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JOINT MODELLING OF RADIOCARBON DATES FROM ULUCAK V (ANATOLIAN LATE NEOLITHIC)

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ABSTRACT

The Neolithic site of Ulucak (Central-Western Anatolia) presents one of the best currently available sequences for the beginning of the Neolithic way of life in the region. Ulucak's crucial phase V features a gradual rise in the variety and importance of pottery and of other clay objects. This phase's dating has wide implications for cultural relations within Anatolia and the Aegean. I present a joint Bayesian model for Ulucak V, resolving problems of the earlier modeling by adding an old-wood probabilistic correction. The obtained model corrects the previous estimates of 6500–6000 calBCE for Ulucak V to a likely considerably shorter period within 6400/6300–6000/5900 calBCE, and raises the possibility of a hiatus between the aceramic Ulucak VI and the pottery-bearing Ulucak V.

KEYWORDS: Ulucak Höyük, Central Western Anatolia, Neolithic, radiocarbon dates, old-wood probabilistic offset

1. INTRODUCTION: THE NEED FOR A JOINT DATING MODEL FOR ULUCAK

The aim of the current research note is to build a satisfactory Bayesian joint dating model for Ulucak phases Ve to Va. The site possesses a very good sequence of radiocarbon determinations, but their previous Bayesian modeling in (Çevik and Erdoğu, 2020) is not consistent. This is due to the fact that without properly accounting for the old-wood effects, the radiocarbon measurements appear to be inconsistent with the stratigraphy. I build a joint model including a probabilistic offset for potentially old-wood charcoal, and report updated estimates for Ulucak V's subphase dating and duration. The implications and remaining open questions that can only be resolved by further archaeological analysis are then discussed.

The tell site of Ulucak Höyük, Fig. 1, is one of the best-investigated Neolithic sites in Central-Western Anatolia, with excavations started in 1995 under the direction of Altan Çilingiroğlu and overtaken in 2009 by Özlem Çevik.

The site features a long sequence, starting from phase VI dated by charred seeds to the first half of the 7th millenium calBCE, and almost devoid of pottery, (Çilingiroğlu et al., 2013). The next phase V, the subject of the current study, has been dated by (Çevik and Erdoğu, 2020) to 6500–6000 calBCE, Table 1. The five layers of this phase, from Ve to Va, demonstrate an impressive temporal development of material culture: the pottery dramatically increases both in quantity and in variety, (Çevik and Vuruskan, 2020), the storage capacities increase, figurines and stamps appear, (Çevik and Erdoğu, 2020). Together with Çukuriçi Höyük that was apparently founded at about the same time, (Horejs et al., 2015; Horejs, 2017), Ulucak offers the best glimpse we have into the start and initial developments of the Neolithic way of life in Central-Western Anatolia.

The pottery of layers Va and Vb is published definitively by (Çilingiroğlu, 2012), who also provides general brief summaries for each layer she studies. The architectural remains of phases VI and V and the pottery of Vc-Ve are described in the preliminary report (Çevik and Erdoğu, 2020). Radiocarbon dates were published by (Çilingiroğlu et al., 2013), while (Çevik and Erdoğu, 2020) extend them with newly obtained measurements and publish the full dataset, including re-assignment of layers to specific dates.[1]

