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A New Radiocarbon Chronology for the Late Neolithic to Iron Age in the Qazvin Plain, Iran

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Abstract

Archaeological excavations on the western part of the Central Iranian Plateau, known as the Qazvin Plain provides invaluable information about the sedentary communities from early occupation to the later prehistoric era. Despite the past archeological data, chronological studies mostly rely on the relative use of the Bayesian modeling for stratigraphically-related radiocarbon dates. The current paper provides a new model for excavations and the chronological framework based on new radiocarbon dating of the six key archeological enclosures in the Qazvin plain. A Bayesian analysis of these data is presented on a site-by-site basis to give the best chronologies. Finally, all dates are combined into a single model of the chronology of the Qazvin Plain from the Late Neolithic to the Iron Age. The procedure aims to use the Bayesian model to predict the

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transition points between the archaeologically-defined periods with the highest possible precision, to redefine the existing chronology for the Qazvin Plain.

Keywords: Chronology, Qazvin Plain, Late Neolithic, Iron Age, Radiocarbon Dating, Bayesian Modeling.

Introduction

Archaeological excavations on the western part of the Central Iranian Plateau, known as the Qazvin Plain, have been carried out since the 1970s, with the aim of understanding the transition from hunter-gatherer societies to more sedentary communities, and the subsequent rise of social complexity (Fazeli et al., 2005; Fazeli et al., 2009). Although several of these studies have used radiocarbon dating to support the ceramic chronologies, few have applied Bayesian modeling to stratigraphically-related radiocarbon dates (Ramsey, 2008), which is freely available through OxCal (https://c14.arch.ox.ac.uk). An exception is the recent re-working of the dates from Tall-i Mushki, Marv Dasht Plain, by Nishiaki (2010).

These studies have been limited by having relatively few radiocarbon dates available for any particular site. As part of a larger collaboration between ICHTO and RLAHA, in which we have produced approximately 300 new radiocarbon dates for prehistoric, historic, and Islamic Iran, we publish 57 new dates from Tepe Chahar Boneh (15), Tepe Ebrahim Abad (15), Tepe Sagzabad (12) and Tepe Shizar (15). Fig. 1 indicates the location of these sites in the Qazvin Plain. Firstly, we present a Bayesian analysis of these data on a site-by-site basis to give the best site chronologies according to present information. We then re-analyze radiocarbon dates from other sites on the Qazvin Plain published by other laboratories - Tepe Zagheh (9 from Waikato and 4 from Gif-sur-Yvette); Tepe Ghabrestan (7 from Waikato and 7 from Gif-sur-Yvette) and add to the analysis of our dates from Tepe Sagzabad a further 4 dates from Gif-sur-Yvette. In this paper, we have used OxCal v. 4.1.7 (Bronk Ramsey, 2009) with the calibration data from Intcal2009 (Reimer et al., 2009), and have adopted the convention of quoting all modeled dates at 2σ (95% confidence), but have also quoted the 'most likely age range' for the modeled transitions dates at 1σ (68% confidence), and, for ease of discussion, we also quote the median age of the modeled range.

Finally, we combine all 88 dates into a single model of the chronology of the Qazvin Plain from the Late Neolithic to the Iron Age. The aim is to use the Bayesian model to allow us to predict the transition points between the archaeologically-defined periods with the highest possible precision, in order to refine the existing chronology for the Qazvin Plain. Our intention in the future is to extend this procedure to other sites on the Central Plateau, and also to other regions of Iran, and to use these regional models to detect any time-transgressive behavior in the transition between different regions.

2. Discussion

2.1. Tepe Chahar Boneh

Chronologically and based on the ceramic finds, Tepe Chahar Boneh is related to the Late Neolithic I (c. 6000-5600 BC) and II (c. 5600-5200 BC) periods. One of the key archaeological problems within the north Central Iranian Plateau is the lack of evidences for the Mesolithic and also the Early Neolithic periods. It was hoped that Chahar Boneh or Tepe Ebrahim Abad (see below) might provide evidence of ceramic Neolithic occupation. Whilst both sites have provided us with securely dated stratigraphs and architectural and artefactual sequences covering over 800 years of occupation, neither demonstrates evidence for this early occupation. Tepe Chahar Boneh was identified during the settlement survey undertaken in 2003, and is located at 1279 m above sea level, 3.3 km to the southeast of Zagheh and 4.2 km southeast of Ghabrestan Tepe, southeast of Boein Zahra. The site lies within a shallow depression, and covers an area of 2000 m^2 – or 4000 m^2 including surrounding scatters – and is being encroached upon by modern agriculture. On the surface of the site painted Buff and Red Ware sherds were visible, marking the site as the earliest example of the ceramic Neolithic of Iran (Fazeli et al., 2009). In order to study the chronology of the site, eight trenches of 2x2 meters were excavated on different parts of the site in 2006. However, despite two months of excavations, few architectural remains or coherent contexts could identify. Instead, we found a series of cultural contexts which were interspersed with natural accumulations.

Seventeen samples of unidentified charcoal from Tepe Chahar Boneh were dated at the Oxford Radiocarbon Accelerator Unit. Two samples failed to produce sufficient carbon for dating, leaving six usable dates for the Late Neolithic I and nine dates from the Late Neolithic II (Table 1).

The radiocarbon data therefore consist of 15 dates from Trenches I, III, IV, V, VI and VII. Several of the dates come from the same context (two from Context 109, Trench I; two from Context 306, Trench III; three each from Contexts 508 and 510, Trench V). Since the aim is to provide amo deled estimate for the age of thetransition from LNI to LNII at Tepe Chahar Boneh, and no single trench covers this transition, we have constructed a phase model consisting of a sequence of two phases (LNI and LNII), within which all dates from the same context were considered as sub-phases. The transition between LNI and LNII was initially modeled as a single event, but in the model shown here (Fig. 2) was divided into ELNI (end of LNI) and SLNII (start of LNII) because there appeared to be a gap between these two periods.

From this model, the start of the Late Neolithic I at Tepe Chahar Boneh occurs at or before 6191 – 5908 cal BC (6058 – 5934 cal BC at 68% confidence, median 6014 cal BC). This is a reasonable estimate for the start of the LN I period. The end of the Late Neolithic I is given as 5773 – 5468 cal BC (5736 – 5618 cal BC at 68% confidence, median 5669 cal BC) and the start of LNII is 5402 – 5233 cal BC (5367 – 5260 cal BC at 68%, median 5322 cal BC). This indicates a hiatus of perhaps 350 years between LNI and LNII at Chahar Boneh, at least in terms of the contexts dated. Taking the E boundary as a *terminus ante quem* estimate for the end of the LNII phase at Chahar Boneh, this suggests an end date of some time after 5296 – 5104 cal BC (5270 – 5184 cal BC at 68% confidence, median 5215 cal BC). This indicates that the LN II period may have been rather short at Chahar Boneh (perhaps only lasting one or two hundred years.

On this evidence, therefore, we can date the LNI period at Chahar Boneh to approximately 6000 to 5700 cal BC, and LNII from 5300 to 5200 cal BC. The calibrated and modeled dates for this site are shown in Table 2.

2. 2. Tepe Ebrahim Abad

Tepe Ebrahim Abad is about 20 km south of Qazvin in the northern half of the plain at an altitude of 1232 meters above sea level. This hill was identified in 1963 during a comprehensive survey by Hassan Fazeli Nashli (Fazeli et al., 2009). It is approximately 250 × 250 metres in area and its height is 8 metres from the surface of the surrounding land. Three trenches were sunk into this ancient hill in 2006. Trenches I and II reached virgin soil, but despite a search to a depth of approximately 7.5 metres Trench III failed to reach virgin soil (Fazeli et al., 2009). The radiocarbon dates are listed in Table 3.

Since two of the three trenches (I and II: Figs. 3-4) contain dates in stratigraphic sequence that straddle a chronological boundary (Late Neolithic II to Transitional Chalcolithic I), we have first modelled each sequence separately to derive a modelled age for this transition in each trench. We have then produced a site model based on a sequence of two phases (LN II and TC I), each of which contains a number of independent phases (three LNII dates from Trench III, six LN II and three TC I from Trench II, and two LN II plus one TCI from Trench I).

Trench I

The three radiocarbon dates are in stratigraphic sequence, two in LN II and one TC I, but none of the dates are close to the base of the LN II sequence or the top of the TC I levels, so will not provide good estimates for the start of the LN II or the end of the TC I. Using a sequence model with a transition (T) inserted between the LN II and TC I phases, and inserting a start and end boundary gives the calibrated and modeled dates shown in Figure 5 (and a poor agreement warning (50%) for the model). The modeled date for the transition (T) from LN II to TC I is 5357 – 5127 cal BC (5330 – 5206 cal BC at 68% confidence, median 5264 cal BC), but the low number of samples in the sequence and the poor agreement in the model would suggest that this estimate is unreliable.

Trench II

Trench II has a longer sequence of nine dates in stratigraphic sequence, three being TC I and six LN II, although again neither the lower LN II or the upper TC I dates are at the bottom or top of the stratigraphic section, respectively. Using a Sequence model with a transition (T) inserted between the LN II and TC I phases, and inserting a start and end boundary gives the calibrated and modelled dates shown in Figure 6. The modelled date for the transition from LN II to TC I (‘T’) is 5276 -5082 cal BC (5257-5164 cal BC at 68% confidence, median 5208 cal BC). The upper part of the sequence (the TC I period) is chronologically ambiguous in this sequence (i.e., shows significant bimodality), indicating that the TC I period is poorly constrained in this sequence.

Analysis of Tepe Ebrahim Abad by Archaeological Phase

From Trenches I and II we can conclude that the LN II to TC I transition most probably occurred sometime around 5200 BC. In order to use all the information from the 15 radiocarbon dates, we have constructed a model which defines all four of the available TC I dates as a single phase (but retaining the stratigraphic sequence of the three dates from Trench II), and the remaining 11 LN II as a single preceding phase (but with the stratigraphic sequence retained for each trench), with a transition T (LN II-TC I) between them.

This model (Fig.7 and Table 4) also has poor agreement in the upper (TC I) section, as was noted in the model for Trench I, but the boundary T is well-defined, at 5203 – 5061 cal BC (5158-5076 cal BC at 68% confidence, median 5122 cal BC). This is probably the best estimate of age of the LN II-TC I transition from Tepe Ebrahim Abad, and suggests that this transition occurred at some time between 5150 and 5050 cal BC. The start of the sequence (but, for stratigraphic reasons, not necessarily the start of the LN II period) is estimated at 5641 – 5480 cal BC (5560 – 5491 cal BC at 68% confidence, median 5534 cal BC). The end (but again not necessarily the end of TC I) is modeled at 5191 – 4875 cal BC (5057 – 4957 cal BC at 68% confidence, median 5008 cal BC). We can conclude that the LN II period at Tepe Ebrahim Abad had begun by c. 5500 cal BC, and the TC I period ended sometime after c. 5000 cal BC.

2.3. Tepe Shizar

The mound of Tepe Shizar is 19m high and is located in a corridor valley linking the Central Plateau with the central Zagros Mountains. It is located about 35 km south of the city of Takestan, near a village with the same name (Shizar). In 2006, a stratigraphic trench was opened in the site but despite excavating a 17m cultural layer, the team could not reach to the virgin soil (Valipour, 2006). 52 and 53 contexts were recorded in Trench I and II, respectively. Trench II was situated directly below Trench I (layer 1052 in Trench I and layer 2003 in Trench II are common) and we can therefore consider them as a single sequence. Trench I covers the two main periods of the Early, Middle (Red slipped ware), and Late Bronze (Polychrome ware) and Iron Age. Because of the lack of charcoal samples, the team could not date the whole sequence of Trench II, but based on the ceramic sequence there is continuity of site occupation with the Kura-Arex ceramic types of burnished dark grey wares of the Early Bronze Age. Based on this observation, the cultural materials of Trench II at Tepe Shizar cover the Middle and Late Chalcolithic, and the Early Bronze Age. The Early Bronze age potteries are comparable with those in Ismaeil-Abad and Duran-Abad in Qazvin plain, Yanik and Haftovan in Northwestern Iran and Gurab, Godin IV and Pissa in Hamadan province. The polychrome potteries of the Late Bronze Age at Shizar, with respect to their forms and decorations, are similar to those in Haftovan Tepe of northwestern Iran and Tepe Sagzabad of the Qazvin Plain (Mostafapour, 2011: 121-4).

The data consist of 15 radiocarbon dates, seven from Trench I and eight from Trench II (Table 5).

The stratigraphs for Trenches I and II are shown in Fig. 8. In order to use all the information from the 15 radiocarbon dates, we assumed a continuous stratigraphy between Trenches I and II, and constructed a model which defines a Middle and Late Chalcolithic period (defined solely from Trench II), a continuous Bronze Age phase from both Trenches (with five dates in the Early Bronze Age and two in the Late Bronze Age), and an Iron Age I phase with a sequence defined from Trench I. The boundaries EC (End of Chalcolithic), SEBA (Start of Early Bronze Age), EEBA (End of Early Bronze Age), SLBA (Start of Late Bronze Age) and T (LBA to IA I transition) were inserted into the model. The two boundaries EC and SEBA were used because there is an obvious gap between the latest Chalcolithic date and the Early Bronze Age date, although the stratigraphy shows (Fig. 8) that there are several undated layers in this gap, so this does not imply a hiatus. Likewise, the inserted boundaries EEBA and SLBA were inserted because there are no dates associated with the MBA layers, although from the stratigraphy these occupy more than a metre of deposit and at least 11 contexts.

