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A HIGHLY PRECISE CHRONOLOGY FOR THE PROCESS OF NEOLITHIZATION IN SOUTHERN SCANDINAVIA: THE ESS PROJECT IN LUND, SWEDEN

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ABSTRACT. In 2013, one of Sweden's largest archaeological excavations started in association with the building of the European Spallation Source (ESS) multidisciplinary research center in Lund. The 160 radiocarbon dates that were produced for the project represent the most exhaustive dating program for a Scandinavian site so far and provide evidence for the human impact and activities on the site from the Mesolithic to the Iron Age. This article presents the results within a Bayesian statistical framework for the 70 ^{14}C dates from the Early Neolithic settlement (object 1) and a burial site with dolmens and wooden façades. For the first time, a highly precise chronology provides deeper insight into the Neolithization processes and the early settlement strategies in southern Scandinavia from ~3800 cal BC onwards.

KEY WORDS: Neolithization, Scandinavia, Bayesian approach.

INTRODUCTION

Our understanding of the Early Neolithic and the transition from the Mesolithic to the Early Neolithic in southern Scandinavia is in many ways contentious and patchy. Quite a few sites have been excavated so far, but there are a limited number of radiocarbon dates available for the early farming societies in this region (cf. Artursson et al. 2003; Nilsson and Rudebeck 2010). In connection with the European Spallation Source (ESS) project, the remains of 14 huts, two houses, pits, several ovens, three wooden post facades, two inhumation burials (one with a wooden post façade), a stone-built façade, and three dolmens were documented along the edge of a shallow wetland (Figure 1). The site is one of the largest early Neolithic settlements excavated in Sweden known to date. Early Neolithic huts and houses are relatively rare, as the remains are not easy to recognize in the archaeological record. The huts at the site were simple, small, round structures, built in a Mesolithic tradition with small posts and organic material covering (e.g. animal skins or vegetation) (Figure 2). After clearing the surface, these structures are just visible as a distinct patch of darker soil, since they have been dug into the ground. In some of these huts, remains of hearths were found. The floor surfaces varied considerably in size and not all were large enough to have functioned as living areas for a whole family. Instead, they may have been used for special activities or for storage. The huts of the settlement were arranged in two segments of a half circle around the wetland with two houses placed in the center. These two long houses were partly overlapping each other, and they are either interpreted as chiefs' houses or special communal buildings used successively. Different Bayesian models were tested with the horizontal stratigraphy of the site and the hypothesis that the huts were built from north to south.

DATING PROGRAM, RADIOCARBON DATES, AND BAYESIAN MODELS

The dating strategy for the ESS site (object 1) was to produce ^{14}C dates for all structures using, where possible, cereals or short-lived charcoal from the hearths inside the huts and houses. The features were undisturbed and the whole settlement was completely excavated. This provided the ideal conditions for establishing a highly precise chronology for the building sequence of the site. We used a Bayesian statistical approach, which is today a well-established method to limit

