Scientific Dating incorporating results of high-precision radiocarbon dating by the Universities Research and Reactor Centre, East Kilbride, and chronological modelling by Dr Peter Marshall

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Scientific dating

Introduction

Three samples of bone (all from articulated animal disposals) were sent to the Scottish Universities Research and Reactor Centre, East Kilbride (SUERC) for high-precision radiocarbon dating as part of the British Academy-/Society of the Antiquaries-funded post-excavation programme.

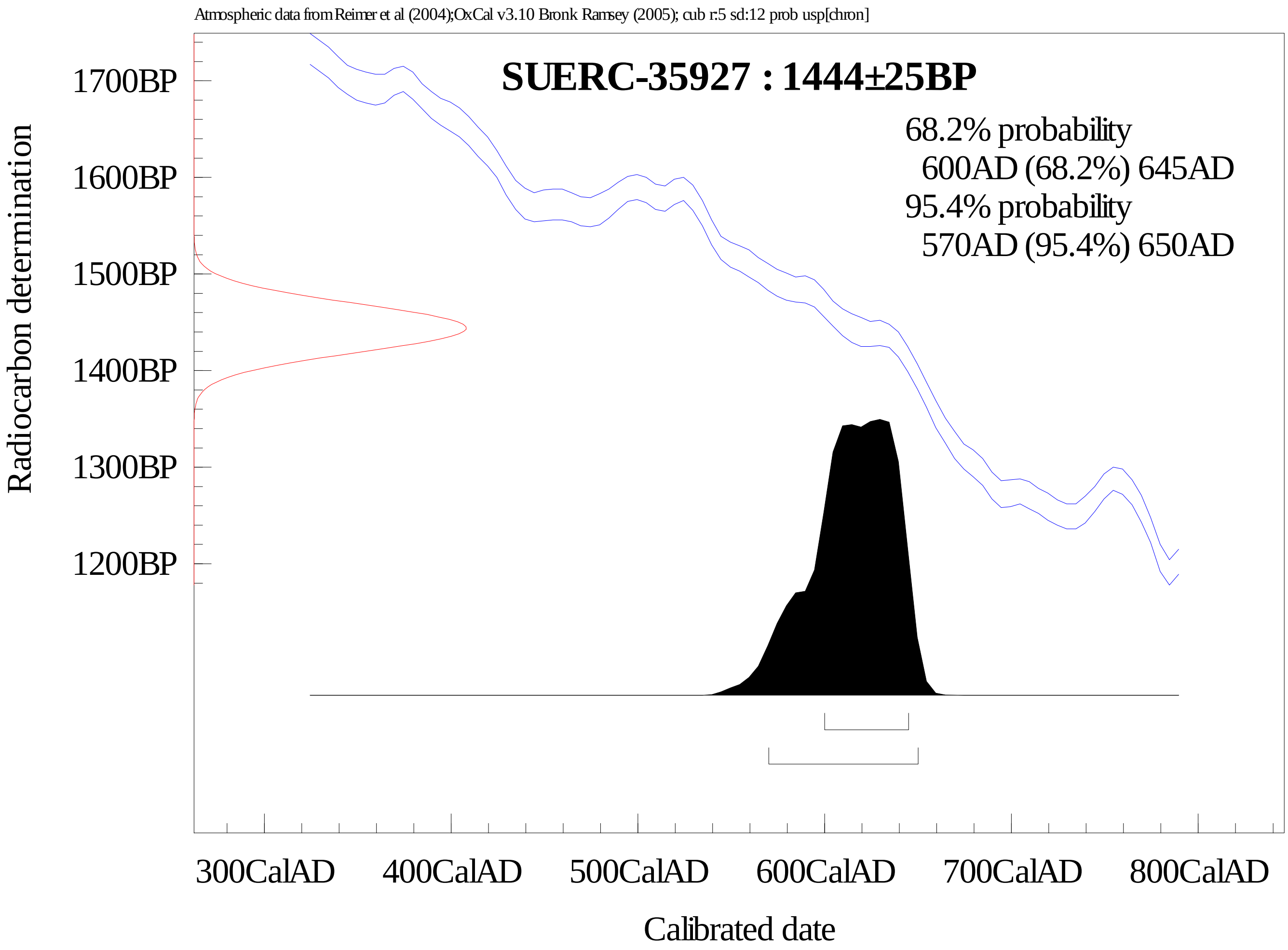
The following documentation falls into three parts: Part 1 (tabulated below) provides a rationale for the sampling strategy; Part 2 presents the laboratory results obtained from SUERC; whereas Part 3 reproduces a report by Dr Peter Marshall based on the production of a chronological model for the construction, use and abandonment of Sunken Feature Building 1, excavated in the 2010 campaign. This stratigraphic horizon is of crucial importance for two reasons: 1) it establishes a terminal date for the pre-monastic settlement represented at Lyminge, and 2) it provides a chronological marker for the deposition of the iron plough coulter – a unique find of international significance.

