

## **<sup>14</sup>C DATING OF A FINAL NEOLITHIC-EARLY BRONZE AGE TRANSITION PERIOD SETTLEMENT AT AGHIOS IOANNIS ON THASSOS (NORTH AEGEAN)**

Y Maniatis

Laboratory of Archaeometry, Institute of Materials Science, NCSR “Demokritos,” 15310 Aghia Paraskevi, Attiki, Greece.  
Corresponding author. Email: maniatis@ims.demokritos.gr.

S Papadopoulos

18th Ephoreia of Prehistoric and Classical Antiquities, Ministry of Culture, 17 Erythrou Stavrou, 65110 Kavala, Greece.

**ABSTRACT.** The transitional period known as the Final Neolithic-Early Bronze Age in Greece, falling in terms of absolute dates within the 4th millennium BC, is an obscure and enigmatic period. Few sites in northern Greece or the southern Balkans have produced evidence of 4th millennium BC occupation, and the sites that do are mainly concentrated in the last third of the 4th millennium toward the beginning of the EBA. This paper presents archaeological evidence and radiocarbon dates from a site that covers part of the gap, Aghios Ioannis on Thassos, the northernmost Aegean island. It is a coastal site of seasonal occupation and most probably depended on organized animal husbandry plus hunting and fishing activities. From the first excavations in 1996, there was evidence that the site was occupied during the Final Neolithic to the beginning of the Early Bronze Age. The <sup>14</sup>C dates obtained fall towards the end of the 4th millennium if not closer to the middle. The presence of human activity in this last part of the 4th millennium “gap” on Thassos is by itself an interesting discovery that enlarges our knowledge for this obscure period and is of environmental and cultural significance.

### **INTRODUCTION**

The natural bay of Aghios Ioannis is situated in the southeastern part of Thassos, a Greek island in the north Aegean Sea (Figure 1). Baker-Penoyre (1909) found the remains of 2 towers on the hills that form the natural limits of the bay. Bon (1930) repeated Baker-Penoyre’s description, pointing out that the isolation of what Bon had believed to be an uninhabited site made the presence of these defensive structures difficult to explain.

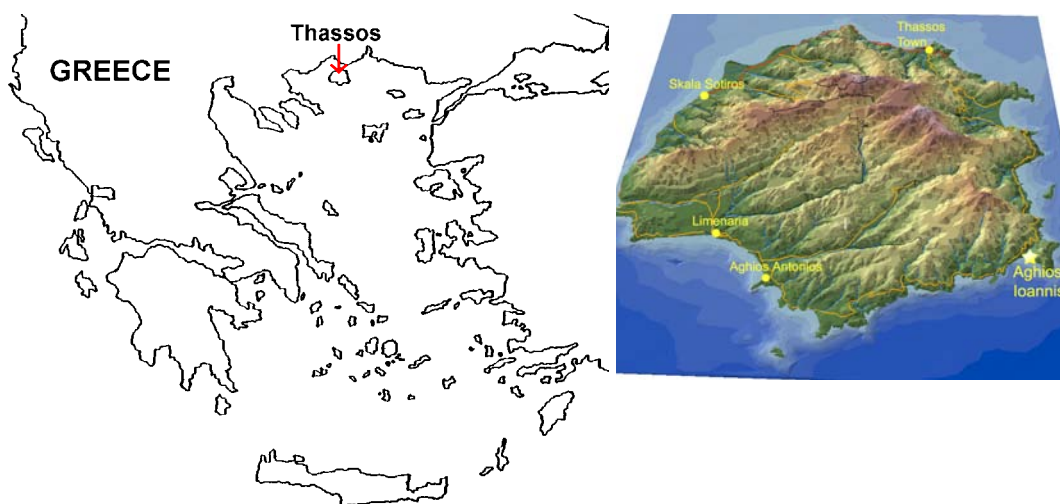


Figure 1 The Aegean Sea and the island of Thassos with the location of Aghios Ioannis site indicated in the southeast bay

A small excavation undertaken by the 18th Ephoreia of Prehistoric and Classical Antiquities at the easternmost edge of the bay (Poulios 1983) brought to light building remains of the Late Roman period, which gave the impression of a small impermanent settlement. A second excavation period at the western part of the bay (Papadopoulos 1998) recovered a large building complex dated to the

second half of the 6th century AD. A large olive-press revealed the identity of the building as an oil-producing installation (Figure 2).



Figure 2 Photo of the Aghios Ioannis bay with the location of the prehistoric settlement and the ruins of later installations.

Handmade prehistoric pottery, not previously known in Thassos, was found at a range of 100 m around the Late Roman oil factory. Ten excavation trenches (5 m<sup>2</sup>) were dug at the areas where the pottery collected appeared in larger quantity and here a settlement consisting of structures made of perishable material was uncovered (Papadopoulos et al. 2001).

Possible stone basements of 2 huts were the only potential indication of the presence of buildings made of perishable materials and unpreserved super structure. Hearths and ovens with clay and pebbled floors on a substructure of flat stones (Figure 3), huge circular slabs of unknown use, stone-built benches, a few storage or trash pits, and clay floors existed outside the huts. It is interesting to note that the majority of these features were contained in an area of ~50 m<sup>2</sup>. The structures were not necessarily all contemporary and seemed to have served multiple household activities. Mortars and pestles, cooking and storage vessels, and a large quantity of spindle-whorls were found in the same area. Many clay loom weights recovered lying next to the spindle-whorls undoubtedly indicate the use of a loom here. The combined evidence pointed to the existence of an outdoor space where people were engaged in cooking and weaving.

The chipped stone tools consist of a small number of quartz and flint flakes. A needle and 2 pendants, one in the shape of an axe, were the only copper artifacts. The pottery used by this community merits discussion in detail because thus far it is the only well-represented category of material. It is a dark pottery, of coarse or medium fabric, made of clay rich in quartz inclusions. The surface treatment is elementary, simply smoothing and rarely burnishing, even in the cases of the decorated pots. Macroscopic examination shows that we are dealing with a pottery baked in an open fire with the firing conditions not fully controlled.



Figure 3 Area with remains of ovens and/or hearths

The shape repertory is restricted. It consists almost exclusively of vessels for everyday use: open bowls, cups, cooking vessels, storage jugs, small spoons, and miniature vases (Figure 4). The percentage of decorated pots is small. The most common ware is a group of vases decorated with a series of cavities or impressions under the rim or on the belly, between the handles. Shallow grooving on the body, often combined with series of cavities, is present as well (Figure 5).

Conical bowls with upright lugs form a special pottery ware, which may have combined practical use with a more complicated function. These bowls have occasionally burnished surfaces and are equipped with simple or pierced lugs, which rise above the rim (Figure 6). They are always decorated with shallow grooves in particular patterns: circles under the lugs and groups of concentric semicircles under the rim. The decoration covers both the inside and the outside of the vessel. A few storage vessels, mostly 2-handled jugs, are sometimes decorated with relief bands. Long, straight, or concave tunnel lugs set on or just below the rim are also a common element among the ceramic material. Most of these features date the settlement of Aghios Ioannis to the transition period of the Final Neolithic (FN) to the Early Bronze Age (EBA) and the earliest phase of the EBA in the Aegean. They also indicate the relationship of this site with a series of settlements, from the Balkans to south Greece and the Aegean: Sitagroi III and IV (Evans 1986:402; Sherratt 1986:435), Katarraktes Cave (Poulaki-Pandermali et al. 2004:67), Petromagoula in Thessaly (Chatziangelakis 1984: Figure 4; Andreou et al. 2001:270), Eutresis II–III (Caskey and Caskey 1960: plates 45–47), the Grotta-Pelos culture in Cyclades (Renfrew 1972: Figure 10.1), the Athenian Agora (Immerwahr 1971: plate 6), and many sites in the Balkans (Johnson 1999:325).