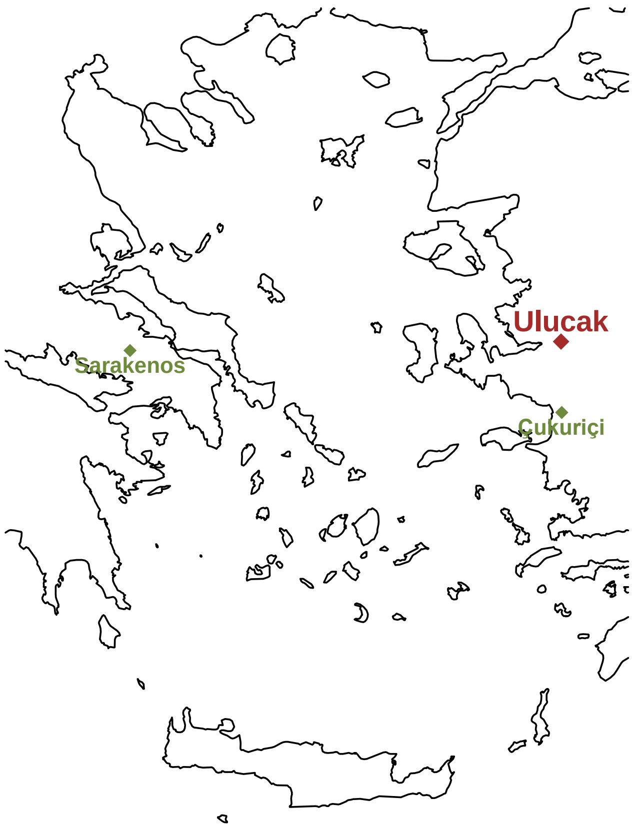

Figure 1. Ulucak Höyük and selected sites mentioned in the text.

[1] (Çilingiroğlu et al., 2013) distinguish six layers within phase V, while recent publications like (Çevik and Erdoğu, 2020) do not discuss Vf any more and reassign dates previously ordered to it to layer Ve.

(Çevik and Erdoğu, 2020) build Bayesian models for the Ulucak radiocarbon dataset they publish, and interpret their results building a history of material-culture development at Ulucak tied to calendar ages. Rather than modelling their dates jointly, the authors built four separate models for phases VI, Ve, Vd-c, and Vb-a. These separate models are not consistent with each other and with the stratigraphy: For example, layer Ve is dated within roughly 6700–6000 calBCE; Vd-c within 6550–5950 calBCE; Vb-a within 6400–5850 calBCE. But the stratigraphy of the site clearly indicates succession Ve-Vd-Vc-Vb-Va. To resolve this problem, the authors in their chronology discuss boundaries at 68% rather than at 95%, and sometimes (incorrectly) cite the wrong part of the boundary: for example, for Vd-c, they cite (correctly) the upper end of 6507 calBCE from the upper-boundary 68% HPD, but then (incorrectly) the upper end of the lower 68% HPD boundary, at 6151 calBCE, whereas the correct lower end is at ca. 6050 calBCE.

Table 1. Ulucak dating according to Çevik and Erdoğu (2020) and to the present study.

	(Çevik and Erdoğu, 2020)	present study
Ulucak VI	6850/6830 to 6500 calBCE	
Ulucak Ve to Vc	6500 to 6200 calBCE	6400??/6225 to 6150/6050 calBCE
Ulucak Vb to Va	6200 to 6000 calBCE	6150/6050 to 6030/5900 calBCE
Ulucak IV	6000 to 5700 calBCE	

This problem of overlapping phases goes beyond the usual statistical uncertainty and could have been largely avoided if the authors modelled all dates jointly, using the stratigraphy to define depositional succession of layers. The reason they have not probably has to do with the fact that in a simple stratigraphical model, the measurements are not consistent, and the simple model is therefore obviously inadequate. This can be illustrated by the following pair of dates. Date Beta-362303 from bone in layer Ve calibrates individually to 6224-6058 calBCE, but date Beta-236889, from charcoal in the younger layer Vd, calibrates to 6568-6272 calBCE. The stratigraphically younger date thus has higher radiocarbon age than the stratigraphically older. Any attempt to model them together in a simple model would produce a deviant model with obvious outliers. I argue that the key to solving the problem is recognizing that some charcoal dates are simply too old, a situation all too well-known. This deviation can be easily modelled probabilistically, using the method suggested by (Bronk Ramsey, 2009b), as I show below. The insightful archaeological generalizations by (Çevik and Erdoğu, 2020) can still be preserved with this updated dating model, they only need to be re-assigned temporally.

2. A JOINT MODEL FOR ULUCAK V, WITH PROBABILISTIC OLD-WOOD CORRECTION FOR CHARCOAL

Though Bayesian modelling of radiocarbon dates is by now frequently employed, its applications to prehistorical datasets do not always employ the full potential of the method. I therefore explain the modelling sequence in some detail, with the hope of demonstrating how the logic of building a more complex model works through iterative steps.