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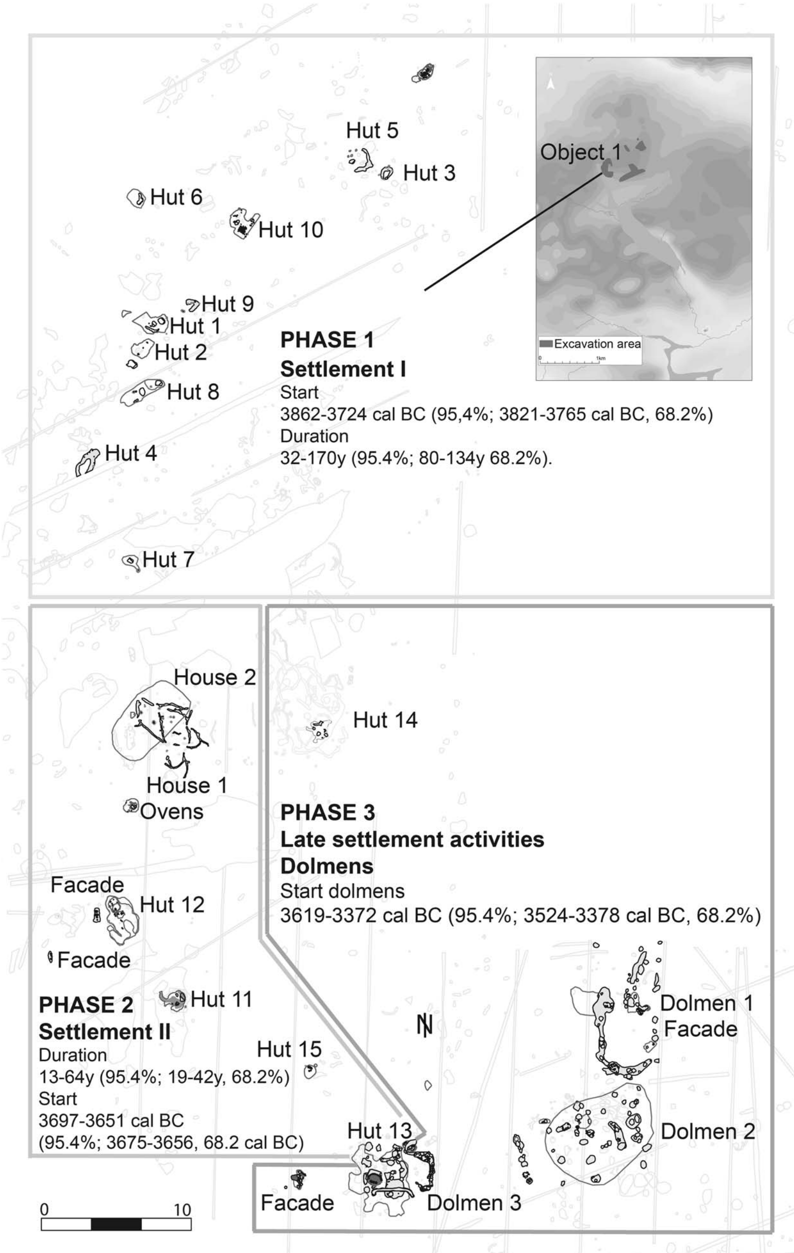

Figure 1 Plan of the settlement with the phases from Model 1. The oversight map with the excavation areas shows a reconstruction of the Stone Age wetland based on topographic mapping from 1810.

considerably the probable time interval for the calendar dates. The models and the calibrated data presented in the analysis have been obtained using the program OxCal v 4.2 (Bronk Ramsey 2001, 2009a, 2009b; Bronk Ramsey et al. 2006, 2010) and the IntCal13 calibration data (Reimer et al. 2013). In total, 70 ^{14}C dates were produced for the early Neolithic site (object 1) (Table 1, Figure 3). The wood species is identified for all 45 charcoal

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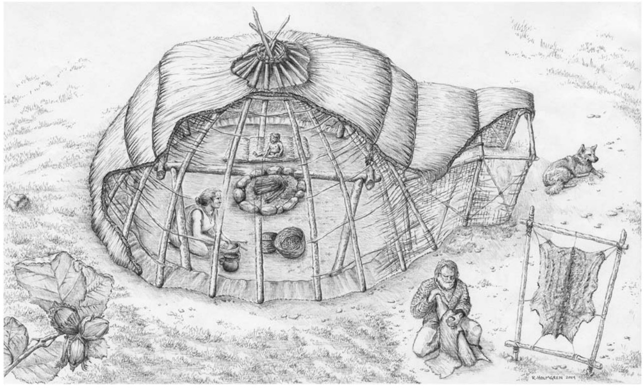

Figure 2 Reconstruction of a hut (drawing Richard Holmgren, ARCDOC)

samples; most are short-lived (1 *Salix*, 1 Pomoidea, 15 hazel, 1 hazel/alder, 8 oak, 4 birch, 1 birch/oak, 4 ash, 1 ash/oak, 4 aspen, 5 alder). In total, 23 charred plant remains (12 naked barley, 5 emmer, 2 bread wheat, 1 wheat, 3 unspecified cereals) were measured. The sample material of two ^{14}C dates is unidentified. For the Bayesian models, we concentrated on the Neolithic phases and excluded 17 ^{14}C dates most from the Bronze and Iron Age.