This model converges extremely well, and suggests (Fig.9, Table 6) that the boundary for the start of the Middle Chalcolithic occurred sometime between 3978– 3703 cal BC (most likely range 3970 – 3907 cal BC, median 3937 cal BC), and the start of the Early Bronze Age was between 3246 – 2658 cal BC (most likely range 2947 – 2725 cal BC, median 2864 cal BC).

Because of the gap between these two boundaries of some 1000 years with no dates, these dates do not necessarily define the end of the Chalcolithic or the beginning of the Early Bronze Age at this site – all that can be said is that the end of the Chalcolithic period is some time after c. 3900 cal BC, and the Early Bronze Age began some time before c. 2850 cal BC.

Likewise, the boundary inserted at the end of the Early Bronze Age (EEBA) is modeled at 2570 – 2139 cal BC (most likely date 2556 – 2391 cal BC, median 2451 cal BC), and that at the start of the Late Bronze Age at 2311 – 1692 cal BC (most likely date 1978 – 1705 cal BC, median 1882 cal BC). The uncertainty in the upper bound of EEBA and the lower bound of SLBA is again due to a lack of dated contexts in the intervening c. 500 years. The stratigraphy (Fig. 8) suggests that the Middle Bronze Age occupies this period. The boundary (T) inserted between the Late Bronze Age and Iron Age I layers gives a modelled date of 1714 – 1535 cal BC (most likely range 1661 to 1571 cal BC, median 1618 cal BC). This is extremely well-constrained by the LBA date of context 1021 and the IA I date of context 1016.

2.4. Tepe Sagzabad

Tepe Zagheh, Tepe Ghabristan and Tepe Sagzabad form a group of three closely-related sites in the Qazvin Plain, 60 km south of the modern town of Qazvin in Zanjan province, 140 km west of Tehran. Zagheh is 2 km east of Sagzabad, and Ghabristan is 300 m west of Sagzabad.

They were excavated in the 1970s by E. O. Negahban (Negahban 1976, 1977 & 1979). Tepe Sagzabad is one of the few sites in the north central Iranian Plateau to show evidence of continuous settlement during the Bronze and Iron Ages, and is therefore an important site to study the transition from Bronze to Iron. Accordingly, Trenches II and IV from the 2008 excavation were selected for dating, respectively in the north east and southern areas of the site (Fazeli Nashli et al., 2011). Nine charcoal samples were submitted from Trench II and 8 from Trench IV, with a further sample from context 5006 in Trench V. Unfortunately results were only obtainable for seven samples from Trench II (including one with a very low yield) and five from Trench IV, as listed in Table 7.

Trench II

Trench II has one date from the base of the Late Bronze Age sequence, and six from Iron Age I - only five are marked on the stratigraphy (Fig. 10): context 2006 is not shown but is assumed to be between 2005 and 2011/2014. A sequence through these dates with a boundary inserted between the LBA and IA I layers gave a poorly-constrained date of 1676 – 1472 cal BC (95%) for this transition, which is undoubtedly due to the presence of only one date early in the LBA phase, at least 3 m below the stratigraphic boundary. This single date (context 2034) is, however, at the base of the sequence, so the S boundary in the model gives a reasonable if poorly constrained estimate for the start of the LBA at this site – 2219 – 1554 cal BC at 95%, or 1841 – 1564 cal BC at 68%, with a median of 1730 cal BC. Convergence on this model is poor due to the presence of OXA-X-2323-10, which is noticeably out of order (see Figure 13). Given that the laboratory labeled this an OxA-X number (which signifies a date of doubtful reliability - see note below Table 7), it would be reasonable to omit this sample from further consideration, although it is unlikely to affect the modeled boundary dates very significantly.

Trench IV

Only five dates were obtained from this trench, with two at the base from the Late Chalcolithic contexts, one on the top of the Late Bronze Age levels, and two from within the Iron Age I (Fig. 11). A sequence was put through these dates, with a boundary at the end of the Late Chalcolithic (ELC), at the beginning of the Late Bronze Age (SLBA), and one (T) between the LBA and IAI. As might be predicted from the position of the single LBA date in the stratigraphy, the ELC and SLBA are poorly constrained, but the LBA/IAI transition is modelled to 1492 – 1221 cal BC (later than in Trench II, although just overlapping: Figure 12). From the stratigraphy (Figure 11), the earliest Late Chalcolithic context (4027) is at the base of the sequence, so the modelled start date (S) is a reasonable estimate of the beginning of the LC at this site. This gives a modelled age of 4049 – 3537 cal BC (95%), or 3728 – 3548 cal BC (68%), with a median of 3667 cal BC.

Tepe Sagzabad Modeled by Archaeological Period

Since both sections are relatively short and have an unknown relationship, we have modeled all the dates from Tepe Sagzabad by archaeological period (two LC dates, two LBA dates and eight Iron Age I dates) rather than by stratigraphic position. Each period is considered as a phase in the model, but with the stratigraphic sequence within each trench retained within the phase description. Boundaries were inserted as for Trench IV (ELC, SLBA, T). There are nine additional radiocarbon dates for Tepe Sagzabad available in the literature. Mashkour et al. (1999) give four dates measured by Gif-sur-Yvette, France, on animal bone from the Iron Age layers at Sagzabad. These are from the excavations in 1970 and 1974. They also list three dates from Sagzabad measured by Bovington and Masoumi (1972) at the Tehran University Nuclear Centre (TUNC-13, TUNC-8 and TUNC-9), and a further two which they appear to misattribute to Ghabrestan (TUNC-11 and TUNC-7), but which in the original publication are described as being from Sagzabad Cemetery, Trench A. All these dates are listed in Table 8.

Mashkour et al. (1999), however, state that the dates from Tehran University cannot be compared with other dates because theywere ‘not adjusted for biological fractionation (δ13C)’. This refers to the necessity to correct radiocarbon dates to a common value of δ13C (-25‰) to account for differential fractionation in the material dated compared to the calibration standards (wood), which has routinely been done on all dates since the late 1970s (Walker 2005, 25-6). Given the date at which the TUNC dates were measured, this seems a reasonable assumption, and we too have therefore omitted these dates.

Initially using only the OxA dates, the model gives ELC as 3698 – 2756 cal BC, the median of which (c. 3550 cal BC) may be a reasonable estimate for the end of the Late Chalcolithic at this site. The start of the Late Bronze Age is still poorly defined (2647 – 1511 cal BC), but transition T (the Late Bronze Age/Iron Age I boundary) is modeled as 1582 – 1453 cal BP. We can combine the Gif-sur-Yvette dates with this model by including them as a phase (i.e., having no declared internal order) within the phase that is Iron Age I (there is no stratigraphic relationship between the Gif-sur-Yvette dates and the OxA dates, nor is their any obvious internal structuring). We have also taken the opportunity to omit sample OxA-X-

2323-10 from the sequence within Trench II. This larger model has little effect on the boundary dates for the lower part of the sequence, but does alter the upper part somewhat. The sequence begins in the Late Chalcolithic at 4124 – 3537 cal BC at 95% (most likely range 3736 – 3549 cal BC, median 3671 cal BC), with the end of the Late Chalcolithic modeled at 3698 – 2730 cal BC at 95% (most likely range 3676 – 3465 cal BC, median 3542 cal BC). The start of the Late Bronze Age is modeled at 2827 – 1524 cal BC (most likely range 1938 – 1546 cal BC, median 1781 cal BC). The upper boundary of the modeled date for ELC and the lower boundary for SLBA are extremely poorly constrained because there are no dates between c. 3500 – 2700 cal BC in the model. The transition from LBA to IA I is modeled at 1539 – 1337 cal BC (most likely range 1486 – 1417 cal BC, median 1451 cal BC), and the end of the sequence is pushed forward in time to 1106 – 844 cal BC (most likely range 1042 to 919 cal BC, median 980 cal BC).

2.5. Tepe Zagheh

The main objectives in the re-excavation of Zagheh in 2001 were to ascertain the settlement size of the site, demonstrate the craft areas and collect radiocarbon samples. Eight trenches were opened, of which five reached virgin soil. Ten dates have been published from the Transitional Chalcolithic I sequence of Trench A (with a defined stratigraphic order), done by the Radiocarbon Dating Laboratory, University of Waikato, New Zealand (Fazeli et al., 2005:44-5), reproduced in Table 10.

The top context (1) was said to be disturbed. Constructing a simple sequence through all ten of these dates fails – context 1 is clearly incongruent with the sequence. Omitting this date does allow a model to be run, although the overall agreement index is not good (Figure 14). The modeled boundaries suggest the sequence starts (context 47) at 5786 – 5246 cal BC (median c. 5400 cal BC) and ends (context 7) at 4448 – 3931 cal BC (median c. 4300 cal BC). There are two other published sources of radiocarbon dates from Tepe Zagheh (Table 11**).** Mashkour *et al* (1999) published four dates done by Gif-sur-Yvette, said to be from Late Neolithic contexts at Zagheh. Bovington and Masoumi (1972) also published two dates from Tepe Zagheh measured at the Tehran University Nuclear Centre radiocarbon laboratory (TUNC), but for the reasons given above we have not included these in our modelling. Combining the four dates from Gif-sur-Yvette assigned to the Late Neolithic with the Transitional Chalcolithic I sequence of Trench A (omitting ZH01, as above), using the four LN dates as a phase within the sequence and declaring a boundary T between the LN and the Transitional Chalcolithic, produces a very unsatisfactory model (Figure 15). Clearly the four LN dates are later than or at least contemporary with the Transitional Chalcolithic dates from Trench A. Combining these four dates as a separate phase within the Transitional Chalcolithic gives a more acceptable model (Figure 16), suggesting the Gif-sur-Yvette dates are better thought of as being Transitional Chalcolithic. This is consistent with the statement in Fazeli *et al*. (2005, 43), that Zagheh 'was a Transitional Chalcolithic site with no Late Neolithic material'. This addition has a small effect on the modeled start and end dates of the sequence at Tepe Zagheh (Table 12), suggesting that the dated phases began between 5607 and 5240 cal BC (95%), most likely range 5464 – 5296 cal BC, median 5384 cal BC, and ended between 4451 and 4103 cal BC (95%), most likely range 4430 – 4269 cal BC, median 4324 cal BC, giving the site a dated lifespan of around 1000 years.

2.6. Tepe Ghabrestan

In the first season of re-excavation of Ghabrestan in 2002, eleven trenches were exposed in the northern, southern and western areas of the mound and further five in the central region of previously excavated area. Dates for he Early Chalcolithic and Middle Chalcolithic sequences for Trench L34 at Tepe Ghabrestan have been produced by the Radiocarbon Dating Laboratory, University of Waikato, New Zealand (Table 13: Fazeli et al., 2005:68). These dates form a single sequence, with a transition (T) inserted at the boundary of the Early Chalcolithic and the Middle Chalcolithic. The model (not shown, since it is included in the discussion below) gives the date of this transition as between 4036 and 3819 cal BC.

Mashkour *et al.* (1999) list seven dates done by Gif-sur-Yvette on animal bone from Ghabrestan, from the excavations in 1970, 1973 and 1974 (Table 14). They also list two dates done by TUNC (TUNC-11 and TUNC-7) as being from Ghabrestan, but according to the original data in Bovington and Masoumi (1972) they are from Sagzabad Cemetery Trench A. However, for the reasons discussed above, we have not included the TUNC dates in our analysis.

Since these Gif-sur-Yvette dates are not from Trench L34, it is not possible to relate them stratigraphically to the dates in Table 13. However, the depths of six of the seven samples in Table 14 are given as 30-40 cm (Gif-10411) to 180-185 cm (Gif-10408). It is clear that all the Waikato dates in Table 10 come from contexts which are deeper than approximately 2 m (context 7), above which is labeled as Late Chalcolithic.

It may be reasonable to assume that the dates in Table 14, despite coming from different Trenches, are all from the top 2 m, and are all Late Chalcolithic. To test this, a model was constructed which uses the model described above from Trench L34 as a sequence, but then has all seven dates in Table 14 as a phase (i.e., of undefined internal relationship) above these, with a boundary (T2) inserted, which corresponds to the assumed position of the MC-LC transition at Tepe Ghabrestan. This model converges well (Figure 17, Table 15), and suggests that the beginning of the Early Chalcolithic sequence at Tepe Ghabrestan is 4869 – 4184 cal BC at 95%; most likely range 4481 – 4270 cal BC, median 4391 cal BC.

The Early Chalcolithic –Middle Chalcolithic boundary (T) is virtually unchanged from the above model at 4036 – 3811 cal BC at 95%; most likely range 3996 – 3874 cal BC, median 3941 cal BC). The boundary between the Middle and Late Chalcolithic (T2, assuming that the dates published by Mashkour et al. (1999) can be assigned to the Late Chalcolithic) is modeled at 3923 – 3702 cal BC at 95%; most likely range 3846 – 3665 cal BC, median 3783 cal BC. This is very close to the upper boundary used in the model above (3951 – 3643 cal BC at 95%), which we assume is close to the end of the Middle Chalcolithic from the stratigraphy in Trench L34. The boundary E in Figure 17 might be taken as the end of the Late Chalcolithic at Tepe Ghabrestan (certainly the end of the dated sequence), but is heavily influenced by a single late date (Gif-10409). The modeled age is 2879 – 2329 cal BC; most likely range 2851 – 2610 cal BC, median 2700 cal BC), but Figure 16 suggests that a date before 3000 cal BC might be more accurate.

