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THE LATE BRONZE TO IRON AGE TRANSITION IN WESTERN SIBERIA - CONTINUITY OR INTERRUPTION? BAYESIAN STATISTICS AND RADIOCARBON DATING IN THE CHICHA SETTLEMENT

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ABSTRACT

The Late Bronze to the Iron Age transition in Western Siberia involved significant cultural and political changes, which were reflected in the emergence of protourban settlements in the forest steppe zone. The transition is roughly dated to the turn from the 2nd to the 1st mil. BC, mainly based on archaeological artefacts and on in general socio-cultural development. A more precise radiocarbon dating for this transition was problematic mainly because of a general lack of data in Western Siberia. This article analyses the chronology of the Late Bronze to Iron Age transition at Chicha, a reference site for this period in this region. The assessment of a possible hiatus between the Late Bronze Age and the following transitional period at Chicha is the key issue of our paper as its presence may have far reaching cultural implications. To increase the precision of the radiocarbon chronology with focus on the possible hiatus, the samples from well-defined stratigraphic contexts were analysed using Bayesian modelling that incorporated the stratigraphic information. The performed chronological modelling supports existing archaeological hypothesis of a hiatus in the very end of the 2nd mil. BC, just before a regular settlement of a new protourban settlement type appeared on the by then abandoned site. A sensitivity analysis including simulated hiatus confirms the reliability of the model. A complete population change seems to be plausible. The protourban settlement of Chicha, a typical feature for the Transitional period, didn't exist very long. With the emergence of the early nomadic cultures in the Southern Siberian steppes in the beginning of the 1st mil BC it most probably stopped functioning. The cultural development of that time, former believed to be continuous, was deeply interrupted for several times.

1. INTRODUCTION

1.1 Historical-cultural settings

At the turn from the 2nd to the 1st mil. BC, during the period of transition from the Bronze to the Iron Age in Western Siberia, significant cultural changes affected almost all aspects of society (e.g., Molodin 2010; Schneeweiß, Rjabogina 2014). This period also coincided with the time of climatic shifts to more humid conditions which resulted in the spread of forests southwards and expansion of the habitat for hunters and fishermen. These events terminated a relatively continuous development of the Bronze Age cultures in the forest-steppe and steppe zone. At the start of the new epoch (beginning of the 1st mil. BC), in the south, mobile nomadic tribes relatively quickly spread to the Asian steppe

zones suitable for grazing. The earliest evidence for the arrival of nomadic horsemen – 9th/8th c. BC – has been found in monumental burial complexes in Tuva (Southern Siberia) (Parzinger 2004, 29-32; Parzinger 2006, 679).

The new cultural phenomenon of nomadic horsemen did not affect all regions of the steppe and forest steppe equally. In Western Siberia, this period (beginning of the 1st mil. BC) is referred to as "Transitional" (Molodin 1979, 1985, Potemkina 1985, Troitskaya 1985, Kosarev 1987, Borzunov 1992, Chlenova 1994). A new type of settlements (large, fortified with regular buildings), previously unknown in the Western Siberian forest steppe, became a characteristic feature. Most likely, the innovations were influenced by the southern steppe population (Parzinger 2006, Molodin 2008, Pilipenko et al. 2008). At the moment, many issues of the cultural development in the Western Siberian forest-steppe zone in the end of the Transitional period and beginning of the Early Iron Age remain unresolved.

Determining of the exact chronology of the Bronze to Early Iron Age transition in Western Siberia is tightly related to the dating of the emergence of the first protourban settlements in the forest steppe. The settlements likely appeared in the beginning of the 1st mil. BC in the same sudden way as monumental nomadic burial complexes in Southern Siberia. A fairly large radiocarbon database has been developed for the archaeological cultures of the Minusinsk Basin (Southern Siberia) (Görsdorf et al. 2001, Svyatko et al. 2009). It became essential for our understanding of the absolute chronology of the Bronze and Iron Age cultural development in Southern and Southwestern Siberia. The analysis of the chronological relationship between the appearance of nomadic societies in the Southern steppe and the protourban settlements in the forest-steppe is a *conditio sine qua non* for the understanding of their nature.

Chicha in the South of the Western Siberian Lowland is the reference site for protourban settlements in Western Siberia. The absolute chronology of this site is particularly important for dating of the Transitional period in Western Siberia. It is the best explored site of this period between Southern Siberia and the Trans-Urals. A series of radiocarbon dates has been obtained from stratified complexes of the site. These are the first absolute-chronological data for a set of LBA/EIA archaeological cultures of Western Siberia. The ¹⁴C data from Chicha are particularly important to fill a gap between Southern Siberia and the East Trans-Urals, where the next series of radiocarbon data for this period come from (Görsdorf et al. 1998, Schneeweiß 2007, Molodin et al. 2012, Zakh et al. 2011, Zakh 2012, Multidisciplinary ... 2013, Molodin et al. 2014).

1.2 Chronological modelling and Bayesian statistics

Bayesian sequencing is a well-established approach in archaeology to combine absolute chronological information from scientific dating methods (such as ¹⁴C dating) and archaeological information, e.g. a stratigraphical sequence of dates.

In short, unlike classical statistics, Bayesian statistics allow incorporating archaeological information – i.e. “priors” – into chronological models. The priors are likelihoods which describe the relationship between two (or more) dates. In terms of radiocarbon dating, the modelled probability function of a date (the posterior probability distribution) is a function of the calibrated ¹⁴C dates (the prior likelihood) and the archaeological prior information (for an introduction see e.g. Bayliss 2009; for details on mathematical solutions see e.g. Buck et al. 1996, Bronk Ramsey 2009 or Weninger 2011).

In archaeology, application of Bayesian chronological modelling is common since the early 1990s (Buck et al. 1992, 1996, van der Plicht 1993, Bronk Ramsey 1994, 1995, Christen 1994, Christen et al. 1995), specifically for re-assessing established chronologies (e.g. Bronk Ramsey et al. 2004, Friedrich et al. 2006, Höflmayer 2012, Friedrich et al. 2014, and Wiener 2014 for the Santorini case). For studying settlement history, Bayesian approaches were used to successfully find one or more hiatus

between archaeological phases (e.g. Bachand 2008, Hamilton 2010, Dye 2011, Riede and Edinborough 2012, Wardle et al. 2014). Thus, Bayesian chronological modelling appears to be useful for analysis of the proposed hiatus in Chicha (see below). Nevertheless, the above mentioned studies lack a critical assessment of the model assumptions – both archaeological and methodological – as claimed by *i.a.* Steier et al. 2001, Bayliss et al. 2007, or Weninger et al. 2010. For the chronology of Chicha settlement we undertook a critical assessment of all model steps.