TWO ALTERNATIVE BAYESIAN MODELS FOR THE ESS SITE (OBJECT 1)

For the ^{14}C dates of the ESS site (object 1), we tried different possibilities with a Bayesian statistical framework focusing on the earliest settlement activities. The beginning of the early Neolithic is rather unclear for the region and we wanted to gain a closer insight into early settlement processes. Thus, here we present and discuss two alternative models with a slightly time-delayed onset for the beginning of the settlement. The main differences of the models are recognizable in phase 1. The two models do, however, differ slightly in the phases 2–4. The OxCal code for the models is given in the online Supplementary Material.

Model 1

The first model (Model 1) was established under the assumption that the earliest ^{14}C date (Beta-375266, 5190 ± 30 BP) does not represent its own earlier phase and is incorporated into phase 1 (phases 1–3). In doing so, the calibrated values of this ^{14}C date show a poor agreement (A = 34.1%). Beta-375266 came from a charcoal sample of the aspen species and originates from a small ditch in hut 3. This includes both a potential old-wood effect and the possibility of intrusive material and a *terminus post quem* (TPQ) value. For Model 1, a potential inbuilt age of 100 yr was corrected (average age of aspen) by the help of a normal distribution. This rather hypothetical approach requires indications for an old-wood effect over the distribution of the data and the species of the wood. We decided to limit this procedure to Beta-375266, which is a crucial ^{14}C date for our main research question regarding the beginning of the early Neolithic in southern Scandinavia. The remaining charcoal samples used are mostly hazel, a tree with a short lifespan, and there are also no other clear indications visible for an old-wood effect. Model 1 thus shows an agreement index of A_{model} = 103.2, $A_{overall}$ = 99.1 (Figure 4).

Model 2

The second model (Model 2) was established under the hypothesis that Beta-375266 represents its own phase with a first prospection of the site or settlement activities (phases 0–3). The date is

Table 1 Radiocarbon dates from the ESS project (object 1).

Site	Lab nr	^{14}C age	STD	Sample material	Identification	Context nr	Context
ESS object 1/Lund	LuS -10978	38,550	1250	ch	birch	5938	stone layer
ESS object 1 Lund	Beta-377576	6290	40	ch	ash	26446	pit
ESS object 1/Lund	Beta-375266	5190	30	ch	aspen	142543	hut 3/ditch
ESS object 1/Lund	Beta-371075	5030	30	ce	emmer	146474	hut 7/hearth
ESS object 1/Lund	Beta-375274	5020	30	ch	alder	15515	hut 6/hearth
ESS object 1/Lund	Beta-375262	5010	30	ch	alder	12436	facade 5/ditch
ESS object 1/Lund	Beta-362993	5000	30	ce	naked barley	34228	hut 1/hearth
ESS object 1/Lund	Beta-340082	4990	30	ch	pomoidea	n/a	hut 10/prel.invest.
ESS object 1/Lund	Beta-371061	4950	30	ch	hazel	27631	hut 8/layer
ESS object 1/Lund	Beta-371068	4950	40	ce	naked barley	20001	oven/pit
ESS object 1/Lund	Beta-371067	4940	30	ch	hazel	27707	hut 9/ditch
ESS object 1/Lund	Beta-371070	4940	30	ce	naked barley	141672	hut 11/hearth
ESS object 1 Lund	Beta-375271	4940	40	ch	oak	145988	hut 5/hearth
ESS object 1/Lund	Beta-371078	4930	30	ch	hazel	20001	oven/pit
ESS object 1/Lund	Beta-340085	4930	30	ce	naked barley	27949	pit/prel.invest.
ESS object 1/Lund	Beta-374038	4920	30	ch	aspen	27869	hut 2/pit
ESS object 1/Lund	Beta-362991	4910	30	ch	hazel	21196	house 1/layer
ESS object 1 Lund	Beta-362995	4910	40	ce	naked barley	28754	pit/same as pit 10867
ESS object 1/Lund	Beta-371073	4910	40	ch	hazel	144563	inside dolmen 3/posthole
ESS object 1/Lund	Beta-371062	4890	30	ce	naked barley	143269	hut 13/stone layer
ESS object 1/Lund	Beta-371072	4890	30	ch	hazel	10867	pit/same as 28754
ESS object 1/Lund	Beta-371074	4890	30	ce	cereals unspec.	26643	hut 4/ditch
ESS object 1 Lund	Beta-375269	4890	30	ch	hazel	5903	hut 12/layer
ESS object 1/Lund	Beta-374039	4880	30	ch	hazel	12235	hut 8/hearth
ESS object 1/Lund	Beta-340087	4880	40	ce	emmer	3185	pit/prel.invest.
ESS object 1/Lund	Beta-374041	4860	30	ch	ash	17207	facade 3/posthole
ESS object 1/Lund	Beta-371069	4850	40	ch	hazel	20001	oven/pit
ESS object 1 Lund	Beta-374044	4840	30	ce	naked barley	36085	hut 11/pit
ESS object 1/Lund	Beta-362998	4820	30	ce	cereals unspec.	20344	house 2/ditch