The restricted spread of the surface pottery indicates that the community was rather small. The duration of the life of the community must also have been short as proven by the limited and non-phased stratigraphic record. The site must have been settled because it offered a rich pastureland and the possibility for fishing and hunting. The impressive number of spindle-whorls and some pigment found amongst the clay structures proves the intensive concentration of the inhabitants on weaving and fabric coloring.

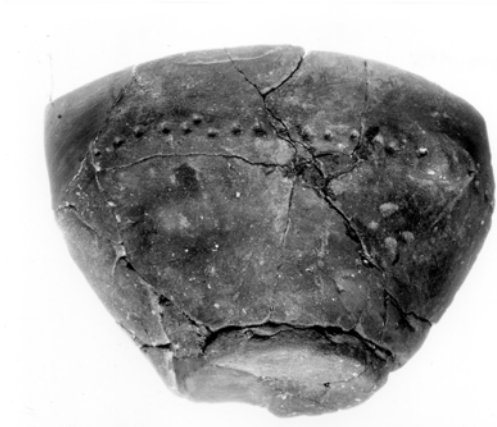


Figure 4 Open bowls found at the site

Figure 5 Open bowls with shallow grooving

The absence of expanded remains of habitation in permanent materials, the scarce presence of trash pits and storage containers, and the small number of tool implements of quartz are crucial indications that the settlement at Aghios Ioannis was likely only part-time or seasonal. The area could not be inhabited for long periods during the year. A comparable seasonal habitation closely linked with transhumant flocks and partially with fishing takes place in this site even today.

In absolute dating terms, the transitional period (FN-EBA) in which the settlement of Aghios Ioannis seems to fall, according to pottery typology, is defined within the 4th millennium BC. However, the number of absolute dates in this period is surprisingly small and problematic (e.g. Manning 1995:161–2, 168–70, Figures 6a–c) and so are the cultural remains and settlements, making this era obscure and enigmatic but at the same time interesting and challenging.

In the last decades, there is increased evidence (Renfrew 1986; Maniatis and Kromer 1990; Johnson 1999; Andreou et al. 2001) showing a possible gap in human occupation during the 4th millennium BC in north Greece and the Balkans. The exact length of time of this gap, in some instances stretching to 1000 yr, and its geographic extent is a matter of growing investigation, as well as the reasons that caused the abandonment of the sites in this region.

For the last several years, the Laboratory of Archaeometry of NCSR “Demokritos” has collected evidence through radiocarbon dating for this period (around the 4th millennium BC) in north Greece, but also in central and south Greece in order to define the occupation gap spatially and temporarily. This data shows that the gap is geographically well spread from west Macedonia to Thrace; its length, however, may vary from site to site from 1000 to 700 yr.



Figure 6 Bowls with simple and pierced lugs

The aim of this particular work is to investigate chronologically, using <sup>14</sup>C dating, the settlement of Aghios Ioannis in south Thassos, north Aegean, which according to the archaeological evidence was occupied during the FN-EBA transition period. The aim is also to accumulate more absolute dating evidence for the period in question, especially in northern Greece.

#### **MATERIALS AND TECHNIQUES**

Eight samples (5 charcoal and 3 animal bones) from different layers from the excavation at the site of Aghios Ioannis in Thassos were dated by <sup>14</sup>C at the Laboratory of Archaeometry, NCSR “Demokritos,” Greece, using the gas (CO<sub>2</sub>) counting technique in proportional counters. All samples were chemically pretreated to remove any carbon compounds of non-archaeological origin (Olson 1979; Mook and Streurman 1983) using the standard acid-base-acid treatment.

#### **Charcoal Samples**

After a mechanical cleaning, during which all obvious non-charcoal particles were removed from the sample, and a light grinding of the charcoal to smaller particles, the samples were put into a 4% solution of HCl acid at 80 °C and stirred well for at least 30 min and as long as it necessary to dilute any carbonates from the soil present. The samples were then transferred to 4% NaOH solution, stirred well, and left overnight at room temperature. Following that, the samples were put again in

an acid solution of 4% HCl at 80 °C and stirred for more than an hour. They were then neutralized with deionized water and dried in a dryer oven at 90 °C.

### **Bone Samples**

The bone was broken into approximately equal size pieces, ~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. Samples were then placed in an 0.6N HCl acid solution at 5 °C and the acid changed frequently until complete demineralization. This process may take 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) 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 combusted using a de Vries-type continuous combustion system (de Vries and Barendsen 1953; Münnich 1957; Nydal 1983) and converted to CO<sub>2</sub>. All the other oxides were removed by reaction with KMnO<sub>4</sub> and the CO<sub>2</sub> was precipitated to calcium carbonate in a CaCl<sub>2</sub>/NH<sub>4</sub> solution. Consequently, the samples were turned again into CO<sub>2</sub> by treatment with HCl acid. In 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 <sup>14</sup>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<sub>4</sub>) 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, ensuring the accuracy and reliability of the results.

## **RESULTS AND DISCUSSION**

The dating results of all samples are shown in Table 1. It should be noted that due to a technical problem during the dating of this particular set of samples, it was not possible to measure the <sup>13</sup>C content. For this reason, mean values for δ<sup>13</sup>C were used for correcting the <sup>14</sup>C results. In choosing the best mean values, we considered the following evidence:

1. Regarding the bone samples, our laboratory has dated a number of animal bones from archaeological sites all over Greece within the period 6000–3000 BP whose δ<sup>13</sup>C values were measured. This data consists of 45 samples, a large number of which come from sites in north Greece including the island of Thassos. In particular, several samples come from the EBA site of Skala Sotiros (Koukouli-Chryssanthaki et al., in press) and the Neolithic/EBA site of Limenaria, both on Thassos (Figure 1). Several other samples come from a range of prehistoric sites in west and east Macedonia and the island of Samothrace in the northeast Aegean. Finally, a number of samples come from Thessaly and south Greece. These 45 animal bone samples give a mean value of δ<sup>13</sup>C = -19.88 ± 0.84‰ (1 σ) with extreme maximum and minimum values of -17.02‰ and -21.75‰ exhibited by a couple of samples. In addition, there is bibliographic evidence for δ<sup>13</sup>C values of herbivore animal bones in Greece (Triantaphyllou et al. 2008; Petroutsa and Manolis 2010) ranging from -18.9 to -21.5‰, values that are included fully in the range of those measured in our laboratory. Furthermore, Polach (1976) and Stuiver and Polach (1977) quote a typical value for herbivore animals worldwide of δ<sup>13</sup>C = -20.0 ± 2‰, which is again within the range of values obtained in our laboratory. Taking all the above into



Table 1 Dating results of the Aghios Ioannis samples.