3. Chronology of Qazvin Plain from Late Neolithic to Iron Age

Table 16 shows a summary of the dates for the modeled boundaries at each site on the Qazvin Plain. As discussed above, because of the different sample availability and stratigraphic constraints at each sites, not all these modeled boundary estimates are of equal reliability or precision. We have indicated this by putting dates in italics in Table 16 if we feel they may be less well-constrained than the others. Unfortunately, no single site covers the entire period, but there is some chronological overlap between some sites. If we take the Qazvin Plain as a chronologically coherent region, we may be able to produce a single model from all six sites which gives better definition of these transition dates, using all the dates from Oxford, and those published by Gif-sur-Yvette and Waikato.

As noted above, however, the dates from Gif-sur-Yvette relating to both Tepe Zagheh (assigned to Late Neolithic, but most likely to be Transitional Chalcolithic) and Tepe Ghabrestan (probably Late Chalcolithic, but not securely so) are unreliably linked contextually to the other dates, and we have therefore not included them in this analysis. The total dataset therefore consists of 77 dates from the six sites [Tepe Chahar Boneh (15), Tepe Ebrahim Abad (15), Tepe Ghabrestan (7, by Waikato), Tepe Sagzabad (12 from Oxford and 4 from Gif-sur-Yvette), Tepe Shizar (15) and Tepe Zagheh (9, from Waikato, omitting one date from a disturbed context)], covering the Late Neolithic I to the Iron Age I.

The model was based on a sequence, using the cultural periods (LNI, LNII, TCI, EC, MC, LC, EBA, MBA, LBA and IA I) as the defined phases, and using the dates from each site which had dates of that period as sub-phases within each phase. No assumptions were made about the relative order of these sub-phases (since they were from separate sites), but the stratigraphic sequences discussed above were used to order the dates within each sub-phase, if available. The results are summarized in Table 17 and Figure 18, which show the modeled ages for each of the inserted boundaries.As general observations, from Figure 18 it can be seen that there appears to be a gap between the end of the Late Neolithic I and the beginning of the Late Neolithic II, and the Transitional Chalcolithic I period appears to have lasted approximately 1000 years (probably because we are missing contexts dated to the Transitional Chalcolithic II).

We have no dates for the Middle Bronze Age, although the gap of c. 800 years which exists between the end of the Early Bronze Age and the beginning of the Late Bronze Age would easily accommodate the MBA. On current evidence, the Late Bronze Age appears extremely brief – perhaps only lasting less than a hundred years. It must be noted, however, that such observations are critically dependant on very few dates, even within this data set, and the model assumes a ‘step function’ transition from one period to the next, which is almost certainly not the case.

4. Conclusion

Excavations of the archaeological sites of Zagheh, Ghabrestan and Sagzabad have provided basic information to study long term of cultural developments within the central plateau of Iran. However, lack of c14 dates and a secure stratigraphic record have resulted in an incorrect chronological framework for the above sites. Before this study, no absolute and relative method followed for the chronology and archaeologists tried to propose a general picture of chronology rather than narrowing it into the chronometric dating. The results of the present study can be summarized as follows:

1. The study reveals the Neolithic period of the Qazvin plain based on the stratigraphic sequences of the two sites of Ebrahim Abad and Chahar Boneh. The two sites belongs to the latest phases of Neolithic period and there is

still no information about the earlier pre-ceramic Neolithic in the northern Central Plateau of Iran.

2. All relative chronologies of the three sites of Zagheh, Ghabristan and Sagzabad have been revised and for example while the previous relative chronology of Ghabristan suggested it starting at 5200 BC, the current study corrects this to c.4390 BC.

3. From 2001 onward some key sites in the Qazvin Plain have been excavated for chronological purposes but in spite of the many advantages of the new research we still need further studies to complete the chronological sequences of the following periods:

i) It is very important to date any site of the transitional Chalcolithic phase, c. 4600 – 4300 BC. No transitional Chalcolithic sites (Phase II) of the three plains of Kahsan, Tehran and Qazvin have not been dated by c14. Some sites such as Ebrahim Abad, Zagheh and Sialk do not cover the cultural materials of this period and although Cheshmeh-Ali has very good sequences of this period it has not been dated by c14. It is important to note that our information about the latest phase of the Transitional Chalcolithic period is still based on vertical excavation and it is crucial to secure more data from horizontal excavation.

ii) Although the current information indicates some chronometric dates of the Late Chalcolithic period, but in general, the beginning and end of this period in the Qazvin Plain is not known.

iii) There is a large gap in the cultural sequences on the Qazvin Plain from c. 3540 to 1780 BC from the key sites of Ghabrestan and Sagzabad. In the Central Iranian Plateau, this period coincides with major climate changes, earthquake activity, and varying sedimentation styles which may have affected human settlement (Schmidt et al., 2011; Berberian et al., 2012). Further chronological studies will be very valuable to determine if such archaeological gaps are caused by natural disasters or the lack of adequate research.

Acknowledgements

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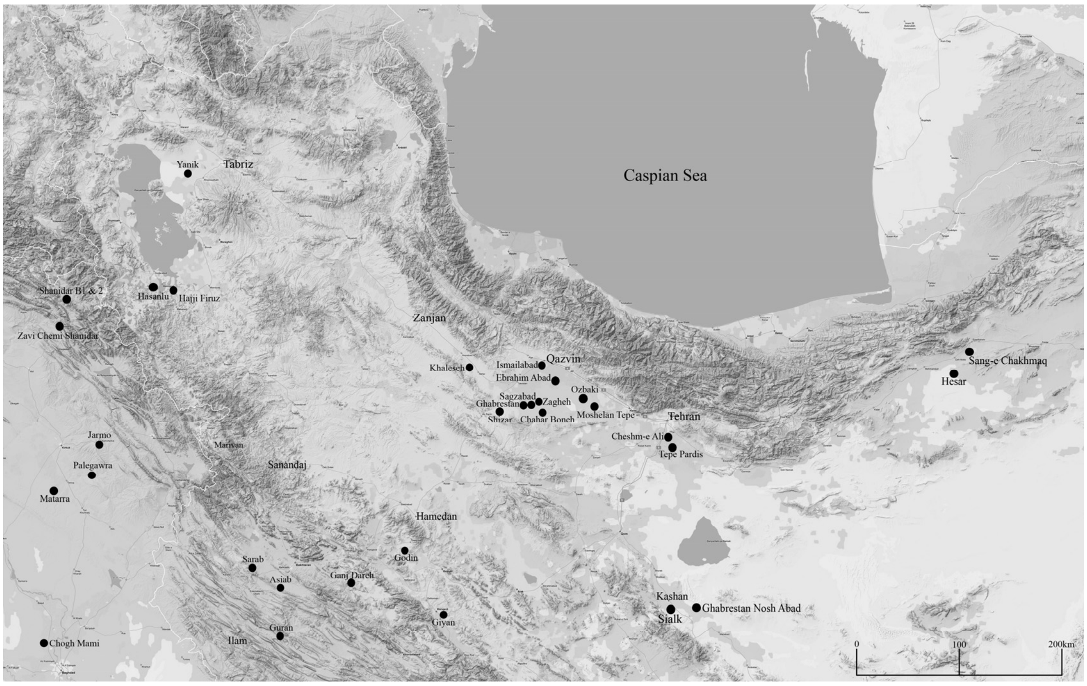

Figure 1. Map showing Location of the Qazvin plain archaeological sites and other neighbours locations in North half of Iran.

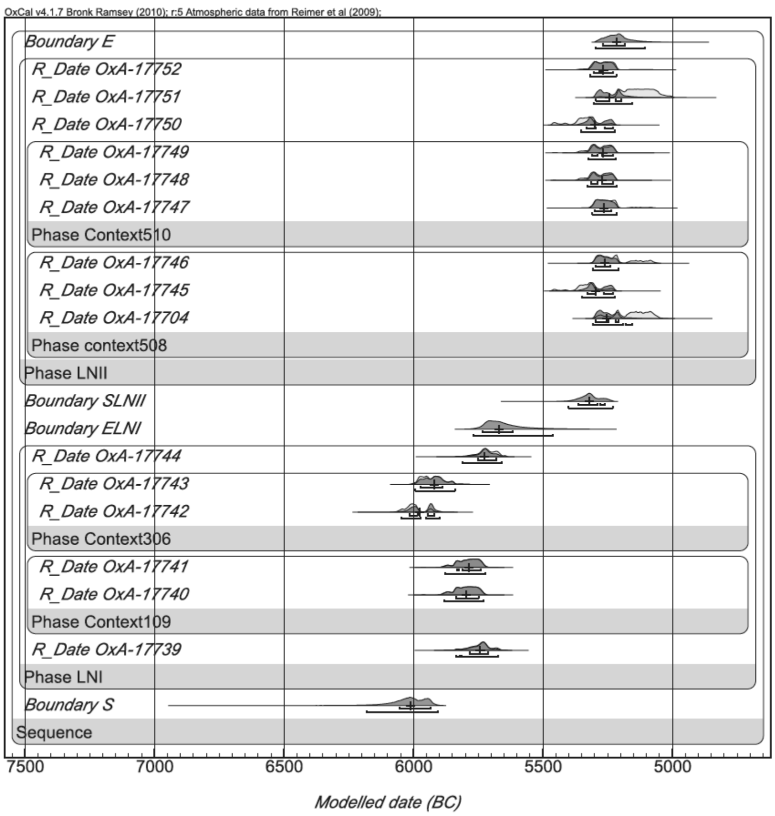

Figure 2. Calibrated and modelled dates for Chahar Boneh LNI and LNII.

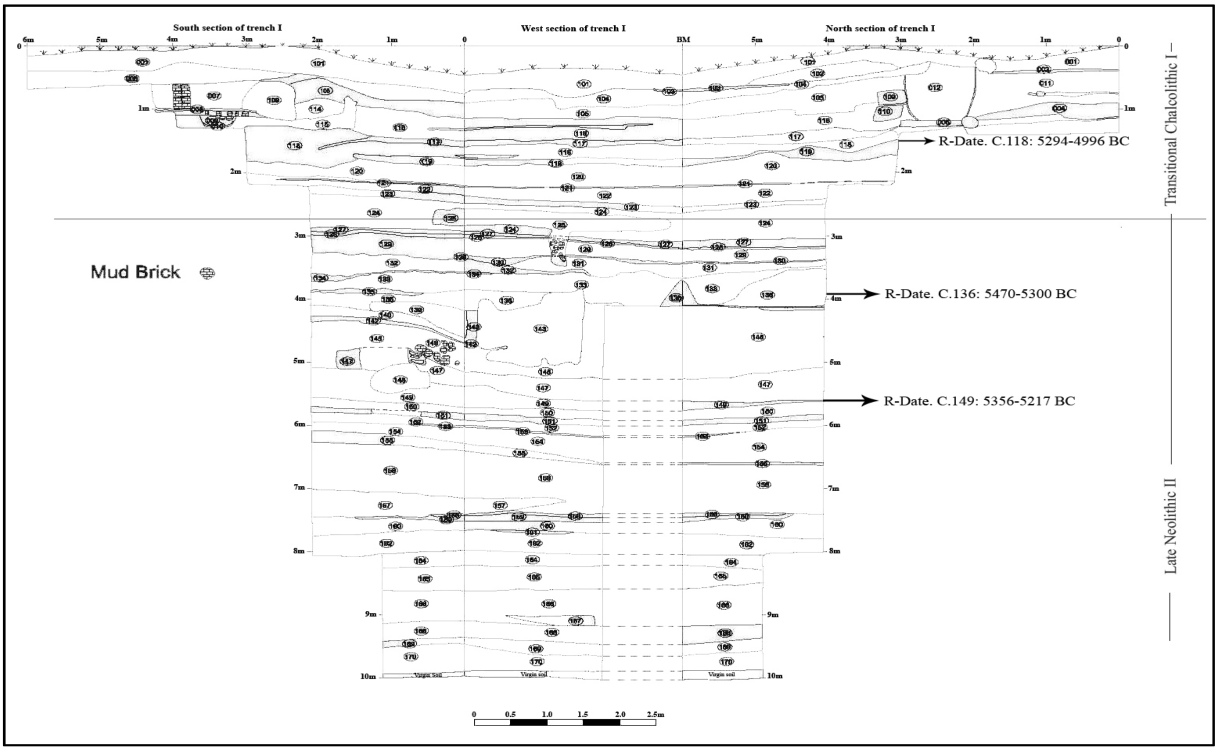

Figure 3. Stratigraphic section of Tepe Ebrahim Abad Trench I with location of radiocarbon samples.

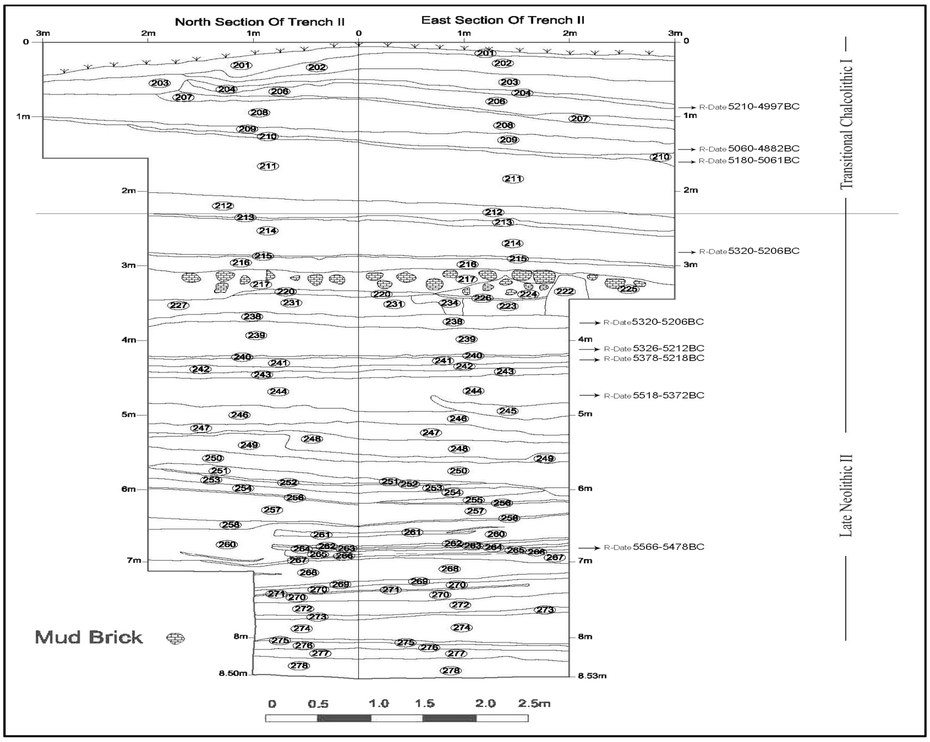

Figure 4. Stratigraphic section of Tepe Ebrahim Abad Trench II and location of radiocarbon samples.