All dates from (Çevik and Erdoğu, 2020) for Ulucak V were used except for one date on shell.[2] The dates were divided according to layer into five successive phases, based on the context information in (Çevik and Erdoğu, 2020).

I built and ran four models in succession, using OxCal 4.4.2, (Bronk Ramsey, 2009a) and the IntCal20 curve, (Reimer et al., 2020). Here in the main text, I report in full only the results of one model, but the supplementary material contains OxCal result tables and command files for all four, so they can be easily reproduced and examined using the OxCal server.

The first model included all dates, but no constraints beyond placing the dates into appropriate phases and imposing succession on layers. This model was only run to obtain a baseline: as was discussed above, the individual dates are not, at face value, consistent with the stratigraphy. This is confirmed by the first model's results (see the supplementary).

[2] The http://calib.org/marine/ database provides only two points with local-offset data in the Aegean, at Nafplion and Piraeus on the western shore. The two have very different ΔR values of -103±40 and +7±40. Recall also that marine calibration is currently performed under the assumption of constant local offsets, which may well be false in the case of the 7th mill. BCE Aegean because of the dynamic processes possibly still proceeding at that time on the interface with the Sea of Marmara. Given these difficulties, I consider it safer to leave out the single date on shell. With all the true uncertainty about this marine date properly accounted for, it would probably not constrain the analysis by much.

The problem with that simplistic model is that some charcoal measurements appear to be too old for their stratigraphic position. The likeliest explanation for this, other things being equal, is that some of the charcoal stemmed from older wood, whose age exceeded that of the age of the charcoal's context. This is a common occurrence in radiocarbon chronology. A simple, but reasonable model for dealing with it is introduced by (Bronk Ramsey, 2009b) and is easy to apply in OxCal. This model infers, together with the dates themselves, a gently parametrized, near exponential-decay offset curve that can look like in Fig. 2(a). One important and visually conspicuous detail of the inferred curve is the length of its tail on the left.

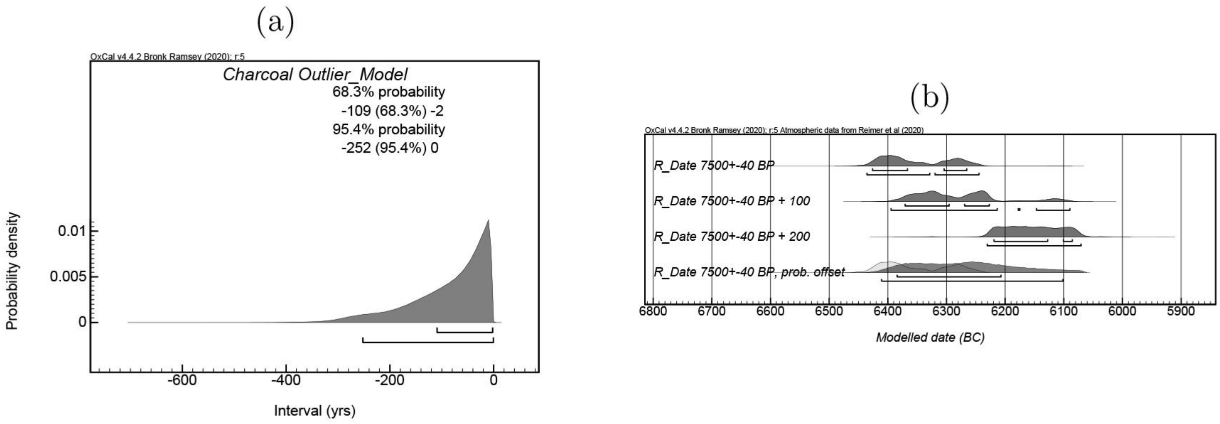

Figure 2. (a) The inferred shape of the probabilistic offset modelling the old-wood effect for the charcoal samples from Ulucak V; from the final model. (b) Illustration of how a probabilistic offset distributed as -Exp(1)*100 works applied to the date of 7500±40 BP, compared to no offset and fixed offsets of 100 and 200 years.