ESS object 1/Lund	Beta-371065	4820	30	ch	hazel	18836	pit
ESS object 1/Lund	Beta-371076	4810	30	ce	cereals unspec.	3665	hut 15/pit
ESS object 1/Lund	Beta-362994	4800	40	ce	emmer/spelt	28754	pit/same as pit 10867
ESS object 1 Lund	Beta-377572	4800	30	ch	birch	27707	hut 9/ditch
ESS object 1/Lund	LuS -10923	4795	45	ch	oak	1004608	facade 4/pit
ESS object 1/Lund	Beta-367671	4780	30	ce	naked barley	27869	hut 2/pit
ESS object 1/Lund	LuS -10921	4770	45	ch	aspen	1789	inhumation burial/ stone layer
ESS object 1/Lund	Beta-374042	4750	30	ch	birch	28122	hut 10/pit
ESS object 1 Lund	Beta-375261	4710	30	ch	hazel	36801	dolmen 3/impression orthostat
ESS object 1/Lund	Beta-362992	4690	30	ce	naked barley	34692	hut 1/hearth
ESS object 1/Lund	Beta-362997	4660	30	ce	naked barley	3759	facade 1/hearth
ESS object 1/Lund	Beta-375267	4450	30	ch	salix	38567	dolmen 2/ditch
ESS object 1/Lund	Beta-375268	4380	30	ch	oak	13808	dolmen 3/ditch
ESS object 1 Lund	Beta-374040	4370	30	ch	hazel	17195	facade 3/posthole
ESS object 1/Lund	Beta-375272	4340	30	ch	hazel	145951	hut 5/ditch
ESS object 1/Lund	Beta-375273	4170	30	ch	aspen	146198	hut 15/ditch
ESS object 1/Lund	Beta-377575	4010	30	ch	ash	145141	layer
ESS object 1/Lund	LuS-10919	3880	45	ch	hazel/alder	140802	hut 14/posthole
ESS object 1 Lund	LuS-10981	3600	45	ch	oak	3252	dolmen 3/ditch
ESS object 1/Lund	LuS -10924	3590	55	ch	alder	31399	hut 6/layer
ESS object 1/Lund	Beta-377574	3560	30	ch	birch	38808	hut 14/posthole
ESS object 1/Lund	LuS -10925	2715	55	ch	oak	147578	facade 4/posthole
ESS object 1/Lund	LuS-10980	2635	40	ch	birch, oak	11324	house 1/ditch
ESS object 1 Lund	Beta-375260	2440	30	ch	alder	21196	inside house 1 & 2/layer
ESS object 1/Lund	Beta-377571	2420	30	ch	alder	146825	pit
ESS object 1/Lund	LuS -10920	2385	45	ch	hazel	20344	house 2/ditch
ESS object 1/Lund	Beta-363014	2090	30	n/n	n/n	7709	well
ESS object 1/Lund	LuS-10979	2020	40	ch	aspen, oak	16446	house 1/posthole
ESS object 1 Lund	Beta-375270	1990	30	ch	oak	145881	dolmen 1/stone layer
ESS object 1/Lund	Beta-375265	1770	30	ch	oak	140124	enclosure 1/posthole
ESS object 1/Lund	Beta-377573	1380	30	ch	oak	33660	oven/pit
ESS object 1/Lund	LuS -10922	1355	40	ch	hazel	36198	enclosure 1/ditch
ESS object 1/Lund	Beta-362996	1300	30	ce	naked barley	20448	inside house 2/ditch