Part 1. Sampling strategy

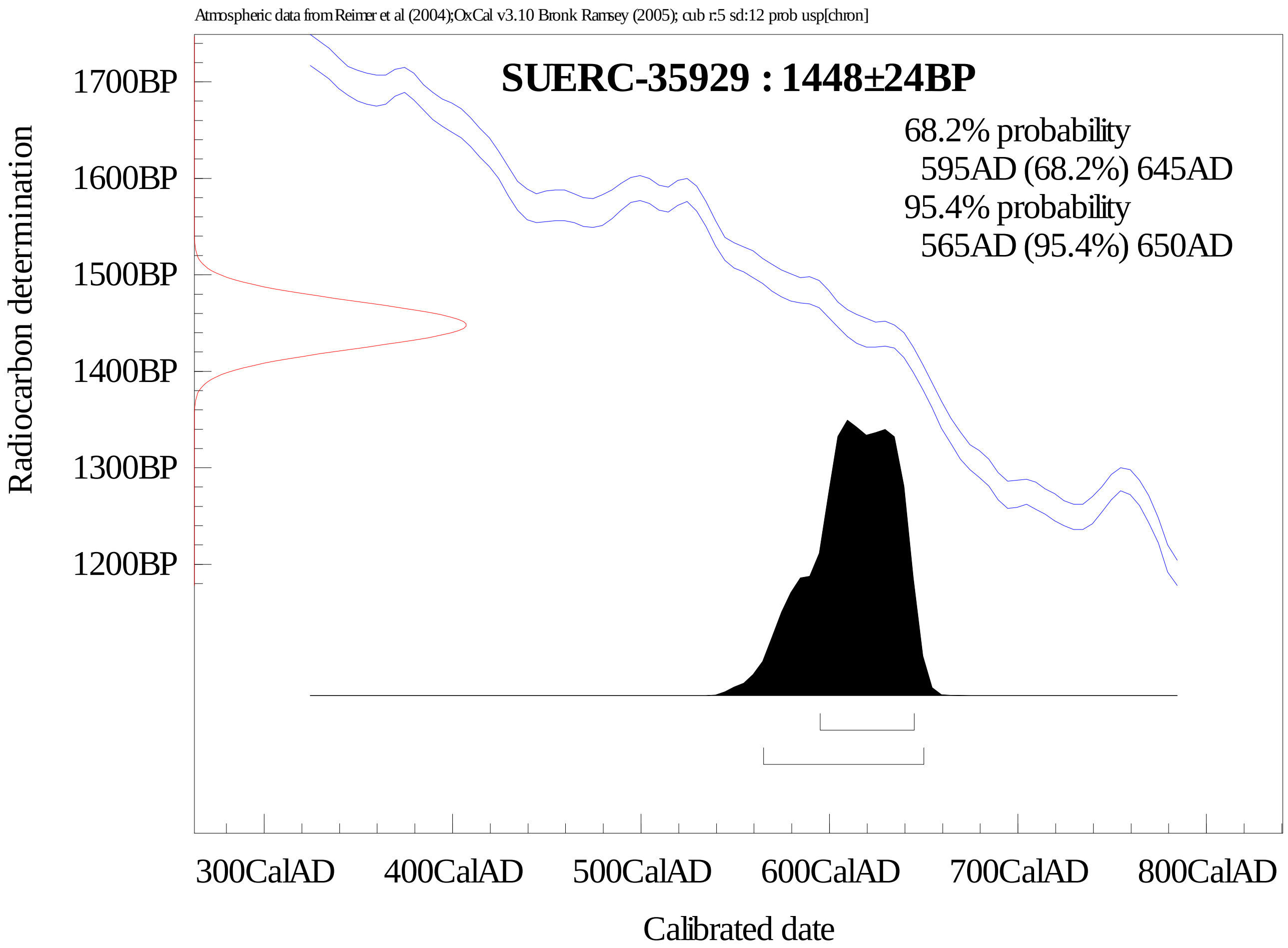
Sample ID	Context	Chronological question
SUERC-35927 (GU-24773).	Prmary fill of SFB 1, 2010 excavation	- to establish a *terminus ante quem* for the abadonment of SFB1 - to provide a chronological horizon for the abandonment of the ‘pre-monastic’ settlement focus - to provide a date for the deposition of the iron plough coulter
SUERC-35929 (GU-24775)	Primary fill of post-hole within southern wall alignment of post-built hall, 2010 excavation	- to establish a *terminus ante quem* for the abandonment of the hall - to establish a terminus post quem for the construction of SFB1 (SFB1 stratigraphically superimposed the post-built hall)
SUERC-35934 (GU-24777)	Primary fill of Mid Saxon boundary ditch, 2009 excavation	- to establish a *terminus ante quem* for the creation of the Mid Saxon boundary - to provide a chronoligical horizon for the earliest stratigraphic phase of the monastic-phase occupation.