Lab code	Description	Material	<sup>14</sup> C date (BP)	δ <sup>13</sup> C <sup>a</sup> (‰)	Calibrated date (BC/AD)
DEM-848	Excav. Unit: 30 Section I, Trench ΓB, Layer 3, Sq. B-E/0-3 Depth: 1.84 m	Charcoal	4816 ± 51	-24.53 ± 2.5	3655–3525 BC (68.3%) 3705–3380 BC (95.4%)
DEM-849	Excav. Unit: 36 Section I, Trench ΓB, Layer 9, Sq. B-Γ/2-3 Depth: 1.80 m (NE of segment K2)	Charcoal	4598 ± 117	-24.53 ± 2.5	3520–3100 BC (68.3%) 3640–2940 BC (95.4%)
DEM-931	Excav. Unit: 8 Section I, Trench ΓΓ, Layer 3, Sq. B-Γ/2-5 Depth: 1.82–1.70m	Animal bones	4113 ± 54	-19.88 ± 2	2860–2580 BC (68.3%) 2880–2495 BC (95.4%)
DEM-932	Excav. Unit: 42 Section I, Trench ΓB, Layer 12, Sq. B-E/0-4 Depth: 1.82–1.62m	Animal bones	4530 ± 43	-19.88 ± 2	3360–3110 BC (68.3%) 3365–3095 BC (95.4%)
DEM-933	Excav. Unit: 38 Section I, Trench ΓB, Layer 11, Sq. A-E/3-5 Depth: 1.78–1.58m	Animal bones	4513 ± 54	-19.88 ± 2	3350–3100 BC (68.3%) 3370–3025 BC (95.4%)
DEM-1071	Excav. Unit: 8 Section I, Trench ΓΓ, Layer 3, Sq. B-Γ/3-4 Depth: 1.82–1.70 m	Charcoal	2185 ± 47	-24.53 ± 2.5	360–180 BC (68.3%) 385–110 BC (95.4%)
DEM-1072	Excav. Unit: 10 Section I, Trench ΓΠ, Layer 4, Sq. B-E/0-1 Depth: 1.28–1.16 m	Charcoal	4563 ± 68	-24.53 ± 2.5	3390–3105 BC (68.3%) 3520–3025 BC (95.4%)
DEM-1288	Excav. Unit: 2 Section II – Well, Layer 2 (Charcoal from inside well) Depth: 1.56–0.19 m	Charcoal	1878 ± 134	-24.53 ± 2.5	40 BC–AD 325 (68.3%) 205 BC–AD 505 (95.4%)

<sup>a</sup>The δ<sup>13</sup>C values are mean values derived from measurements of a large number of animal bone and charcoal samples. The errors are chosen so that they cover even the most extreme values measured (see text).

account, we assume that the mean value of  $-19.88$  with an error of  $\pm 2\%$  ( $>2\sigma$ ), obtained from the animal bone samples dated in our laboratory and covering the region and period of interest, is a fairly good approximation and includes even the most extreme measured values, plus those reported in the literature. This value of  $\delta^{13}\text{C} = -19.88 \pm 2\%$  is therefore used for the correction Aghios Ioannis animal bone dates.

- Regarding the charcoal samples, our laboratory has similarly dated a fair number of archaeological charcoal samples whose  $\delta^{13}\text{C}$  values were measured. This data consists of 160 samples, 48 of which come from prehistoric sites on Thassos and east Macedonia (the mainland opposite Thassos), and cover a very long time period (9000–0 BP). These samples give a mean value of  $\delta^{13}\text{C} = -24.53 \pm 0.998\%$  ( $1\sigma$ ) with extreme maximum and minimum values of  $-21.98\%$  and  $-27.15\%$ , respectively. Concerning the flora species from which these samples originate, it is more than certain that they represent all different kinds of species used for building and fuel, since they come from geographically and temporarily different sites and a variety of materials. These materials are a) big wooden beams used for house walls, floors, and roofs, smaller trunks used for posts and branches of trees used in constructions, all burned in destruction fires; b) charcoal pieces found inside ovens and hearths that most likely come from small tree branches and/or a variety of short-lived species like bushes, hollies, etc. Thus, it seems the above range of  $\delta^{13}\text{C}$  values should be considered fairly representative of charcoal samples in the whole of Greece and particularly in the region of Thassos and the nearby mainland. In order to cover the full range of the above values, we use the mean value of  $-24.53\%$  and allow for an error of  $\pm 2.5\%$ , which is 2.5 times the standard deviation. This increases inevitably the final error in the obtained dates, perhaps even more than it is statistically sound, but it takes into account the remote possibility that some extreme  $\delta^{13}\text{C}$  concentrations maybe present in the Aghios Ioannis charcoal samples.

Therefore, the mean values used to correct the  $^{14}\text{C}$  dates of Aghios Ioannis are  $\delta^{13}\text{C} = -19.88 \pm 2\%$  for the bone samples and  $-24.53 \pm 2.5\%$  for the charcoal samples. Using these values with the indicated errors implies that the final error in the  $^{14}\text{C}$  dates should include an error of  $\pm 32$  and  $\pm 40$  yr for bone and charcoal samples, respectively, in order to account for the estimated maximum variation in  $\delta^{13}\text{C}$  of  $\pm 2\%$  or  $\pm 2.5\%$ . It should be noted that the initial error bands in the  $^{14}\text{C}$  dates were in many instances larger than usual, as the original amount of sample obtained in these cases was much smaller ( $<2$  g of carbon) than the amount necessary (4.5 g of carbon) to produce a full gas sample ( $\sim 8.5$  g of  $\text{CO}_2$ ). Thus, the  $^{14}\text{C}$  measuring error bands exceeded in many cases the errors of  $\pm 32$  or  $\pm 40$  yr possibly imposed by a  $^{13}\text{C}$  variation. However, in all cases we incorporated the possible extra error due to  $^{13}\text{C}$  variation into the final error by using the following known simple rule for summing errors:

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

The final  $^{14}\text{C}$  dates after the  $^{13}\text{C}$  corrections and the combined errors in the dates, calculated from the above equation for each sample, are given in Table 1. These dates and errors are used in the calibration procedure and the following statistical treatment of the results. The calibrated dates given in Table 1 were produced using CALIB 6.0.1 (Stuiver and Reimer 1993; [www.calib.org](http://www.calib.org)) with the IntCal09 data set (Reimer et al. 2009). Both uncertainty ranges, corresponding to 1 and 2 standard deviations (probability 68.3 and 95.4%, respectively) are given.

Figure 7 shows a probability distribution plot of the 2- $\sigma$  calibrated (95.4%) dates of all samples using the program OxCal v 4.1.5 (Bronk Ramsey 2009) and the IntCal09 data set. The samples are ordered according to age from older (lower) to younger (higher). It appears that 2 samples give ages



in the historical era, namely in the Hellenistic/Roman periods, which reflect the later settlements at the site evidenced by the discovery of nearby Roman buildings, as mentioned in the Introduction. In the same diagram, the distribution of the function *Sum* is also plotted, which shows the time periods where most dates accumulate (Bronk Ramsey 2010).

