RADIOCARBON, Vol 53, Nr 3, 2011, p 461–478

SYSTEMATIC ^{14}C DATING OF A UNIQUE EARLY AND MIDDLE BRONZE AGE CEMETERY AT XEROPIGADO KOILADAS, WEST MACEDONIA, GREECE

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ABSTRACT. Systematic radiocarbon dating was performed on a unique EBA-MBA cemetery at Xeropigado Koiladas situated at the edge of the Kitrini Limni basin in the Kozani area, northwest Greece. It was found that this cemetery had a particularly long period of use of ~700 yr (between about 2420 and 1730 BC), which is especially pronounced if compared with the relatively small number of burials totaling 222. The dating revealed no spatial differentiation with time; the entire area of the cemetery was used throughout the time. There is a tendency of the dates to concentrate mostly in the time ranges 2200–2030 and 2000–1850 BC, which may tentatively suggest a more intense use of the cemetery during these periods. The results from multiple or consequent burials revealed that this cemetery was a landmark visible to the people of that time for at least 500 yr, if not for the entire period of its use. Some of the graves were built on top of, or adjacent to, older ones without disturbing the old burials. This implies that the Xeropigado cemetery was an important place of reference for at least 25 generations! No settlements have been found yet in the area that could be associated with the Xeropigado cemetery. Some synchronizations with various other sites in west Macedonia, for which ^{14}C dates are available, are presented.

INTRODUCTION

The site of Xeropigado Koiladas is situated at the edge of the Kitrini Limni (Yellow Lake) basin in the Kozani area, northwest Greece (Figure 1). The basin was densely populated during the Late Neolithic, but during the Final Neolithic a population decrease was already evident (Andreou et al. 2001; Hondroyianni-Metoki 2009a; Karamitrou-Mentesidi, in press; Ziota et al., in press). During the excavations at Xeropigado Koiladas, which took place before the construction of the Egnatia highway joining the Greek-Turkish border on the east with the Ionian Sea on the west (Figure 1), an organized cemetery of the Bronze Age was brought to light. The cemetery covered a 1500-m^2 area and consisted of 214 graves (examples of which are shown in Figures 2–6 and 9), containing the skeletal remains of 222 individuals[1] (Ziota and Triantaphyllou 2004; Ziota 2007, 2010a). A large majority of the graves were surrounded with rows of stones (limestone) (Figure 2). There were also cist graves, either built or shaped with upright rough stones (Figures 3, 4). In addition, there were burials in simple oval-shaped pits and burials in large storage jars, mostly in pithoi or pithos-like vessels (Ziota 2010b) (Figures 5, 6). They were all covered by soil or stone piles.

The practice that was used for most of the dead was interment in a contracted position on their side. The direction depended on the gender: men were placed on their right sides, while women on their left sides. This was systematic at least for the adults. Also, 12 burials contained cremated bones. These were found in vessels (Figure 6), simple pits, small cists, and stone-lined graves. Most of them belonged to subadults. In 2 cases, an interment of an individual and the cremated bones of another individual coexisted in the same grave. No cremation fire places (pyres) were found in the graveyard.

[1]A modern water supply duct running across the southwest part of the cemetery has destroyed a number of graves. However, it is estimated that the number of graves lost is no more than 10 and the original total number of burials should not have exceeded 235.

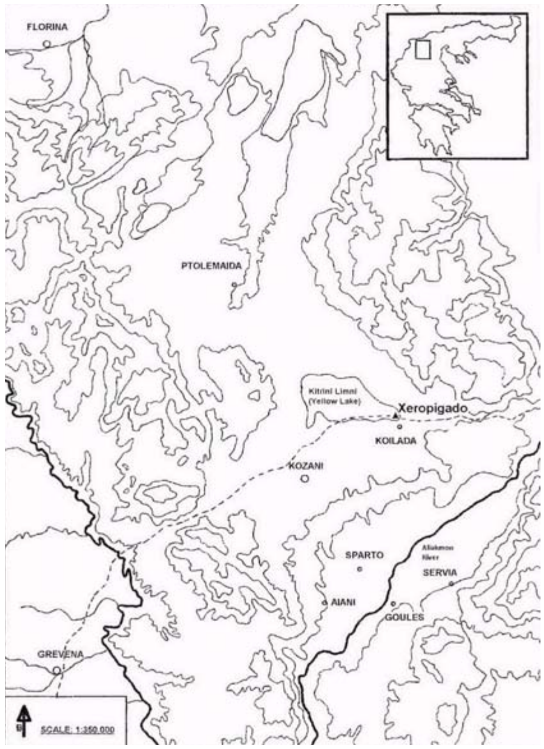

Figure 1 Map of the area of the Xeropigado cemetery. The dash line indicates the new Egnatia highway.

The orientation of the graves and of the bodies inside them is mostly consistent. More than 70% of the undisturbed burials had been placed with their head towards the S or SW. Most of the graves contained a single individual. There were 9 cases of double or triple burials, particularly of infants and children. Even fewer were the cases that contained an older burial, whose bones had been accumulated aside. Most of the undisturbed burials had grave offerings, usually 1 to 3 vessels, placed beside the head of the dead. Common pottery shapes include cups with 1 or 2 handles, or no handles at all, and small jugs (Figures 7, 8). Very few copper, bone, clay, and stone tools accompanied the dead. The pieces of jewelry have been made of the same materials and of silver, gold, and seashells. Of particular interest was the composition of 3 circular earrings made of a rare alloy of silver and gold. One of these objects was analyzed chemically by means of scanning electron microscopy supplemented by energy-dispersive X-ray microanalyzer (SEM-EDXA) and X-ray fluorescence (XRF) analyses at the Laboratory of Archaeometry at NCSR "Demokritos," giving a composition of Ag = 58%, Au = 37%, Cu = 5% (Ziota 2007). As it appears (Tylecote 1979; Craddock 1995), this is not a naturally occurring alloy and it resembles more the composition of the artificially produced *electrum* found in later coinage (600 BC). The naturally occurring *electrum* has a gold content of 70–90%, although in some rare cases the silver content can reach up to almost 50%, but the copper content is always below 1%. Hence, we deduce that this alloy was most likely produced artificially.