Part 2. Results

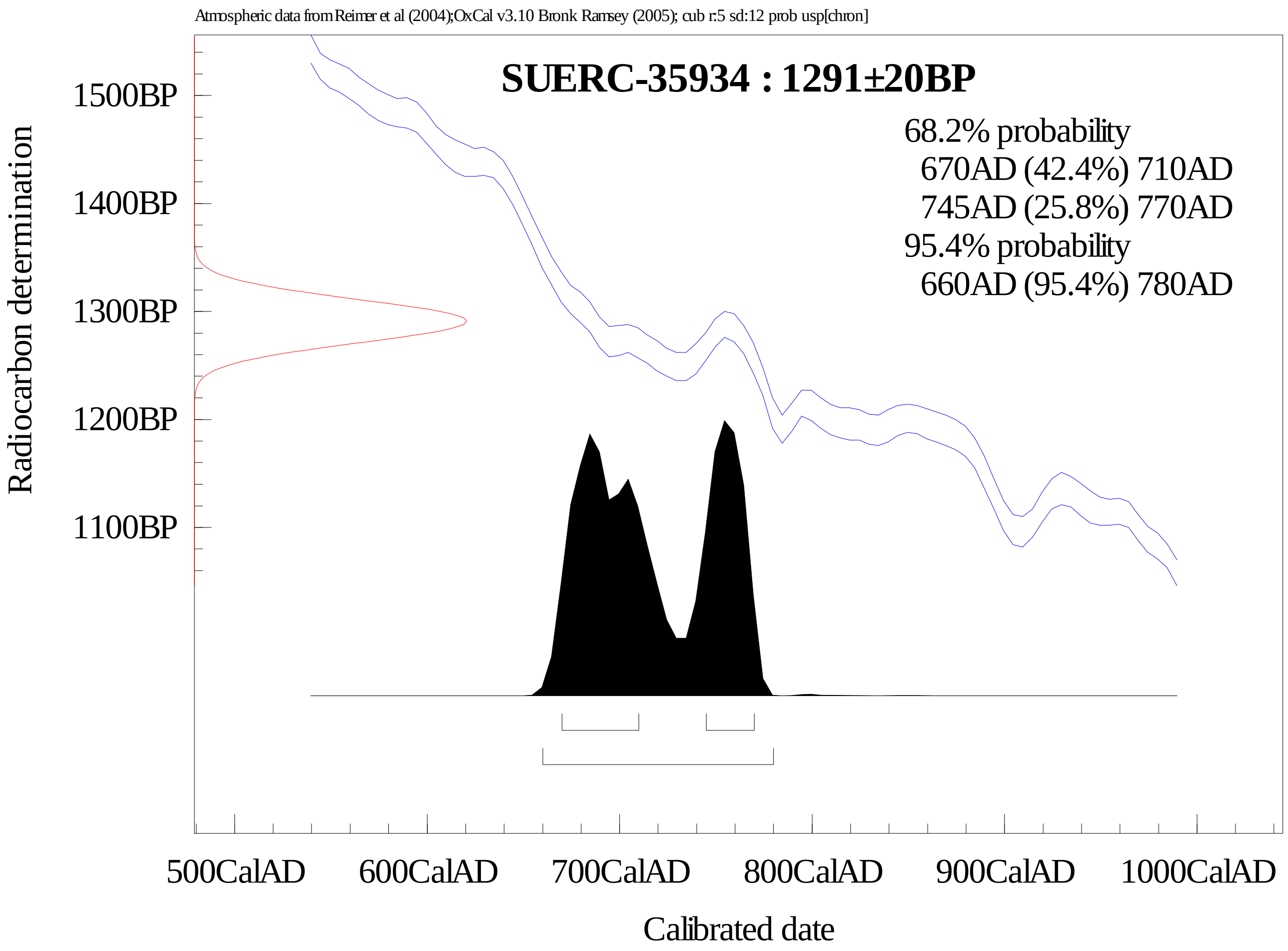
Laboratory Code	SUERC-35927 (GU-24773)
Material	Animal bone : Juvenile pig tibia (left)
$\delta^{13}C$ relative to VPDB	-21.4 ‰
$\delta^{15}N$ relative to air	3.6 ‰
C/N ratio(Molar)	3.8
Radiocarbon Age BP	1444 ± 25



