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Maumbury Rings, Dorchester

Radiocarbon Dating and Chronological Modelling

Peter Marshall, Susan Greaney, Michael Dee and Irka Hajdas

Scientific Dating

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Summary

Radiocarbon dating and chronological modelling of samples from Maumbury Rings, Dorchester, Dorset was undertaken in support of a PhD funded by the AHRC through the South, West and Wales Doctoral Training Partnership at Cardiff University undertaken by Susan Greaney. The results estimate Maumbury Rings to have been constructed in *2470–2405 cal BC* (*95% probability*) and probably in *2465–2445 cal BC* (*68% probability*).

Contributors

Peter Marshall, Susan Greaney, Michael Dee and Irka Hajdas

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Front cover image

Maumbury Rings. Photograph by Damian Grady, 18 September 2007. [© Historic England Archive].

Archive location

Dorset Museum, High West Street, Dorchester, Dorset, DT1 1XA

Historic environment record

Dorset Historic Environment Record, Dorset History Centre, Bridport Road, Dorchester, Dorset, DT1 1RP

Date of survey/research/investigation

Sampling of material held in the Maumbury Rings archive took place at Dorset Museum in 2018 with radiocarbon dating at the Centre for Isotope Research, University of Groningen and ETH Zurich undertaken in 2018–2019. The report was compiled in 2024.

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Introduction

This document is a technical archive report on the radiocarbon dating and chronological modelling of samples from Maumbury Rings, Dorchester, Dorset (Fig. 1). The work was undertaken in support of a PhD funded by the AHRC through the South, West and Wales Doctoral Training Partnership at Cardiff University undertaken by Susan Greaney (Greaney 2022). Elements of this report may be combined with additional research at some point in the future to form a comprehensive publication on the chronology of Maumbury Rings.

Maumbury Rings

The henge at Maumbury Rings survives as a substantial earthwork, largely due to its later use as a Roman amphitheatre and Civil War fortification (Fig. 2). It has an internal diameter of 47m and an external diameter of 101m, with the banks standing up to 5.6m high. It was excavated between AD 1908–13 by Harold St George Gray (Gray 1908; 1909; 1910; 1913; 1914), who confirmed the overarching sequence of activity, and found that the prehistoric northern entrance causeway was 15m wide (Fig. 3). He also found an unusual circuit of deep shafts, some 52m in diameter and probably comprising 45 shafts in total, with depths ranging from 9–11.7m (Bradley 1976; Fig. 4). These shafts appear to have been cut down from the base of a pre-existing ditch and material within them included Grooved Ware pottery, carved chalk objects, worked flint, fossils and antler fragments. Some objects were deliberately placed, such as a red deer skull with its antlers found close to a chalk phallus. It seems that the shafts were deliberately backfilled with chalk rubble, perhaps after each episode of deposition (Bradley 1976, 33). A possible portal standing stone had been noted in the entrance prior to AD 1846 (Gray 1908) and the circuit was surrounded by an external bank.

Objectives

The aim of this research was to produce a more precise and robust chronology for Maumbury Rings. This would enable us to disentangle the temporal relationship between this monument and the other major late Neolithic sites in and around Dorchester, eg Mount Pleasant (Greaney et al. 2020) and Greyhound Yard (Marshall et al. 2024).