The anthropological study showed that all social groups, defined by sex and age, had the opportunity to be buried at the common burial place (Triantaphyllou 2001; Ziota and Triantaphyllou 2004). Both sexes were equally represented and no age category was absent even from the subadult population.

Figure 2 Characteristic stone-lined grave, nr TΛ63

Figure 3 Characteristic cist grave built with stones, nr T144

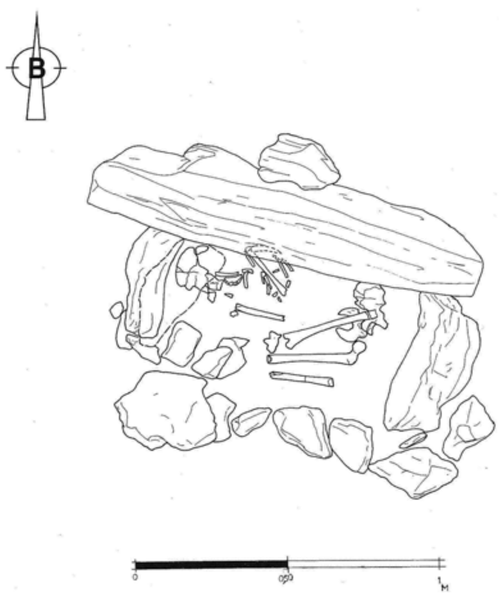

Figure 4 Characteristic cist grave, shaped with upright stones, nr T115.

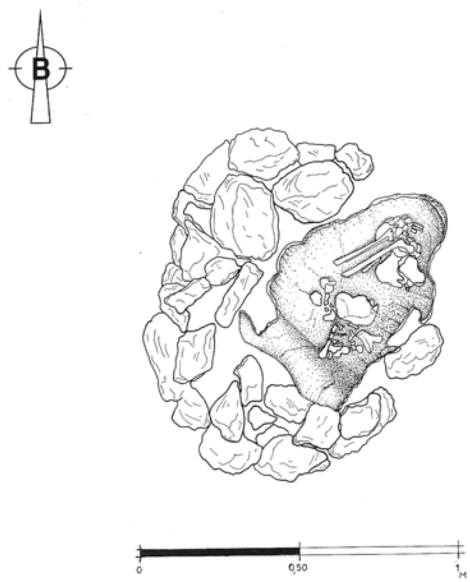

Figure 5 Burial in a pithos (Grave T89) on top of a stone pile (Grave TΛ53).

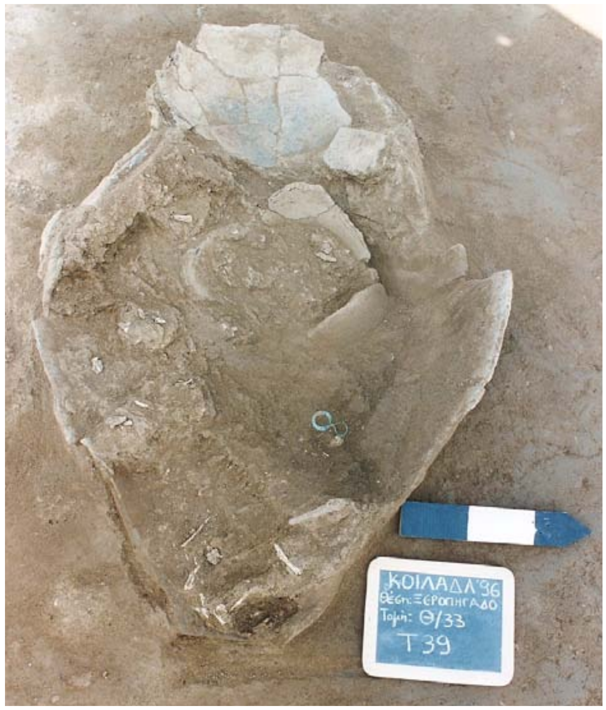

Figure 6 Grave T39: cremated bones and a copper earring in a pithos

Figure 7 Pottery offerings: small jugs

At the last stage of the cemetery configuration, the graves were densely built and expanded horizontally and vertically inside a restricted area, clearly defined, although there were no natural or artificial boundaries preserved (Figure 13). The top of the stone piles, which covered 35.5% of the graves, was certainly visible and it is very likely that small stone circles were also used as additional markers. A curvilinear construction made of small stones in the NE part of the graveyard, associated with a group of at least 15 vessels, was probably meant for some kind of ritual activities.

Apart from the few multiple burials, there were more associations of the dead evident at Xeropigado, as indicated by the fact that 26 graves were found built on top, or very close to 20 older ones, without disturbing the earlier burials (Figures 5, 9). These formed small groups of 2 or 3 individual

Figure 8 Pottery offerings: 2-handled cups

burials, for which based on the stratigraphy we can infer their exact chronological sequence. This finding shows clearly a deliberate action of burying people that had some sort of connection among them in assemblage. These were actually the only cases in the cemetery in which the chronological sequence of the burials was known, and therefore a selected set of their bone samples was submitted for radiocarbon dating in order to define their chronological differences.

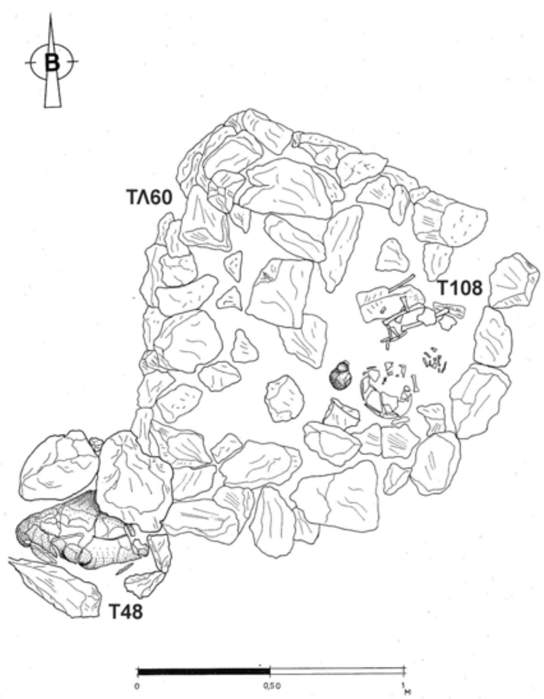

Figure 9 Successive burials: graves TΛ60, T48, and T108

On the whole, there is lack of evidence that would allow to establish an internal chronological sequence and place the graves to specific cultural phases, and which in turn is not only due to the limitations of the pottery typology at Xeropigado, but mostly to the overall weakness of the pottery of this period to be used as a means of establishing specific cultural stages.

