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Title: Radiocarbon evidence for the pace of the M-/L-PPNB transition in eighth millennium BC south-west Asia

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Abstract:

The transition from the Middle to Late Pre-Pottery Neolithic B (PPNB) happened throughout south-west Asia in the mid-8th millennium cal BC. It entailed the abandonment of a number of sites, rapid growth of others, as well as the widespread of morphologically domestic caprines. What remains an unknown is how rapid these processes were in real time. Over the period when the transition was taking place, the calibration curve has two shallow sections divided by a sudden drop, which for many of the older dates creates an illusion of a sudden cultural break around 7600-7500 cal BC. Yet a more detailed study presented in this paper suggests that the transition event could have been spread over a more extended period of time. This, however, is still far from certain due to risks of old wood effects and complexities of site formation.

Keywords: Legacy dates, Pre-Pottery Neolithic, Bayesian analysis

The tempo of cultural transformations is fundamental to understanding their nature and thus identifying factors that caused (pre)history to follow the specific path it took. When rapid changes take place, corresponding major causal factors, such as abrupt climate change (Childe 1936; Weninger et al. 2009)□, or a socio-political upheaval (Gebel 2004)□, have to be invoked and explored. Slower rates of change often imply greater continuity (Harding 2004)□ and the study of the transitions in question becomes one of tracing the connections in the processes involved. These are basic considerations, but they show that understanding change in prehistory often requires specific chronological resolution and that in turn leads to specific requirements of ^{14}C chronologies. This paper discusses whether these requirements are fulfilled for the transition from the Middle to Late Pre-Pottery Neolithic B (M- and L-PPNB), which took place in south-west Asia in the eighth millennium BC. The aim is to look beyond the apparent abruptness of the transition, induced by the shape of the calibration curve, and evaluate whether it is possible to derive good temporal estimates for some of its associated processes. The discussion takes place from a ^{14}C perspective and makes no assertions as to how the transition might appear from the perspective of other markers, such as lithic technologies.

Archaeological background to the M-/L-PPNB transition and effects of the calibration curve

The Neolithic of south-west Asia (mid-tenth to the sixth millennium cal BC) was a period when a number of earlier practices persisted, such as the wide-ranging exchange networks (Richter and Maher 2013; Watkins 2008), other practices, such as agriculture began (Cauvin 2000) and other still, such as the formation of large communities, took hold but then collapsed (Akkermans and Schwartz 2003; Simmons 2007). The overall division of the south-west Asian Neolithic is based on excavations at Tell es-Sultan (Jericho), where, based on material culture and stratigraphy, two Pre-Pottery Neolithic stages (PPN A and B) followed by the Pottery Neolithic A and B were defined (PNA and B) (Kenyon 1981). The PN chronological labels were since re-organized to reflect increasing regional fragmentation in the seventh millennium BC (Akkermans and Schwartz 2003; Garfinkel 1993), but the bulk of the PPN sequence is still based on the A/B division, with further subdivision of the PPNB into Early, Middle and Late, followed by what is defined either as Final PPNB or the PPNC (Cauvin and Cauvin 1993; Kuijt and Goring-Morris 2002; Rollefson 1990). It is most common to think of these broad entities as interaction zones of diverse groups, sharing elements of ideology and material culture(Bar-Yosef and Belfer-Cohen 1989; Watkins 2008), but also showing much regional diversity (Asouti 2006).

This paper focuses on the transition from M- to the L-PPNB. The M-PPNB can be characterized, in the broadest of terms, through the consolidation of agricultural practices (Kuijt and Goring-Morris 2002), continued reliance on hunting (Moore et al. 2000), evidence for wide-ranging exchange of specific objects, such as shells and beads (Bar-Yosef Mayer and Porat 2008), and elaborate mortuary practices (Kenyon 1981; Moore et al. 2000). While the L-PPNB sees the continuation of many of the earlier trends, changes take place. In the southern Levant, east of the Jordan river, “mega-sites” exceeding 8.5 ha emerge (Rollefson 1989; Simmons 2007). There also appears to be a disruption of settlement in the southern Levant west of the Jordan (modern-day Israel and Palestine) (Kuijt and Goring-Morris 2002). Although more recent discoveries identified both Middle and Late PPNB activity on sites west of the Jordan (Khalaily et al. 2008; Goring-Morris et al. 2008), abandonment of a number of settlements is attested and vertical relationships between structures at continuing sites are often unclear. The one known exception might be Kfar Hahoresh in Galilee, where continuous deposits from M- to L-PPNB were observed. However, both in terms of location and archaeological finds, Kfar Hahoresh is very unusual (Goring-Morris 2005) and as such might not be representative of settlement trends throughout the region in general. Other changes throughout the Levant include shifts in patterns of lithic production exchange (Abbes 2003; Barzilai 2010), as well as greater reliance on domestic animals for meat (Wasse 2002). The L-PPNB may have also witnessed the emergence of pastoral nomadism (Cauvin 2000; Makarewicz 2013). For a more in-depth elaboration of the PPNB in general, refer to the review by Kuijt and Goring-Morris (2002).