Table 1 (*Continued*)

Site	Lab nr	^{14}C age	STD	Sample material	Identification	Context nr	Context
ESS object 1 Lund	Beta-371077	125	n/n	n/n	n/n	6422	pit
ESS object 1/Lund	Beta-340086	4570	30	ch	ash	57806	dolmen 1/impression orthostat
ESS object 1 Lund	LuS 11172	4850	45	ce	wheat	3185	pit
ESS object 1/Lund	LuS 11173	4835	40	ce	naked barley	15440	facade 1/pit
ESS object 1/Lund	LuS 11174	4805	40	ce	emmer	20001	oven/pit
ESS object 1/Lund	LuS 11175	4960	35	ce	bread wheat	36085	hut 11/pit
ESS object 1/Lund	LuS 11176	4925	40	ce	emmer	20001	oven/pit
ESS object 1 Lund	LuS 11177	4855	35	ce	bread wheat	38946	hut 11/hearth

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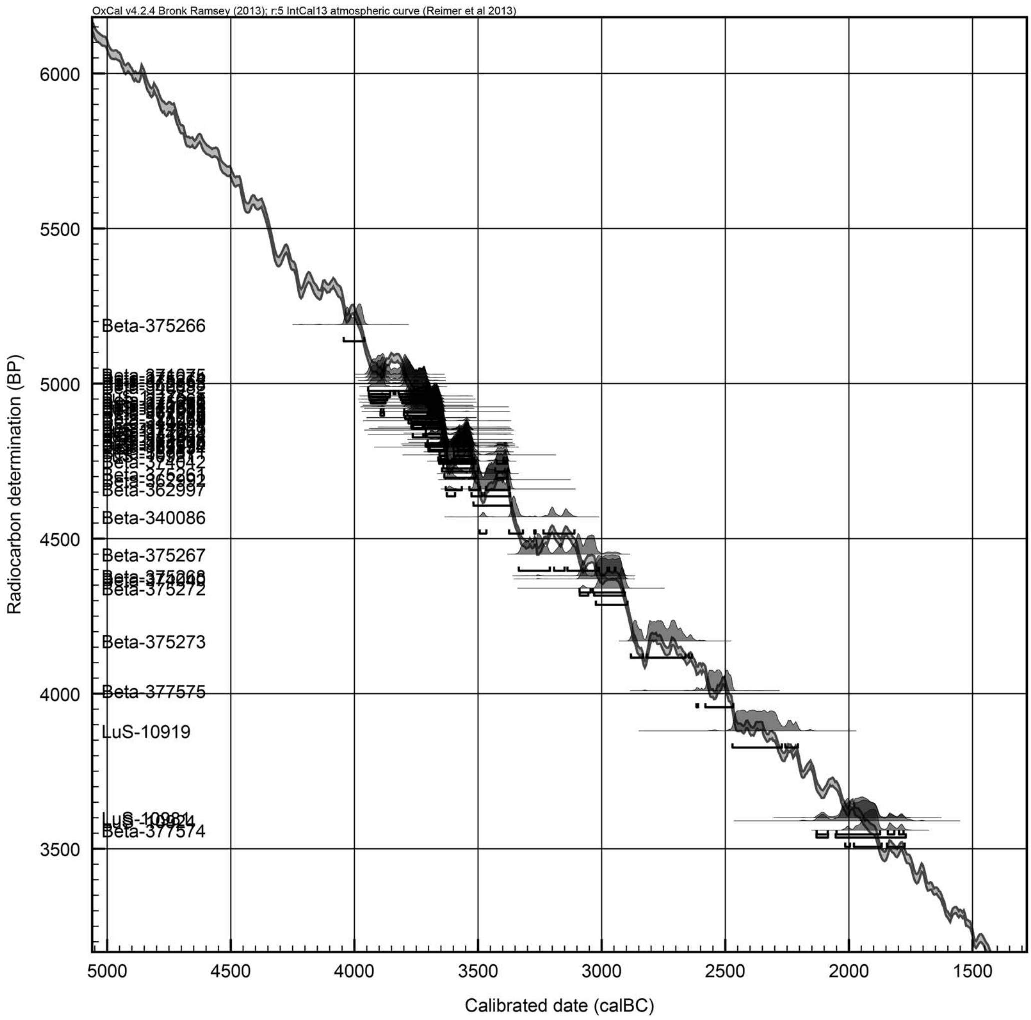