In this paper, we therefore use the ^{14}C dating technique to establish in absolute age terms the overall period of use of the Xeropigado cemetery, its potential spatial expansion through time, the time gaps in between multiple burials found at the same location, and to attempt synchronizations with other known EBA/MBA sites in the general geographic area.

SAMPLES AND EXPERIMENTAL TECHNIQUES

The bone samples chosen for ^{14}C dating had to belong to well-preserved skeletons in order to ensure good quality of material for dating. This inevitably excluded the subadult individuals, whose bones were not that well preserved. The samples came from 9 male and 8 female burials that were found at different parts of the cemetery and in graves of different types. Some of them contained grave offerings, while others not. A particular effort was made for the sampling to cover uniformly the whole area of the cemetery. However, the exclusion of the badly preserved bones of subadults, whose burials were concentrated in certain areas of the cemetery, may have influenced to a certain extent the absolute uniformity of the sample distribution.

All samples were chemically pretreated to extract the collagen and remove any carbon compounds of nonarchaeological origin (Olsson 1979; Mook and Streurman 1983) by using the standard acid-base-acid (ABA) treatment. In particular, the preparation of the bone samples involved the following stages: The bone was broken in approximately equal size pieces, roughly 2 cm long. The spongy bone and any encrustations were removed with a lancet. The samples were then washed with deionized water and put in an ultrasonic bath to remove soil or dirt precipitations. They were then placed in a 0.6N HCl acid solution at 5 °C and the acid changed frequently until complete demineralization. This process usually takes weeks. The soft collagen was then transferred into a base solution (0.5% KOH) at 5 °C, which was changed daily until the solution was clear and then put in acid again (0.6N HCl) at 5 °C overnight. Following that, the samples were neutralized and placed in a copper disk in a drying oven at 90 °C and gelatinized.

The dry samples were then combusted using the de Vries-type continuous combustion system (de Vries and Barendsen 1953; Münnich 1957; Nydal 1983) and converted to CO_2. All the other oxides were removed by reaction with $KMnO_4$ and the CO_2 was precipitated to calcium carbonate in a $CaCl_2/NH_4$ solution. Consequently, the samples were turned again into CO_2 by treatment with HCl acid. At the final purification step, the impurities of the gas were removed by passing the sample through a column filled with activated charcoal kept at 0 °C (Kromer and Münnich 1992). Finally, the mass of every sample was adjusted to a fixed amount and then measured in the counters.

The ^{14}C measuring system consists of a series of copper cylindrical gas proportional counters, with capacities of 4 and 3 L. The counters are surrounded by continuous-flow (Ar + 10% CH_4) guard counters, which monitor all incoming environmental radiation and separate it electronically from the actual sample counts by an anticoincidence system. The samples are alternated every few days between the different counters and measured repeatedly. In this way, the accuracy and reliability of the results are ensured.

RESULTS AND DISCUSSION

The ^{14}C dating results are given in Table 1, together with their excavational information, and the number of the grave from which they come. In addition, the sex and age of each individual burial is given to the best possible approximation. Concerning the $\delta^{13}C$ values, it should be noted that due to technical reasons during the measurement of this set of samples, it was not possible to measure the ^{13}C content for 8 of the 17 samples. We therefore had to select a mean $\delta^{13}C$ value for the correction of the ^{14}C dates of the nonmeasured samples. For this, we used the following available scientific information: The $\delta^{13}C$ values of the 9 measured samples ranged from –20.2‰ to –19.2‰ (Table 1), a rather narrow distribution considering that the measured samples cover the whole span of ^{14}C dates and a random variety of sex and age. Apart from these samples, independent measurements for dietary purposes using stable isotope analysis have been performed on 54 individuals from the same cemetery, covering all sexes and ages. The results of these studies are awaiting publication (Triantaphyllou 2010; Triantaphyllou, in press), but Dr S Triantaphyllou kindly let us have the $\delta^{13}C$ values of the whole set of measurements, which evidently range from –20.3‰ to –18.9‰. This range, representing statistically the whole population of the cemetery, is just slightly wider than the range of our measured samples. In order to check the compatibility of these independent stable isotope measurements with our own ^{13}C measurements, we compared 1 pair of samples taken from the same skeleton and coincidentally measured by both parties. The values were the same within 0.04‰. We can therefore safely use the $\delta^{13}C$ values of the independently measured 54 calculations in order to obtain a representative mean value. Thus, taken all together (the values of our measured samples and those measured independently, a total of 63 samples), they give a mean $\delta^{13}C$ value of –19.7‰ with a standard deviation of ±0.3‰. This mean value covering practically the entire population of the cemetery is obviously the best approximation to be used for the ^{13}C correction of the ^{14}C dates of the nonmeasured samples. In addition, by allowing an uncertainly to this value of ±0.8‰, calculated to cover the entire range of values (–20.3‰ to –18.9‰) and even more, we make sure that every probable isotopic fractionation of the dated samples whose $\delta^{13}C$ value was not measured is absolutely covered. Therefore, the mean value of –19.7 ± 0.8‰ was used for correcting the dates of the nonmeasured samples (denoted with an asterisk in Table 1). The error induced to the ^{14}C date by the anticipated extreme variation of ±0.8‰ is approximately 13 yr and hence, the overall error in the ^{14}C age was calculated from the known equation of summing errors:

$$\sigma_{final} = \sqrt{\sigma_{14C}^{\ 2} + \sigma_{13C}^{\ 2}}$$

The calibration of the ^{14}C ages was performed using the software CALIB Rev. 6.0.1 (Stuiver and Reimer 1993) with the latest calibration data set IntCal09 (Reimer et al. 2009). Both uncertainty ranges of the calibrated dates, corresponding to 1 and 2 standard deviations (probability 68.3% and 95.4% respectively) are given in Table 1. For the statistical treatment of the results, the program OxCal v 4.1.5 (Bronk Ramsey 2009, 2010) was used.