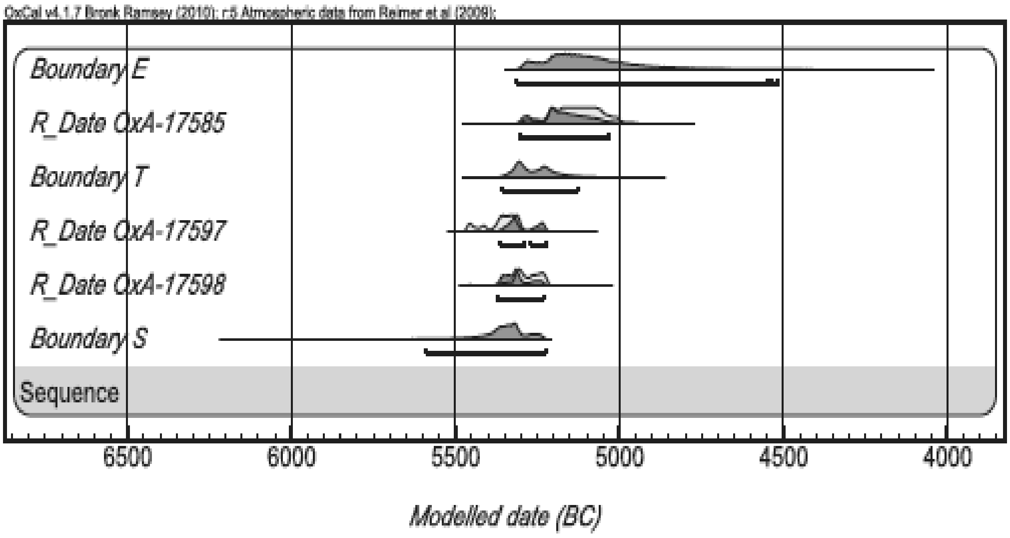

Figure 5. Calibrated and Modelled dates for Ebrahim Abad Trench I.

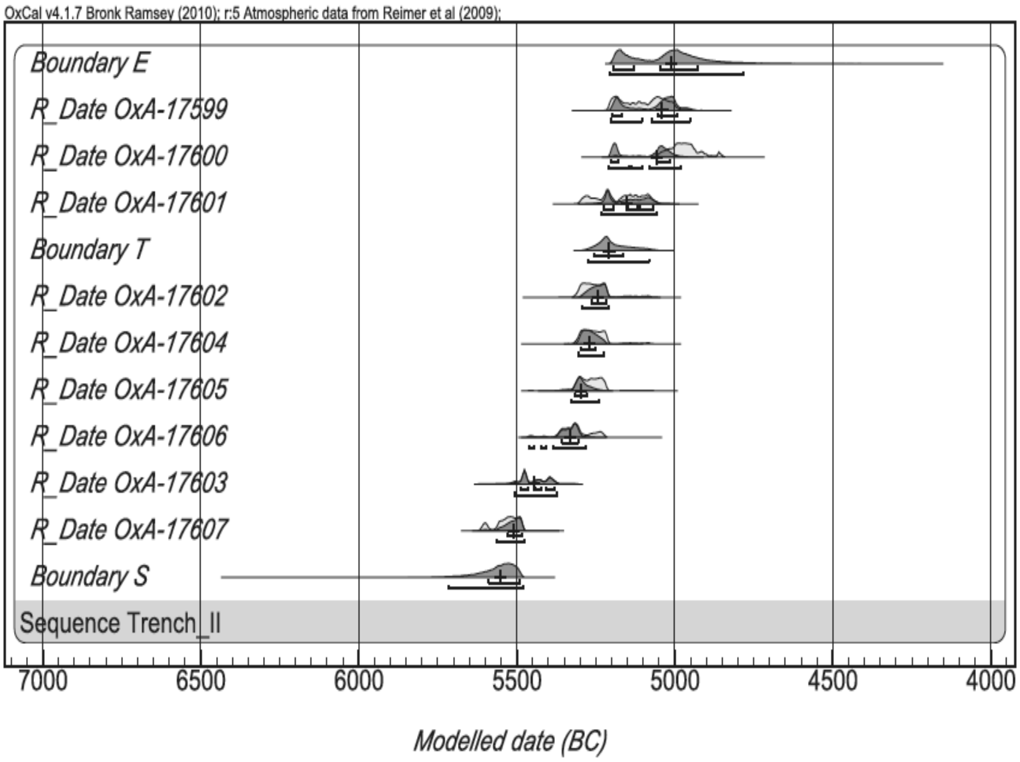

Figure 6. Calibrated and Modelled dates for Ebrahim Abad Trench II.

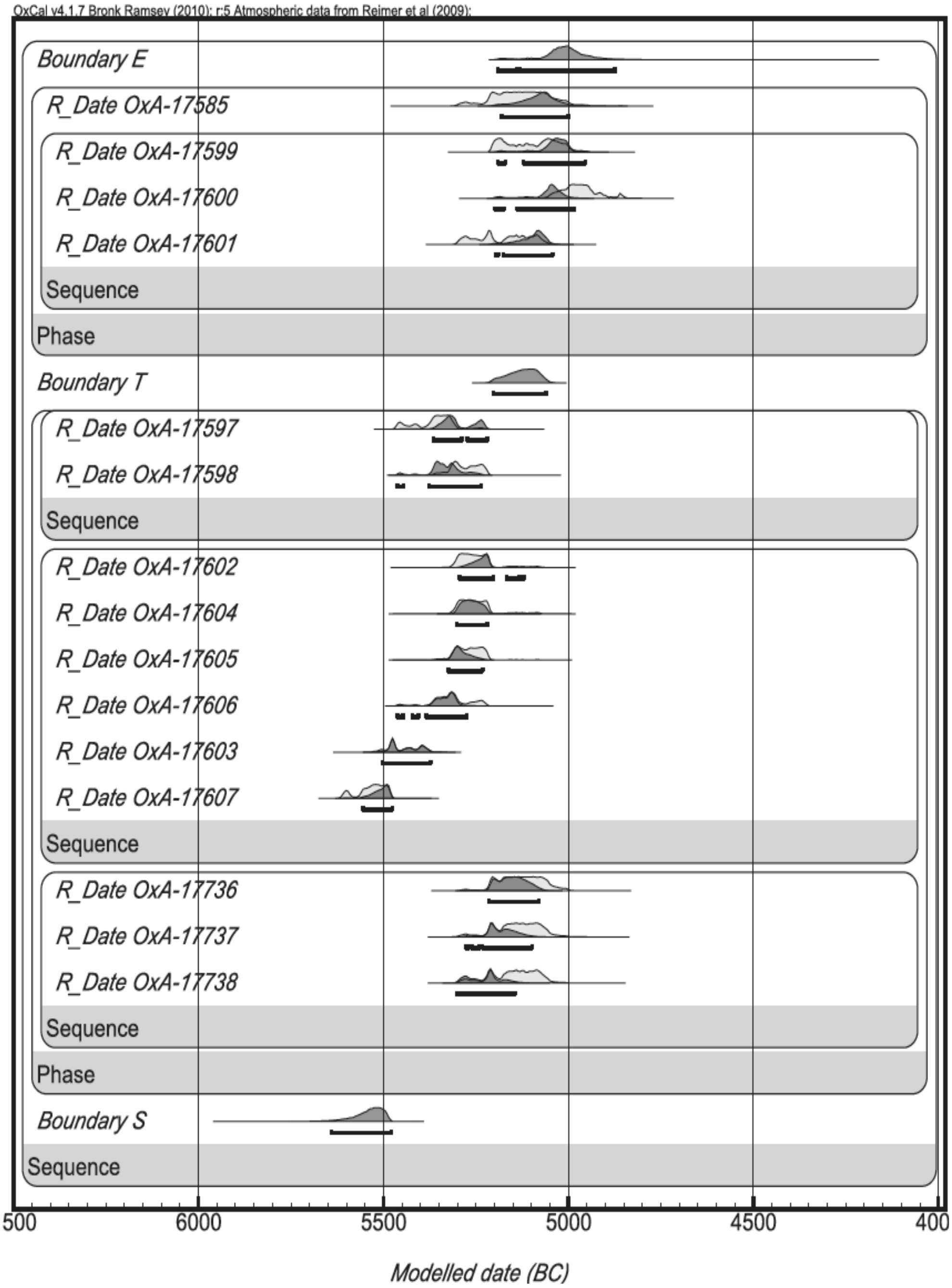

Figure 7. Calibrated and Modelled dates for Tepe Ebrahim Abad classified by archaeological phase.

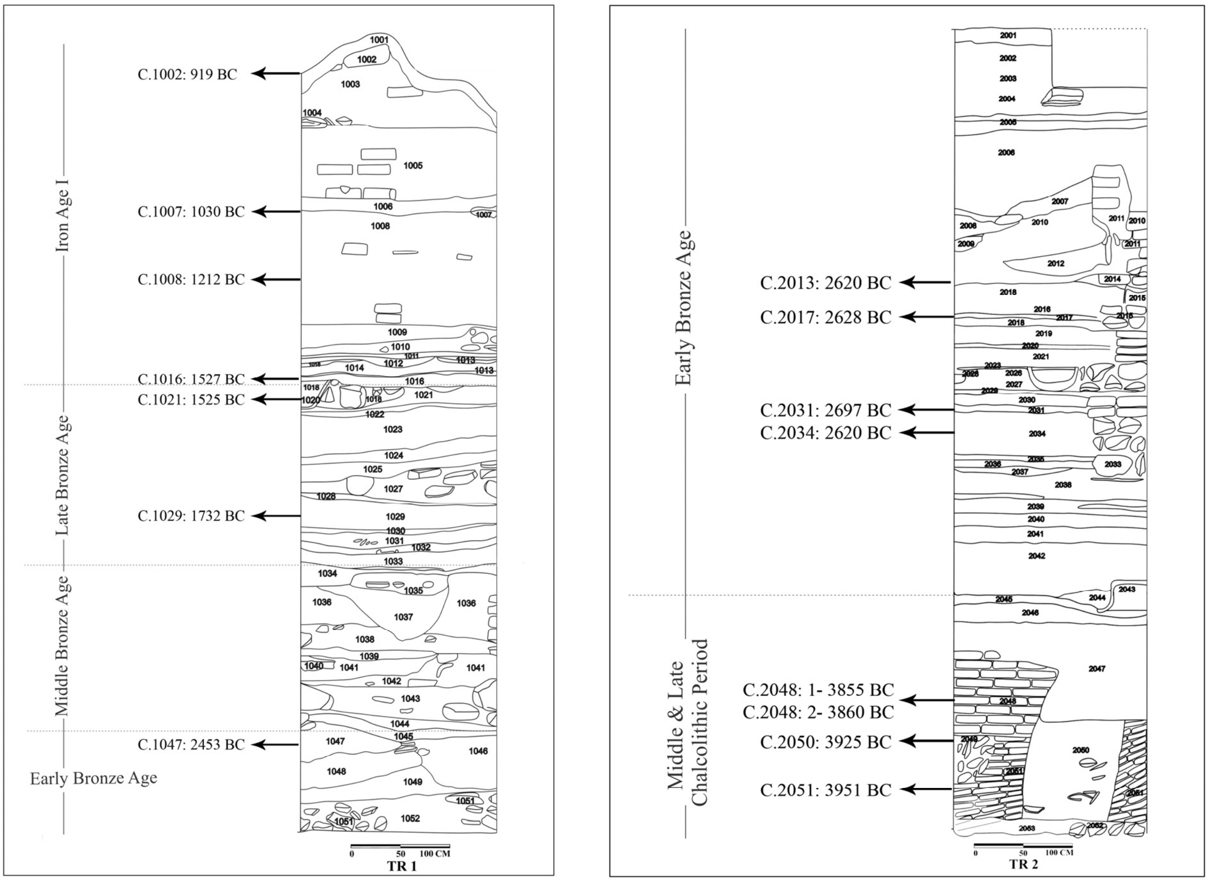

Figure 8. Stratigraphic sections of Tepe Shizar Trenches I and II with contexts selected for C14 dating.