Fig. 2(b) illustrates how such a probabilistic offset works in practice. The top graph shows how a single date 7500±40 BP would be calibrated. Suppose this measurement was made on the heartwood of an old tree. Then the event it measures predates the fire event by some amount of time. To correct for this, we need to shift the measurement forward, towards the present — towards the actual fire event. One obvious option would be to choose a single specific offset. The second and third graphs on Fig. 2(b) show the calibrations that result in applying such fixed offsets of 100 and 200 years, respectively. But how do we know which offset is correct for a given charcoal sample? This is a problem we cannot really solve in most real-life cases. Applying a probabilistic offset incorporates this uncertainty: we do not know when exactly the tree part sampled died, but we can hypothesize a probability distribution similar in shape to that in Fig. 2(a): most likely, the distance between the death of the sampled part of the tree and the fire event is just several decades, but with some probability, it could also be a few hundred years (the thick left tail on Fig. 2(a)). We can then adjust our calibration based on this uncertainty. Intuitively, this achieves two effects at one, visible on the fourth graph on Fig. 2(b): first, the calibrated distribution is distributed over a wider range of calendar dates, and second, as a whole it is shifted towards younger ages relative to the calibration without any offset, on top of Fig. 2(b).

Intuitively speaking, in our model for Ulucak V, each charcoal sample receives the same probabilistic offset, which results in much wider, and somewhat younger, individual age ranges. Non-charcoal samples are not affected by this. The overall model then tries to fit the resulting distributions together, producing a joint overall model. A bit more rigorously, the shifting and fitting does not follow sequentially, but occurs together, and the exact shape of the probabilistic offset is also inferred so as to fit the data best, rather than fixed in advance. Resulting offset curves like the one in Fig. 2(a) would usually somewhat differ from a simple exponential distribution. In particular, in Fig. 2(a) the tail on the left is even thicker than it would have been for a true exponential.

My second model included all dates in appropriate phases, and had a flexibly parametrized probabilistic offset applied to charcoal samples (see the supplementary for the actual script and the result table). This joint model, unlike the first one, was generally internally consistent. However, it featured an obviously problematic inference: the durations for all layers but the earliest layer Ve were inferred to be possibly as low as 0 years. This is arguably too short: all five subphases feature architectural remains, (Çilingiroğlu, 2012, p. 52-3,55), (Çevik and Vuruskan, 2020, p. 102), so it is improbable that some of them could have been so short.