Laboratory Code	SUERC-35929 (GU-24775)
Material	Animal bone : Cow, mandible including mandibular M3 (young adult)
δ^{13}C relative to VPDB	-21.8 ‰
δ^{15}N relative to air	5.0 ‰
C/N ratio(Molar)	3.4
Radiocarbon Age BP	1448 ± 24



Laboratory Code	SUERC-35934 (GU-24777)
Material	Animal bone : Cow, first cervical vertebrae
δ^{13}C relative to VPDB	-21.7 ‰
δ^{15}N relative to air	6.7 ‰
C/N ratio(Molar)	3.3
Radiocarbon Age BP	1291 ± 20



Part 3. Radiocarbon modelling

By Peter Marshall

Methods

Two samples were submitted for radiocarbon analysis to the Scottish Universities Research and Reactor Centre in East Kilbride. The two animal bone samples were pre-treated using a modified Longin method (Longin 1971), converted to carbon dioxide in pre-cleaned sealed quartz tubes (Vandeputte *et al* 1996), and graphitised as described by Slota *et al* (1997). They were measured by Accelerator Mass Spectrometry (AMS) as described by Xu *et al* (2004).

The laboratory maintains a continual programme of quality assurance procedures, in addition to participation in international inter-comparisons (Scott 2003). These tests indicate no laboratory offsets and demonstrate the validity of the precision quoted.

Sampling strategy

The first stage in sample selection was to identify short-lived material, which was demonstrably not residual in the context from which it was recovered. The taphonomic relationship between a sample and its context is the most hazardous link in this process, since the mechanisms by which a sample came to be in its context are a matter of interpretative decision rather than certain knowledge. Both samples consisted of single entities (Ashmore 1999) and were selected as there was evidence that both had been put fresh into their contexts – they were articulated animal bones. Articulated animal bone deposits must have been buried with tendons attached or they would not have remained in articulation, and so were almost certainly less than six months old when buried (Mant 1987, 71

Results

The radiocarbon results in Table 1 are quoted in accordance with the international standard known as the Trondheim convention (Stuiver and Kra 1986). They are conventional radiocarbon ages (Stuiver and Polach 1977).

The calibration of the results, relating the radiocarbon measurements directly to calendar dates, are given in Table 1 in outline in Figure 1. The radiocarbon determinations have been calibrated with data from Reimer *et al* 2009 using OxCal (v4.1) (Bronk Ramsey 1995; 1998; 2001; 2009). The date ranges have been calculated according to the maximum intercept method (Stuiver and Reimer 1986), and are cited at two sigma (95% confidence). They are quoted in the form recommended by Mook (1986), with the end points rounded outwards to 10 years. The ranges quoted in italics are *posterior density estimates* derived from mathematical modelling of archaeological problems (see below). The probability distributions (Fig 1) are derived from the usual probability method (Stuiver and Reimer 1993).