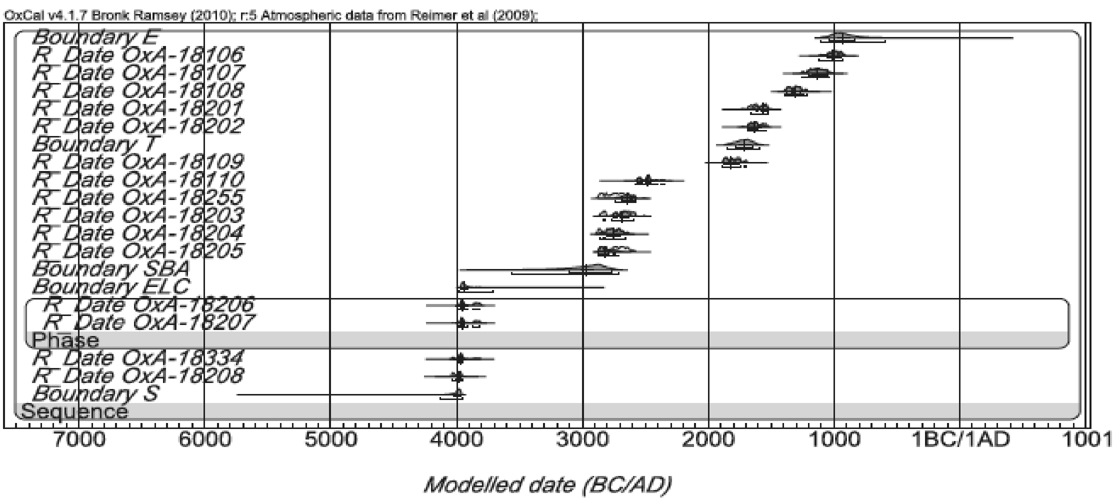

Figure 9. Calibrated and modelled dates from Tepe Shizar assuming a single sequence from Trench II to Trench I.

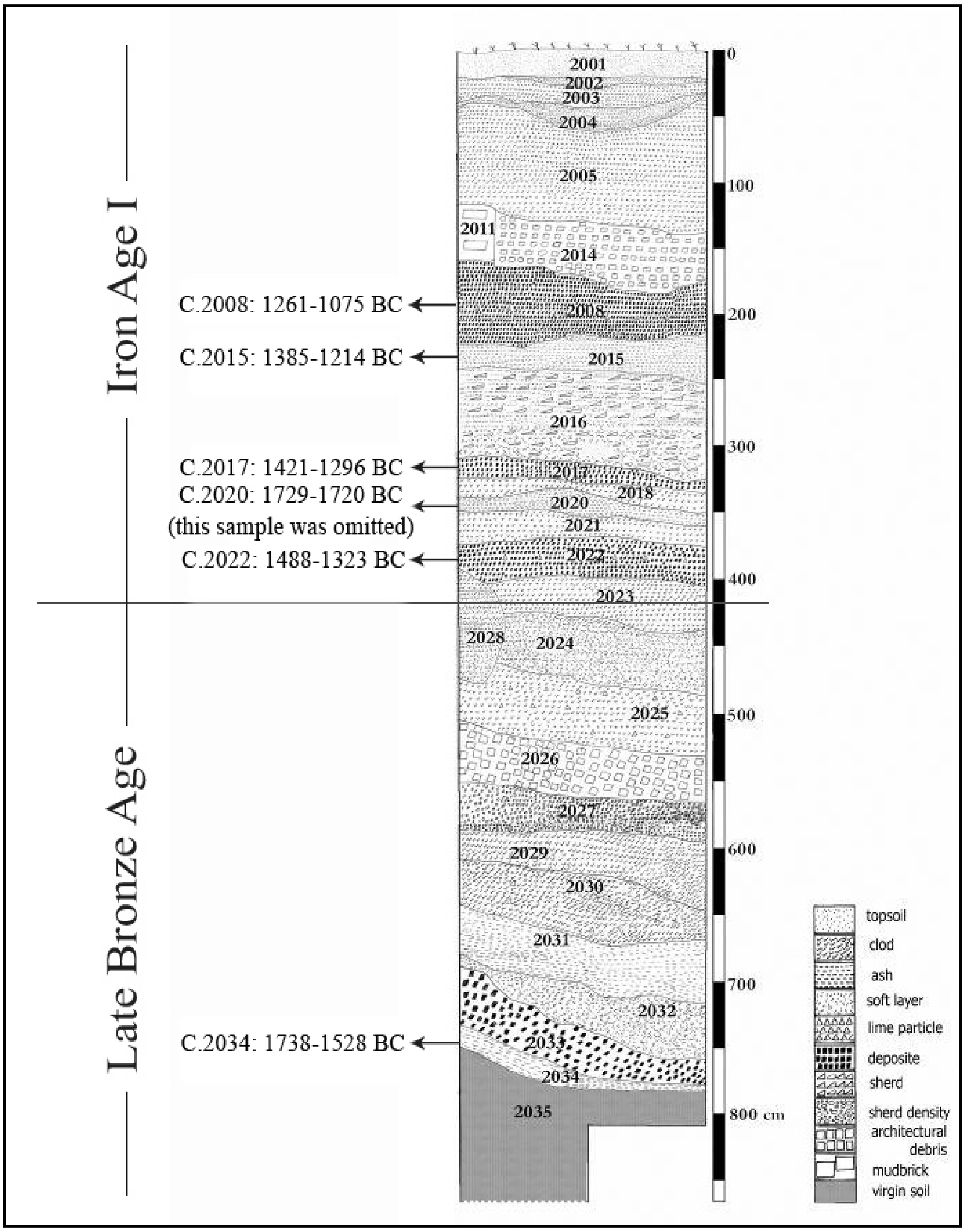

Figure 10. Stratigraphic section of Tepe Sagzabad Trench II with contexts selected for C14 dating.

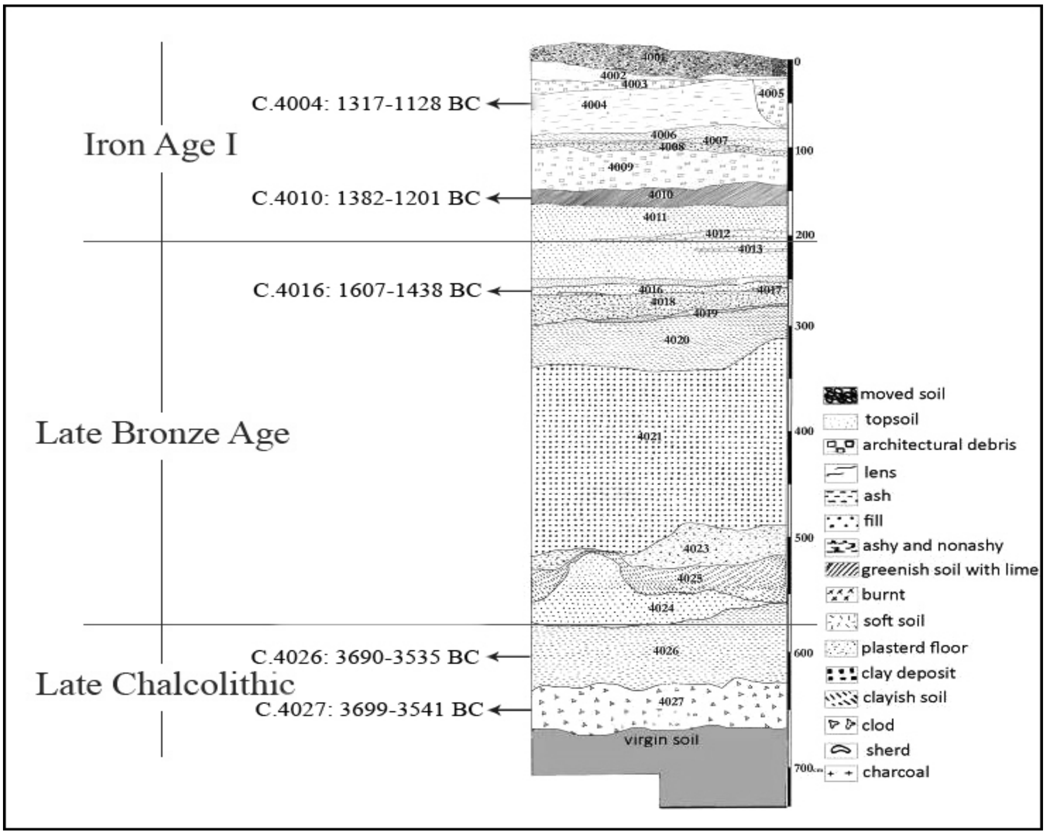

Figure 11. Stratigraphic section of Tepe Sagzabad Trench IV with contexts selected for C14 dating.

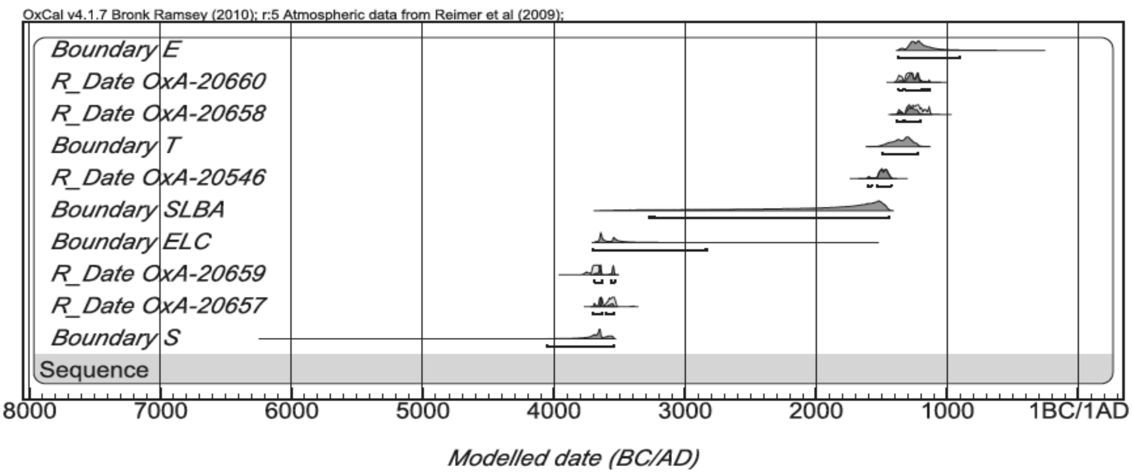

Figure 12. Calibrated and modelled dates for Tepe Sagz Abad Trench IV.

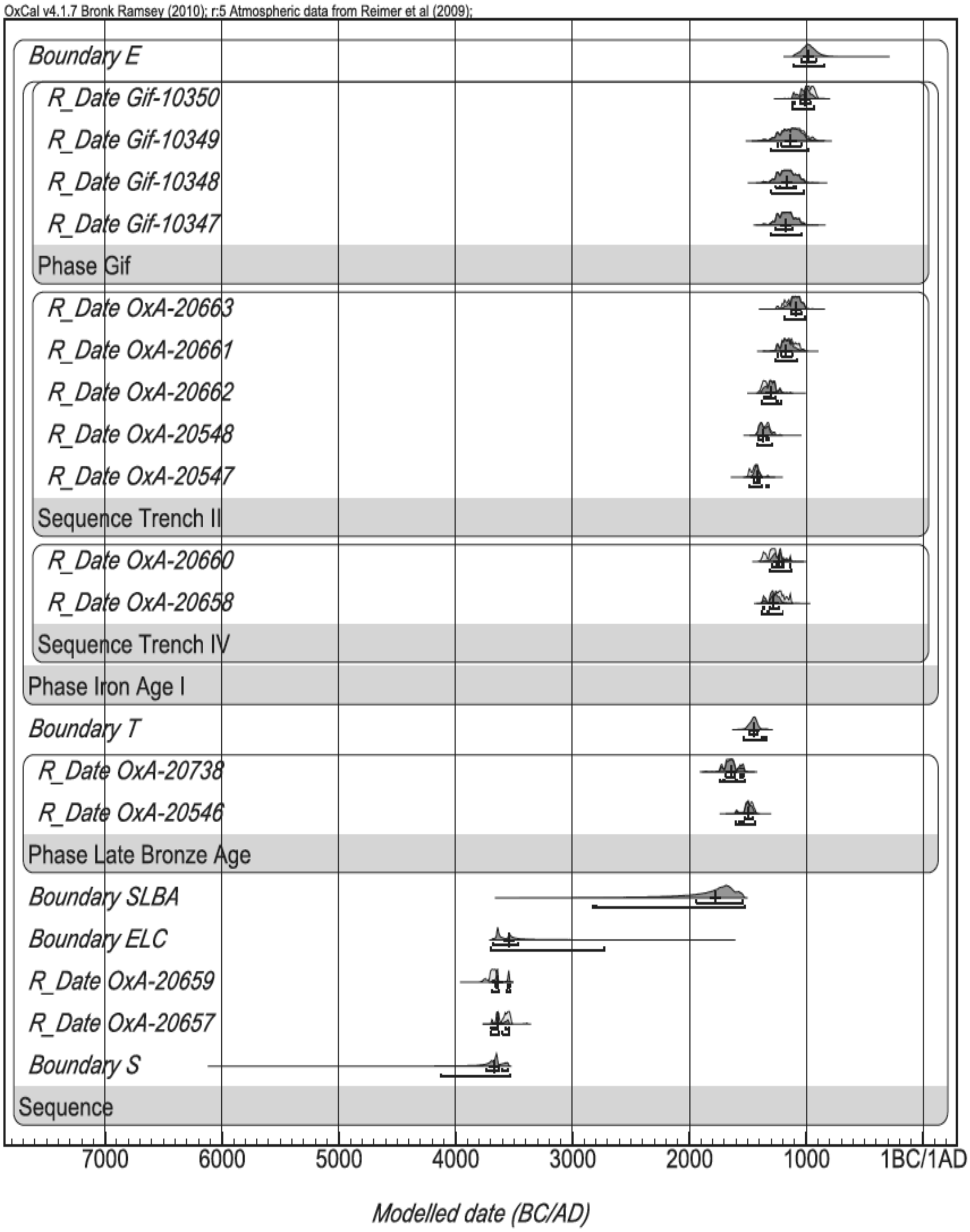

Figure 13. Calibrated and modelled dates for Tepe Sagzabad based on archaeological periods, including dates from Gif-sur-Yvette.