There is a range of suggested causal factors for the M-/L-PPNB transition. In the southern Levant much of the discussion focuses on the transformation of settlement patterns, with apparent decline of settlement west of the Jordan River and an increase in site footprint to the east. This shift is seen either in terms of increasing population pressures associated with agriculture (Gebel 2004), ecological deterioration driven by overexploiting of local resources (Rollefson and Kohler-Rollefson 1989), or as an effect of the merger of different kin lineages driven by the ideological practices of the M-PPNB (Kuijt 2000). The emergence of an expansive ideology is also proposed by Cauvin (2000), who writing from a more northern Levantine perspective, associated the M-/L-PPNB transformation with the general expansion of the Neolithic.

All of these propositions stress some combination of factors precipitating a more or less sudden set of changes to the archaeological record. From the perspective of the 1980s, when the outlines of the M-/L-PPNB transition emerged, this perception was supported by the radiocarbon record. Pre-dating the 1993 extension of the Holocene calibration series of ^{14}C from German and Irish oaks to 7890 BC (Pearson et al. 1993), the majority of discussions had to take place in terms of uncalibrated radiocarbon ages. Given the substantial uncertainties on many of these determinations, the 2-σ measurement uncertainties of the M-PPNB associated radiocarbon samples came to an end around 8500 ^{14}C BP, creating an appearance of a watershed event. From the perspective of the 2010s the emergence of this watershed can be traced to radiocarbon calibration. The calibration curve around the time of interest consists of two shallow slopes separated by a sudden break between 7600 and 7500 cal BC. For many of the older measurements the shallow sections of the curve act as effective calibration plateaux with the calibrated date ranges stopping at the break in the calibration curve (Supplementary Figure 1). Hence the chronological variability on either side of 7500 cal BC was hidden and an impression of an abrupt transition emerged in the ^{14}C record. While the interpretation in terms of sudden change might be correct, its radiocarbon basis is an artifact of the radiocarbon calibration curve.

Assessing the abruptness of the M-/L-PPNB transition: methodology

With the development of the calibration curve for the eighth millennium cal BC, the increasing number and precision of ^{14}C determinations, and the ability to construct chronological site models, it becomes possible to overcome the homogenizing effects of the calibration curve on either side of 7500 cal BC. Several earlier studies estimated the dating of the M-/L-PPNB transition using calibrated radiocarbon dates (Benz 2013) and even Bayesian modelling (Maher et al. 2011). These studies were focussed at estimating the date of the transition and not its duration. Their methodology was based on aggregating determinations from a range of sites and using different methods to establish the boundary between cultural phenomena. Hence, even with Bayesian analysis the parameter sought is a point in time and the model outputs cannot be interpreted for rates of change.

An alternative approach is to dissociate the various attributes that we use to define a cultural stage and look at the timing of their occurrence within the study area. In this particular case, this would be the distribution of the cultural attributes of the M-/L-PPNB transition: the more clustered they are in the mid-eighth millennium cal BC, the stronger the case for interpreting the cultural shift as an abrupt change. Here the focus is on the timing of site disruption or abandonment, appearance of domesticated caprines and the development of mega-sites in the southern Levant. These categories were selected because they rely on binary observations and therefore avoid the difficulties of attributing more subtle forms of cultural behaviour to particular phases.

The underpinning methodology of this study relies on the pre-screening of sites and material, and subsequent modelling of the screened ^{14}C determinations. The pre-screening process identifies sites with sufficient chronological information on the transition, and rejects samples that might be misleading due to technical reasons or poor contextual association. The importance of the latter part of the pre-screening process was demonstrated by a range of studies on chronometric precision (Fitzpatrick 2006; Taché and Hart 2013; Spriggs 1989). The importance of selecting suitable sites is manifested by Beidha in Jordan, where both M- and L- PPNB deposits were dated using material from well-defined contexts (Byrd 2005)□, but the sampling strategy omitted the structures that brackets the transition. Therefore, the first stage of the pre-screening was the identification of sites with a large enough assemblage of ^{14}C determinations and good overall stratigraphic description that would allow placing the samples within the site history. The actual amount of determinations desired varies on a case-by-case basis: five determinations are enough to date a specific feature, but are not enough to build a chronology of a long-lived mega-site.