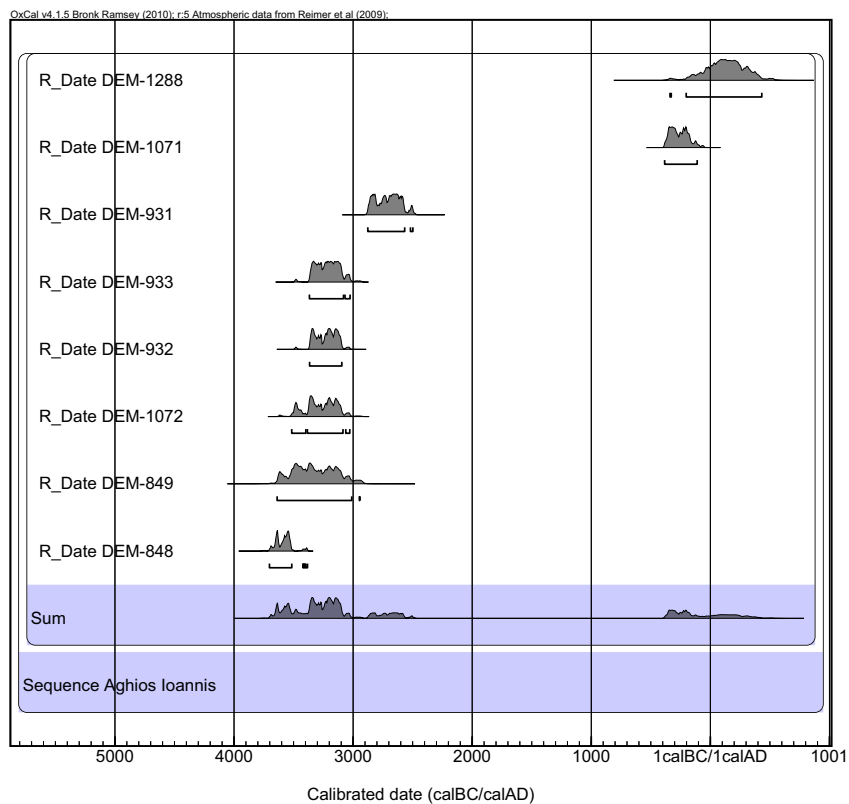


Figure 7 Plot of calibrated 2- $\sigma$  ages plus the *Sum* with probability distributions using the program OxCal v 4.1.5 (Bronk Ramsey 2010) of all dated samples from Aghios Ioannis.

If we focus on the prehistoric period samples, we observe in Figure 7 that there are 5 samples dating within the 4th millennium BC and 1 sample (DEM-931) that dates to the beginning of the 3rd millennium. The latter comes from an open-air space without indications of dense occupation and without presence of other structures. Hence, it probably reflects a later phase and is not connected directly with the other 5 samples dating to the 4th millennium.

### THE FINAL NEOLITHIC/EARLY BRONZE AGE (FN/EBA) TRANSITION PHASE

The 5 samples within the 4th millennium (DEM-848, -849, -1072, -932, -933) are definitively associated with the main occupation level and with the ovens and hearths of the FN/EBA transition period. In particular:

1. DEM-848 and -849 are charcoal samples coming from inside the ovens and hearths and most probably represent the fuel used for cooking;
2. DEM-1072 is also a charcoal sample coming from the surface of a pit in the same area;

3. DEM-932 and -933 are animal bone samples located around the ovens and hearths and were most probably connected with the food cooked inside these structures and consumed around them. There was not much stratigraphic difference (no apparent phasing or other features indicating temporal phases) between these 5 samples except perhaps for the fact that the charcoal samples DEM-848 and -849 were located a few centimeters higher in the stratigraphy of the site. All excavation evidence therefore suggests that this main occupational phase of Aghios Ioannis represented by these 5 samples is a single occupation event in the FN/EBA period confined in a narrow time period in the history of the site.

Yet, the calibrated dates of these 5 samples span from approximately 3700 to 3025 BC, which is far too wide to represent the age span of this monophase occupational event. Considering the nature of the samples, one may argue that the bone samples (DEM-932 and -933), which are shorter lived, should give age estimates more likely to be contemporary with the human occupation of the settlement. However, the charcoal samples connected with ovens or hearths are not normally expected to come from big tree trunks, but rather from bushes or branches that are also short lived. Indeed, the  $^{14}\text{C}$  dates of 4 of the 5 samples (DEM-849, -1072, -932, and -933) consisting of 2 charcoal and 2 bone samples are fully overlapping within the error (Table 1), although the 2 charcoal samples, and especially DEM-849, appear to have rather large error bars due to the small initial amount of available sample. This leaves only 1 sample out of the 5 (DEM-848) that shows a clear shift to a slightly older age. This shift is emphasized in the calibrated dates (Figure 7) by the smaller error of this sample due to a relatively larger initial sample quantity and its position on the calibration curve, avoiding a plateau that exists between 3400 and 3060 BC. Given the fact that this sample comes from a slightly higher level in the stratigraphy, any possible age deviation would be expected to be towards a slightly younger age. Thus, the shift to an older age could reflect either some possible undetected stratigraphic disturbances or an old-wood effect that has affected only this particular sample out of the 3 charcoal samples in this phase. The latter assumption is not unrealistic, although in the clay structures (ovens and hearts) shorter-lived materials such as small branches or bushes are more likely to have been used for fuel, a fact that was affirmed with the other 2 charcoal samples giving similar ages with the bone samples. Nevertheless, one cannot exclude the possibility that small wood pieces cut from a bigger tree were used in this oven or hearth for cooking or for warmth at a certain occasion. Also, there is a possibility that this charcoal sample comes from a construction element, such as a big wooden beam or frame, above or close to the clay structure supporting a possible roof or cover, which was burnt down and pieces of it fell inside the structure.

Whatever the causes for this sample's shift to an older age, its clear deviation from the uniform group behavior of the other 4 samples in this single occupation horizon gives it the characteristics of an outlier. Furthermore, an examination of the accumulated probability distribution of the function *Sum* in Figure 7 shows that within the 4th millennium, the accumulation is highest within about 3380 to 3100 BC, where all samples in this phase, except DEM-848, contribute mostly. Then, the accumulation drops towards higher ages before it rises again above 3400 and until 3700 BC due primarily to the contribution of sample DEM-848. All the above is corroborating evidence that this sample can be considered as an outlier and therefore treated as such.

In an attempt to define better the period of human activity of this single occupational phase within the 4th millennium, we used a statistical analysis model applied only on the samples of this phase. The model used consists of an *outlier - single phase model* without any constraints for the order of samples within the phase and it was suggested to us by Christopher Bronk Ramsey as the most suitable for this case to be used in conjunction with the OxCal program (Bronk Ramsey 2010). The function *Sum* has also been added to this model. Sample DEM-848 is the one assigned as an outlier in this analysis for the reasons discussed above. The output of this model is shown in Figure 8.