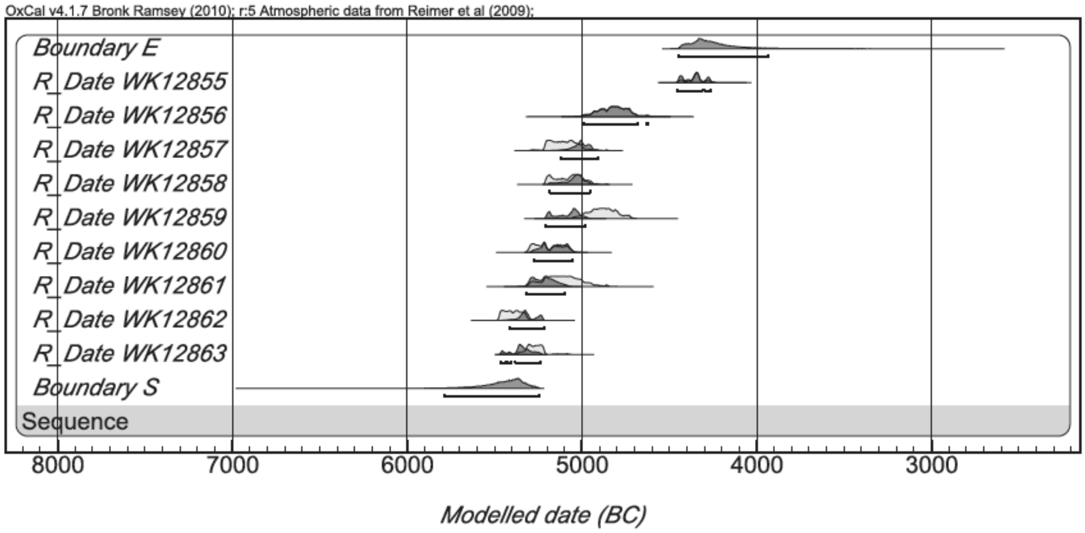

Figure 14. Calibrated and modelled sequence, Trench A, Tepe Zagheh, using 9 of 10 Waikato dates.

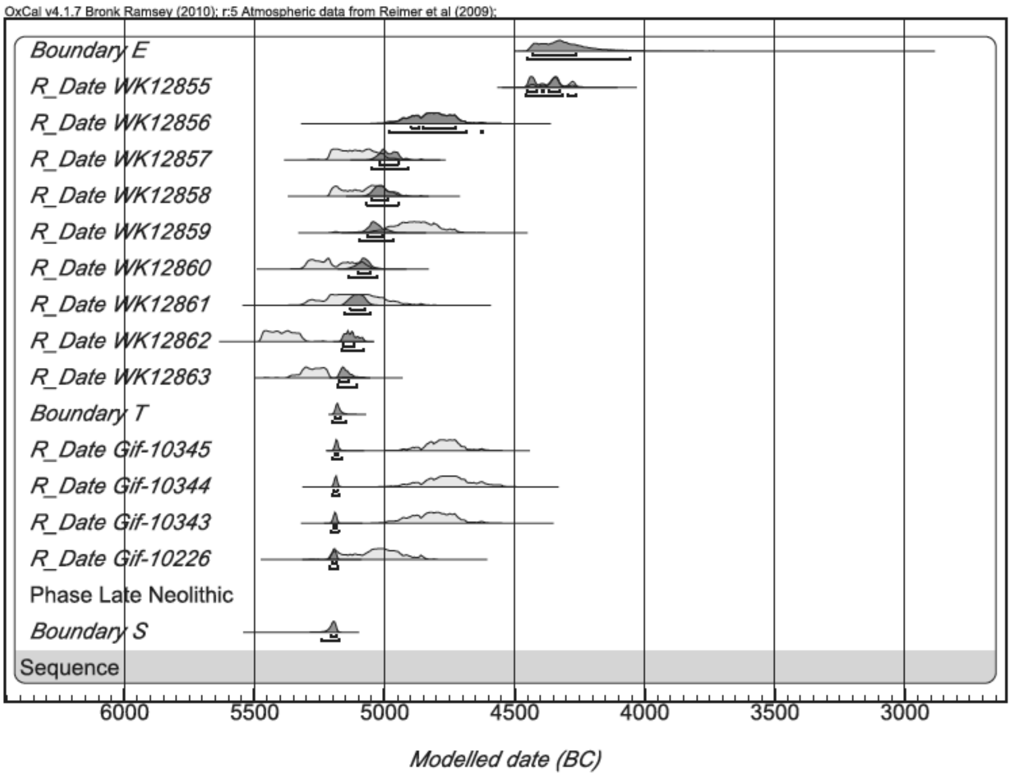

Figure 15. Dates from Trench A at Tepe Zagheh combined with dates from Gif-sur-Yvette, modelled as Late Neolithic.

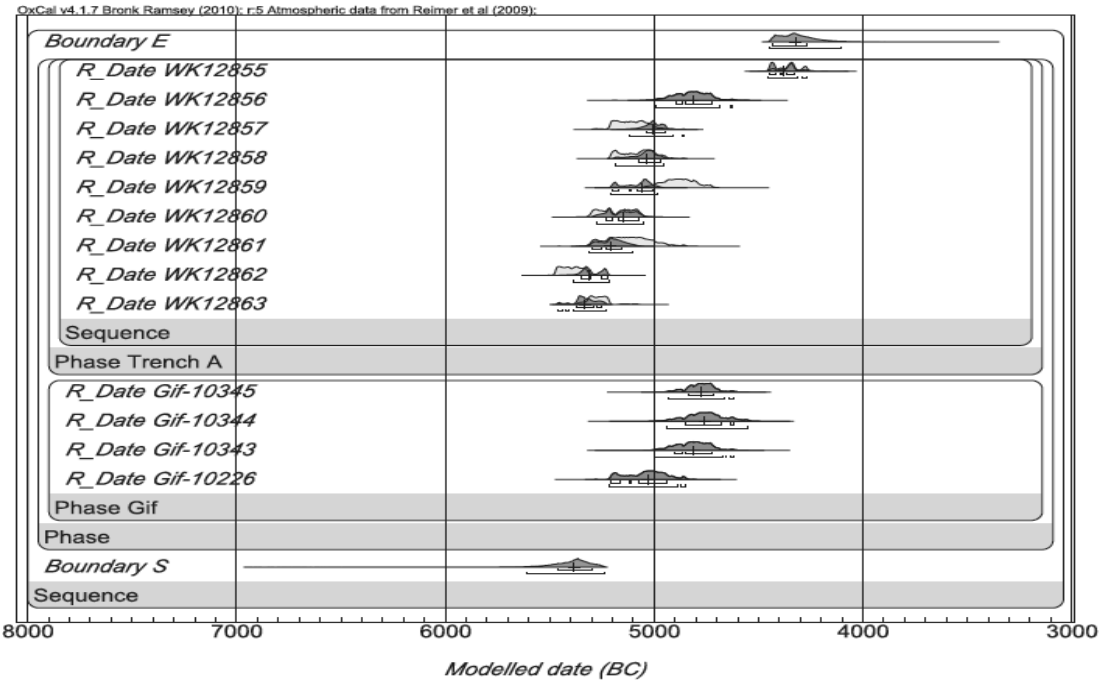

Figure 16. Dates from Trench A at Tepe Zagheh combined with dates from Gif-sur-Yvette, modelled as Transitional Chalcolithic.

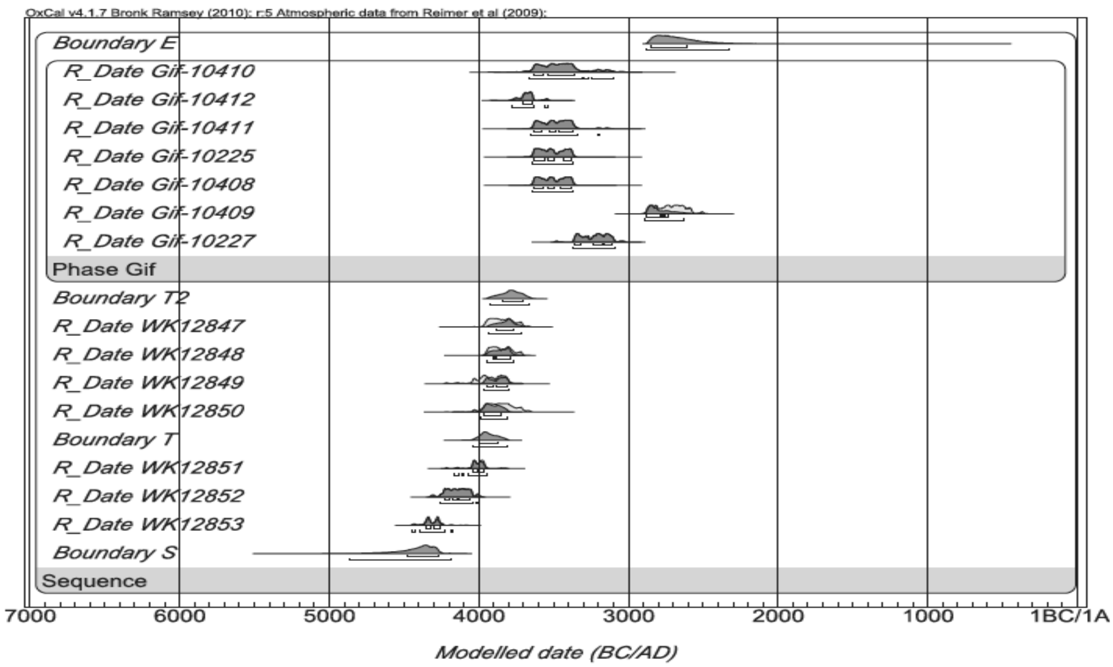

Figure 17. All dates from Tepe Ghabrestan, including those published by Mashkour et al. (1999) as a Late Chalcolithic phase.

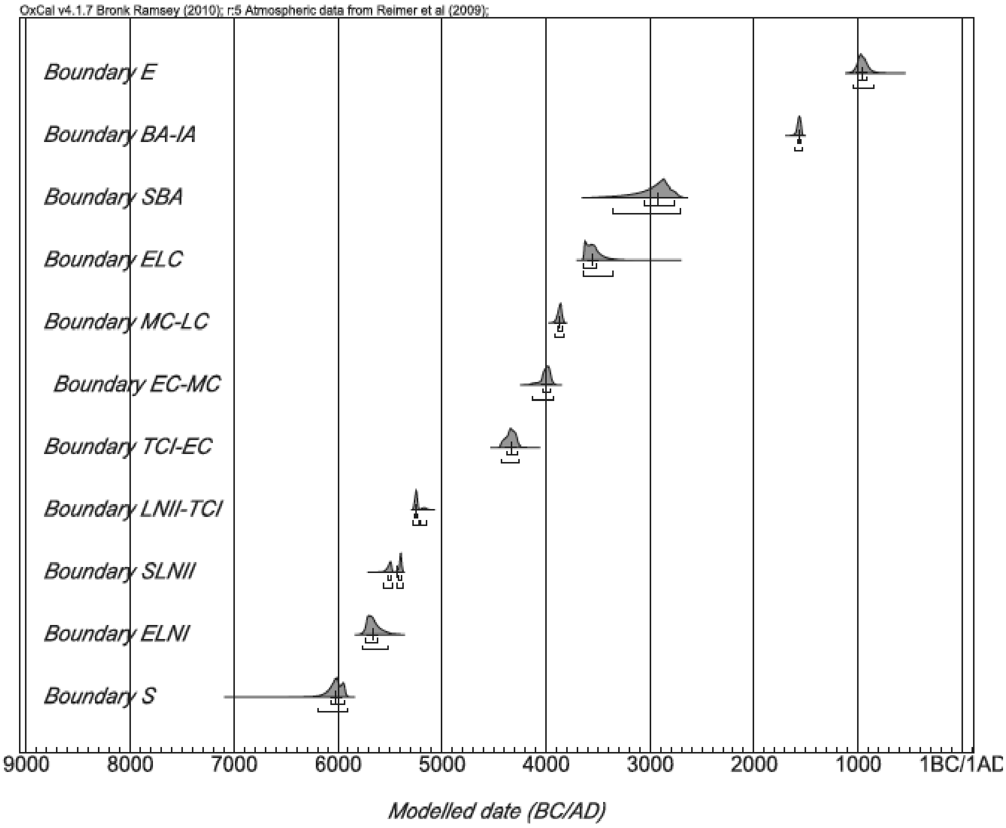

Figure 18. Modelled Boundary Dates for all sites on the Qazvin Plain.