The next step was the technical assessment of the pre-treatment and measurement protocols. Bone determinations were rejected due to known issues of poor collagen preservation (Zazzo and Saliege 2011)□. Charred plant and charcoal assemblages were screened for the application of the complete AAA or equivalent protocols. Samples that underwent only an acid wash were for the most part rejected; one exception here are two samples from 'Ain Ghazal (KN-5054 and KN-5056) where the laboratory notes and agreement with stratigraphy provide the basis for the exception. Tracing pre-treatment protocols would not be possible without the help from a number of ^{14}C laboratories (see acknowledgements). Technical assessment also included tracing of the error estimation method to ensure that factors other than the counting rates were taken into account, so as to avoid or mitigate error underestimation (Hewson 1980), and that Oxalic Acid I or II (Stuiver 1983; Waterbolk 1960) were used as the primary standard. What the samples were not screened for was measurement precision. While this is often used as a criterion of chronometric hygiene (Flohr et al. 2016; Maher et al. 2011; Taché and Hart 2013), low measurement precision itself does not mean that the measurement is inaccurate. If there is sufficient evidence to disregard the low precision measurements, this will happen through shrinkage of the modelled date ranges once they are incorporated into chronological models; otherwise rejecting determinations on account of low precision courts over-certainty.

The final step was the contextual assessment of samples in terms of whether they represented the primary burning event (e.g. hearths), dumping soon after burning (e.g. discrete ash lenses), or depositions of unknown origin (e.g. isolated charcoal concentrations). In the last case the samples would be treated in models as *Terminae Post Quos* (*TPQs*) only, or outright rejected. Note that with varying field methods and approaches to contextual description any contextual screening of ^{14}C determinations is, to an extent, arbitrary. This is a recurrent theme in studies on legacy data, where often application of a stringent contextual screening protocol, of the kind described by Spriggs (1989), would leave too few samples to draw any meaningful inferences (Fitzpatrick 2006). Five sites passed all the relevant stages (Fig. 1), though circumstantial evidence from elsewhere is taken into account in the discussion. The small size of the sample is mitigated by the logic of inference used (it is enough to show that some of the aspects attributed to the transition may have happened outside of the 7600-7500 BC watershed) and allows for greater trust in the immediate results. All radiocarbon determinations from the five sites, as well as those considered as circumstantial evidence, can be found in tables in the supplementary material.

The pre-screening stage was followed by construction of site models concerned with events of interest to the current enquiry. The site models were built in a Bayesian framework outlined by Buck et al. (1996) and implemented in OxCal 4.2 (Bronk Ramsey 2009a). The construction followed a feature-by-feature approach as much as possible. This approach relies on relating the samples to one another based on direct stratigraphic observations, of the kind reported in a Harris matrix, rather than on synthetic stratigraphic interpretation, such as allocating samples to site "layers", or "phases". By providing more detailed information the feature-by-feature approach allows for better model precision and can make resolution of conflicts between the data clearer (Bayliss 2015). Note that in some cases implementing a feature-by-feature approach was not possible due to too limited site publication and overall site phases had to be used instead. Whenever estimating the expected timing of a process (be it a stage of site occupation, or time during which a particular feature was deposited) the empty Date(); parameter was used. In these circumstances this command returns the expected distribution of a random sample from the particular deposition process associated with the ^{14}C measurements of interest. In other words, it tells us the probable dates for samples relating to the given process and thus provides an estimate of the time during which the given process took place. For example, if we are interested in the dating of a specific phase of activity at a site, the empty Date(); parameter nested within the representation of that phase in the model will tell us the probable dates for any potential samples that could be obtained and thus an estimate of where we can put the said phase in time. Empty Date(); parameters are chosen over the more conventional use of the sum of posteriors (e.g. Bayliss et al. 2013), as the low number of determinations in many cases precluded the complete exclusion of the artefacts of the calibration curve and also resulted in more precise but less reliable estimates. Use of Boundary(); parameters was limited to instances where they were necessary for technical reasons, to isolate different deposition regimes, or where they had to be implemented to prevent excessive shrinkage and hence unwarranted precision. Charcoal outlier models (Bronk Ramsey 2009b), were used for any samples other than short-lived materials. The outlines of all the models, the underpinning data and the relevant OxCal scripts (including outlier model specifications) are provided in the supplementary material.