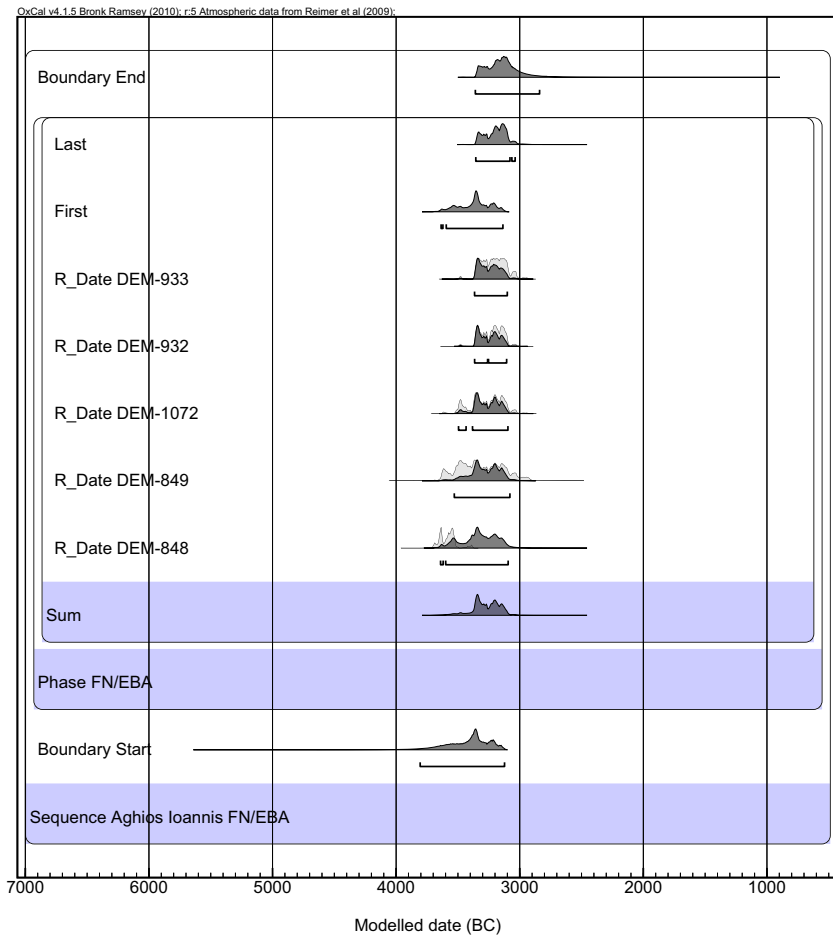


Figure 8 Modeled calibrated 2- $\sigma$  dates for the 5 samples in the main occupation FN/EBA phase (within the 4th millennium) of Aghios Ioannis. The model included 1 outlier (sample DEM-848) and a single phase; analysis performed with OxCal v 4.1.5 (Bronk Ramsey 2010).

Due to the small number of samples and to the large errors involved in the <sup>14</sup>C ages, the model does not give very confined dates for the start and the end of the occupation phase. The boundaries that include not only the dated samples but also probable undated events show very broad ranges. For this reason, we focus our interpretation only on the dated events. If we examine the *Span* function, which gives the probability distribution of the duration of the phase based on the dated samples (Figure 9), we observe that although the whole span for 95.4% probability is 451 yr, the highest probability is accumulated within the first few tens of years, which means there is a high probability all the dated samples represent a single occupation event of very short duration. This is a reassuring result, given the errors involved in the dated samples, and agrees extremely well with the archaeological evidence pointing to a single occupational horizon. However, it is more difficult to define the exact period in calendar years within which this human activity took place. We can use for that the *First* and *Last* functions, which give the modeled first and last dated events. *First* gives a range of 3595–3137 BC, with 94.2% probability, for the start of the occupation, and *Last* gives a range of 3356–3080 BC, with probability 93.1%, for the end. It appears there is a large overlap of the first and last events, making it difficult to determine the start and end date of the occupation precisely .

From the above overlapping ranges, their probability distributions and the fact that we are dealing with a rather short duration of occupation, we may tentatively hypothesize that human activity at the site could have occurred around 3200 BC, but this may be considered only a rough estimate.

In a further attempt to extract a bit more information from the above statistical analysis, in order to confine better the dates for this FN/EBA occupation, we examine the output of the function *Span* (Figure 10). This clearly shows that the highest accumulation of all calibrated dates is between 3380–3080 BC. Furthermore, the modeled dates of the 2 bone samples, which have smaller errors and thus are more likely to give more confined dates for this phase, both give the same date of 3370–3100 BC. This is practically the same with the highest probability accumulation of all samples in the *Span* above. The evidence suggests that there is a very high probability that the time period within which the main occupation of Aghios Ioannis occurred is **3370–3100 BC**. This time range, confining the FN/EBA occupation activity within the last 1/3 of the 4th millennium BC, is the best possible approximation and cannot be narrowed further down, even if we had much smaller error bars, due to the presence of a plateau in this period of the calibration curve.

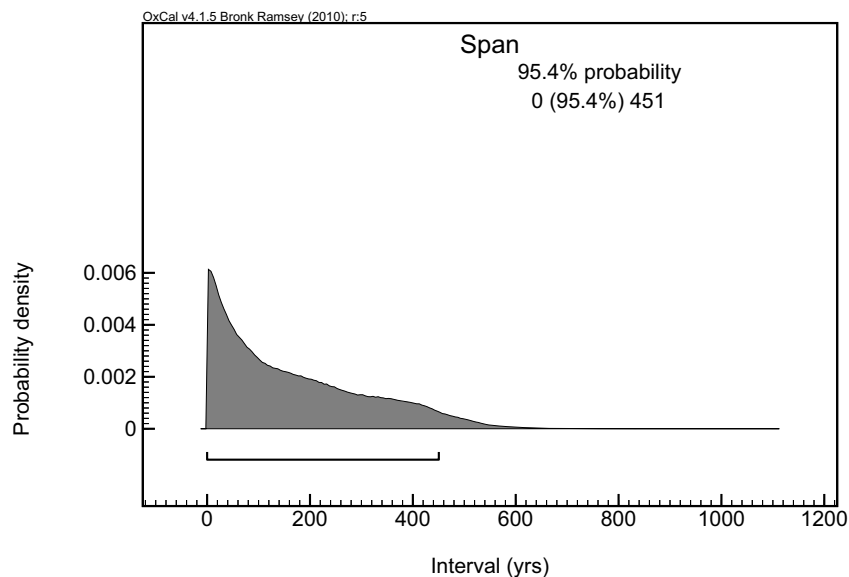


Figure 9 The probability distribution of the function *Span* as resulted from the statistical analysis of the *outlier - single phase* model, shown in Figure 8 and applied on the 5 samples of the main occupation phase of Aghios Ioannis.

## FURTHER DISCUSSION

The presence of human activity at Aghios Ioannis, even for a short time within the period 3370–3100 BC, fills in, to a certain extent, the “gap” that exists in Thassos between the later phase of the Final Neolithic at Limenaria (4000–3800 BC)<sup>1</sup> (Maniatis and Facorellis, in press) and the earliest occupational phase at Skala Sotiros (2570–2460 BC) (Koukouli-Chryssanthaki et al., in press).

<sup>1</sup>During the writing of this paper 2 new dates (DEM-2027 and -2028) from animal bones were produced for the site of Limenaria and gave preliminary calibrated 2- $\sigma$  dates in the range of 3360–3090 BC, which is exactly the same as these of Aghios Ioannis.

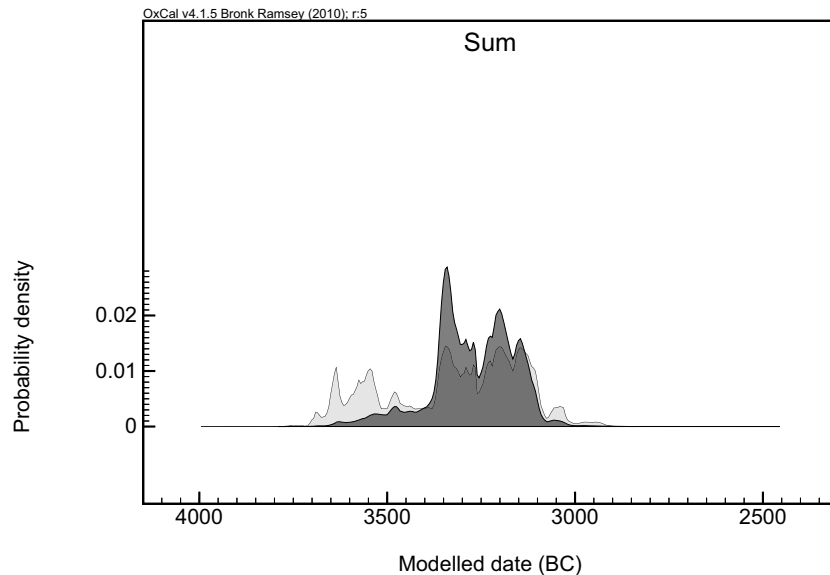


Figure 10 Accumulated probability distribution as produced by the function *Sum* from the statistical analysis of the *outlier - single phase* model, shown in Figure 8 and applied on the 5 samples of the main occupation phase of Aghios Ioannis.