Table 1. Radiocarbon Dates from Tepe Chahar Boneh

OxA	Location	Context	Depth (cm)	Phase	Material	$\delta^{13}C$	Date (Uncal BP)
OxA-17739	Trench I	110	334	LNI	charcoal	-24.7	6858 ± 35
OxA-17740	Trench I	109	334	LNI	charcoal	-24.5	6919 ± 35
OxA-17741	Trench I	109	334	LNI	charcoal	-24.7	6909 ± 35
OxA-17742	Trench III	306	246	LNI	charcoal	-25.5	7123 ± 35
OxA-17743	Trench III	306	246	LNI	charcoal	-25.3	7035 ± 36
OxA-17744	Trench IV	403	403	LNI	charcoal	-24.6	6835 ± 37
OxA-17704	Trench V	508	64	LNII	charcoal	-24.0	6210 ± 35
OxA-17745	Trench V	508	64	LNII	charcoal	-23.7	6345 ± 34
OxA-17746	Trench V	508	64	LNII	charcoal	-23.5	6241 ± 34
OxA-17747	Trench V	510	140	LNII	charcoal	-26.2	6267 ± 34
OxA-17748	Trench V	510	140	LNII	charcoal	-23.3	6311 ± 36
OxA-17749	Trench V	510	140	LNII	charcoal	-23.6	6308 ± 35
OxA-17750	Trench V	512	191	LNII	charcoal	-23.8	6355 ± 35
OxA-17751	Trench VI	606	102	LNII	charcoal	-24.0	6177 ± 36
OxA-17752	Trench VII	702	82	LNII	charcoal	-24.9	6289 ± 37

Table 2. Calibrated and modelled dates for Chahar Boneh LNI and LNII

	Umodelled (BC/AD) (95.4%)			Modelled (BC/AD)				
				(68.2%)		(95.4%)		
	from	**to**	**median**	**from**	**to**	**from**	**to**	**median**
Boundary E				-5270	-5184	-5296	-5104	-5215
OxA-17752	-5353	-5211	-5268	-5304	-5231	-5318	-5217	-5267
OxA-17751	-5221	-5007	-5129	-5296	-5197	-5305	-5152	-5243
OxA-17750	-5467	-5227	-5340	-5332	-5230	-5355	-5223	-5302
OxA-17749	-5358	-5217	-5282	-5313	-5229	-5324	-5219	-5271
OxA-17748	-5362	-5217	-5287	-5314	-5229	-5328	-5218	-5271
OxA-17747	-5321	-5080	-5260	-5300	-5239	-5310	-5215	-5265
Phase								
OxA-17746	-5308	-5072	-5235	-5299	-5240	-5309	-5207	-5263
OxA-17745	-5465	-5222	-5329	-5329	-5229	-5351	-5222	-5297
OxA-17704	-5296	-5056	-5149	-5296	-5209	-5308	-5152	-5255
Phase								
Phase LNII								
Boundary SLNII				-5367	-5260	-5402	-5233	-5322
Boundary ELNI				-5736	-5618	-5773	-5468	-5669
OxA-17744	-5792	-5642	-5715	-5751	-5680	-5811	-5660	-5726
OxA-17743	-5998	-5843	-5929	-5976	-5889	-5994	-5841	-5920
OxA-17742	-6063	-5919	-6005	-6016	-5920	-6049	-5897	-5979
Phase								
OxA-17741	-5878	-5724	-5787	-5833	-5741	-5877	-5725	-5788
OxA-17740	-5882	-5729	-5795	-5837	-5748	-5881	-5730	-5796
Phase								
OxA-17739	-5836	-5666	-5737	-5784	-5712	-5837	-5674	-5743
Phase LNI								
Boundary S				-6058	-5934	-6191	-5908	-6014

Table 3. Radiocarbon dates from Tepe Ebrahim Abad.

OxA	Location	Context	Depth	Phase	Material	$\delta^{13}C$	Date (Uncal BP)
*OxA-17585	Trench I	118	-	TC I	charcoal	-26.6	6175 ± 50
OxA-17597	Trench I	136	-	LN II	charcoal	-22.4	6369 ± 34
OxA-17598	Trench I	149	-	LN II	charcoal	-26.5	6307 ± 34
OxA-17599	Trench II	204	69	TC I	charcoal	-24.9	6138 ± 32
OxA-17600	Trench II	209	122	TC I	charcoal	-25.5	6068 ± 33
OxA-17601	Trench II	210	129	TC I	charcoal	-9.2	6220 ± 33
OxA-17602	Trench II	214	304	LN II	charcoal	-24.9	6265 ± 33
OxA-17603	Trench II	224	384	LN II	charcoal	-23.8	6493 ± 34
OxA-17604	Trench II	238	413	LN II	charcoal	-24.9	6266 ± 33
OxA-17605	Trench II	239	434	LN II	charcoal	-24.3	6291 ± 33
OxA-17606	Trench II	241	486	LN II	charcoal	-24.6	6335 ± 35
OxA-17607	Trench II	266	722	LN II	charcoal	-25.6	6579 ± 33
OxA-17736	Trench III	325	257	LN II	charcoal	-25.8	6176 ± 35
OxA-17737	Trench III	341	323	LN II	charcoal	-26.0	6191 ± 35
OxA-17738	Trench III	355	533	LN II	charcoal	-24.0	6201 ± 34

Lab Comment:

* OxA-17585. This sample produced a very low pretreatment yield. After pretreatment using the regular ORAU treatment of an acid-base-acid sequence the yield was only 20.4 mgs from over 200 mgs of starting material. This is much lower than we would normally expect. When the treated material was combusted for graphitization, the sample yielded only 7.1% carbon (we would expect this normally to be ~60%). This suggests either that the sample was poorly preserved and possibly highly degraded (we did note that it appeared to be poor quality), or that it was only partially composed of charcoal, with the remainder made up of low carbon sediment. This date should therefore be looked at with caution.

Table 4. Calibrated and Modelled dates for Tepe Ebrahim Abad classified by archaeological phase.

	Umodelled (BC/AD) (95.4%)			**Modelled (BC/AD)**				
				(68.2%)		**(95.4%)**		
	from	**To**	**median**	**from**	**to**	**from**	**to**	**median**
Boundary E				-5057	-4957	-5191	-4875	-5008
OxA-17585	-5294	-4996	-5127	-5117	-5034	-5181	-5001	-5076
OxA-17599	-5210	-4997	-5095	-5056	-5000	-5192	-4954	-5031
OxA-17600	-5194	-4848	-4976	-5069	-5016	-5198	-4985	-5046
OxA-17601	-5300	-5061	-5165	-5124	-5057	-5198	-5044	-5090
Sequence								
Phase								
Boundary T				-5158	-5076	-5203	-5061	-5122
OxA-17597	-5470	-5300	-5353	-5346	-5228	-5365	-5220	-5313
OxA-17598	-5356	-5217	-5280	-5367	-5303	-5464	-5236	-5334
Sequence								
OxA-17602	-5321	-5080	-5259	-5259	-5212	-5295	-5121	-5232
OxA-17604	-5321	-5080	-5260	-5291	-5241	-5303	-5220	-5263
OxA-17605	-5327	-5212	-5268	-5316	-5271	-5326	-5233	-5294
OxA-17606	-5463	-5219	-5317	-5355	-5306	-5463	-5275	-5331
OxA-17603	-5519	-5372	-5449	-5488	-5383	-5503	-5373	-5445
OxA-17607	-5613	-5479	-5526	-5522	-5481	-5557	-5476	-5504
Sequence								
OxA-17736	-5221	-5011	-5128	-5207	-5115	-5216	-5081	-5152
OxA-17737	-5291	-5032	-5135	-5219	-5145	-5277	-5099	-5184
OxA-17738	-5293	-5051	-5141	-5295	-5195	-5301	-5146	-5219
Sequence								
Phase								
Boundary S				-5560	-5491	-5641	-5480	-5534

Table 5. Radiocarbon dates from Tepe Shizar.

OxA	**Location**	**Context**	**Phase**	**Material**	**$\delta^{13}C$**	**Date (Uncal BP)**
OxA-18106	Trench I	1002	IA I	charcoal	-20.2	2836 ± 28
OxA-18107	Trench I	1007	IA I	charcoal	-24.6	2925 ± 28
OxA-18108	Trench I	1008	IA I	charcoal	-21.8	3034 ± 27
OxA-18201	Trench I	1016	IA I	charcoal	-24.7	3333 ± 29
OxA-18202	Trench I	1021	LBA	charcoal	-23.9	3334 ± 30
OxA-18109	Trench I	1029	LBA	charcoal	-24.0	3467 ± 29
OxA-18110	Trench I	1047	EBA	charcoal	-21.9	3961 ± 30
*OxA-18255	Trench II	2013	EBA	charcoal	-24.2	4143 ± 35
OxA-18203	Trench II	2017	EBA	charcoal	-22.8	4106 ± 32
OxA-18204	Trench II	2031	EBA	charcoal	-24.9	4174 ± 33
OxA-18205	Trench II	2034	EBA	charcoal	-25.7	4137 ± 32
OxA-18206	Trench II	2048	M & LC	charcoal	-24.8	5123 ± 32
OxA-18207	Trench II	2048	M & LC	charcoal	-24.9	5127 ± 32
OxA-18334	Trench II	2050	M & LC	charcoal	-25.4	5152 ± 32
OxA-18208	Trench II	2051	M & LC	charcoal	-25.3	5184 ± 33

* Comment: Very low carbon content

Table 6. Calibrated and modelled dates from Tepe Shizar assuming a single sequence from Trench II to Trench I.

	Umodelled (BC/AD) (95.4%)			**Modelled (BC/AD)**				
				(68.2%)		**(95.4%)**		
	from	**to**	**median**	**from**	**to**	**from**	**to**	**median**
Boundary E				-1040	-840	-1113	-587	-929
OxA-18106	-1111	-913	-990	-1051	-942	-1115	-926	-1007
OxA-18107	-1256	-1021	-1128	-1194	-1060	-1257	-1036	-1133
OxA-18108	-1395	-1212	-1308	-1375	-1264	-1394	-1213	-1308
OxA-18201	-1689	-1527	-1617	-1619	-1528	-1653	-1518	-1565
Boundary T				-1661	-1571	-1714	-1535	-1618
OxA-18202	-1691	-1525	-1619	-1688	-1623	-1740	-1579	-1659
OxA-18109	-1883	-1694	-1800	-1862	-1694	-1878	-1690	-1768
Boundary SLBA				-1978	-1705	-2311	-1692	-1882
Biundary EEBA				-2556	-2391	-2570	-2139	-2451
OxA-18110	-2571	-2347	-2483	-2567	-2468	-2577	-2407	-2535
OxA-18255	-2876	-2620	-2737	-2670	-2581	-2728	-2575	-2638
OxA-18203	-2866	-2505	-2676	-2742	-2630	-2771	-2588	-2675
OxA-18204	-2886	-2634	-2767	-2792	-2675	-2851	-2636	-2731
OxA-18205	-2874	-2620	-2731	-2869	-2719	-2876	-2679	-2790
Boundary SEBA				-2947	-2725	-3246	-2658	-2864
Boundary EC				-3970	-3907	-3978	-3703	-3937
OxA-18206	-3986	-3801	-3915	-3970	-3945	-3980	-3820	-3956
OxA-18207	-4032	-3801	-3935	-3970	-3945	-3981	-3819	-3956
Phase								
OxA-18334	-4041	-3810	-3967	-3977	-3958	-3992	-3948	-3968
OxA-18208	-4047	-3951	-3991	-3992	-3962	-4038	-3957	-3979
Boundary S				-4020	-3962	-4126	-3953	-3993

Table 7. Radiocarbon dates from Tepe Sagzabad.

OxA	Location	Context	Phase	Material	$\delta^{13}C$	Date (Uncal BP)
OxA-20663	Trench II	2006	IA I	charcoal	-23.7	2912 ± 31
OxA-20661	Trench II	2008	IA I	charcoal	-25.6	2935 ± 29
OxA-20662	Trench II	2015	IA I	charcoal	-22.6	3041 ± 30
OxA-20548	Trench II	2017	IA I	charcoal	-25.7	3082 ± 32
*OxA-X-2323-10	Trench II	2020	IA I	charcoal	-22.5	3329 ± 36
OxA-20547	Trench II	2022	IA I	charcoal	-25.9	3162 ± 34
OxA-20738	Trench II	2034	LBA	charcoal	-23.9	3362 ± 34
OxA-20660	Trench IV	4004	IA I	charcoal	-23.3	3021 ± 28
OxA-20658	Trench IV	4010	IA I	charcoal	-26.5	2990 ± 29
OxA-20546	Trench IV	4016	LBA	charcoal	-23.1	3225 ± 30
OxA-20659	Trench IV	4026	LC	charcoal	-26.5	4909 ± 33
OxA-20657	Trench IV	4027	LC	charcoal	-24.2	4791± 32

* Only 3.2% = low carbon yield (not charcoal)

Table 8. Other published radiocarbon dates from Tepe Sagzabad (Mashkour et al. 1999). TUNC dates (Tehran University Nuclear Centre) originally published by Bovington and Masoumi (1972).