Assessing the abruptness of the M-/L-PPNB transition: results

Overall the results of the analyses of individual sites and processes suggest that some aspects of the M-/L-PPNB transition might have taken place well before and after the expected dates around 7500 cal BC. The notion of the abandonment of sites at the end of the M-PPNB in south-west Levant originated at Tell es-Sultan. The site was one of the first to be ^{14}C dated in the world and there are 44 determinations from the Neolithic layers (Burleigh 1981; 1983), although only 27 passed the technical pre-screening and a number had to have their measurement uncertainties extended. The model based on the information provided in the final report on Tell es-Sultan (Kenyon 1981) suggests that the end of the PPNB at the site could have been much earlier than 7500 cal BC (Fig. 2) with the penultimate phase of the PPNB on the site ending in *8230-7725 cal BC* (*Jericho PPNB end Boundary*; *95.4%*

probability), with the *68.2%* modelled date range lying between *8175* and *7895 cal BC*. A case can also be made for discontinuity of settlement in Yiftahel in Galilee. While the settlement produced material culture from both Middle and Late PPNB (Garfinkel et al. 2012; Khalaily et al. 2008), this did not come from superimposed layers, implying that the otherwise vertical replacement of structures might have been disrupted sometime over the course of the M-/L-PPNB transition. PPNB radiocarbon determinations associated with the M-PPNB come from Areas C, E and I, three of the multiple excavation Areas at the site (Garfinkel et al. 2012). The published radiocarbon determinations from Area I all come from experimental studies on dating lime plaster (Poduska et al. 2012). While some of the dates are concurrent with the PPNB, it would be risky to include them in a site chronology until protocols for preparing radiocarbon samples from lime plaster and mortars become more consistent in their reliability (Ringbom et al. 2014). The results from Area E come from four different *Vicia faba* deposits whose relationship to one another is not clear (Garfinkel et al. 2012). As such, they provide little information about the dating of their associated structures, beyond the observation that they belong to the M-PPNB. This leaves Area C, where a burnt building, Structure 700, yielded multiple radiocarbon samples that can be used to build a model estimating the date of the conflagration to *8170-8120 cal BC* (*3.1% probability*) or *7980-7660 cal BC* (*92.3% probability*; *Structure 700 conflagration*), with the *68.2%* modelled date range lying in two ranges: *7940-7780 cal BC* (*62.3%*) and *7775-7755 cal BC* (*5.9%*). Given that Structure 700 lay underneath no more than two structural layers of collapsed mud-brick M-PPNB houses and, given the excavators estimation that these houses would have lasted for two to three decades at most, it becomes possible to speculate that the M-PPNB acidity in Area C at Yiftahel ceased hundreds of years before the break in the calibration curve around 7500 cal BC. If that is indeed the case, then the results from Yiftahel and Tell es-Sultan might indicate that the disruption to the settlement patterns west of the river Jordan, attributed to the L-PPNB, begun already during the M-PPNB. It might be that early abandonments also took place east of the river Jordan, as suggested by isolated ^{14}C determinations from the later stages of the M-PPNB Shkarat Msaied (Hermansen et al. 2006)□. However, the number of dates in that last case is too slight to make any definitive statements at the moment.

Another characteristic of the L-PPNB is the appearance of morphologically domestic caprines. While much recent research stresses that caprines would have underwent close management long before the onset of the L-PPNB (Makarewicz and Tuross 2012; Zeder 2008; 2011), in the Levant caprines come to dominate the zooarchaeological assemblages only with the end of the M-PPNB (Horwitz et al. 1999). This is clear at Abu Hureyra (Moore et al. 2000)□, where the shift from a meat economy based on gazelle and other wild species to one based on domesticated caprines is associated with a shift between the two phases of the Neolithic settlement (Phases 2A and 2B). Thanks to the detailed enough publication of contextual information and a sufficient number of ^{14}C determinations, it was possible to build a reliable model for this transition event, indicating that it took place in *7465-7175 cal BC* (*AbuH 2A-B Transition*; *95.4% Probability*), with the *68.2%* modelled date range lying between *7410* and *7250 cal BC*. However, there are sites in southern Levant where substantial number of caprines could have made an earlier appearance, as seen in the broad ranges for the final stage of activity at Ayn Abu Nukhayla (Henry and Beaver 2014)□ (*Ayn Abu N Phase 3: 7705-7065 cal BC at 95.4% Probability* and *7610-7420 cal BC* at *68.2% probability*). Even earlier occurrence of a large number of caprines displaying a domesticated-like culling pattern takes place at Ghuwayr I (Simmons and Najjar 2006)□, where the final stages of the ^{14}C dated belong to the interval *7740-7430 cal BC* (*Area I Phase III*; *95.4% probability*) (see supplementary information), but insufficient stratigraphic and contextual information means that any modelled results from this site might yet be shown to be inaccurate. In any case, the radiocarbon record indicates that the shift from hunting a range of species to herding caprines could have taken place in different areas in times separated by centuries.