This period, culturally characterized mostly as Early Bronze Age I, has also been located in some other settlements on eastern Macedonia, just opposite the island of Thassos (Figure 11, Table 2). In particular, human activity is documented in the shelter-cave Sidirokastro-Katarraktes in the Serres area (Figure 11), where <sup>14</sup>C dates of 3 samples done by the Laboratory of Archaeometry of NCSR “Demokritos” give a value of 3340–3020 BC (Poulaki-Pandermali et al. 2004). Also, <sup>14</sup>C dates of short-lived material (seeds) of phase IV at Sitagroi, a site situated in the Drama Plain (Figure 11), fall practically in the same age range, 3360–2780 BC (Renfrew 1986; Johnson 1999). Two charcoal samples from Sitagroi IV whose dates seem to reach the middle of the 4th millennium have such huge error bars that they cover the whole second half of the 4th millennium (3600–2900 BC), and thus not useful to confirm a higher or lower age in the 4th millennium. Furthermore, sporadic <sup>14</sup>C dates, which do not actually document systematic human activity, have been produced by the Laboratory of Archaeometry for a few more sites in the same general area of eastern Macedonia. These sites are Kryoneri (3360–2910 BC) (Malamidou 2007:301) and Diakili-Tash (3260–2920 BC) (Koukouli-Chryssanthaki et al. 1996:690) (Figure 11, Table 2).

It seems that this absolute age range in the final third of the 4th millennium BC traced in some sites in northern Greece signifies the earliest appearance of the Early Bronze Age in the Aegean. As discussed above, due to a plateau in the calibration curve, the exact time of the onset of the EBA cannot be defined more precisely than 3370–3100 BC, which means that the earliest possible start indicated by <sup>14</sup>C dating could be at 3370 BC, although in practice it may have occurred later. This means that even at these sites, in which the earliest appearance of the EBA is testified, a blank period of at least 700 yr elapsed, from the end of the FN (~4000 BC), with no evidence of human occupation. Furthermore, in this very early period of EBA when some sites started to be reoccupied (in the last third of the 4th millennium) human activity was neither systematic nor widespread, as the settlements with intense evidence of activity in this early period are scarce. In other sites, for example, Mandalo in west Macedonia (Maniatis and Kromer 1990) and Mikro Vouni on the island of Samothrace (unpublished <sup>14</sup>C results of this laboratory), the Early Bronze Age does not start until the beginning of the

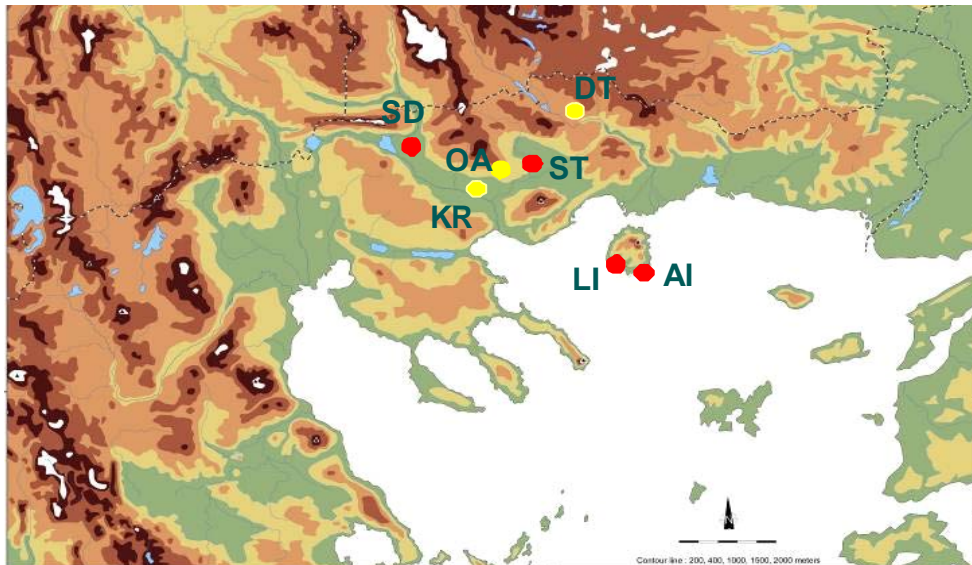


Figure 11 Map of east Macedonia showing sites where samples have dated to the 4th millennium (SD = Sidirokastro; ST = Sitagroi; DT = Dikili Tash; OA = Orfeas; KR = Kryoneri; LI = Limenaria; AI = Aghios Ioannis). See also Table 2.

Table 2 Dating results from other sites in east Macedonia in the 4th millennium.

Site/Phase	Calibrated age BC (95.4%)	Nr of samples	Reference
Aghios Ioannis (Thassos)	3600(3360)–3100	5	This paper
Limenaria (Thassos)	4000–3780	1	Maniatis and Facorellis, in press
Limenaria (Thassos)	3360–3090	2	Unpublished (DEM-2027, DEM-2028; this laboratory)
Sitagroi IV (Drama Plain)	3600(3360)–2700	7	Renfrew 1986; Johnson 1999
Cave Sidirokastro-Katarraktes (Serres County)	3350–2900	3	Poulaki-Pandermali et al. 2004
Kryoneri (Serres County)	3360–2910	1	Unpublished (DEM-790; this laboratory)
Dikili Tash (Kavala County)	3270–2920	1	Unpublished (DEM-641; this laboratory)
Cave Orfeas Alistratis (Serres County)	3090–2770	1	Kontaxi et al. 2004

3rd millennium BC, producing thus a longer gap of ~1000 yr from the end of the FN at ~4000 BC. The beginning of the 3rd millennium is actually the period when more systematic and widespread occupation activity occurs again after the obscure 4th millennium interval.

The main human activity at Aghios Ioannis is synchronized with the few sites that produce the earliest EBA activity in the last third of the 4th millennium, most of them located in the area of east Macedonia close to Thassos, indicating that this particular area of north Greece witnesses some of the earliest concentrated human activity within the Early Bronze Age of the whole north Aegean.

Using the pottery typology information, the settlement at Aghios Ioannis is dated, as mentioned in the Introduction, to the FN-EBA transition period and the earliest phase of the EBA. Most of the pottery elements consolidate the “coincidence” of the site with settlements as Sitagroi IV in northern Greece (Sherratt 1986:435) and a lot of sites in the central and south Aegean (Johnson 1999:325). Nevertheless, some elements in the pottery material could be considered even earlier than the FN/EBA transition period, and dated in the latest phase of the FN period. Red-colored jugs with relief decoration on the body and hemispheric bowls with pierced vertical lugs on the rim could date to the middle of the 4th millennium. These pottery categories are also found in Kephala on Kea (Coleman 1977: plates 33, 78), in the Athenian Agora (Immerwahr 1971: plates 8–9) and at a lot of sites in the Aegean and Balkans (Johnson 1999:325). However, some of these elements, such as the storage vessels with plastic bands on the belly, are also common in the FN/EBA transition pottery material (Chatziagelakis 1984:81). On the other hand, the 4-legged dishes, a common shape in Thassos by the Middle Neolithic (Papadopoulos and Malamidou 2008:430), are present in Aghios Ioannis as well, although in small quantities.

