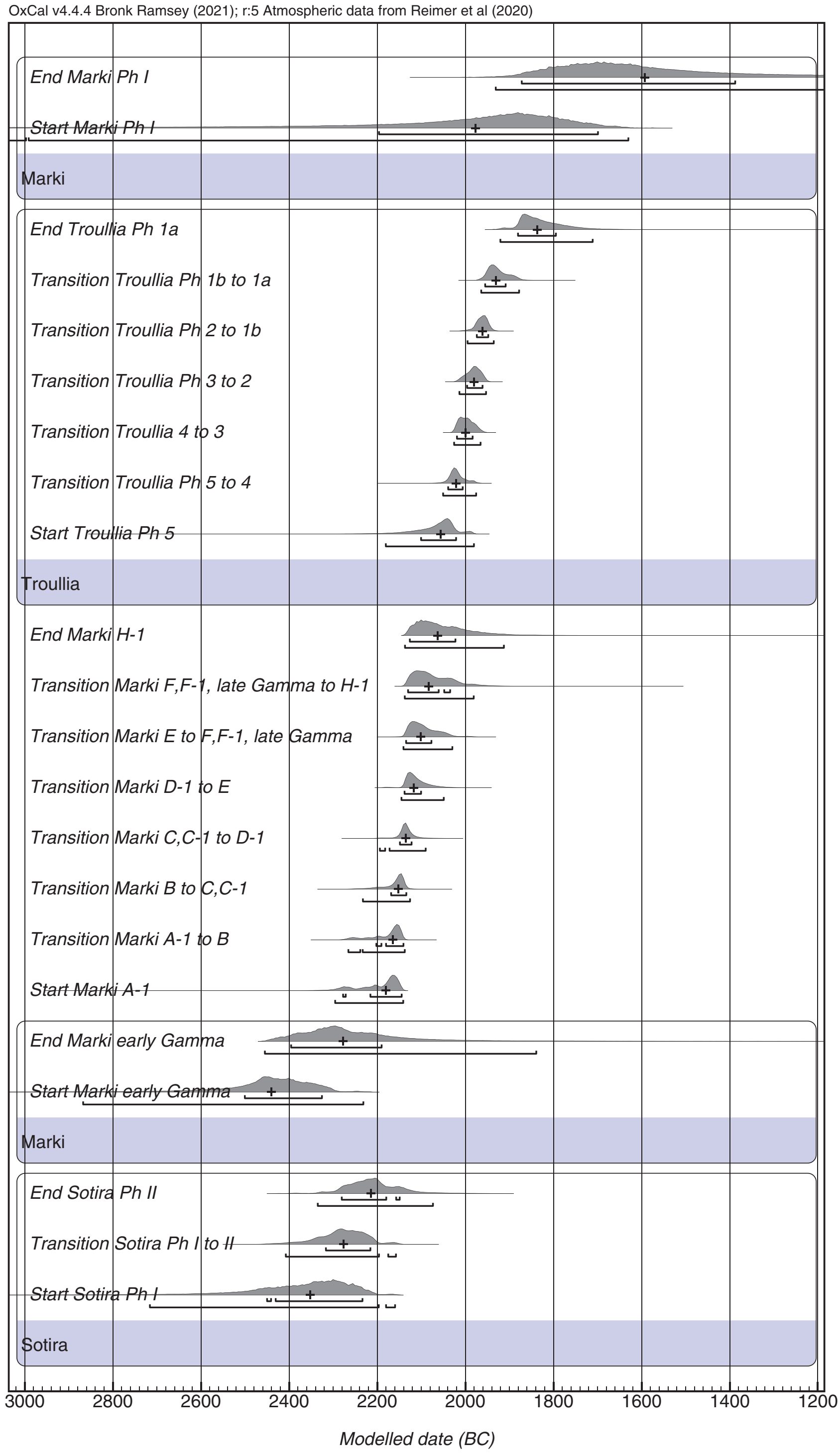

Figure 7 Bayesian sequencing of phase boundaries based on calibrated radiocarbon ages for seed and charcoal samples from Sotira *Kaminoudhia*, Marki *Alonia* and Politiko-*Troullia*, Cyprus; $A_{model} = 182.5$. The dark curves indicate modeled calibration distributions. Calibrations and Bayesian modeling based on OxCal 4.4.4 (Bronk Ramsey 2009a) using the IntCal20 atmospheric curve (Reimer et al. 2020; van der Plicht et al. 2020).

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CONCLUSIONS

This study presents Bayesian modeling of 25 calibrated AMS ages from Politiko-*Troullia* as the newest contribution to elucidate a radiocarbon-based chronology for the formative pre-urban Prehistoric Bronze Age of Cyprus. Our modeling estimates the occupation of Politiko-*Troullia* between about 2050 and 1850 cal BCE, from the late Prehistoric Bronze Age 1 through the first half or more of Prehistoric Bronze Age 2. We identify a juncture of major architectural modification at Politiko-*Troullia* (~1980 cal BCE), which was a response to local stream downcutting and may reflect wider environmental change (e.g., due to increased regional precipitation), which provides temporal resolution for the boundary between Prehistoric Bronze Age 1 and 2. The evidence from Politiko-*Troullia* provides improved chronological resolution for the Prehistoric Bronze Age 2 in particular, which was attested previously by small numbers of unstratified charcoal ages from three disparate settlements. Our modeling of six phases of occupation at *Troullia* articulates with other stratified Prehistoric Bronze Age radiocarbon sequences on the island (from Sotira *Kaminoudhia* and Marki *Alonia*) to constitute a multi-site chronology from the late third millennium through the early second millennium cal BCE as a foundation for inferring the late prehistoric social and environmental dynamics of Cyprus.

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AUTHOR CONTRIBUTIONS

Falconer: conceptualization, methodology, investigation, resources, writing—original draft and editing; Ridder: methodology, analysis, visualization, data curation, writing—review and editing; Pilaar Birch: methodology, analysis, investigation, resources, data curation, writing—review and editing; Fall: conceptualization, methodology, investigation, resources, writing—original draft and editing.

DECLARATION OF COMPETING INTERESTS

The authors declare no conflicts or competing interests.

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SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/RDC.2022.99

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