Duration of Use

In order to obtain statistically sound information for the beginning, the end, and the periods of most frequent use of the Xeropigado cemetery, we used an OxCal model that contains `Boundaries`, and the `First`, `Last`, and `Sum` functions. The results of this treatment are shown in Figure 10 where the 2σ calibrated and modeled dates of all samples are plotted in a probability distribution diagram.

As there was no archaeological dating information or stratigraphic ordering, the samples in this diagram are plotted according to the ^{14}C age, from older to younger. However, no constraints have been used in the model for the order of samples or phase(s); hence, the statistical analysis treats them all simply as a set of random samples with no ordering.

The model predicts that the beginning of use could be somewhere between 2539 and 2305 cal BC (`Boundary start`) and the end at 1873–1582 cal BC (`Boundary end`) based on dated and undated events (estimated from the distribution of dates). If we examine the probability distribution plots of the 2 boundaries `Start` and `End` (Figures 11, 12), we see that for the `Start` boundary the

Table 1 Radiocarbon dates and archaeological and anthropological information of all samples.

Lab code	Archaeological context	Sex/age	^{14}C age (BP)	δ^{13}C (‰)	Calibrated age (BC)
DEM-713	Trench: Θ33/Θ34 Grave: T45 Depth: 0.15 m	Man/28–32 yr	3588 ± 33	–19.7 ± 0.8[a]	2010–1890 (68.3%) 2030–1880 (95.4%)
DEM-714	Trench: Θ38/I38 Grave: T70 Depth: 0.27 m	Man/30–40 yr	3591 ± 33	–19.7 ± 0.8[a]	2010–1900 (68.3%) 2030–1880 (95.4%)
DEM-785	Trench: I30 Grave: T8 Depth: 0.51 m	Woman?/uncertain	3910 ± 33	–19.8	2470–2340 (68.3%) 2480–2290 (95.4%)
DEM-786	Trench: IΔ30 Grave: TΛ2 Depth: 1.28 m	Woman/24–32 yr	3823 ± 46	–19.7 ± 0.8[a]	2390–2150 (68.3%) 2460–2140 (95.4%)
DEM-810	Trench: Θ33/Θ34 Grave: TΛ42 Depth: 0.91 m	Man?/20–30 yr	3920 ± 33	–19.7 ± 0.8[a]	2480–2340 (68.3%) 2480–2290 (95.4%)
DEM-1168	Trench: Z/H-33/34 Grave: TΛ68 Depth: 0.48 m	Man/18–30 yr	3583 ± 30	–19.8	1980–1890 (68.3%) 2030–1830 (95.4%)
DEM-1169	Trench: Z/H34 Grave: T144 Depth: 0.95 m	Woman?/18–30 yr	3727 ± 33	–19.7 ± 0.8[a]	2200–2040 (68.3%) 2210–2030 (95.4%)
DEM-1171	Trench: IΔ34 Grave: TΛ43 Depth: 0.56 m	Woman?/30–40 yr	3703 ± 33	–19.7 ± 0.8[a]	2140–2030 (68.3%) 2200–1980 (95.4%)
DEM-1183	Trench: IΔ34 Grave: TΛ43 A Depth: 0.82 m	Woman/30–40 yr	3763 ± 30	–20.0	2280–2130 (68.3%) 2290–2040 (95.4%)
DEM-1204	Trench: H33 Grave: TΛ64 Depth: 0.95 m	Man/40–50 yr	3714 ± 33	–19.4	2200–2030 (68.3%) 2210–1980 (95.4%)
DEM-1214	Trench: H33 Grave: TΛ64 A Depth: 0.40 m	Man/18–30 yr	3738 ± 60	–19.8	2270–2030 (68.3%) 2340–1950 (95.4%)
DEM-1215	Trench: IB/IΓ36 Grave: T82 Depth: 0.55 m	Man/24–30 yr	3380 ± 38	–19.7 ± 0.8[a]	1740–1620 (68.3%) 1760–1530 (95.4%)
DEM-1240	Trench: IB/IΓ36 Grave: TΛ58 Depth: 0.82 m	Woman?/20–24 yr	3684 ± 33	–19.7 ± 0.8[a]	2140–2020 (68.3%) 2200–1960 (95.4%)
DEM-1259	Trench: H32/33 Grave: T114 Depth: 0.24 m	Woman?/30–40 yr	3562 ± 30	–19.9	1960–1830 (68.3%) 2020–1770 (95.4%)
DEM-1293	Trench: H32/33 Grave: T116 Depth: 0.47 m	Woman?/28–40 yr	3519 ± 30	–20.2	1890–1770 (68.3%) 1920–1750 (95.4%)
DEM-1327	Trench: I35 Grave: TΛ29 Depth: 0.26 m	Man/24–32 yr	3590 ± 30	–19.7	2010–1890 (68.3%) 2030–1880 (95.4%)
DEM-1328	Trench: I35 Grave: TΛ29 A Depth: 0.87 m	Man/18–30 yr	3605 ± 80	–19.2	2130–1830 (68.3%) 2200–1740 (95.4%)

[a]The δ^{13}C value of these samples was not measured for technical reasons. Instead, we used the average (–19.69 ± 0.8‰) of the measured samples plus 54 samples measured independently (see text for details).