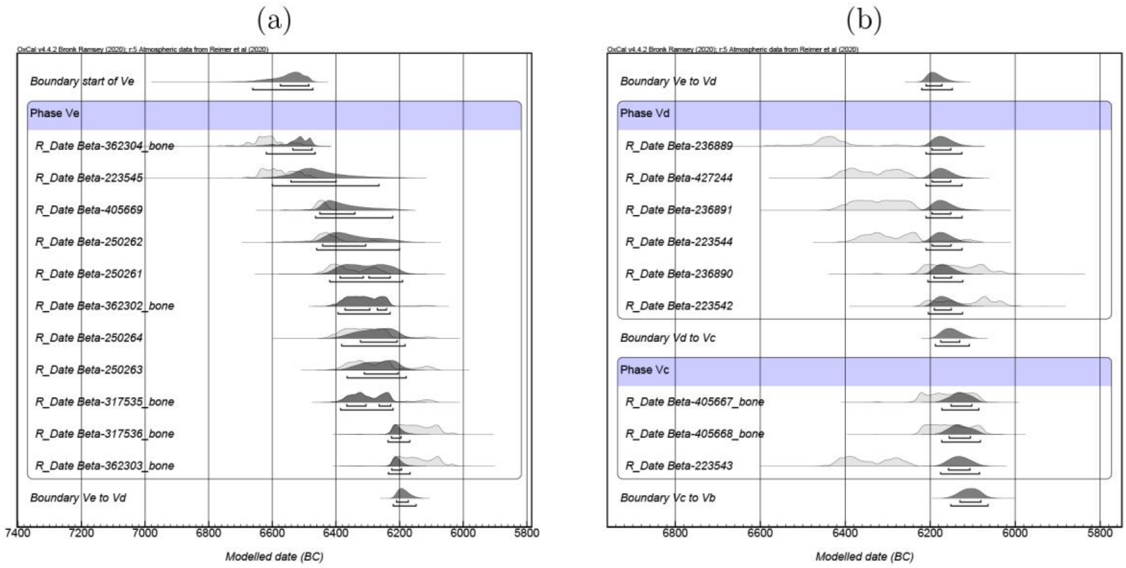

Figure 3. Inferences from the joint model of Ulucak V dates with a probabilistic offset forcharcoal, layers Ve to Vc.

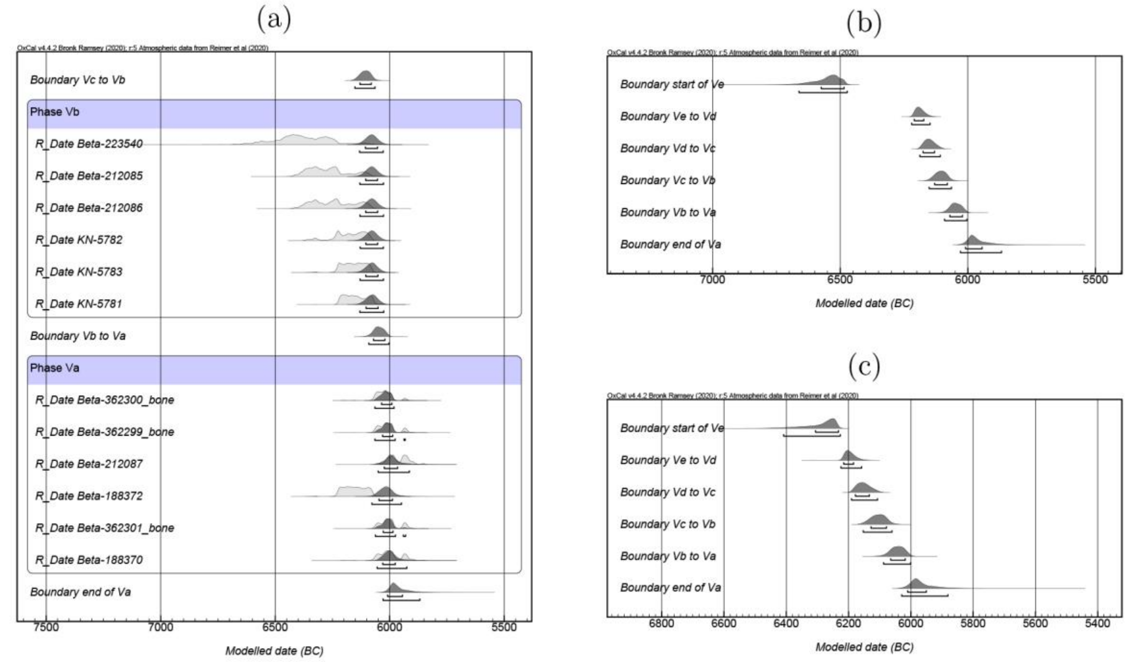

Figure 4. (a) Inferences from the joint model of Ulucak V dates with a probabilistic offset for charcoal, layers Vb and Va. (b) Inferred phase boundaries in the same model. (c) Inferred phase boundaries in the same model without the outlier Beta-362304.

To prevent such undesirable behavior, I added a further constraint to the model that restricts the length of each phase to be > 20 years.[3] It is the results of this model that I report in Fig. 3 and 4. Examining the graphs, it is easy to see that the dates taken on bone show rough agreement between: (i) the calibrations as they would be done on each date in isolation, light-shaded; and (ii) the calibrations according to the joint model, dark-shaded. In contrast, for the charcoal calibrations (which bear no name suffix on the graphs), the dark-shaded area is sometimes shifted

[3] Apparently due to numerical precision issues, the actual 95% lower boundaries were in fact shorter than 20 years in this analysis.

significantly to the right relative to the light-shaded area, towards younger ages. This, however, does not happen to all charcoal dates uniformly: some of them are not forward-shifted. This is exactly the expected effect of a probabilistic calendar-age offset.