Figure 1: The position of the Chicha site in central Northern Eurasia (Western Siberia).

1.3 Chicha site description

The Chicha site is located in the south of the Baraba forest-steppe on the shore of the Small Chicha Lake (54°43'11"N 78°35'27"E; Figure 1 and 2). First excavations in Chicha were performed in 1979 (Molodin 1985, Molodin et al. 1999). In 1999-2003, a large-scale interdisciplinary Russian-German research project took place (Molodin et al. 2001a, 2001b, 2002a, 2002b, 2004, Schneeweiß 2007, Molodin and Parzinger 2009). A total area of 3500 m² was uncovered, including 21 dwellings (mainly half-sunken pit houses), fortification structures (moats) and several burials. The preceding geomagnetic survey revealed a five hectare plan of a fortified settlement with a clear layout of buildings, and a necropolis beside it (Becker H and Fassbinder 1999, Molodin et al. 1999). Referring to this magnetometer plan, the settlement was conventionally divided by archaeologists into a "Citadel" (the only preserved, unploughed part of the site at the edge of the lake terrace; Figure 2) and a "Periphery" or "outer settlement" (the major ploughed area of the site with a regular plan). The new radiocarbon dates, as well as comparative-typological analysis of bronze objects, generally attributed the Late Bronze Age – Transitional period settlement at Chicha to the 14th–9th/8th c. BC (Schneeweiß 2007, Molodin 2008, Molodin and Parzinger 2009).

Figure 2: Chicha site in the Western Siberian Lowlands between the Ob' and Irtysh rivers (A) and the magnetometer plan of the settlement part of the site with division into "Citadel" and "Periphery" parts (B).

Analysis of planigraphy, stratigraphy, artefacts (first of all pottery and bronze objects) and scientific data revealed the relative chronology of the site and the key stages of its development (Molodin et al. 2003, Schneeweiß 2007, Molodin and Parzinger 2009). However, there are several approaches regarding the settlement phases. Based on the dynamics of the supposed spatial development of the site, some scholars propose four main construction phases with six sub-phases for the Late Bronze Age and the Transitional period (Molodin et al. 2003). Among these, phases 1 and 2 refer to the Late Bronze Age population of the "Citadel" area by the Irmen culture people, while the construction phases 3 and 4 refer to the arrival of a migrant population in the Transitional period with different pottery in the "Periphery" area. Another approach, mainly relying on the chronostratigraphical and typological analyses of pottery (Schneeweiß 2007), is tending to distinguish three main successive phases: the Late Bronze Age period as phase 1, the Transitional period from Bronze to the Early Iron Age as phase 2, and the later Early Iron Age as phase 3¹. According to this approach, the phase 2 settlement extended over the entire territory of the site, while the phase 1 and 3 settlements were more or less restricted to the "Citadel" area at the immediate lake shore. However, the Late Bronze Age necropolis (phase 1) was located outside the "Citadel" area and partly overlapped with the "peripheral" phase 2 settlement (Schneeweiß 2007). This was confirmed by a detailed typological analysis of small finds (Molodin and Parzinger 2009).

Thus, in essence, the different approaches outline the similar periodisation of the site, with two main controversial points, namely – the exact moment and character of the transition from the first stage (Late Bronze Age) to the second stage (Transitional period from Bronze to Iron Age), and the nature of the Late Irmen culture as either an independent culture of the Transitional period (Molodin and Parzinger 2009) or as an advanced stage of the Late Bronze Age Irmen culture (Molodin 1985, Schneeweiß 2007). The Irmen culture is a well studied archaeological culture of the Late Bronze Age in the Western Siberian forest zone between the Irtysh and Ob river valleys (Molodin 1985, Matveev 1993). It is synchronous and related to the well-known Karasuk culture of the Minusinsk Basin. In this paper we argue the chronological relationship between the first two main stages of the site, with the

¹ The cultural layers of the succeeding Early Iron Age (phase 3 by Schneeweiß 2007) are beyond the focus of this paper, so are not considered here.

cultural implications to be discussed elsewhere. We are focusing, firstly, on the nature of the transition from the first to the second settlement phase, and, secondly, on its exact dating. We consider a probable hiatus between those two phases as a key issue. Closely related to this topic is the dating of the protourban-like "Periphery" of the settlement, which probably marks the beginning of the transitional period from Bronze to Iron Age in the Western Siberian forest-steppe zone.

2. MATERIAL AND METHODS

2.1 Stratigraphical information

Stratigraphical observations are of major importance for arguing the development of the Chicha site through time and space. It has been pointed out that pit houses or half-sunken pit houses of the forest-steppe zone cannot be considered as closed complexes, as the inventory of the filling was often accumulating over a long period, in some cases over hundreds of years (Gryaznov 1956, Matveev 1993, Schneeweiß 2007). The usually deep black colour of the cultural layers and the high portion of bioturbations make it nearly impossible to recognize different layers within the fillings. So in Chicha it was only possible to distinguish a certain floor level of a house by *in situ* finds of crushed vessels. The filling of the different moats provided, in contrast, quite recognizable layers, so that the analysis of the stratigraphy using Harris-Matrix revealed reliable results (Schneeweiß 2007). It also needs to be kept in mind that a significant proportion of the finds has been relocated by taphonomic processes.

The interpretation of stratigraphical information is not the only, but the main argument in favour of the existence of a chronological hiatus between the Late Bronze Age and the Transitional Period phases in Chicha. Further indirect evidence derives from the typological analysis of the pottery and the archaeozoological data (Schneeweiß 2007). The archaeological interpretation of the stratigraphic sequence, supported by Harris-Matrix, provided the initial point for modelling of the absolute chronology.

2.2 Sampling and radiocarbon dating

The most complex stratigraphy was observed in the cross-sections of the moats in the "Citadel" area. Fillings of moats were often cut through or overlaid by sunken dwellings or pits; multiple digging activities led to a significant redeposition of older material. This made the chronological analysis of layers and structures difficult. Thus, sampling was always accompanied by taphonomic observations and careful assessment of the specimen provenance. Despite we attempted to sample only the most reliable parts of stratigraphical contexts, the redeposition of earlier material could not be completely excluded. Apparently as a result of this, the radiocarbon data put into a stratigraphic order showed a number of inconsistencies (e.g., Hd-24527) (Schneeweiß 2007, Abb. 19). Therefore, before including the data in statistics and modelling, the individual assessment of each date concerning the compliance with the stratigraphy was carried out.

A series of 45 radiocarbon dates was obtained from different material (Appendix 1, cf. Schneeweiß 2007, Appendix 3): charcoal, bone samples of herbivores (elk, horse), man, fish, as well as residues on potsherds and soil samples (humic acid).