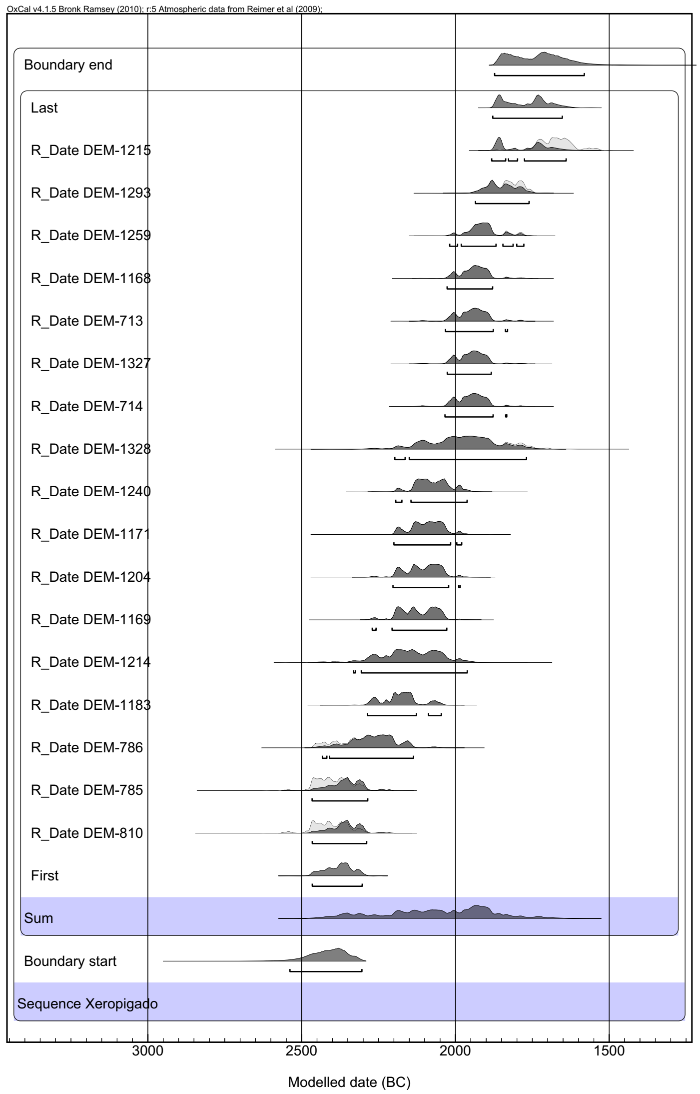

Figure 10 Xeropigado Koiladas: multiplot diagram of 2σ calibrated dates with probability distributions using *Boundaries*, `First`, `Last`, and `Sum` functions. The analysis was performed with OxCal v 4.1.5 (Bronk Ramsey 2009, 2010).

highest probability is accumulated mostly between 2480 and 2340 BC. The date of *2417 ± 63 BC* is given by the analysis as the mean date for the `Start` (Figure 11) and we may take this as the best approximation for the beginning of use of the cemetery. The `End` boundary has a kind of bimodal probability distribution (Figure 12) producing 1 peak between 1870 and 1760 BC and a second peak, with slightly higher probability, between 1760 and 1600 BC. This bimodal distribution is caused by only 1 sample (DEM-1215), which exhibits the youngest date in the whole sequence and from the statistical analysis is found in poor agreement (A = 56.1%) with all the rest in the sequence (A = above 88%). Perhaps, again here we can take the mean date of the distribution *1732 ± 87 BC* (Figure 12) as representing the most probable date for the end of use of the cemetery, however, allowing for a higher error as given by the analysis.

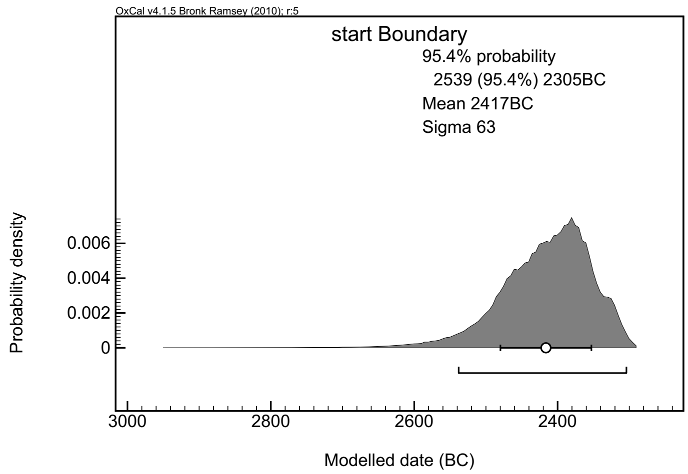

Figure 11 `Start Boundary` from statistical analysis with OxCal v 4.1.5 (Bronk Ramsey 2009, 2010).

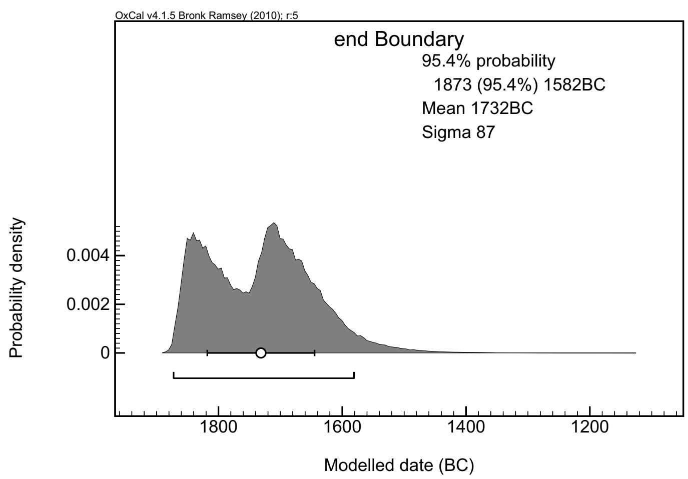

Figure 12 `End Boundary` from statistical analysis with OxCal v 4.1.5 (Bronk Ramsey 2009, 2010).

The above most probable dates for the expected beginning and end of use of the Xeropigado cemetery indicate that this graveyard was used for quite a long period of time, which can be estimated to *685 ± 150 yr.* This duration of use is unusually long for a prehistoric cemetery, especially in relation to the rather small number of burials, which could not exceed by far the 222 individuals that were found in the 214 excavated graves (Ziota and Triantaphyllou 2004; Ziota 2007).