Isotopes

Carbon and nitrogen stable isotope analysis was applied to the animal bone samples as the potential for diet-induced radiocarbon offsets if an animal has taken up carbon from a reservoir (ie the sea) not in equilibrium with the terrestrial biosphere (Lanting and van der Plicht 1998) might have implications for the chronology of the site..

The stable isotope results (Table 1) indicate that the animals consumed a diet predominantly based upon temperate terrestrial C_3 foods (Schoeninger and DeNiro 1984; Katzenberg and Krouse 1989) and the C:N ratios (Table 1) suggests that bone preservation was sufficiently good for us to have confidence in the accuracy of the radiocarbon determinations (Tuross, Fogel and Hare 1988). The C:N ratio of sample SUERC-35929 is outside the range usually quoted as being indicative of good quality collagen preservation (2.9-3.6, DeNiro 1985), however, those ratios should only be used as a guide because variability does exist (G Cook pers comm).

Methodological approach
A Bayesian approach has been adopted for the interpretation of the chronology from the two samples (Buck *et al* 1996). Although the simple calibrated dates are accurate estimates of the dates of the samples, this is usually not what archaeologists really wish to know. It is the dates of the archaeological events, which are represented by those samples, which are of interest. In the case of these samples, it is the dates of the SFB that is under consideration, not the dates of the individual samples. The dates of this activity can be estimated not only using the absolute dating information from the radiocarbon measurements on the samples, but also by using the stratigraphic relationships between samples.

Fortunately, methodology is now available which allows the combination of these different types of information explicitly, to produce realistic estimates of the dates of archaeological interest. It should be emphasised that the *posterior density estimates* produced by this modelling are not absolute. They are interpretative *estimates*, which can and will change as further data become available and as other researchers choose to model the existing data from different perspectives.

The technique used is a form of Markov Chain Monte Carlo sampling, and has been applied using the program OxCal v4.1 (http://c14.arch.ox.ac.uk/). Details of the algorithms employed by this program are available from the on-line manual or in Bronk Ramsey (1995; 1998; 2001; 2009). The algorithm used in the models described below can be derived from the structures shown in Figure 1.

The sequence
The articulated animal disposal from the post-hole of a timber hall (Timber Hall1; SUERC-35929) provides a *terminus ante quem* for the occupation of the building and the articulated animal disposal (SUERC-35927) from the primary abandonment deposit of a sunken featured building that cut Timber Hall 1 a *taq* for the use of the building.

Results
The model (Figure RC1) shows good agreement between the radiocarbon dates and stratigraphy (Amodel=110%) and provides a *taq* for the use of Timber Hall 1 of *cal AD 570-645* (*95% probability*; SUERC-35929; Fig. 1) and probably *cal AD 595-635 (68% probability).* The sunken featured building must therefore have been built sometime after this date and itself been abandoned by cal AD 595-655 (*95% probability*; SUERC-35927; Fig. 1) or *cal AD 615-645 (68% probability).*

The interval between SUERC-35927 and SUERC-35929 provides an estimate for the use of SFB1 of 1-55 years (*95% probability*; Fig. 2) and probably 1-25 years *(68% probability).*

Discussion
The two dated samples fall on a very helpful piece of calibration curve from the mid-sixth to late eight century AD (Fig. 3). The submission of further samples from secure contexts could therefore if the settlement was relatively short-lived result in a very precise chronology for its history.

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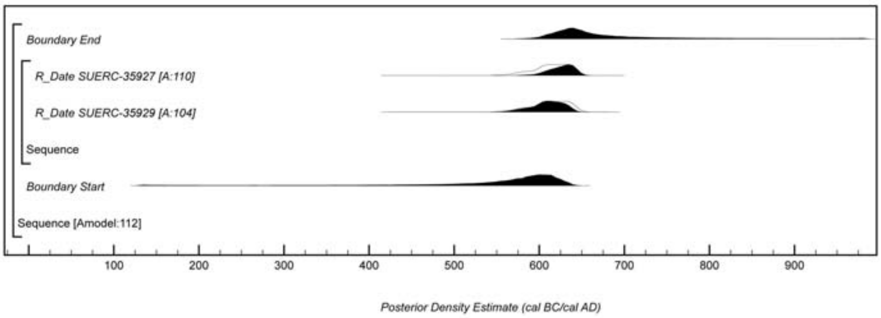