At the same time, the stratigraphic sequence does not testify to the deposition of these elements in discernible layers of the site, at least in the excavated trenches. It seems that we have to consider a single or non-differentiated layer in which the majority of the material seems to have departed from the Neolithic pottery tradition and to have already embraced an Early Bronze Age cultural identity.

## **CONCLUSIONS**

The excavation work and <sup>14</sup>C dating at Aghios Ioannis offered the opportunity for investigating and monitoring a site, the first in Thassos and one of a very few in north Greece, that shows human activity in 4th millennium BC, in particular in the last third of the 4th millennium, if not slightly earlier. In addition, this work contributed to a re-examination and reconsideration of the issue of the scarcity of dates in the 4th millennium BC in the region of north Greece. Obtaining several dates in the last third of the 4th millennium at settlements like Aghios Ioannis, Sitagroi, or Katarraktes Cave may indicate that the so-called 4th millennium occupational “gap” may be reduced from ~1000 to ~700 yr in the general area of eastern Macedonia, including Thassos. However, in other sites like Mandalo (west Macedonia) or Mikro Vouni (Samothrace) and in general until systematic occupation begins in the EBA, the gap remains a full 1000 yr. Furthermore, if we take for granted the indication based on pottery typology that the settlement at Aghios Ioannis may have been founded by the middle of the 4th millennium, the gap mentioned above could be further restricted in Thassos to ~500 yr. This assumption raises dramatically the interest and need for more systematic excavations and <sup>14</sup>C sampling on settlements that may potentially be active in the first half or first three quarters of the 4th millennium. In this case, Thassos may prove to be an exception to the generally observed gap, but that remains to be shown by further work.

The existence of a number of installations of the first half of the 4th millennium BC on island or mainland coastal places in north Greece, where there was a subsequent rise in the sea level and hence difficult to be located today, cannot be excluded. However, the evidence for this possibility, which would justify partly the rarity of such places, is not yet sufficient.

The excavation evidence at Aghios Ioannis suggests that we are most probably dealing with a “seasonal” settlement with perhaps a specific purpose. Possibly, the impermanent character of the site suggests the recurrent movement of a number of families from a main settlement so that specific needs of the community could be accommodated. The selection of the site most probably served the need for organized animal husbandry plus hunting and/or fishing activities. Similar economic strategies have been discussed repeatedly for the last phases of the Neolithic period and the earliest



phases of the Bronze Age. They concern mainly the intensified use of caves and utilization of secondary products through innovative survival practices (Sherratt 1981, 1983; Papadopoulos 2002, 2007). The strengthening of these economic practices in the 4th millennium BC could perhaps explain the difficulty of locating the small and short-lived settlements of this period.

In any case, it is obvious that Thassos needs more systematic excavations that will produce material for archaeological research and  $^{14}\text{C}$  dating. Only then will it become clear whether this island represents an exception to the abandonment of sites in the 4th millennium. Future work with  $^{14}\text{C}$  dating in Thassos, Greece, and the Balkans addressing this particular problem of the 4th millennium BC is now underway through a French-Greek research project called BALKANS-4000, funded by the French ANR Program (Coordinator: Z Tsirtsoni, CNRS/Universités Lyon 1 et 2, France).

#### ACKNOWLEDGMENTS

We would like to thank Dr Bernd Kromer head of the Radiocarbon Laboratory of Heidelberg Academy of Science for constant help and advice with the  $^{14}\text{C}$  laboratory practices. Also, we thank sincerely Dr Christopher Bronk Ramsey, head of the Oxford AMS Radiocarbon facility and programmer of the OxCal calibration program, for extremely valuable help with the statistical analysis models. Finally, we thank Prof Sturt Manning and Mr Malcolm Wiener for their valuable comments on the manuscript.

#### REFERENCES

- Andreou S, Fotiadis M, Kotsakis K. 2001. Review of Aegean Prehistory V: The Neolithic and Bronze Age of northern Greece. In: Cullen T, editor. *Aegean Prehistory: A Review. American Journal of Archaeology Supplement I*. Boston: Archaeological Institute of America. p 259–327.
- Baker-Penoyre J ff. 1909. Thasos. *Journal of Hellenic Studies* XXIX:202–50.
- Bon A. 1930. Les ruines antiques dans l'île de Thasos et en particulier les tours helléniques. *Bulletin de Correspondance Hellenique* LIV:147–94.
- Bronk Ramsey C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1):337–60.
- Bronk Ramsey C. 2010. OxCal v.4.1.5 [software]. URL: <http://c14.arch.ox.ac.uk/embed.php?File=oxcal.html>.
- Caskey JL, Caskey EG. 1960. The earliest settlements at Eutresis. *Supplementary Excavations, 1958. Hesperia* 29:126–67.
- Chatziangelakis L. 1984. Ο προϊστορικός οικισμός της Πετρομαγούλας. *Ανθρωπολογικά* 5:75–85. In Greek.
- Coleman JE. 1977. *Keos I. Kephala. A Late Neolithic Settlement and Cemetery*. Athens: American School of Classical Studies at Athens.
- de Vries H, Barendsen GW. 1953. Radiocarbon dating by a proportional counter filled with carbon dioxide. *Physica* 19:987–1003.
- Evans RK. 1986. The pottery of Phase III. In: Renfrew C, Gimbutas M, Elster ES, editors. *Excavations at Sita-groi: A prehistoric village in northeast Greece I*. Los Angeles: University of California. p 393–428.
- Johnson M. 1999. Chronology of Greece and south-east Europe in the Final Neolithic and Early Bronze Age. *Proceedings of the Prehistoric Society* 65:319–36.
- Immerwahr SA. 1971. *The Athenian Agora 13: The Neolithic and Bronze Ages*. Athens: American School of Classical Studies at Athens.
- Kontaxi Ch, Yiannopoulos V, Kasnesi A. 2006. Το σπήλαιο του «Ορφέα» Αλιστράτης Σερρών και η ευρύτερη περιοχή: πρώτες σπηλαιολογικές και αρχαιολογικές έρευνες. *Το Αρχαιολογικό Έργο στη Μακεδονία και στη Θράκη* 18:57–62. In Greek.
- Koukouli-Chryssanthaki C, Teuill R, Malamidou D. 1996. Προϊστορικός οικισμός Φιλίππων 'Ντικιλί Τας'. Δέκα χρόνια ανασκαφικής έρευνας. *Το Αρχαιολογικό Έργο στη Μακεδονία και Θράκη* 10B: 681–704. In Greek.
- Koukouli-Chryssanthaki C, Malamidou D, Papadopoulos S, Maniatis Y. In press. Νεότερη φάση της Πρώιμης Εποχής του Χαλκού στη Θάσο: Νέα Δεδομένα. Στο: *Διεθνές Συνέδριο «Η Πρώιμη Εποχή του Χαλκού στο Αιγαίο: Νέα Δεδομένα»*, (επιμ. Χρ. Ντούμας, Γ.Α. Γιαννικουρή και Ο. Κουκά. Αθήνα, 11–14 Απριλίου 2008 (υπό εκτύπωση). In Greek.
- Kromer B, Münnich KO. 1992.  $\text{CO}_2$  gas proportional counting in radiocarbon dating - review and perspective. In: Taylor RE, Long A, Kra RS, editors. *Radiocarbon After Four Decades: An Interdisciplinary Perspective*. New York: Springer-Verlag. p 184–97.
- Malamidou D. 2007. Kryoneri: a Neolithic and Early Bronze Age Settlement. In: Todorova H, Stefanovich M, Ivanov G, editors. *The Lower Strymon Valley, Proceedings of the International Symposium 'Strymon Praehistoricus.'* 27 September–1 October 2004. Sofia: Gerda Henkel Stiftung. p 297–308.