Lab No.	Site/year	Trench/ square	Level/ Depth	Sample	$\delta^{13}C$	Age BP
Gif-10347	SAG 1974	O XXI/2	L XIII	Bone (equid, cattle)	-18.0	2950 ± 40
Gif-10348	SAG 1974	N XXI/2	L IX	Bone (equid, caprine)	-19.2	2945 ± 45
Gif-10349	SAG 1970	A	L XXIV previous XIII	Bone (equid)	-18.0	2915 ± 60
Gif-10350	SAG 1970	A	L XXX previous VII	Bone (equid)	-19.6	2820 ± 30
TUNC-13	SAG 1970	A	L III	Burnt wood		3696 ± 62
TUNC-8	SAG 1970	A	L II	Burnt wood		4086 ± 66
TUNC-9	SAG 1970	A	L I	Burnt wood		4426 ± 69
TUNC-11	SCM 1970	A	268	Burnt wood		6083 ± 84
TUNC-7	SCM 1970	A	160	Burnt wood		3665 ± 61

Table 9. Calibrated and modelled dates for Tepe Sagzabad based on archaeological period, including dates from Gif-sur-Yvette

	Umodelled (BC/AD) (95.4%)			Modelled (BC/AD)				
				(68.2%)		(95.4%)		
	from	to	median	from	to	from	to	median
Boundary E				-1042	-919	-1106	-844	-980
Gif-10350	-1070	-898	-972	-1114	-968	-1121	-931	-1014
Gif-10349	-1302	-932	-1119	-1249	-1042	-1306	-980	-1133
Gif-10348	-1304	-1013	-1164	-1259	-1088	-1301	-1019	-1167
Gif-10347	-1299	-1026	-1171	-1260	-1116	-1303	-1038	-1173
Phase Gif								
OxA-20663	-1252	-1010	-1105	-1131	-1039	-1189	-1011	-1090
OxA-20661	-1261	-1042	-1150	-1248	-1120	-1261	-1075	-1172
OxA-20662	-1406	-1213	-1317	-1356	-1261	-1385	-1214	-1300
OxA-20548	-1425	-1268	-1356	-1408	-1318	-1421	-1296	-1368
OxA-20547	-1504	-1326	-1441	-1448	-1401	-1488	-1323	-1423
Sequence Trench II								
OxA-20660	-1389	-1133	-1288	-1295	-1134	-1317	-1128	-1233
OxA-20658	-1371	-1126	-1233	-1368	-1235	-1382	-1201	-1284
Sequence Trench IV								
Phase Iron Age I								
Boundary T				-1486	-1417	-1539	-1337	-1451
OxA-20738	-1741	-1535	-1654	-1690	-1536	-1738	-1528	-1639
OxA-20546	-1606	-1427	-1488	-1525	-1461	-1607	-1438	-1500
Phase Late Bronze Age								
Boundary SLBA				-1938	-1546	-2827	-1524	-1781
Boundary ELC				-3676	-3465	-3698	-2730	-3542
OxA-20659	-3764	-3641	-3684	-3656	-3538	-3690	-3535	-3641
OxA-20657	-3646	-3520	-3567	-3694	-3546	-3699	-3541	-3644
Boundary S				-3736	-3549	-4124	-3537	-3671
Sequence								

Table 10. Radiocarbon dates for Tepe Zagheh Trench A produced by Radiocarbon Dating Laboratory, University of Waikato, NZ (unpublished data on δ13C values kindly provided by Alan Hogg and Dan Potts).

Sample No.	**Lab No.**	**Context No.**	**Depth (cm)**	**Sample**	**$\delta^{13}C$**	**Result (BP)**
ZH01	WK12854	1	2	Charcoal	-25.3	6154 ± 49
ZH02	WK12855	7	44	Charcoal	-24.0	5489 ± 45
ZH03	WK12856	11	50	Charcoal	-25.7	5936 ± 69
ZH04	WK12857	16	95	Charcoal	-23.7	6152 ± 46
ZH05	WK12858	17	111	Charcoal	-24.9	6124 ± 46
ZH06	WK12859	35	140	Charcoal	-25.4	5991 ± 65
ZH07	WK12860	38	170	Charcoal	-24.5	6233 ± 48
ZH08	WK12861	45	255	Charcoal	-25.6	6169 ± 78
ZH09	WK12862	45	305	Charcoal	-24.4	6410 ± 50
ZH10	WK12863	47	460	Charcoal	-24.3	6295 ± 47

Table 11. Other published radiocarbon dates from Tepe Zagheh byGif-sur-Yvette (Mashkour et al. 1999). TUNC dates (Tehran University Nuclear Centre) originally published by Bovington and Masoumi (1972).

Lab No.	Site/year	Trench/ square	Level/ Depth	Sample	$\delta^{13}C$	Age BP
Gif-10226	TZ 1973	TT FGX	325-335	Bone (cattle)	-18.6	6100 ± 60
Gif-10343	TZ 1994	A8/4	35	Bone (caprine)	-17.7	5930 ± 70
Gif-10344	TZ 1973	D IX	110-130	Bone (mammal)	-17.7	5883 ± 75
Gif-10345	TZ 1970	F IX		Bone (cattle)	-17.8	5900 ± 55
TUNC-10	TZ 1970	F X	Level I	Burnt wood		4909 ± 73
TUNC-12	TZ 1970	F X	289	Burnt wood		7147 ± 91

Tabl e 12. Calibrated and Modelled dates from Trench A at Tepe Zagheh combined with dates from Gif-sur-Yvette, modelled as Transitional Chalc olithic.

	Umodelled (BC/AD) (95.4%)			Modelled (BC/AD)				
				(68.2%)		(95.4%)		
	from	to	median	from	to	from	to	median
Boundary E				-4430	-4269	-4451	-4103	-4324
WK12855	-4449	-4257	-4342	-4451	-4328	-4458	-4267	-4379
WK12856	-5001	-4619	-4819	-4897	-4725	-4990	-4624	-4815
WK12857	-5220	-4961	-5110	-5038	-4947	-5120	-4859	-5004
WK12858	-5211	-4946	-5065	-5074	-4973	-5186	-4952	-5033
WK12859	-5043	-4722	-4884	-5203	-5005	-5206	-4983	-5060
WK12860	-5311	-5056	-5209	-5228	-5071	-5274	-5055	-5148
WK12861	-5311	-4912	-5118	-5299	-5158	-5313	-5100	-5212
WK12862	-5477	-5312	-5397	-5350	-5226	-5387	-5217	-5314
WK12863	-5375	-5078	-5272	-5371	-5256	-5465	-5231	-5333
Sequence								
Phase Trench A								
Gif-10345	-4934	-4618	-4774	-4836	-4715	-4934	-4618	-4774
Gif-10344	-4938	-4553	-4758	-4848	-4621	-4938	-4554	-4758
Gif-10343	-4998	-4618	-4812	-4900	-4721	-4998	-4619	-4813
Gif-10226	-5213	-4849	-5030	-5205	-4936	-5213	-4849	-5029
Phase Gif								
Phase								
Boundary S				-5464	-5296	-5607	-5240	-5384
Sequence								

Table 13. Radiocarbon date ranges for trench L34, Tepe Ghabrestan produced by Radiocarbon Dating Laboratory, University of Waikato, NZ (unpublished data on δ13C values kindly provided by Alan Hogg and Dan Potts).

Sample No.	Lab No.	Depth (cm)	Context No.	Result (BP)	Sample	$\delta^{13}C$	Phase
GB01	WK12847	233	7	5045 ± 61	Charcoal	-24.2	MC
GB02	WK12848	273	8	5041 ± 44	Charcoal	-25.8	MC
GB03	WK12849	343	11	5140 ± 68	Charcoal	-24.5	MC
GB04	WK12850	372	12	5071 ± 83	Charcoal	-24.9	MC
GB05	WK12851	380	14	5188 ± 46	Charcoal	-25.2	EC
GB06	WK12852	455	24	5310 ± 47	Charcoal	-25.1	EC
GB07	WK12853	495	28	5475 ± 45	Charcoal	-21.5	EC

Table 14. Gif-sur-Yvette radiocarbon dates from Tepe Ghabrestan (Mashkour et al. 1999).

Lab No.	Site/year	Trench/ square	Level/ Depth	Sample	$\delta^{13}C$	Age BP
Gif-10227	SCM 1970	A	L XXII	Bone (equid, caprine)	-19.6	4530 ± 45
Gif-10409	SCM 1973	E/J15	100	Bone (equid, cattle)	-17.3	4130 ± 50
Gif-10408	SCM 1973	E/J15	180-185	Bone (equid)	-17.3	4720 ± 70
Gif-10225	SCM 1973	E/J15-407	200-210	Bone (caprine)	-17.1	4730 ± 70
Gif-10411	SCM 1973	EA/G14	30-40	Bone (equid, caprine, mammal)	-17.8	4700 ± 80
Gif-10412	SCM 1973	E/H14	140-150	Bone (equid, cattle)	-17.5	4890 ± 50
Gif-10410	SCM 1974	K xx/3	85-90	Bone (cattle)	-18.6	4690 ± 105

Table 15. Calibrated and Modelled dates from Tepe Ghabrestan, including those published by Mashkour et al. (1999) as a Late Chalcolithic phase.

	Umodelled (BC/AD) (95.4%)			Modelled (BC/AD)				
				(68.2%)		(95.4%)		
	from	to	median	from	to	from	to	median
Boundary E				-2851	-2610	-2879	-2329	-2700
Gif-10410	-3692	-3104	-3466	-3631	-3366	-3661	-3103	-3465
Gif-10412	-3789	-3536	-3680	-3704	-3640	-3774	-3536	-3673
Gif-10411	-3652	-3195	-3485	-3628	-3373	-3652	-3194	-3485
Gif-10225	-3641	-3370	-3518	-3632	-3380	-3641	-3370	-3517
Gif-10408	-3638	-3370	-3508	-3632	-3378	-3638	-3370	-3508
Gif-10409	-2878	-2577	-2722	-2880	-2732	-2889	-2626	-2813
Gif-10227	-3370	-3091	-3214	-3357	-3111	-3369	-3091	-3214
Phase Gif								
Boundary T2				-3846	-3702	-3923	-3665	-3783
WK12847	-3966	-3706	-3849	-3879	-3764	-3931	-3721	-3815
WK12848	-3955	-3713	-3858	-3906	-3790	-3947	-3773	-3845
WK12849	-4225	-3718	-3937	-3948	-3812	-3966	-3798	-3872
WK12850	-4040	-3664	-3861	-3965	-3854	-3987	-3807	-3908
Boundary T				-3996	-3874	-4036	-3811	-3941
WK12851	-4226	-3811	-3999	-4043	-3968	-4161	-3943	-4012
WK12852	-4316	-3996	-4141	-4232	-4062	-4264	-4004	-4147
WK12853	-4446	-4240	-4330	-4355	-4259	-4442	-4179	-4297
Boundary S				-4481	-4270	-4869	-4184	-4391
Sequence								

Table 16. Modelled Transition Dates for Each Site on the Qazvin Plain.

Cultural Periods		**Tepe Chahar Boneh**	**Tepe Ebrahim Abad**	**Tepe Zagheh**	**Tepe Ghabrestan**	**Tepe Sagzabad**	**Tepe Shizar**
Iron Age	Iron Age III 800-550						
	Iron Age II 1200-800						
	Iron Age I 1550-1200					*End 980* Start 1450	*Start 1700*
Bronze Age	Late Bronze Age 1700-1550					End 1450 *Start 1780*	*End 1700*
	Middle Bronze Age 2200-1700					*Missed millennium*	
	EB II Kura-Araxes 2900-2200						
	EB I Proto-literate 3400-2900						*Start 2970*
Chalcolithic	Late (LC) 3700-3400				*End 2700* Start 3780	*End 3540* Start 3670	
	Middle (MC) 4000-3700				End 3780 Start 3940		Start 3940
	Early (EC) 4300-4000				End 3940 Start 4390		

Table 17. The Modelled Transition Dates for all six sites on the Qazvin Plain.

Boundary	**Transition**	**Modelled Age (Cal BC) 95% confidence**	**Modelled Age (Cal BC) 68% confidence**	**Median (cal BC)**
S	Start of dated contexts	6182-5911	6061-5936	6018
ELNI	End of Late Neolithic I	5764-5516	5732-5626	5671
SLNII	Start of Late Neolithic II	5560-5377	5519-5387	5482
LNII-TCI	Late Neolithic II to Transitional Chalcolithic I	5276-5137	5267-5229	5243
TCI-EC	Transitional Chalcolithic I to Early Chalcolithic	4437-4258	4377-4279	4336
EC-MC	Early Chalcolithic to Middle Chalcolithic	4124-3925	4030-3955	3996
MC-LC	Middle Chalcolithic – Late Chalcolithic	3914-3831	3887-3847	3868
ELC	End of Late Chalcolithic	3649-3346	3636-3510	3553
SEBA	Start of Early Bronze Age	3221-2666	2950-2726	2865
EEBA	End of Early Bronze Age	2571-2082	2557-2379	2445
SLBA	Start of Late Bronze Age	1825-1569	1706-1634	1678
BA-IA	Bronze Age to Iron Age I	1667-1540	1651-1579	1615
E	End of dated contexts	1045-827	1002-909	952

گاهنگاری دشت قزوین از نوسنگی متأخر تا عصر آهن بر مبنای داده‌های رادیوکربن جدید

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پژوهش‌های باستان‌شناختی انجام شده در حوزهٔ غرب فلات مرکزی ایران، در جایی که به نام دشت قزوین شناخته می‌شود، اطلاعات ارزشمندی را در خصوص جوامع یکجانشین از نخستین استقرارها تا دورانهای تاریخی فراهم آورده است. برخلاف پژوهشهای باستان‌شناسی در گذشته، مطالعات گاهنگاری جهت استفاده و تبیین سن‌سنجی داده‌های به‌دست‌آمده از لایه‌ها، بیشتر بر مدل‌سازی منحنی‌های احتمالات تأکید دارد. مقالهٔ پیش روی بر اساس داده‌های سن‌یابی‌شدهٔ شش محوطهٔ کلیدی دشت قزوین، الگوی نوینی در خصوص کاوشها و چهارچوب تازه‌ای برای گاهنگاری دشت قزوین ارائه نموده است. پردازش منحنی‌های احتمالات برای تک تک محوطه‌ها لحاظ گردیده تا منجر به بهترین و دقیق‌ترین گاهنگاری گردد. در نهایت تمامی نتایج سن‌سنجی‌ها جهت دست‌یابی به الگویی واحد برای گاهنگاری دشت قزوین از نوسنگی متأخر تا عصر آهن با یکدیگر تلفیق گردیدند. هدف غایی این پژوهش این است که با مدد منحنی‌های احتمالات بتوان نقاط انتقالی مابین اعصار شناخته شده

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واژگان کلیدی: گاهنگاری، دشت قزوین، نوسنگی متأخر، عصر آهن، گاهنگاری رادیوکربن، الگوسازی منحنی احتمالات.