Figure 1: Probability distributions of dates from Lyminge: each distribution represents the relative probability that an event occurs at a particular time. For each of the radiocarbon dates two distributions have been plotted, one in outline, which is the result of simple calibration, and a solid one, which is based on the chronological model used. Figures in brackets after the laboratory numbers are the individual indices of agreement which provide an indication of the consistency of the radiocarbon dates with the prior information included in the model (Bronk Ramsey 1995). The large square brackets down the left hand side along with the OxCal keywords define the model exactly.

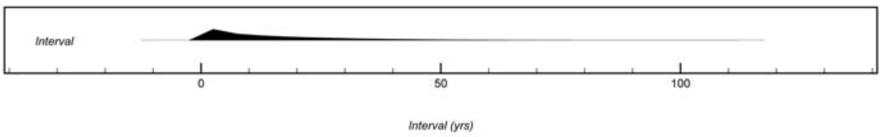

Figure 2: Probability distributions of the number of years between SUERC-35927 and SUERC-35929. The distribution is derived from the model sjown in Figure 1.

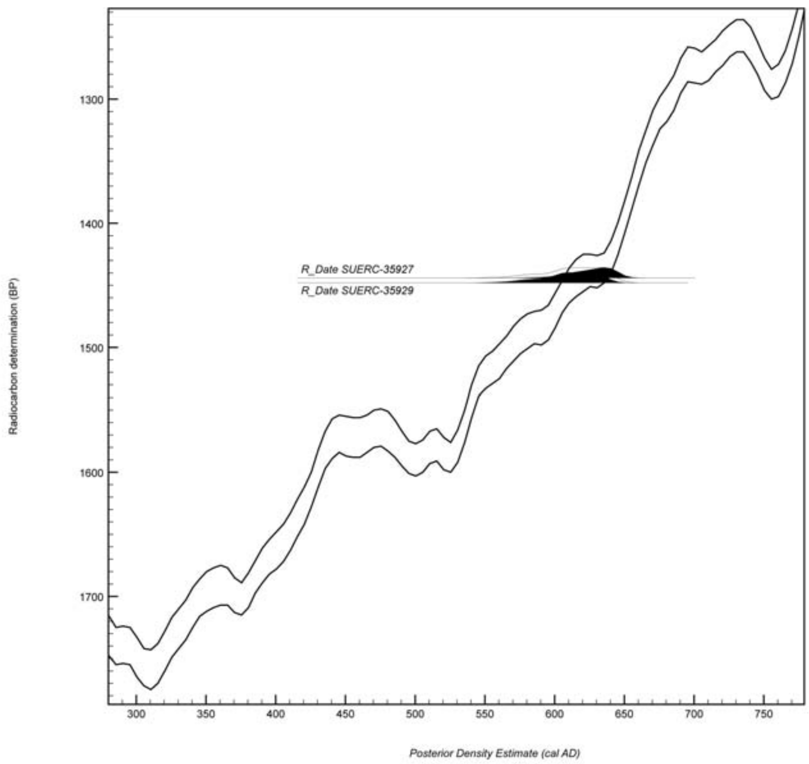

Figure 3: SUERC-35927 and SUERC-35929 plotted on the radiocarbon calibration curve c. 300-750 AD

Table 1: Lyminge radiocarbon and stable isotope results

Laboratory Number	Sample reference	Material	Radiocarbon Age (BP)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C:N ratio	Calibrated date range (95% confidence)	***Posterior density estimate (95% probability)***
SUERC-35927	LYM 2010 SFB1, context 2508, SF 1.35	Animal bone, juvenile pig tibia (left) from an articulated animal disposal in primary abandonment deposit ina sunken featured building (SFB1)	1444±25	-21.4	3.8	3.5	cal AD 565-655	*cal AD 595-635*
SUERC-35929	LYM 2010, context 2653, SF 59	Animal bone, cow (young adult) mandible including mandibular M3 from an articulated animal disposal in a post-hole of a timber hall (Timber Hall 1)	1448±24	-21.8	5.0	3.4	cal AD 565-655	*cal AD 570-645*