The dating of the growth of Neolithic mega-sites can be discussed with reference to the extensive ^{14}C series from the broad exposures at 'Ain Ghazal in modern day Amman (Rollefson 1998; Rollefson and Kafafi 1996; Rollefson and Simmons 1986; Zielhofer et al. 2012)□□. The site was excavated in four main areas ("Fields"): Central, South, North and East. Within the Central Field a cut through the site, created in the course of road construction, gave the excavators direct access to several meters of M-PPNB deposits, with multiple hearths and in-door ash lenses providing a basis for placing the end of that stage of activity at 'Ain Ghazal at *7800—7145 cal BC* (*Ain Ghazal 14C M-PPNB end Sigma_Boundary*; *95.4% probability*), with the *68.2%* modelled date range lying between *7670—7300 cal BC*. At the same time in the North Field there are L-PPNB structures made use of the abandoned M-PPNB buildings, in one case utilizing an M-PPNB room as a courtyard (Rollefson and Kafafi 1996)□. The date for one of those buildings, Shrine I, is *7430—6820 cal BC* (*early shrine I activity*; *95.4% probability*), with the *68.2%* modelled date range lying between *7210* and *6930 cal BC*, making it later than the expected onset of the L-PPNB. It is therefore plausible that at least some of the M-PPNB buildings in the North Field could have been abandonned for some time before their inclusion into the L-PPNB built environment. If this was the case, some of the expansion of 'Ain Ghazal would have happened several centuries after the expected onset of the mega-site phenomenon around 7500 cal BC. In this context it is very interesting to note that the most recent estimation for the onset of the L-

PPNB at the distant Çatalhöyük indicates a similar, late eighth millennium onset of what may have been a settlement of a comparable footprint (Bayliss et al. 2015).

Taken together, these case studies do not support the notion of a rapid M-/L-PPNB transition around 7500 cal BC. The estimates for the abandonment events associated with the event are earlier than the 7600-7500 cal BC expectation, the development of the mega-site at 'Ain Ghazal might have taken place towards the end of the millennium, while the transition to a meat economy based on domestic caprines could have taken place over multiple centuries.

Assessing the abruptness of the M-/L-PPNB transition: critique

Modelling of the legacy dates from sites bearing witness to different aspects of the M-/L-PPNB transition suggests that the change might have been far more gradual than calibrated ^{14}C date ranges alone would suggest. However, results of Bayesian models only provide the values of the parameters given the data (Hoff 2009) and so, if the data are somehow flawed, or the relation of the parameters to the data is different from that assumed by the analyst, the results themselves might be flawed. Therefore, further scrutiny of the data and the parameters is always necessary. In case of the current study this takes the form of concerns about old wood effects and site formation.