3. DISCUSSION

The main result we can read from the obtained model, Figs. 3 and 4, is that the phases Vd to Va must have been considerably shorter than it appeared previously: as shown by the boundaries in Fig. 4(b), they follow in rapid succession one after another. At 95% HPDs, the earliest that layer Vd can start is 6221 calBCE, and Va ends at 5869 calBCE at the latest. This estimate for the end of Va would surely go up if we included into the model dates from level IV, which point to the beginning the 6th mill. calBCE. But even on the most generous apportioning from the level-V-only model, Vd to Va take not more than 350 years together, and most likely considerably less.

Within level V, considerable changes happen. Thus this shorter duration of individual phases and their shift towards closely before 6000 calBCE have implications for Ulucak's sequence on its own and for its place in the wider region. The evolution of material culture towards diversification of archaeologically preserved objects in Ulucak V proceeded more rapidly than assumed in previous work. This rapid development of the cultural sequence can only be recognized thanks to the large number of radiocarbon dates obtained and published by (Çilingiroğlu et al., 2013) and (Çevik and Erdoğu, 2020), which allows remarkable certainty when modelled jointly.

The rapid evolution at Ulucak V appears now to take place rather close to 6000 calBCE, and therefore the presence of novelties such as figurines or stamp seals since Vb can well, on present evidence, occur later in Ulucak than at Neolithic sites in Greek Macedonia, such as Mavropigi (Karamitrou-Mentessidi et al., 2015). If true, this raises a host of new questions about cultural links across the Aegean: Ulucak's Vb-a pottery shows both similarities and differences with the Lake District in the Anatolian interior, and Thessaly and Macedonia across the Aegean, as described in detail by (Çilingiroğlu, 2012). This suggests that Ulucak represented a part of a distinct, self-conscious and independent Central-West Anatolian cultural tradition that could interact creatively with its neighbors. If Ulucak's adoption of certain new forms is a later phenomenon than in other Circum-Aegean and adjacent Anatolian regions, why did its inhabitants adopt some new ways, but not others? Is it the case that at the beginning of Ulucak V, its inhabitants practiced cultural conservatism, but then started to increasingly adopt new material forms? If yes, then why such a change in behavior? If, on the other hand, the near absence of new forms in Ulucak Ve-c was due to lack of possibility to learn about them through contact, then why was early Ulucak V so isolated?

The second significant result concerns phase Ve. In the presented model in Fig. 3,4(a-b), this phase differs from the others by lasting at least 230 years, and most probably longer. This, however, has no correspondence in the archaeological data as described in preliminary reports: there is no sign that Ve was several times longer than the following layers. In fact, this inferred long duration is most likely an anomaly due to a single problematic measurement. It is a single date on bone Beta-362304 that drives Ve to be so long. Importantly, calibrated in isolation, this date corresponds to 6688–6506 calBCE, (Çevik and Erdoğu, 2020). The sample is reported by (Çevik and Erdoğu, 2020) to stem from Building 40, from which three charcoal sampled come as well. Those, calibrated individually without old-wood corrections, lead to roughly 6500–6250 calBCE, the youngest of the three even to 6418–6228 calBCE. As charcoal must provide terminus ante quem, the bone date Beta-362304 does not appear to be consistent with the others from the same building. Unless there are good reasons to believe that its depositional context was genuinely older by at least a century that that of the youngest charcoal, Beta-362304 must be an outlier. Taking it out of the analysis reduces the inferred length of layer Ve, Fig. 4, namely to somewhere within 6409–6159 calBCE at 95%, and within 6307–6185 calBCE at 68%.