2.3 Prior and model specifications

We used OxCal v. 4.2 (Bronk Ramsey 2009) and the IntCal13 calibration curve (Reimer et al. 2013) for calibration and chronological modelling of the radiocarbon measurements from Chicha, already published by Schneeweiß 2007 (Appendix 3). All models were written in the Chronological Query Language of OxCal (Bronk Ramsey 1998).

For the estimation of dating and duration of the "hiatus" between the first two phases in the development of the Chicha site, 45 models were developed in OxCal. Each of them includes different

variants of archaeological assumptions. The main chronological models are presented by Becker F and Schneeweiß (2016). In this study, six models are discussed in detail (0, I, II, IIIa, IIIb, IIIc).

The main prior information of all models is the stratigraphic sequencing elaborated by Schneeweiß (2007). Based on that, following up models were set up by an recursive adjustment of model assumptions (as described in Bayliss 2009). The main criterion not to reject a model and to revisit the prior information is the agreement index (Bronk Ramsey 1995) of single ages (A) and the model (A_{model}). The agreement index indicates to what degree a modelled age matches the original data.

The unconditional null model (M0) is only based on stratigraphic sequencing, without explicitly modelling a Sequence in OxCal; a Sequence is implicitly modelled in Model I (MI).

All dates where $A < 60\%$ were successively analysed and revisited in relation to the archaeological context of the dated sample, beginning with the date with the lowest agreement index. The appropriate prior information for each date were included in a new model (MII1, ..., MII n). The stop criterion for the successive integration of new prior information is an agreement index of the model $A_{\text{model}} > 60\%$. A final Model including all prior information is shown in [Figure 3](#). The priors include firstly a *terminus post quem* (TPQ, After) of an elk bone from a filling layer, which might have been redeposited; the samples of this layer are characterized by an age inversion, as the sample stratigraphically overlies a much younger one. The same is true for other samples, which were taken from a thick, mixed, ashy layer. Samples from this burnt layer “Prokal 6” and stratigraphically encircled dates² were summarized in a second prior — Phase; thus, a sequence of these samples is not modelled. The genesis of this burnt layer may be explained by earthworks e.g. surface grading after a fire event. A third prior apply for Model II are Outlier, which are samples from moat E (trench 1), which were set as TQP beforehand or are insufficiently modelled ($A < 60\%$).

Ages from bulk organic soil samples were excluded from Model II, as they do not clearly date any process related to the settlement activity in Chicha, but rather soil formation processes. Fourthly and finally, multiple dates from the same sample were combined (Combine).

Based on Model II, the late Bronze Age period and the Transitional period are explicitly incorporated in the model (Model III, Figure 3; Sequence and Boundary). We used three different prior distributions – a uniform prior (Model IIIa) and two types of trapezoid prior (Models IIIb and IIIc) – to model the archaeological activity (*sc.* deposition) in each of the phases. Whereas the uniform prior (e.g. Bronk Ramsey 2008) is based on the assumption of a uniform deposition of material in a specific phase - and thus a more or less abrupt end/start of the phase – the trapezoid prior (Boundary and Transition; Karlsberg 2006, Bronk Ramsey and Lee 2012) is divided into three sections; a transitional phase of increasing deposition of material, a main phase of constant deposition and a terminal phase of decreasing deposition. Our first trapezoid model (IIIb) assumes a transitional and a terminal phase for both archaeological phases, whereas the second trapezoid model assumes no terminal phase at the end of the late Bronze Age period assuming a devastating fire event (IIIc).

Test for hiatus

We used the Interval-query in OxCal as a statistical tool to test the significance of a possible hiatus between the late Bronze Age period and the Transitional period, accepting an interval as significant if the lower boundary of its confidence interval is ≥ 1 .

² KIA-12434, Bln-5536, KIA-16426, Bln-5534, Bln-5535, Bln-5294, Bln-5614, Bln-5485A.

Figure 3: Stratigraphical model of all dates included in the chronological models: statistical measures (64.2% and 95.4% levels of confidence, median, and standard deviation) of posteriori age distributions; Phases and periodization are not included in the model (see Figure 4).

Sensitivity analysis

As models from a limited set of radiocarbon dates with archaeological prior information are lacking an independent age control (e.g. Telford et al. 2004), chronological models are *per se* wrong (ibid, Bayliss et al. 2007). In addition, single prior information (here, the separation of the sequence in two phases) can be a strong assumption (Scott 2000) and have a huge impact on the results of the chronological models. Nevertheless, there are several techniques to cope with uncertainty and strong assumptions in the models, such as leave-*p*-out cross-validation, or age simulations (Telford et al. 2004, Bayliss et al. 2007). As leave-*p*-out cross-validation might not be suitable for the Chicha-data-set (only a few — the marginal dates of the periods — are relevant for the problem under observation), we applied a critical sensitivity analysis (*sensu* Buck and Menson 2015) of all model parameters, including the uncalibrated ^{14}C measurements, the calibration curve, and the main archaeological prior information.

The sensitivity of the uncalibrated ^{14}C measurements was tested by multiplying the laboratory error of the measurements by a factor of 0.5, 1.5, and 2.0. In addition, the mean of the gauss distributed ^{14}C dates were changed by ± 40 and ± 80 years. To test the influence of the calibration curve uncertainty, we calibrated the radiocarbon measurements applying IntCal13 (Reimer et al. 2013), but also IntCal98 (Stuiver et al. 1998), IntCal04 (Reimer et al. 2004), and IntCal09 (Reimer et al. 2009).

As one of the main foci of the present paper is the possible chronological gap, we had to cope with the problem of an increase in the precision of the hiatus duration at the expense of its accuracy (e.g. Steier and Rom 2000), and thus having an importantly wrong model (*sensu* Bayliss et al. 2007). In addition, we run the risk to simply preconceive the archaeological chronological framework if we use the pre-existing periodisation as prior information for the models (cf. Griffiths 2014).

Thus, we insert simulated hiatus in the model by setting the position of the end of a first hypothetical period (*ergo* Sequence) and the beginning of a second hypothetical period in the model. In consequence, the significance of the archaeologically sound hiatus is only valid if randomly simulated hiatus are not significant. Otherwise, the significance of a hiatus might only be an immanent characteristic of the chronological model but not inevitably of the archaeological data.

Also the use of different prior distributions (uniform/trapezoid) is part of the sensitivity analysis.