With the exception of Yiftahel, the models discussed above rely to a large extent on charcoal samples that may be subject to an old wood effect. This risk was mitigated using OxCal's charcoal outlier model capacity (Bronk Ramsey 2009b), which evaluates the typical offset between the actual dates of the samples that might be old wood and their expected values given stratigraphy and dates of short-lived material. The outlier model requires some kind of prior probability distribution (often referred to as a "prior"). If the detail of stratigraphic information is sufficient and backed by enough determinations, this prior will be overcome to provide a reliable posterior probability distribution. Otherwise the model results reflect only the prior specification and hence the accuracy of the model results depends to a large extent on our beliefs about the plausible magnitude of old wood effects. The simplest way of checking whether this is the case is to re-run the models using extreme prior probabilities and check if they conflict with the data. In case of Abu Hureyra and 'Ain Ghazal this was the case and hence the old wood effect estimates are dominated by the empirical evidence. However, at Tell es-Sultan and Ayn Abu Nukhayla any prior would fit well with the data and hence the reliability of the priors used had to be considered. This could be achieved by either considering the tree species in the charcoal assemblage, which dictates the maximum extent of the old wood effects, or through comparison to studies which defined old wood effects by pairing short-lived samples with possible old wood specimens. Of the sites discussed herein, one such study was conducted for a Bronze Age layer from Tell es-Sultan (Bruins and van der Plicht 1995), revealing only marginal offsets and is indistinguishable from the one derived for the Neolithic Tell es-Sultan through the use of the default model specification (χ^2= 1.503; 5% critical value at 2 d.f.=3.841). The situation at Ayn Abu Nukhayla is different, as a substantial amount of the charcoal assemblage consists of juniper (Henry and Beaver 2014), which has been associated with millennial offsets towards older dates (Wicks et al. 2016). Therefore, the specification of the outlier model at Ayn Abu Nukhayla was modified to allow both for the greater possibility of substantial old wood effects and for a greater maximum age (Outlier_Model("Charcoal", Exp(25, -10, 0), U(0, 3.5), "t"). It is this outlier model specification that is responsible for the very long tails on the estimates from the site. Note that the actual model result suggests a much smaller scale of the offsets (see above), which can be attributed to the determinations clustering around 8500 ^{14}C BP break in the calibration curve. Overall, both in the case of Tell es-Sultan and Ayn Abu Nukhayla there are reasons to trust the old wood estimates provided. Having said that they are rooted in analogies to either different periods or different archaeological sites.

The next thing to consider is what features of the site are dated and what their relationship to the questions asked is. In case of Abu Hureyra, Tell es-Sultan and, to a lesser extent Ayn Abu Nukhayla these are clear, but conceptual challenges emerge at Yiftahel and 'Ain Ghazal. At Yiftahel the modelled ^{14}C determinations provide the means of estimating the end of activity only in Area C. Nevertheless, Area C is only a fraction of the total extent of archaeological remains and so it is conceivable that M-PPNB could have persisted elsewhere on the location. Indeed, evidence from Area E of Yiftahel might support this possibility. Excavated as part of a rescue project in the early 2000s, Area E yielded four radiocarbon determinations. Two of these determinations, RT-2971 and RT-2972 calibrate to several intervals in the range 7940-7585 cal BC and 7745-7590 cal BC (95.4% probability). This means that Yiftahel could have witnessed continued activity after the abandonment of Area C and that this activity could have persisted without disruption into the L-PPNB.

Extrapolating from excavated to unexcavated areas also affects 'Ain Ghazal, although the impact on the inferential process is different. As discussed in the previous section there are buildings in the North Field of 'Ain Ghazal that make use of earlier M-PPNB structures, but placed by the radiocarbon model several centuries after the expected onset of the L-PPNB, welcoming the possibility that the mega-sites emerged only towards the end of the latter phase. This perspective, however, does not take into account the nature of the processes responsible for the emergence of the large site footprint. Had these processes been ones of rapid expansion, the radiocarbon dates from the site would indeed mark the onset of the mega-site phenomenon at 'Ain Ghazal. Nevertheless, alternative interpretations are plausible, from a more steady, or perhaps punctuated expansion of the site, to the extreme possibility that large footprint is a result of a palimpsest of occupations (Richter and Maher 2013). If any of the scenarios on this spectrum are correct, than the actual onset of the mega-site phenomenon would have taken place when the processes resposible for the increased footprint begun and not when the archaeological site reached its full extent. In this context it is interesting to note that two of the ^{14}C determinations from the South Field of the site (GrN-12971 and GrN-14259), which have been attributed to the L-PPNB by the excavator (Rollefson 1998), might be older than the modelled onset of that activity phase (Fig. 3). If this is indeed the case, than the expansion of the site would have begun earlier than the radiocarbon determinations from the North and East Fields of the site would suggest. However, until the site is better understood these discussions remain speculative.

Having to rely on prior estimates of old wood effects and difficulties in relating the collections of features dated to the parameters of interest means that the picture of the gradual transition developed in the previous section could be inaccurate. With the possibility that the old wood effects at Tell es-Sultan were underestimated and that the current ^{14}C data might be insufficient to trace the events of interest at Yiftahel and 'Ain Ghazal, a valid argument can still be made for the M-/L-PPNB transition taking place in one or two centuries around 7500 cal BC, if supported by other strands of evidence. This in turn illustrates the broader problem of drawing complex chronological inferences from sites that are likewise complex, but excavated and understood only in part, while being limited to working with only a small sub-sample of charred plant assemblage due to contextual ambiguities and difficulties in dating other forms of archaeological material.