Whether we eventually accept or discard Beta-362304, the inferences about Ve raise many new questions. If the bone date is correct for the layer it is found in, then we are dealing with a phase apparently not featuring exceptional archaeological remains, but lasting much longer than more material-rich later phases Vd to Va. In this case, what exact social processes could be behind such a low-intensity occupation several centuries long, but resulting in a relatively shallow level poor in remains, (Çevik and Vuruskan, 2020, p. 102)?

Alternatively, the hypothesis of a hiatus between Ulucak VI and Ulucak V suggests itself. The dates from Ulucak VI do not individually go much below 6500 calBCE. The radiocarbon data from Ve, if the outlier Beta-362304 is taken out, are consistent with a short occupational phase falling somewhere within 6409–6159 calBCE at 95% and within 6307–6185 calBCE at 68%. This leaves at least a century-long hiatus, and quite likely longer. Only further archaeological analysis can confirm or deny whether such a hiatus is consistent with the actual evidence from the site. However, one might note that such a marked material feature as red plastered floors were present in Ulucak VI, but no longer appear in Ulucak V, (Çilingiroğlu, 2012, p. 16). Such floors have been connected to those of Mesolithic Girmeler Cave in Southwestern Anatolia by (Çilingiroğlu, 2016) and (Horejs, 2019), and might well be a significant detail as far as the early non-pottery agriculturalists of Ulucak VI are concerned. If their makers from Ulucak VI chose to relocate, why, and why at that time? Further, why was the same site occupied again relatively shortly thereafter?

4. CONCLUSION

As the preceding section shows, the new modelling of the dates raises more questions than it answers. This is as it should be: data gained through natural sciences and statistics can point to issues that need archaeological attention, but it is only archaeological work — both excavation and its analysis — that can provide answers, and in turn bring us closer to understanding the lives of Anatolian and Aegean pioneer agriculturalists from the 7th millennium BCE.

I would like to conclude by stating explicitly some of the more immediate desiderata, fulfilling which can help integrate the newly obtained statistical inferences into a more general archaeological model. That, in turn, will quite likely necessitate building a novel statistical model that incorporates the new knowledge, and then applying it in a new cycle of statistical inference.

- Reexamination of the archaeological data for the durations of individual subphases within phase V: Is 10-20 years too short for one occupational level? Is duration of >250 years for level Ve compatible with the evidence from that level?
- Reexamination of the excavation materials to determine if a hiatus is possible between Ulucak VI and V. Alternatively, is Ve consistent with a particularly low-intensity occupation? (Also, why was the originally distinguished layer Vf eliminated in later analyses?) Finally, as yet another alternative to a hiatus, could some deposits originally above Ulucak VI have been removed during some landscaping or building activities on the site before phase V?
- The archaeological context of bone sample Beta-362304 from layer Ve: this bone sample disagrees with most others in its phase, including the charcoal dates from the same building 40. What is the exact archaeological context of those samples — could the bone be truly deposited so much earlier? Alternatively, could we be dealing with a "heirloom" old bone, actually from phase VI, or otherwise significantly preceding the occupation level Ve?

Resolving these questions should bring us closer to incorporating the data from Ulucak into their wider context, before and during the start of Neolithization in the Aegean basin. With our new dates, the developments during Ulucak V turn out to be faster than envisaged before: the end of the 7th mill. BCE must have been an extremely dynamic time at the site. On the one hand, this should be evaluated against the background of long-term traditions persisting in the Aegean, such as obsidian exploitation throughout the Aegean from Mesolithic and even earlier (Laskaris et al., 2011), yet having a very clear regional pattern focussed on the Aegean islands in the Mesolithic (Carter et al., 2018, esp. Fig. 10), and with considerable differences between near-coastal Western-Anatolian sites of the late 7th millennium BCE (Perlès et al., 2011). On the other hand, the rapid developments at Ulucak should be viewed within the context of potentially far-flung contacts, direct or indirect: see (Çilingiroğlu, 2012) for an extensive discussion of Ulucak's pottery typological connections, and (Papageorgiou and Liritzis, 2007; Liritzis et al., 2021, Sec. 6) for an intriguing potential direct link between pottery in Ulucak and the Sarakenos cave in Boeotia, Greece, on the other side of the Aegean.

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