Phases of "More Intense" Use

From the distribution of dates (Figure 10), it can be seen that within this long period of use (~700 yr) there are some specific periods whereby similar burial dates accumulate, indicating perhaps a more intense use of the cemetery in these periods. In order to define these periods more accurately, we used the distribution plot of the function `Sum` (Figure 10). This plot represents the probability density (accumulation) of the modeled dates of all samples. As can be seen from this plot, there is an initial period with a small accumulation of burials approximately in the range 2460–2250 BC. Then, there is a second phase with more burials accumulated in the range 2200–2030 BC, and finally there is a third period with the highest accumulation of burials in the range 2000–1850 BC. The dates of the samples in each of these periods group together and the 1 period follows the other with some intermediate samples. The third period is rather well defined with 5 samples giving practically the same age.

It should be noted that the accumulation of dates in the above periods could be an artifact: a) of the sampling, which although representative had certain deficiencies as discussed earlier; and b) the small number of dated burials (17) out of the total (222) existing in the cemetery. On the other hand, it is striking that about 70% of the dated samples, covering a large area of the cemetery, accumulate in just the second and third of the above periods. Thus, although the evidence is statistically weak, the existence of some phases of more intense use of the cemetery, particularly in the periods 2200–2030 BC and 2000–1850 BC, cannot be excluded.

Geographical Distribution of Dates

Despite the long length of time of use of the cemetery and the possible existence of specific phases of more intense use, there seems to be no geographical differentiation or expansion of the cemetery through time. Figure 13 shows a schematic diagram of all the graves over the whole area of the cemetery and the unmodeled 2σ calibrated dates obtained for each burial. It is clear that there is no preference for using specific sectors of the cemetery at different times. The whole area is used at all times, with the older graves being revisited hundreds of years later and new ones built on top or next to them without disturbing the old ones. This is an astonishing fact, revealed with the ^{14}C dating, and may imply that the whole Xeropigado cemetery was visible and maintained throughout the 7 centuries of its use.

Multiple Burials and Their Time Difference

As discussed earlier, a number of multiple burials were found at Xeropigado in which the newer ones were built very close, or on top of, the older ones, without disturbing the earlier burials; an indication of a conscious ritual continuity and association of the younger generations with the older ones. We sampled 14 individuals from these multiple burials, which form 7 pairs (upper and lower burial). The graves containing these multiple burials together with the 2σ calibrated dates obtained for the upper and lower burial are shown in Figure 13. In a few cases, the lower burials gave much older dates, but in some cases the dates greatly overlap due to shorter time difference and also to higher error bars. In order to get a statistical value for the expected time difference between the upper and lower burials of these pairs we use the function `Difference` with the OxCal v 4.1.5 calibration program. We subtract the date of the upper burial from the date of the lower burial in each case. This returns a probability distribution for the difference in number of years at a 95.4% level and also the mean value of the difference with 1σ error. The results for these 7 pairs of burials are given in Table 2. The extreme differences within 95.4% probability as well as the mean difference and its standard deviation are also given. Positive differences mean that the lower burial is older, while a negative value means the lower burial is younger. As can be seen from Table 2, the upper burials may be later than the lower ones by a mean difference ranging from as high as 460 yr to as low as 18 yr, and there are 2 cases with a negative mean age. The highest difference appears in pair 4 (DEM-713 and -810), showing a mean value of 458 ± 75 yr. In this case, the grave T45 was built on top of the stone pile of grave TΛ42. This means that grave TΛ42 was still visible ~458 yr after its construction, a fact indicating that this cemetery was a landmark and a point of reference for about 14 generations of the people in the area; an astonishing revelation! The same situation holds

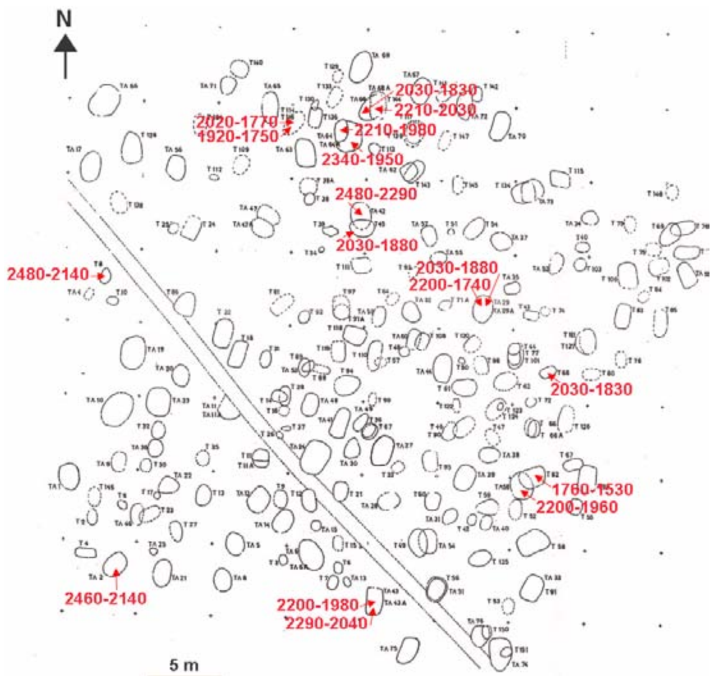

Figure 13 Schematic diagram of all graves of Xeropigado cemetery with 2σ calibrated dates shown for each burial pointed with an arrow.

for pair 1, with the 2 graves being built one on top of the other with a mean difference of 141 ± 80 yr between them and for pair 3, however, with a smaller difference (85 ± 79 yr). In pair 5, grave TΛ68 was built partially on top of grave T144 after about 183 ± 74 yr.

An interesting case is pair 2. The 2 burials are in the same grave, one on top of the other, and separated with a stone layer. Here, the time difference seems to be very small with a mean value of 18 ± 63 yr. The large error, which is due to sample DEM-1328 producing only a small amount of collagen, swings the mean difference also to negative values. However, from the secure stratigraphy it is clear that the upper burial cannot be older that the lower one. We can therefore trim the negative error at –18 yr that would make the mean difference equal to 0, which is the minimum difference accepted, and leave the positive one intact. This would make the probable mean time difference between these 2 burials varying from 0 to 81 yr.