3. RESULTS

3.1 The relative chronology

The reconstruction of the relative chronology of the site development in Chicha is based mainly on stratigraphical observations and typological investigations. The same is true for the consideration of the existence of a hiatus in the development of the Chicha settlement. Detailed analysis of the stratigraphy of the site on the basis of representative cross sections has been previously presented from different perspectives (Schneeweiß 2007, Molodin et al. 2008b, Becker F and Schneeweiß 2016). The most complex stratigraphy was found in the central part of the site, the so-called "Citadel". Multiple reconstructions and re-use led to multilayered deposits in that area, while those alterations remained rare in the area of the so-called "Periphery". The oldest structures are represented by the moat A and several large pits on its bottom (Figure 2B).

The deposits at the bottom of the moat A mainly consisted of thin layers of domestic waste (mainly consisting of large amounts of animal bones and fish remains). The nature of deposits gives reason to assume that the moat remained open for a long time. The ceramics from the lowest layers of the moat filling belong exclusively to the Late Bronze Age. At a moment when moat A was already partially filled, the dwelling 21 and the construction 24 were cut into its filling. Those features also belong to

the Late Bronze Age. The construction 24 obviously was burnt down. Further to the north, a thick layer of burned rubble was deposited in the moat A. Therefore, the end of the first settlement phase in Chicha in the Late Bronze Age is considered to be connected to a hostile fire (phase 1). Subsequently, the moat A was completely filled, and dwelling pits were made, partially cutting into its filling and borders³. It is very likely that those reconstructions were connected to a modified general plan of the dwelling locations beyond the former moat A, including the "Citadel" as well as the "Periphery". In the dwelling pits of the "Citadel" area, several occupation layers have been detected, which cannot be stratigraphically connected to specific construction horizons⁴. The different occupation horizons could only be recognized by burnt layers and, specifically, crushed ceramic vessels (e.g. Schneeweiß 2007, 20-21, Abb. 13). The reconstruction of the exact settlement structure or the shape of the Late Bronze Age dwellings and that of the following periods in the "Citadel" remains impossible because of multiple significant earthworks in prehistoric times. Stratigraphical observations within the "Citadel" reveal evidence for a long-term development of Chicha. The settlement structure was changed several times. Every phase of the site development (Late Bronze Age, Transitional period and Early Iron Age) included several sub-phases, which left their particular characteristics. So it has to be recognized that, in general, the structure of the site is much more complex than it was thought before referring just to the magnetogram. Analysis of the Chicha pottery revealed also a remarkable cultural diversity, which can be interpreted in different ways (Schneeweiß 2007, Molodin et al. 2008a, 2009a; see below).

The "Periphery" shows a different picture. This area was ploughed for a long time, so that this part of the site was levelled and no features were visible above ground. However, this levelling resulted in a much clearer magnetogram than in the unploughed "Citadel" area. The dwelling pits most likely were not filled straight after their abandonment, but remained open for a long time. Very likely, they were completely filled only by subrecent ploughing. In the periphery, burials of the Late Bronze Age, synchronous to the earliest settlement in the "Citadel", were found (phase 1). During the Transitional period (phase 2), the built-up area included parts of the older necropolis, and it is obvious that the constructors were negligent of the burials. Thus, the surface indications for the burials were either levelled naturally, or the (new) population did not recognize the burials as their own and neglected or destroyed them. We do not know any burials belonging to the Transitional period (phase 2), except a number of infant ones inside the dwellings. The lack of burials is a general phenomenon of the Transitional period in the forest-steppe zone. Several cemeteries dating to the beginning of the 1st mil. BC were investigated in adjacent southern regions, such as the Zevakinskij site in the East Kazakhstan Irtysh River basin (Arslanova 1974), Izmajlovskij (Ermolaeva 1974), as well as some other single complexes of that time (Ermolaeva 1985, Samashev and Bokovenko 1985), including Northern Kazakhstan sites (Khabdulina 1986).

3.2 Modelling the absolute chronology - Posterior probabilities and the question of a hiatus

The radiocarbon dates in our database calibrate to ranges between 1495–1296 cal BC (beginning of activity in the Late Bronze Age period) and 806–543 cal BC (end of Transitional period) at 95.4% probability ("Model 0"). The last conventional date of Prokal 6 (the last dates in the Late Bronze Age period) and the earliest dates of the Transitional period intercept with a small plateau of the calibration curve, thus having relatively wide confidence intervals compared to other dates (for details see Becker F and Schneeweiß 2016). The end of the Late Bronze Age period calibrates to 1269–1051 cal BC (or 1224–1119 at 68.4% probability; latest date), whereas the beginning of the Transitional period calibrates to 1208–977 cal BC (or 1224–1119 at 68.4% probability; first date). Based on (prior) likelihoods, a hiatus between the Late Bronze Age and the Transitional period is not evident, as the marginal dates of the periods clearly overlap.

³ First of all the second phase of dwelling 21 and construction 23.

⁴ Dwellings 3, 3a, 3b, 17, 20, 20a.

The posterior 68.4 and 95.8% modelled age ranges are summarized in **Table 1**. With a simple single-phase model (Model I) age ranges are slightly different from the calibrated ranges. Activity in the Late Bronze Age period is modelled to have ended 1188–1079 cal BC (youngest age) at 95.8% confidence, the beginning of the Transitional phase dates between 1157 and 1044 cal BC. At 68.4% confidence, the end of the first period and the beginning of the second period date to the ranges of 1162–1112 and 1125–1075 cal BC, respectively. Thus, the marginal dates of the two periods are overlapping at both levels of confidence; the model yield a 95.8% duration of the hiatus of 0–86 yr (or 0–45 yr at 68.4% confidence).

Table 1: Archaeological modelling of a hiatus between phase 1 and 2 in different models and the results of the sensitivity analysis. Significant interval durations (hiatus) are highlighted in grey (columns 3 and 4); non-overlapping of bounding dates of the end of phase 1 and the beginning of phase 2 (68.2% level of confidence) are also highlighted in grey (columns 5 and 6). The position of simulated hiatus (IIIa1–IIIa6, IIIb3, and IIIc3) are shown in Figure 4.