- Maniatis Y, Kromer B. 1990. Radiocarbon dating of the Late Neolithic-Early Bronze Age site of Mandalo, W Macedonia. *Radiocarbon* 32(2):149–53.
- Maniatis Y, Facorelis Y. In press. Χρονολόγηση με Ραδιοάνθρακα των οικιστικών φάσεων του προϊστορικού οικισμού στα Λιμενάρια Θάσου. Στο: *Δέκα Χρόνια Ανασκαφικής Έρευνας στον Προϊστορικό Οικισμό Λιμεναρίων Θάσου*, (επιμ. Σ. Παπαδόπουλος και Δ. Μαλαμίδου). Ημερίδα, 11 Ιουλίου 2003, Υπουργείο Πολιτισμού, Θεσσαλονίκη. In Greek.
- Manning SW. 1995. *The Absolute Chronology of the Aegean Early Bronze Age: Archaeology, History and Radiocarbon*. Monographs in Mediterranean Archaeology 1. Sheffield: Sheffield University Press.
- Mook WG, Streurman HJ. 1983. Physical and chemical aspects of radiocarbon dating. In: *Proceedings of the First International Symposium on <sup>14</sup>C and Archaeology*. Groningen 1981. PACT. p 31–55.
- Münnich KO. 1957. Messung natürlicher radiokohlenstoff mit einem CO<sub>2</sub> proportional zahlrohr. Einige anwendungen der methode. Inaugural-dissertation zur erlangung der doktorwurde hohen naturwissenschaftlich-mathematischen fakultat der Ruprecht-Karl-Universität zu Heidelberg, Germany.
- Nydal R. 1983. The radon problem in <sup>14</sup>C dating. *Radiocarbon* 25(2):501–10.
- Olsson IU. 1979. The importance of the pre-treatment of wood and charcoal samples in radiocarbon dating. In: Berger R, Suess HE, editors. *Proceedings of the 9th International Radiocarbon Conference*. Berkeley: University California Press. p 135–46.
- Papadopoulos S. 1998. Άγιος Ιωάννης Λουκάς. *Αρχαιολογικόν Δελτίον* 53:722–5. In Greek.
- Papadopoulos S. 2002. Η Μετάβαση από τη Νεολιθική στην Εποχή του Χαλκού στην Ανατολική Μακεδονία. *Δημοσιεύματα του Αρχαιολογικού Δελτίου*, n. 82, Αθήνα. In Greek.
- Papadopoulos S. 2007. Decline of the painted pottery in eastern Macedonia and north Aegean at the end of the Chalcolithic period. In: Todorova H, Stefanovich M, Ivanov G, editors. *The Lower Strymon Valley, Proceedings of the International Symposium 'Strymon Praehistoricus.'* 27 September–1 October 2004. Sofia: Gerda Henkel Stiftung. p 317–28.
- Papadopoulos S, Aristodimou G, Kougioutzoglou D, Megaloudi F. 2001. Η Τελική Νεολιθική και η Πρώιμη Εποχή του Χαλκού στη Θάσο: Η ανασκαφική έρευνα στις θέσεις Άγιος Ιωάννης και Σκάλα Σωτήρος. *Το Αρχαιολογικό Έργο στη Μακεδονία και Θράκη* 15:55–65. In Greek.
- Papadopoulos S, Malamidou D. 2008. Limenaria. A Neolithic and Early Bronze Age settlement at Thasos, north-east Aegean. In: Erkanal H, Hauptmann H, Sahoglu V, Tuncel R, editors. *The Aegean in the Neolithic, Chalcolithic and the Early Bronze Age*. Proceedings of the International Symposium at Urla-Izmir, 13–19 October 1997. Ankara University: Research Center for Maritime Archaeology (Ankusam), Publication nr 1. p 427–45.
- Petroutsas EI, Manolis S. 2010. Reconstructing Late Bronze Age diet in mainland Greece using stable isotope analysis. *Journal of Archaeological Science* 37(3):614–20.
- Polach HA. 1976. Radiocarbon dating as a research tool in archaeology: hopes and limitations. In: Barnard N, editor. *Proceedings of the Symposium on Scientific Methods of Research in the Study of Ancient Chinese Bronzes and Southeast Asian Metal and Other Archaeological Artifacts*. Australian National University, Department of Far Eastern History. p 255–98.
- Poulaki-Pandermali E, Vaxevanopoulos M, Koulidou S, Siros A. 2004. Καταρράκτες (Φράγμα) Σιδηροκάστρου 2004. *Το Αρχαιολογικό Έργο στη Μακεδονία και τη Θράκη* 18:63–71. In Greek.
- Poulios V. 1983. Θεολόγος Θάσου. Άγιος Ιωάννης Λουκάς (Ελαιόκτημα Παπαδόπουλου). *Αρχαιολογικόν Δελτίον* 38:316–8. In Greek.
- Reimer PJ, Baillie MGL, Bard E, Bayliss A, Beck JW, Blackwell PG, Bronk Ramsey C, Buck CE, Burr GS, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Hajdas I, Heaton TJ, Hogg AG, Hughen KA, Kaiser KF, Kromer B, McCormac FG, Manning SW, Reimer RW, Richards DA, Southon JR, Talamo S, Turney CSM, van der Plicht J, Weyhenmeyer CE. 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. *Radiocarbon* 51(4): 1111–50.
- Renfrew C. 1972. *The Emergence of Civilisation. The Cyclades and the Aegean in the Third Millennium B.C.* London: Methuen.
- Renfrew C. 1986. The Sitagroi sequence. In: Renfrew C, Gimbutas M, Elster ES, editors. *Excavations at Sitagroi: A Prehistoric Village in Northeast Greece I*. Los Angeles: University of California. p 147–74.
- Sherratt AG. 1981. Plough and pastoralism: aspects of the secondary products revolution. In: Hodder I, Isaak G, Hammond N, editors. *Pattern of the Past. Studies in Honour of D. Clarke*. Cambridge: Cambridge University Press. p 261–305.
- Sherratt AG. 1983. The secondary exploitation of animals in the Old World. *World Archaeology* 15(1):90–104.
- Sherratt AG. 1986. The pottery of phases IV and V: the Early Bronze Age. In: Renfrew C, Gimbutas M, Elster ES, editors. *Excavations at Sitagroi: A Prehistoric Village in Northeast Greece I*. Los Angeles: University of California. p 429–76.
- Stuiver M, Polach HA. 1977. Discussion: reporting of <sup>14</sup>C data. *Radiocarbon* 19(3):355–63.
- Stuiver M, Reimer PJ. 1993. Extended <sup>14</sup>C data base and revised CALIB 3.0 <sup>14</sup>C age calibration program. *Radiocarbon* 35(1):215–30.
- Triantaphyllou S, Richards MP, Zerner C, Voutsaki S. 2008. Isotopic dietary reconstruction of humans from Middle Bronze Age Lerna, Argolid, Greece. *Journal of Archaeological Science* 35(11):3028–34.