Pair 6 is a difficult case as the upper burial sample gives a slightly older ^{14}C age than the lower one. However, the error of the upper burial date overshoots by far the difference. The mean time difference between the 2 burials is given as –42 yr but with an error of 110 yr, which confuses the issue. The stratigraphy is again very clear in this case. Grave TΛ64A was built on top of the stone pile covering the grave TΛ64. Therefore, the negative difference and hence older age for the upper burial should be excluded. Following the same procedure as in the previous case (pair 2), we deduce that the second (upper) burial was laid 0–68 yr after the first one, indicating again a small time difference between the two.

Finally, pair 7 is quite surprising as the mean time difference as shown in Table 2 has a strong negative value (–68 ± 71 yr). Here the 2 burials, both women, are in the same grave one on top of the other. Excluding the negative values, the positive mean difference can be between 0–3 yr. However, the extreme positive value within 95.4% probability can go up to +88 yr (Table 2) with the extreme negative to –201 yr. The high negative value may be due to a possible small aberration in one of the 2 ^{14}C dates of this particular pair of samples, although they overlap within the error. Taking into account the fact that the mean difference between them remains close to zero, it means that these 2 burials are indeed simultaneous or with a very small time difference. This is reinforced by the fact that they are both in the same grave separated only by a layer of soil, indicating a simultaneous burial or in such close time proximity between the two that there was no need to rearrange the grave or build a new one.

The Cemetery, the Population, and the Settlements

The period around 2500–1850 BC, marking the late EBA and the largest part of the MBA, is still an obscure period in northwestern Greece, with only a few sites discovered and excavated so far (Andreou et al. 2001; Stefani 2002; Ziota 2007; Hondroyianni-Metoki 2009b; Akamatis 2009). The geographic area around the cemetery (Kitrini Limni basin) was densely populated during the Neolithic period (Andreou et al. 2001; Hondroyianni-Metoki 2009a; Karamitrou-Mentesidi, in press; Ziota et al., in press). However, during the EBA/MBA no settlements at all have been found in the area that could be related to the cemetery. This is a surprise considering how persistently and for how long this cemetery was in use. On the other hand, the low number of burials (at the most 235) compared to the length of time (~700 yr) leads to the conclusion that the living population at any given time should have been rather small, although at periods of probable more intense use the number could have increased. One can calculate an average of about 3 burials per decade or about 9 per generation, and in periods of speculative more intense use these numbers can reach 5 per decade or 15 per generation, still remaining small. In order to obtain a rough estimate of the population using the cemetery at any given time, we can use the crude death rate of the whole world for the year 2009 given as 0.837% (http://en.wikipedia.org/wiki/Mortality_rate). This leads to a calculation of a community with about 40 individuals if there are no fluctuations and about 60 individuals in periods of speculative more intense use. Taking into account the fact that the death rate in prehistoric times would have been higher than today, the number of individuals living at any time was probably even smaller than the above calculated figures.

An alternative explanation for the relatively small number of burials compared to its long use could be that this cemetery was used only by certain groups of the whole society and not by the whole population. In this case, there would exist also another or several other cemeteries for the same community. Even if burials took place within the limits of the settlement, in parallel with the use of the cemetery, a practice rather common in this period (Cavanagh and Mee 1998), the number of these burials would have not been large. The possibility for the settlement to be of an inpermanent nature (Stefani 2002) and hence the use of the cemetery periodically cannot be excluded, but at the same time it cannot be documented with sufficient evidence. The existence of small scattered settlements of the MBA, which are difficult to locate, is ascertained in the Aliakmon River valley (Hondroyianni-Metoki 2009b). A possible widespread adoption of such a settlement mode is probably responsible for the relatively small number of settlements that have been found in this period in northwest Greece (Andreou et al. 2001).

A direct comparison of the ^{14}C dates of Xeropigado cemetery with dates of relevant settlements in the vicinity that could have used Xeropigado as a graveyard is therefore not possible. Some comparisons can be made, however, with known settlements in western and central Macedonia in order to provide some synchronizations between cultures and human activities present in northern Greece during that period.

Table 2 Probabilistic differences in 2σ calendar dates for pairs of stratified burials.

Pair	Lab code	Archaeological context	Sex/Age	^{14}C age (BP)	Position	Extreme differences in years of upper from lower burial (95.4%)	Mean difference (yr)
1	DEM-1215	Trench: IB/IΓ36 Grave: T82 Depth: 0.55 m	Man/24–30 yr	3380 ± 38	Upper	–21 to +308	141 ± 80
	DEM-1240	Trench: IB/IΓ36 Grave: TΛ58 Depth: 0.82 m	Woman?/20–24 yr	3684 ± 33	Lower		
2	DEM-1327	Trench: I35 Grave: TΛ29 Depth: 0.26 m	Man/24–32 yr	3590 ± 30	Upper	–116 to +140	18 ± 63
	DEM-1328	Trench: I35 Grave: TΛ29 A Depth: 0.87 m	Man/18–30 yr	3605 ± 80	Lower		
3	DEM-1171	Trench: IΔ34 Grave: TΛ43 Depth: 0.56 m	Woman?/30–40 yr	3703 ± 33	Upper	–71 to +241	85 ± 79
	DEM-1183	Trench: IΔ34 Grave: TΛ43 A Depth: 0.82 m	Woman/30–40 yr	3763 ± 30	Lower		
4	DEM-713	Trench: Θ33/Θ34 Grave: T45 Depth: 0.15 m	Man/28–32 yr	3588 ± 33	Upper	+298 to +605	458 ± 75
	DEM-810	Trench: Θ33/Θ34 Grave: TΛ42 Depth: 0.91 m	Man?/20–30 yr	3920 ± 33	Lower		

Table 2 Probabilistic differences in 2σ calendar dates for pairs of stratified burials. *(Continued)*