Conclusion

This paper discussed the timing of a transition within the Neolithic of south-west Asia. While the temporal aspect of the prevalent interpretations can be traced to an artefact of the calibration curve, a detailed site-by-site study fails to either confirm or refute the notion of a rapid M-/L-PPNB transition. At the few sites with sufficient reliable radiocarbon determinations, the evidence taken at face value would suggest an extended transition period, which would perhaps require a new set of interpretations as to what might have happened. Having said that, considerations of old wood effects and site formation processes mean that the ^{14}C evidence for the "slow transition" remains weak.

Some of the technical and empirical issues can be resolved with relative ease. Ongoing work on single amino-acid and mortar dating (McCullagh et al. 2010; Poduska et al. 2012) may help to overcome the challenges induced by necessary reliance on charred plant remains. Improved field sampling techniques (e.g. Asscher et al. 2015), could extend the range of reliable contexts and hence provide the basis for more reliable dating at a larger range of site. These technical developments can also be supplemented by the development of secondary dating programmes of archival material. Such programmes have been implemented in the past in the study of the Neolithic and the Iron Age in the UK (Hamilton et al. 2015; Whittle et al. 2011)□, where combining limited legacy evidence with new determinations made a substantial contribution to the understanding of past cultural developments at a low cost. Many of the sites excluded from the current study have some dating evidence that could be used in a similar fashion.

Technical improvements and increase in sheer quantity of data are essential to the resolution of the chronology of the M-/L-PPNB transition, but they might need to be accompanied by conceptual developments when selecting the modelled parameters. As demonstrated in the Yiftahel and 'Ain Ghazal case studies, this is not always straightforward, as the excavated and dated portion of the site might not contain the strata witnessing the parameters of interest, or might be too limited to extrapolate on issues such as onset and termination of human activity. Some of this is a matter of field archaeology and can only be resolved by persistent, long-term excavation projects. In the meantime, conceptual awareness and paying strictest attention not only to the immediate context of the samples, but also the broader picture of the site is paramount. One promising direction of work are improvements in the dating of sites where the M-/L- PPNB transition is identified in the stratigraphy. Attempts to date features containing traces of diagnostic practices can also prove valuable. While such care at choosing the modelling parameters might in the short run limit our inferential ability, over the longer term it will contribute to a more focused application of the limited resources and a more conscious and hence more robust chronological understanding of the transition.

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Figures

Figure 1 Sites mentioned in text. Modified from an original map by "Fulvio 314", obtained from https://commons.wikimedia.org/wiki/File:Middle_East_topographic_map-blank_3000bc_crop.svg (last accessed 8th October 2016) under a Creative Commons Licence 3.0.