Figure 3 IntCal13 calibration curve (Reimer et al. 2013) for the period with the probability distribution of individual samples used for the models.

either associated with an early hut (3) or representing a TPQ value for hut 3. This model shows an agreement index of $A_{model} = 127.2$, $A_{overall} = 120.5$ (Figure 5). Model 2 starts with a phase 0.

Phase 0: First Prospection/Early Settlement Activities

This early phase in Model 2 is possibly describing a first activity on site in the early Neolithic as, for example, a prospection of the place in 4044–3957 cal BC (95.4%; 4035–3965 cal BC, 68.2%) or the very first hut (3) on site. The sample for Beta-375266 (charcoal, aspen) originates from a small ditch in hut 3. The context and direct association to hut 3 are therefore insecure.

Models 1/2 Phases 1–3

Phase 1: Settlement I

The time interval for the start of this phase is calculated for Model 1 to 3862–3724 cal BC (95.4%; 3821–3765 cal BC, 68.2%). In the very beginning, between 32–170 yr (95.4%; 80–134 yr,

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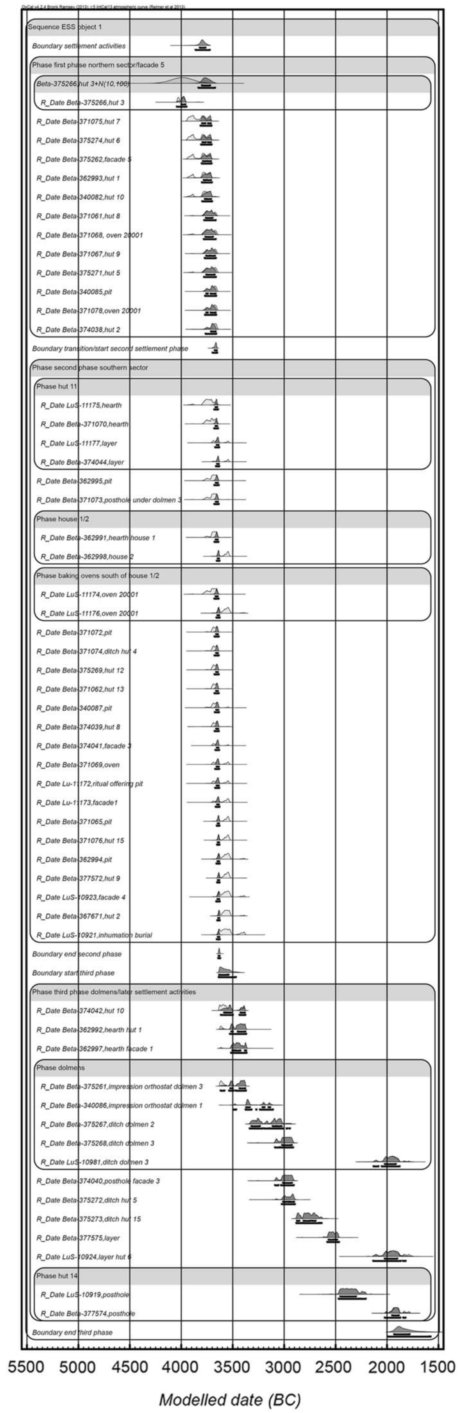

Figure 4 Model 1. Probability distributions of dates from the settlement ESS (object 1). Beta-375266 is belonging to the first settlement phase. A hypothetical inbuilt age is corrected by 100 yr (average age of aspen) (A_{model} = 103.2, $A_{overall}$ = 99.1).