Pair	Lab code	Archaeological context	Sex/Age	^{14}C age (BP)	Position	Extreme differences in years of upper from lower burial (95.4%)	Mean difference (yr)
5	DEM-1168	Trench: Z/H-33/34 Grave: TΛ68 Depth: 0.48 m	Man/18–30 yr	3583 ± 30	Upper	+324 to +30	183 ± 74
	DEM-1169	Trench: Z/H34 Grave: T144 Depth: 0.95 m	Woman?/18–30 yr	3727 ± 33	Lower		
6	DEM-1214	Trench: H33 Grave: TΛ64 A Depth: 0.40 m	Man/18–30 yr	3738 ± 60	Upper	–267 to +174	–42 ± 110
	DEM-1204	Trench: H33 Grave: TΛ64 Depth: 0.95 m	Man/40–50 yr	3714 ± 33	Lower		
7	DEM-1259	Trench: H32/33 Grave: T114 Depth: 0.24 m	Woman?/30–40 yr	3562 ± 30	Upper (same grave)	–201 to +88	–68 ± 71
	DEM-1293	Trench: H32/33 Grave: T116 Depth: 0.47 m	Woman?/28–40 yr	3519 ± 30	Lower (Same grave)		

One of the closest settlements to the Xeropigado cemetery that gave a series of ^{14}C dates in the EBA is the site of Servia, some 20 km south of Xeropigado (Figure 1). Servia flourished mainly in Neolithic times, but after a decline it shows activity again in the EBA. The dates of Xeropigado partially overlap with the occupational phase 9 of Servia (2570–1770 BC, corrected BM dates) (Ridley et al. 2000). The prehistoric settlement of Servia is situated in the Aliakmon River valley and it is now submerged in the waters of the artificial lake of Polyfyto. In the same area and at the location of Polemistra near Aiani (Figure 1), relics of a prehistoric settlement were excavated, for which we have only a single ^{14}C date (DEM-555) that gave a 2σ calibrated age of 1968–1765 BC. A few kilometers north of it, at Paliochano near Sparto (Figure 1), a settlement of the same period was investigated, from which another single ^{14}C date (DEM-850) derives, 1880–1746 BC (Hondroyianni-Metoki 2009b). In both sites, isolated burials were found in pithoidal vessels within the limits of the settlements. At another site, Tourla near Goules (Figure 1), a cemetery with 42 burials in pithoi and rectangular cist graves were found (Ziota 2007). Two of them, which were dated with AMS at NSF-Arizona (AA-58172 and AA-58174), gave 2σ calibrated ages of 2140–1770 and 1960–1680 BC, respectively. The settlement to which this cemetery most probably belongs has been found but not excavated.

Another site of that period is Archontiko, a tell site near the city of Yannitsa, which was dated systematically with ^{14}C (Papadopoulou et al., in press) at our laboratory. The main occupational phases of Archontiko (B-IV and B-III) associated also with an intense building activity at the site, date in the range 2135–2020 BC. This period falls practically in the center of the Xeropigado distribution of dates. In addition, the occupational phase B-II of Archontiko, dating to 1980–1890 BC, is apparently cotemporal with the range of 2000–1850 BC of the Xeropigado cemetery in which an increased number of burials is observed. Furthermore, the period of 2000–1850 BC of the Xeropigado cemetery synchronizes with the highest concentration of ^{14}C dates (2250–1900 BC), and hence intense occupational activity, at Mesimeriani Toumba, also a tell site, at Trilofo of Thessaloniki, central Macedonia (Maniatis 2002).

Finally, it seems that the early part of the Xeropigado cemetery burials (2450–2030 BC) is cotemporal with a fair number of burials of the Pella prehistoric cemetery discovered inside the ancient city of Pella (Akamatis 2009)[2], the capital of the Macedonian Kingdom in central Macedonia. The ^{14}C dating of this cemetery is still in progress at the Laboratory of Archaeometry of NCSR "Demokritos."

CONCLUSIONS

The systematic ^{14}C dating work of the Koilada Xeropigado cemetery provided an absolute time range of its use and proved that it was an important and unique, in many aspects, prehistoric burial place in the Kozani area. It was shown that the period of its use covers the later phase of the Early Bronze Age and the Middle Bronze Age, periods that are not so well documented in terms of human culture and activity in northern Greece. In particular, the beginning of use of the cemetery was determined at 2417 ± 63 BC, while the end of its use and abandonment was determined at 1732 ± 87 BC. This defines a period of use of ~700 yr; a very long period indeed, especially if compared with the relatively small number of burials, no more than 235 in total. This indicates an average rate of about 3 burials per decade.

[2]The prehistoric cemetery of Pella was discovered under the ruins of Classical buildings inside the ancient city and covers a rather large area. It was excavated by Professor I Akamatis of the Aristotle University of Thessaloniki.

The dates show a nonuniform distribution in time, most of them accumulating in the periods 2200–2030 and 2000–1850 BC. These may reveal tentatively the existence of specific periods of "more intense" use of the cemetery, although the statistics are very weak. Furthermore, the dating revealed no spatial differentiation of the cemetery through time. The whole area was used throughout the entire period of 700 yr.

In addition, from the treatment of the dates from consequent burials in combination with the archaeological evidence, it was revealed that this cemetery was a landmark and visible to the people of that time for at least 500 yr, if not for the entire period of its use. This implies that the Xeropigado cemetery was an important place of reference for at least 25 generations (!), for the communities living permanently or temporarily in the area.

Settlements in the area of the community who could have used the Xeropigado cemetery for such a long time have not been found yet and the limited finds have not been systematically ^{14}C dated. Thus, the Xeropigado cemetery, now documented chronologically with ^{14}C, is seeking its associated settlement. It is likely that this settlement may have been a small flat occupation, from which no surface evidence have survived, or which still remains covered by modern sediments. In spite of that, and of the nature of that occupation, whether being a distinct occupational landmark or not by itself, the visibility, the stability, and the longevity in the use of the Xeropigado cemetery indicates that the cemetery had a particular significance for the cohesion of the social group associated to it and for the expression of its identity.

Future excavations and systematic ^{14}C dating combined with archaeological research is needed in order to reveal the human activity in the area and the customs of the society that were associated traditionally with the Xeropigado cemetery for such a long time.

ACKNOWLEDGMENTS

We would like to thank Dr Bernd Kromer head of the Radiocarbon Laboratory, Heidelberg Academy of Science, for continued help and advice with ^{14}C laboratory practices. We would also like to thank sincerely Dr Sevi Triantaphyllou, lecturer at Aristotle University of Thessaloniki, for giving us access to her isotopic $\delta^{13}C$ data series, under publication, of human bone collagen for a number of burials from Xeropigado cemetery.

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