Model	Duration of Interval [years]			68.2%-probability range of phases [BC]	
	$\mu \pm \sigma$	68,2%	95,4%	End I	Beginning II
Archaeological modelling					
Archaeologically justified hiatus					
I (no modelling)	35±26	0–45	0–86	1162–1112	1125–1075
II (stratigraphical order)	36±26	1–46	–2–88	1162–1112	1124–1074
IIIa (two phases: uniform-prior)	95±44	52–145	4–173	1208–1137	1094–1034
IIIb (trapezoid prior)	122±52	74–166	30–209	1218–1153	1091–1026
IIIc (uniform and trapezoid prior)	108±46	60–155	14–197	1209–1145	1093–1026
Sensitivity analysis					
Simulated, <i>random</i> hiatus [†]					
IIIa1 (Bln-5477–KIA-18874)	34±21	0–47	0–73	889–845	841–814
IIIa2	26±19	0–36	0–64	879–829	837–808
IIIa3	15±15	0–20	0–51	835–803	820–797
IIIa4	25±20	0–33	0–66	1007–963	978–938
IIIa5	26±20	0–34	0–66	1385–1336	1349–1310
IIIa6	35±27	0–45	0–90	1385–1298	1323–1277
IIIb1	3±0	0–5	0–5	837–803	872–799
IIIb3	31±20	6–41	0–70	854–810	816–796
IIIc1	40±25	14–58	3–78	891–850	840–814
IIIc3	20±16	0–25	0–57	907–828	849–812
Variation of measurement inaccuracy of radiocarbon ages					
IIIa (0.5 σ)	79±36	42–121	7–143	1187–1128	1091–1040
IIIa (1.5 σ)	110±52	58–168	4–199	1247–1149	1108–1024
IIIa (2.0 σ)	115±59	50–178	0–217	1238–1154	1102–1031

Calibration curve					
IIIa (Intcal98)	121±50	76–182*	17–212*	1241–1155	1082–1026
IIIa (Intcal04)	115±49	72–174*	13–202*	1241–1161	1096–1035
IIIa (Intcal09)	116±49	71–173*	16–204*	1242–1162	1097–1034

For the second single-phase model – including Outlier, After, Phase, and Combine (Model II) – the time range of the end of the Late Bronze Age period is calculated to be 1162–1112 cal BC at 68.4% confidence, and the beginning of the Transitional period to be 1124–1074 cal BC. The 95.8% probability modelled age ranges are 1187–1077 and 1156–1041 cal BC, respectively. Although all ranges are overlapping (again), the modelled duration of the hiatus is significant at 68.4% confidence, ranging between 1 and 46 yr. At 95.8% confidence, the hiatus is nevertheless not significant, as its duration is estimated to be between –2 and 88 yr.

Explicitly modelling the two periods and assuming an abrupt end/beginning of the phases (Model IIIa), the ages of the marginal dates of the two periods are estimated to be in the 95% ranges 1208–1137 or 1132–1019 cal BC, or 1208–1137 and 1094–1034 cal BC at 68.4% confidence, respectively. The resultant 68.4% and 95.8% modelled duration ranges of the hiatus are 52–145 yr and 4–173 yr. Applying a trapezoid prior distribution, the duration of the hiatus is estimated to be between 30–209 yr at 95.8% confidence for Model IIIb (continuous end/beginning of the periods) or between 14 and 197 yr for Model IIIc (abrupt end of period 1/ continuous beginning of period 2). The resultant modelled age ranges for the marginal dates are shown in [Table 1](#); none of the resultant ranges overlap at 68.4% confidence, but all ranges overlap at 95.8% confidence; modelling provided an age range the end of the Late Bronze Age period of 1246–1116 cal BCE and a age range of 1130–992 for the beginning of the Transitional period (Model IIIb).

The probability distributions of the phase boundaries at 68.2% and the 95.4% confidence are shown in [Figure 4](#); their numerical representation is given in [Table 1](#). The *a-posteriori* probabilities of the simulated phase boundaries do not overlap at 68.2% confidence distribution, while there is a slight overlap at a 95.4% level of confidence. At least at a level of confidence at 68.2% the hiatus hypothesis cannot be rejected.

Figure 4: Prior and posterior age distributions of the main chronological model (IIIa), explicitly including the Late Bronze Age and the Transitional phase and the Interval-query. The position of the archaeological and the simulated hiatus are marked with dots; the posterior distributions of their durations are shown on the right.

In addition, besides determining the boundaries by arguing with the extreme values of the two phases, an explicit Interval query is implemented. The results for the determination of the duration of the interval, i.e. the hiatus, in different models are shown in Table 1. The hiatus is significant at a probability of 68.2% or even 95.4% (Table 1, Figure 4b).

This is also the case if the two phase hypothesis is not included in the model as a prior assumption. Its mathematical duration is between 1 and 46 yr. Figure 4b shows the significance and duration of the

hiatus in the different models: on the one hand, including the assumption of two explicit phases (Models IIIa-c), and on the other hand – based on a simple, modelled sequence of ^{14}C dates without separation of phases (Models I and II). The graph in [Figure 4b](#) shows the probability density function. Summarizing, in all models with explicit implementation of two phases (Models II and IIIa-c), the hiatus between them is significant at the 95.4% probability range ($\pm 2\sigma$). In Model I (modelled data sequence without separate phases), the hiatus is significant only in the 68.2% probability range ($\pm 1\sigma$). Thus, a hiatus between phase 1 and 2 is probable in all models, with varying level of significance. To assess the reliability of the obtained models, they were subjected to a comprehensive sensitivity analysis ([Table 1](#)).

4. DISCUSSION

4.1 *The chronology of the beginning and the end of the Chicha settlement*⁵

The Late Bronze Age and the Transitional period complexes in Chicha are clearly distinct from those of the later Early Iron Age. As a result of modelling the data the calibrated age of those periods has changed. Initially (Model 0), the age ranges of the Chicha samples covered a time span from 1389 $\pm$ 49 cal BC (Bln-5480) to 692 $\pm$ 86 cal BC (Bln-5419). Depending on the model, the calibrated dates of these two samples vary. In Model I, the first date (Bln-5480) refers to 1421 $\pm$ 19 modBC, in Model II – to 1409 $\pm$ 20 modBC. The second date (Bln-5419) in Model I refers to 670 $\pm$ 84 modBC and Models II to 781 $\pm$ 14 modBC, respectively. In Models III a-c the age of the oldest sample (Bln-5480), as compared to non-modelled age, is slightly younger (Model IIIa: 1378 $\pm$ 38 modBC) or slightly older, respectively (Model IIIb: 1390 $\pm$ 35 modBC and Model IIIc: 1394 $\pm$ 34 modBC). While the age of the modelled latest sample (Bln-5419) is older in all cases (IIIa: 783 $\pm$ 12 mod BC; IIIb: 777 $\pm$ 21 modBC; IIIc: 777 $\pm$ 19 modBC). Thus, in various models, the probable moment of the beginning of the settlement in Chicha falls within 15th-14th c. BC, while the probable age of the end of the activity in the second stage can be dated to the 8th c. BC.