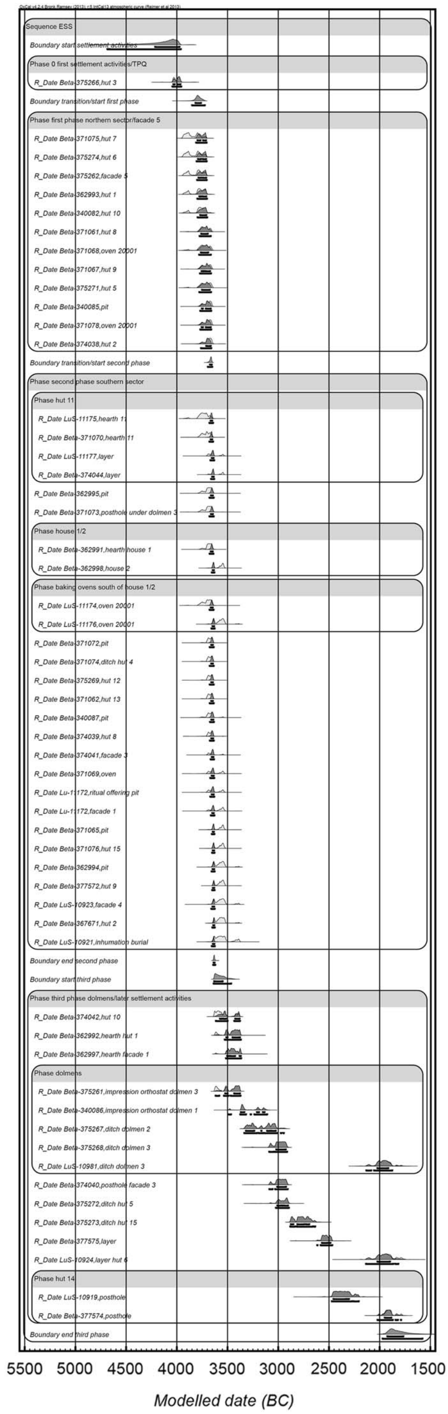

Figure 5 Model 2. Probability distributions of dates from the settlement ESS (object 1). Beta-375266 is representing an own phase with a first prospection of the site or settlement activities and the data is either associated with an early hut (3) or representing a TPQ value to hut 3 (A_{model} = 127.2, $A_{overall}$ = 120.5).

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68.2%), 10 huts (huts 1–10) were built throughout the northern sector of the settlement. The ^{14}C dates for this phase are mostly of short-lived sample materials from hearths. These data reflect the earliest activities in the huts and on site, even if we could expect to find here most likely find remnants of the last uses. The huts had a short lifetime of a few years and required regular restoration work or renewing. From most of the huts, several ^{14}C dates are available, indicating activities in the huts also in later phases or, taking the last argument into consideration, the renewing of these huts on site. Whether or not the 10 huts of phase 1 existed at the same time or some of them consecutively cannot be resolved by the ^{14}C dates. The spatial distribution of the huts in a half circle along the wetland would allow both interpretations.

Façade 5, situated under dolmen 3 in the southern sector, is either built in this phase or there is some earlier settlement material in the filling of the postholes. The dates may cluster towards the last use of the huts, which would favor a different Bayesian model. Yet, we have no clear indication for such a phasing over the horizontal stratigraphy or the artifacts; thus, from a Bayesian point of view, it would be incorrect to split phase 1 into two phases. In Model 2, the interval for the start of phase 1 is calculated somewhat later to 3811–3707 cal BC (95.4%; 3779–3713 cal BC, 68.2%). The duration of this phase is between 37–150 yr (95.4%; 77–130 yr, 68.2%).