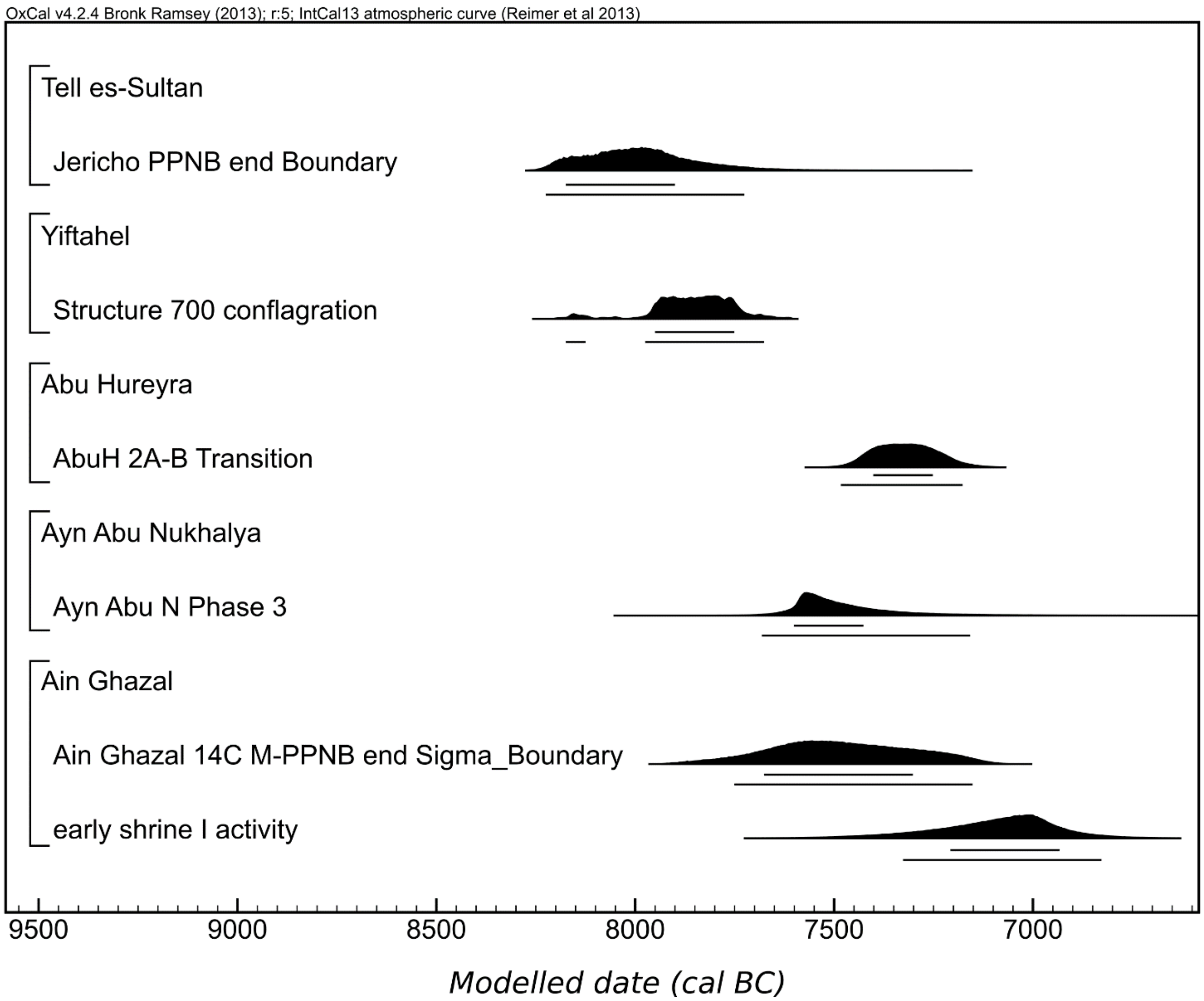

Figure 2 Results of the parameters of interest

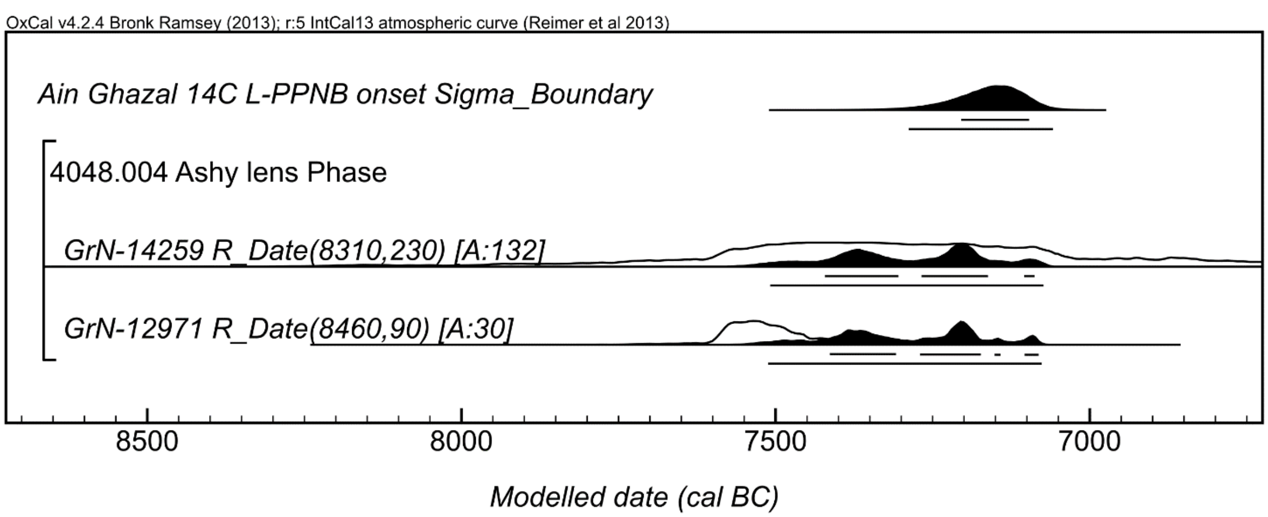

Figure 3 The estimates for the end of the M-PPNB activity, the onset of the L-PPNB activity and posterior distributions of the determinations GrN-12971 and GrN-14259 from 'Ain Ghazal.