4.2 *Model quality – sensitivity analysis*

A hypothesised hiatus between the Late Bronze Age period 1 and the Transitional period 2 is significant at 68.2 and 95.4% confidence based on the OxCal Interval-query. In addition, the *a-posteriori* probability distributions of the outer dates of the periods do not overlap. The outer dates and the Interval criterion were used in other studies as suitable for hiatus detection (Riedle and Edinborough 2012, Wardle et al. 2014, and Hamilton 2010, respectively), even at lower levels of significance (Dye 2011, Barchard 2008). Nevertheless, the significance of the Chicha-hiatus might be a result of model sensitivity. Based on the prior information of Model IIIa, the test of significance for the uncalibrated ^{14}C measurements shows a slight variability of the hiatus duration, being estimated to ranges from 4–173 years at 95.8% when halving the laboratory error, to 4–199 years when multiplying the error by 1.5 and to 0–217 yr when doubling the error. In the latter case, the hiatus is not significant. A systematic error in the age estimation by ± 40 and -80 yr would not affect the significance of the hiatus, whereas an error of $+80$ yr would result in a non-significant hiatus. Nevertheless, such large systematic errors are not known from the laboratories involved (Berlin, Bln, and Kiel, KI) and might not influence the model quality. The hiatus is significant for all applied calibration curves.

There are dates with an agreement index $A < 60\%$ integrated in the model. Due to their stratigraphical position and the distance to the hypothesised hiatus, the relatively low agreement might not have an influence on the overall significance of the hiatus. In addition, the agreement of the entire model is greater than 60%.

⁵ We consider the period from the Late Bronze Age up to the Transitional period to the Early Iron Age.

A sensitivity analysis of the stratigraphical prior assumptions was not applied as specific model as the stratigraphy has been discussed elsewhere (Schneeweiss 2007, Molodin et al. 2008b). Different possible intensities of activity during the two settlement phases under estimation are included in the sensitivity analysis by applying different prior distributions of activity (uniform prior, trapezoid prior, and a trapezoid prior with a sudden end of the Late Bronze Age period). The selection of these priors changed the duration of the hiatus, but not its significance.

The most important aspect of the significance analysis is the integration of simulated (artificial) hiatus in the models. The shortest simulated hiatus in Model IIIa has a duration of 0–47 yr (at 95.8% confidence, IIIa1), the longest hiatus a duration of 0–90 yr (IIIa6). Thus, these simulated hiatus are not significant. Also in model IIIb, no simulated hiatus is significant at 95.8% confidence (only in Model IIIb3, the simulated hiatus is significant at 68.2% confidence, having a duration of 6–41 yr). One of the simulated hiatus in Model IIIb is significant at 95.8% confidence, having a duration of 3–78 yr (Model IIIc3). Nevertheless this simulated hiatus is much shorter than the archaeological validated hiatus in the same model, where the hiatus has a duration of 108 ± 46 yr (a fact that is clearly shown in Figure 4b). Thus, the sensitivity analysis, including the simulations, is useful to verify that the archaeological verified is not only significant, but also not sensitive to uncertainties in prior assumptions or a random product of modelling.

4.3 Circular argument of Bayesian statistics and modelling?

With regard to the results of the chronological modelling for the settlement phases of Chicha, a circular argument can be illustrated by Figure 5, showing the different *A-posteriori*-probabilities of the youngest date of phase 1 (Bln-5485A), and the oldest date of phase 2 (Bln-5479) with (Figure 5c) and without (Figure 5b) of a two phase assumption in the model and the calibrated, unmodelled ages (Figure 5a). Using the OxCal Sequence function (i.e., a condition specifying the sequence of events) to model the Late Bronze Age and the Transitional Period explicitly (Figure 5c), the older date is getting older and the younger date even younger. It is obvious that the archaeological assumption of the two phases favours the archaeological argumentation and the verification of the hiatus hypothesis.

In literature, this problem is known as “algorithm artefact” (Weninger et al., 2010). It essentially means that chronological models, indeed, provide precise data (which is also true for the Chicha data), but with lower accuracy. Therefore Weninger et al. (2010) consider the implementation of archaeological information in mathematical distributions as a critical point when using Bayesian statistics for chronological modelling. This problem can be avoided by varying the assumptions (Weninger et al. 2010), in our case by simulating artificial hiatus. Bayliss et al. (2007) used a similar approach when they calculated several models with different distribution assumptions.

However, the simulations in the course of sensitivity analysis for the Chicha data clearly show that a hiatus is only significant, if it is archaeologically justified. Artificially simulated hiatus are significant only in one of ten models. Thus, the *a priori* assumption of multiple phases clearly affect the *a-posteriori* probabilities of the data in comparison to the *a-priori* probabilities (Figure 5), but a significant hiatus can be modelled only at an archaeologically sound position in the sequence, and not at an artificial position of a simulated hiatus. In addition, the use of different priors (uniform-prior, trapezoid prior or a combination of both) does not reduce the significance of the hiatus (Table 1).

Figure 5: The effect of archaeological prior information on posterior age distributions of the last age in the Late Bronze Age period (Bln-5485A) and the first age in the Transitional Period (Bln-5479). 95.4%-confidence levels are given below the distributions; arrows mark the postponement of the posterior distributions after modelling. The potential (archaeologically justified) hiatus (as modelled in model IIIa, [c]) is marked with dashed vertical lines.

4.4 The absolute chronology of the Transitional period

Regular and fortified large-scale settlements as Chicha are considered to be typical for the transitional period from Bronze Age to Iron Age in the forest-steppe of Western Siberia (Molodin 2006, Molodin and Parzinger 2006, Schneeweiß 2010). Arguing with the Chicha case they were believed to be a result of a continuous evolutionary process triggered by climatic changes (Molodin 2006, 2008, 2010). Modelling the absolute chronology of Chicha, in contrast, does support the existence of a hiatus between settlement phases 1 and 2, which implies that the new big regular settlement of phase 2 was established on the site of an older, abandoned Late Bronze Age settlement. Furthermore the sudden appearance of this early protourban settlement type, obviously, was not directly connected to the early nomads in the Southern Siberian steppes, as was believed earlier (e.g. Parzinger 2006, Molodin 2009, Schneeweiß 2010), since the radiocarbon data shows that the regular settlement was already established probably in the 11th/10th c. BC, what is somewhat prior to the appearance of the early nomads in the 9th c. BC.

In addition, the data is suggesting that the settlement was continuously used during the phase 2 until the 8th or even 7th c. BC, i.e. over several centuries. Such a long period of site utilization seems to contradict, at a first glance, the archaeological evidence, as there are only rare features showing reconstructions or stratigraphical overlapping, respectively, especially in the peripheral area of the settlement. As the archaeological evidence so the strikingly regular settlement plan in the magnetogram is suggesting as well a relatively short occupation period of the settlement. However, this dilemma can be solved when considering several essential moments.