Phase 2: Settlement II

In Model 1, the time interval for the start of phase 2 or the transition to this phase is calculated to 3697–3651 cal BC (95.4%; 3675–3656 cal BC, 68.2%). In phase 2, the settlement is extended between 13–64 yr (95.4%; 19–42 yr, 68.2%) to the southern sector. Huts 11, 12, 13, and 15 are built, and activities continue in the huts of the northern sector. Near the huts, façades 2 and 3 are constructed. The first long house (1) is built in the northern part of the southern sector. There is evidence for activities in this house from 3678–3640 cal BC (95.4%; 3666–3647 cal BC, 68.2%) onwards. The break between phases 1 and 2 occurs before the building of house 1. To place the ^{14}C dates for house 1 in the end of phase 1 would result in poor agreement for the beginning of phase 2 and the huts of the southern sector (hut 11; Model 1/2, A = 35.6%). To then insert hut 11 into phase 1, under the hypothesis that hut 11 was built contemporaneous to the huts of the northern sector, would also give a poor agreement for the beginning of phase 1 (hut 7, A = 57.9%) and for hut 11 itself (A = 36.1%).

House 1 was rebuilt (house 2) in place somewhat before 3656–3629 cal BC (95.4%; 3647–3634 cal BC, 68.2%). Large baking ovens placed to the south of the houses were in use during both stages. An inhumation burial with a wooden façade (4) from 3656–3626 cal BC (95.4%; 3645–3631 cal BC, 68.2%) in the southern sector belongs to this horizon, along with an inhumation burial without markings. In Model 2, these time intervals differ only slightly. The onset of the phase is calculated to 3695–3651 cal BC (95.4%; 3675–3656 cal BC, 68.2%), with the duration of the phase to between 12–62 yr (95.4%; 20–41 yr, 68.2%).

Phase 3: Dolmens and Late Settlement Activities

This phase starts between 3616 and 3377 cal BC (3584–3282 cal BC), when the settlement's main building phases have ended. ^{14}C dates from cereals in the hearths of huts (1 and 10) in the northern and southern sector indicate either possible late activities in former built huts, or rather, since these are short-lived structures, the renewing of these huts on site (Beta-374042; 4750 ± 30 BP; Beta-362992; 4690 ± 30 BP). These data closely follow ^{14}C dates gained from samples from a hearth at stone façade 1 and from the impression of a side stone from a

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megalithic grave. The stone façade 1 is associated with three megalithic graves (dolmens 1–3) in the southeastern part of the sector, which are built in this later phase. The dating of these dolmens is more problematic than the dating of the huts. The cereals in the hearths of the huts indicate direct activities, while the charcoal from the impression of the stones is not necessarily connected to the construction and use of the megaliths. The four dates from the dolmens suggest a time interval of 3619–1878 cal BC (95.4%; 3524–1916, 68.2%). The beginning of the dolmens is calculated to 3619–3372 cal BC (95.4%; 3524–3378 cal BC, 68.2%), while LuS-10981 obviously reflects a later activity at dolmen 3. These dolmens have been built after regular habitation at the site stopped. One hut (14) is newly built in the Late Neolithic. In Model 2, this phase of late settlement activities and grave construction is calculated to 3618–3372 cal BC (95.4%; 3524–3378 cal BC, 68.2%).

CONCLUSION

The sample for the earliest ^{14}C date (Beta-375266, 5190 ± 30 BP) originates from the ditch around hut 3. This context is uncertain and the arguments for an earlier prospection of the site and a TPQ phase for hut 3 or even a first hut ~200 yr earlier than the remaining 10 huts of this phase, which are built contemporaneous or within a short time interval, are limited. We prefer Model 1 with a later onset for the ESS settlement and the start of the Early Neolithic activities on site at 3862–3724 cal BC (95.4%; 3821–3765 cal BC, 68.2%) (Figures. 1, 4). The Beta-375266 sample (5190 ± 30 BP) may originate from clearing the place in connection to the first building activities and an old-wood effect seems plausible. We corrected this hypothetical old-wood effect with a normal distribution of 100 yr (average age of aspen). The dating strategy to produce ^{14}C dates from cereals and other short-lived samples from the hearths of the huts and houses allowed us to calculate the duration of the phases to short time intervals [phase 1 between 32–170 yr (95.4%; 80–134 yr, 68.2%); phase 2 between 13–64 yr (95.4%; 19–42 yr, 68.2%)]. These results provide concrete insight into settlement processes and strategies from the beginning of the Neolithic in southern Scandinavia.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/RDC.2016.72

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