Firstly, a differentiated consideration of the radiocarbon data allows to recognize several subphases within the phase 2, concentrating primarily in the 11th, 10th and 9th/8th c. BC. The two isolated youngest dates Bln-5418 and Bln-5419 probably reflect an additional subphase in 8th/7th c. BC, which could be underrepresented in the radiocarbon data series (Appendix 1). It happens, in particular, that all data which can be used for dating the dwelling features of phase 2⁶ belong to the 11th and mainly 10th c. BC (Appendix 1). Therefore, they are probably reflecting an older horizon within the phase 2, while all data which represent a younger horizon in the 9th-8th/7th c. BC, exclusively originate from bone or charcoal samples from objects, which obviously found their way into the half-sunken dwellings only after their abandonment⁷, if not originating from fillings of the moats (Appendix 1)⁸. In all cases, those objects are large accumulations of bones and potsherds, which could hardly be associated with a regular use of the dwellings. It is worth recalling that objects from sunken dwellings can be considered as closed find complex only in exceptional and well-argued cases (e.g. Gryaznov 1956, 53, Matveev 1993, 85-86, Schneeweiß 2007, 83-84). Moreover, it becomes clear that the full extent of the regular settlement ("Periphery") was already achieved in the older subphase of phase 2. This correlates with the idea, based on the magnetogram, that the regular large settlement was erected within a relatively short time which, apparently, corresponds with the Transitional period from the Late Bronze Age to the Early Iron Age and can be attributed to the 11th and 10th c. BC. The later horizon of phase 2 suggests a further utilization of the settlement in the 9th-8th/7th c. BC. However, at the moment no dwellings can be clearly assigned to this narrower period.

Secondly, the remarkable variability of forms, ornamentations and cultural affiliation of the phase 2 pottery (Molodin and Mylnikova 2004, Schneeweiß 2007, 41-107, 103-106, 269-271), which were thought to be synchronous, could be explained obviously to a certain extent by chronological differences. Typological analysis revealed clear connections of the Chicha phase 2 pottery with ceramic complexes from a number of regions of the Western Siberian forest steppe and adjacent southern and northern regions (Schneeweiß 2007, Molodin et al. 2008a, 2008b, 2009a, 2009b). Different attempts to interpret this situation failed to be convincing. On the one hand, the general explanation of the phase 2 as belonging to the archaeological Krasnozero culture of the Middle Irtysh region (Schneeweiß 2007, 212-214) was criticized as too limited (Molodin and Parzinger 2009, 71). On the other hand, the interpretation of Chicha as a central trading place with inhabitants of different cultures living together seems to underestimate to a certain extent the chronological stratification of the data (e.g. Molodin et al. 2008a, 2009a). A correlation of different ceramic traditions of Chicha phase 2 with different chronological subphases, as argued above, might offer a compromise and more plausible explanation for the aforementioned apparent contradiction between the geomagnetic picture and the archaeological evidence.

The detailed typological analysis of the small finds from Chicha (Molodin and Parzinger 2009) not only clarified the chronology of the Late Bronze Age (Irmén culture) settlement in phase 1, but primarily revealed close parallels of the Chicha phase 2 finds to the first (Bajnov) stage of the Tagar culture in the Minusinsk Basin (ca. 9th c. BC), as well as to the following Early Scythian cultures of nomadic horsemen in Southern Siberia (Arzhan 2, ca. 7th c. BC). These typologically identified connections largely correspond with the radiocarbon data from Chicha and from Southern Siberia (Görsdorf et al. 2001, Schneeweiß 2007, Svyatko et al. 2009). Therefore, the regular protourban settlement of Chicha is likely to be attributed mainly to the relatively short Transitional period in the 11th/10th c. BC. From the 9th c. BC onwards, in the following Early Iron Age period, a probably nomadic population reused the dwelling pits to a certain extent. A nearby nomadic burial complex

⁶ Bln-5479, Bln-5478, KIA 12433, KIA 16429, Bln-5417, KIA 12436, KIA 16428, KIA 12435, KIA 16430.

⁷ Bln-5477, Bln-5297, Bln-5482, Bln-5298, Bln-5418, Bln-5419.

⁸ KIA 12437, Bln-5481, KIA 18874.

(Zdvinsk 1) supports the interpretation of their nomadic lifestyle (Molodin 2006). It is likely, that this Iron Age nomadic population used a certain pottery type, which was described first while analysing the pottery complex from Chicha (Molodin et al. 2004, 275, Schneeweiß 2007, 36-37⁹), and later named "Berlik culture" (Molodin 2008). The bearers of the Berlik culture could be the latest inhabitants of the phase 2 in the 8th/7th c. BC. In another perspective, the discovery of Berlik type sherds in the "Citadel" area gave reason for their dating to the 9th c. BC (Molodin 1985, 2015).

5. Conclusions

The main focus of this paper is the quantitative and qualitative estimation of the probability of a possible hiatus between two settlement phases in Chicha, using Bayesian statistics and chronological modelling for the revaluation of the radiocarbon data from this site. The archaeological evidence for the existence of a hiatus is based on stratigraphical observations, pottery typology, analysis of burial rituals and differences in subsistence economy between the Late Bronze Age and Transitional period populations.

The following conclusions can be drawn as the result of the absolute chronology modelling for Chicha. The archaeologically validated hiatus between the Late Bronze Age and the Transitional period is (a) not visible in the unmodelled, calibrated dates and is (b) not significant in a chronological sequence without explicitly modelling two phases of activity. The implementation of (c) the archaeological prior assumption of two phases leads to the significance of a modelled hiatus. As the hiatus does not necessarily follow from the unmodelled radiocarbon data it cannot be considered as primary for the model. Finally, all chronological models using Bayesian statistics have the problem of a circular argumentation of the original archaeological hypothesis. In the case of Chicha chronology, this problem could be avoided by sensitivity analysis of the modelling —simulated hiatus are almost all not significant.

Summing up, Bayesian statistics and chronological modelling proved to be an efficient tool for estimating a supposed hiatus and for a certain specification of phases in radiocarbon data series. The confirmation of a hiatus in the development of the Chicha settlement, the evaluation of its chronological extent, as well as assessing of other existing data permit to look at cultural processes of the Transitional period in another perspective. The probably main implication of an interruption in the development of the Chicha is that there was no continuous evolution from the Late Bronze Age to the protourban settlement type of the Transitional period. These large regular sites, obviously, appear suddenly and do not function very long; they probably remain restricted to the Transitional period at the very turn of the 2nd to 1st mil. BC. The profound cultural changes on all archaeologically recognisable levels suggest a complete change of population in comparison to the previous Bronze Age. The alteration to the following Iron Age was associated again with significant cultural changes. The population was from then on nomadic. It replaced – or absorbed – the former "protourban" inhabitants of the Transitional period in the forest-steppe zone. The nomads show clear cultural connections to the Southern adjacent steppe regions.

Notwithstanding the good results for the chronological framework, there are still many open questions concerning the reasons, function, character, cultural background, protagonists and end of the protourban settlements and the Transitional period of Western Siberia to be discussed, since most of the existing interpretations and models do not correspond to the presented chronological results.

⁹This type of pottery was difficult to date. It was then correlated with a so called "phase 3a", which could be dated approximately to the first half or the middle of the 1st mil. BC.

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Lab. ID	14C age (BP)	Sample context	Material	Calibrated date range ($\pm 2\sigma$)	$\delta^{13}C$
Hd-24527	3792 $\pm$ 23	moat E, layer 10	soil	2292-2142 BC	-25.9
Bln-5480	3128 $\pm$ 32	moat E, layer 7	horse (<i>Equus</i>)**	1495-1296 BC	-20.9
KIA-18873	3128 $\pm$ 28	moat B, layer 7	elk (<i>Alces</i>)**	1493-1301 BC	—
KIA-12439b	3106 $\pm$ 26	burial 1(1)	food crust	1432-1295 BC	-28.1
Bln-5483	3087 $\pm$ 30	moat A, layer 38	animal bone**	1424-1271 BC	-21.4
KIA-16427	3086 $\pm$ 27	moat A, layer 29/66	food crust	1421-1276 BC	-30.2
Bln-5533	3082 $\pm$ 32	burial 3	human**	1424-1263 BC	-20.8
KIA-12439a	3080 $\pm$ 28	burial 1(2)	fish**	1416-1266 BC	-18.7
Bln-5484a	3071 $\pm$ 36	moat A, layer 42b	elk (<i>Alces</i>)**	1420-1231 BC	-21.3
KIA-12438	3048 $\pm$ 39	moat E, layer 11	fish**	1416-1208 BC	-25.1
KIA-12434	3045 $\pm$ 38	house 7, burned layer	charcoal	1414-1208 BC	-24.6
KIA-16426	3045 $\pm$ 28	house 3b	food crust	1396-1222 BC	-29.0
Bln-5536	3032 $\pm$ 30	burial 6	human**	1398-1207 BC	-20.1
Bln-5486	3027 $\pm$ 28	moat A, layer 24	elk (<i>Alces</i>)**	1393-1135 BC	-22.3
Bln-5532	3018 $\pm$ 33	burial 1(3)	human**	1392-1129 BC	-21.5
Bln-5534	2999 $\pm$ 34	burial 4	human**	1382-1121 BC	-21.5
Bln-5535	2996 $\pm$ 32	burial 5	human**	1378-1121 BC	-21.3
Bln-5614	2959 $\pm$ 32	house 20, pit 445a	charcoal	1262-1056 BC	-27.3
Bln-5485a	2959 $\pm$ 34	moat A, burned layer 6	horse (<i>Equus</i>)**	1269-1051 BC	-21.6
Bln-5294	2933 $\pm$ 28	pit 155	Charcoal	1222-1038 BC	-27.0
Hd-24518	2929 $\pm$ 31	moat E, layer 8	Soil	1219-1022 BC	-25.7
Bln-5479	2891 $\pm$ 34	house 12, layer 3b	horse (<i>Equus</i>)**	1208-977 BC	-21.8
Bln-5478	2890 $\pm$ 31	object 3	horse (<i>Equus</i>)**	1207-976 BC	-21.6
KIA-12433	2878 $\pm$ 26	pit 27	charcoal	1188-942 BC	-25.4
KIA-16429	2839 $\pm$ 27	house 3a	food crust	1107-916 BC	-26.1
Bln-5417	2838 $\pm$ 32	house 3	charcoal	1109-914 BC	-26.8
KIA-12436	2824 $\pm$ 36	house 2, pit 282	charcoal	1109-899 BC	-24.8
KIA-16428	2818 $\pm$ 25	house 8a, layer 3	food crust	1042-907 BC	-28.9
Bln-5412	2813 $\pm$ 27	moat A, layer 10, object 6	charcoal	1042-903 BC	-26.8
KIA-12435	2812 $\pm$ 28	house 5, pit 11	charcoal	1044-901 BC	-25.4
KIA-18871	2793 $\pm$ 28	moat E2, layer 3e	animal bone**	1013-848 BC	—
KIA-16430	2773 $\pm$ 30	house 8a, pit 34b	food crust	999-841 BC	-27.1
Bln-5477	2736 $\pm$ 27	house 10, object 2	horse (<i>Equus</i>)**	930-817 BC	-20.9
Bln-5481	2705 $\pm$ 37	moat B, layer 4	horse (<i>Equus</i>)**	918-803 BC	-21.6
KIA-18874	2684 $\pm$ 24	moat G	animal bone**	896-804 BC	—
KIA-12437	2680 $\pm$ 36	moat E, layer 9	charcoal	901-800 BC	-22.2
Bln-5297	2677 $\pm$ 42	house 2, object 5	charcoal	907-796 BC	-25.0
Bln-5482	2665 $\pm$ 34	object 5	horse (<i>Equus</i>)**	896-796 BC	-20.8
Bln-5298	2643 $\pm$ 30	house 2, object 7	charcoal	894-787 BC	-25.2
Bln-5418	2623 $\pm$ 54	house 8, object 5	animal bone**	909-554 BC	-20.0
Bln-5419	2551 $\pm$ 38	house 8a, object 10	animal bone**	806-543 BC	-20.0
KIA 12432*	2008 $\pm$ 25	house 4, layer 2	charcoal	83 BC-59 AD	—
KIA 18872*	1984 $\pm$ 23	house 6, layer 2	neat (<i>Bos</i>)**	41 BC-66 AD	—
Bln-5296*	1120 $\pm$ 28	moat C	charcoal	778-994 AD	—

Bln-5295*	1076±27	burial (moat)	charcoal	895-1019 AD	—
Appendix 1					

Radiocarbon ages, calibrated date range and carbon stable isotope values from Chicha site. The dates were calibrated in OxCal 4.2 (Bronk Ramsey 2009) using IntCal13 calibration curve (Reimer et al. 2013). (*samples belonging to the later Early Iron Age (phase 3 by Schneeweiß 2007) or Middle Ages, respectively. They are far beyond the focus of this paper and were not included in the analysis, ** collagen dated).