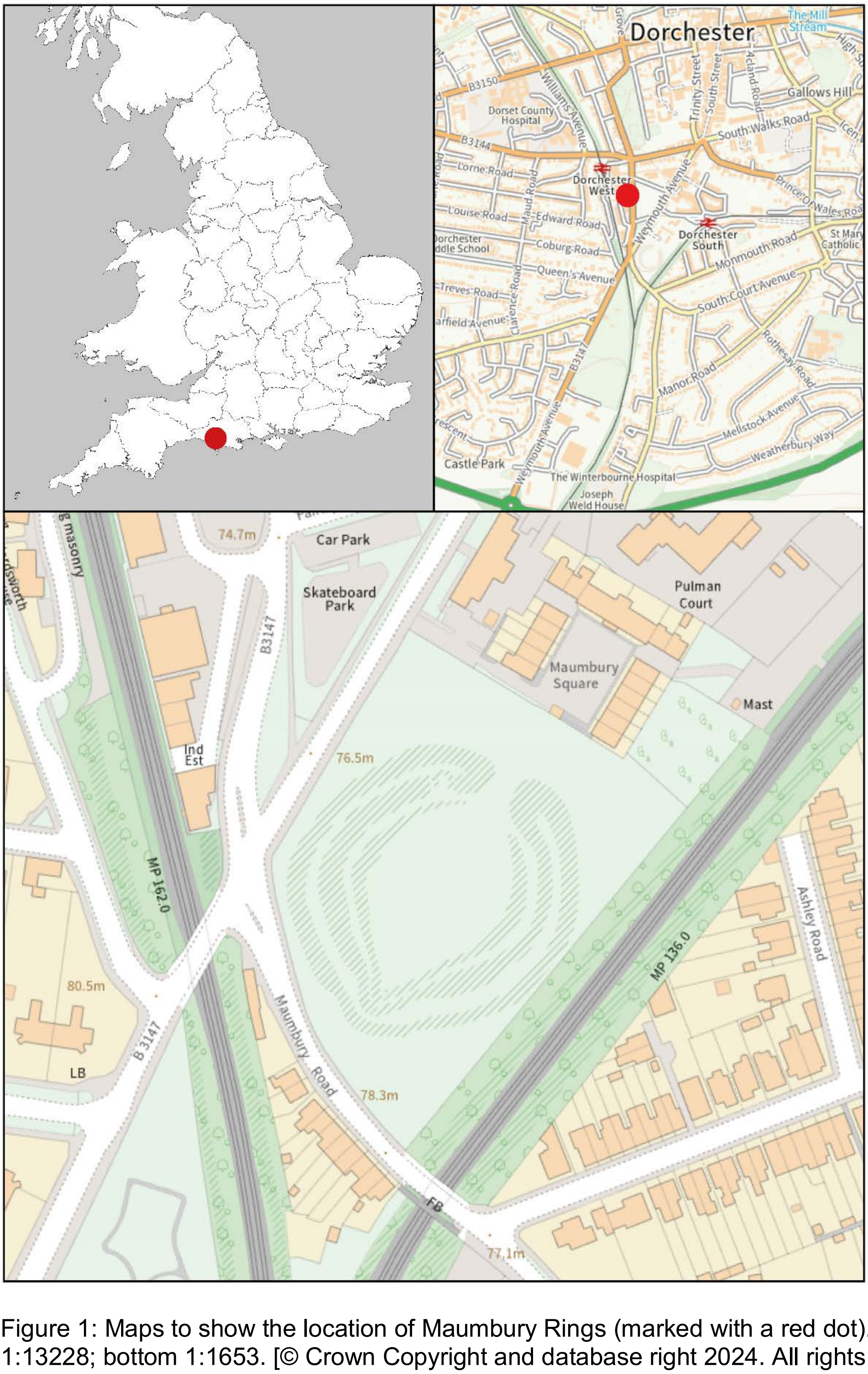

Figure 1: Maps to show the location of Maumbury Rings (marked with a red dot). Scale: top right 1:13228; bottom 1:1653. [© Crown Copyright and database right 2024. All rights reserved. Ordnance Survey Licence number 100024900]

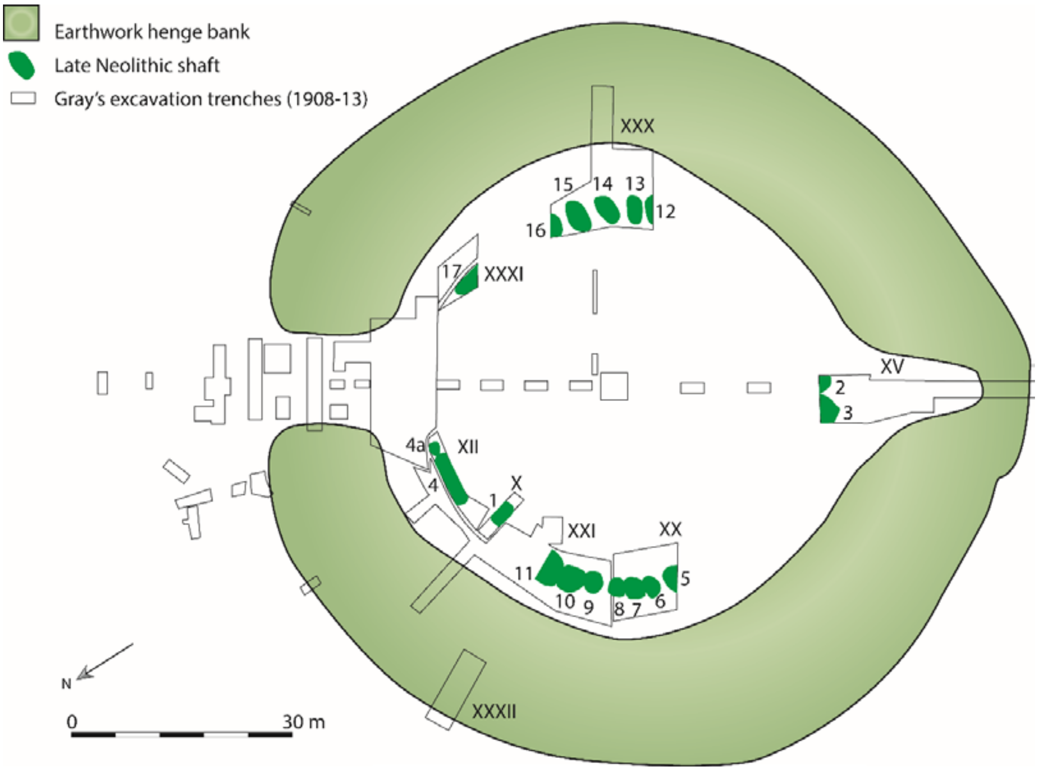

Figure 2: Plan of Maumbury Rings. Cutting numbers are given in Roman numerals (based on Gray 1914, plate 1 and Bradley 1976, fig 3). [© Susan Greaney]

Figure 3: General view of cuttings XXX and XXXI looking SSE, during Gray's excavations in 1913. The Civil War well can be seen in the foreground (surrounded by planking) and strut holes are visible in the arena wall. Photographer: Harold St George Gray. [© Dorset Museum]

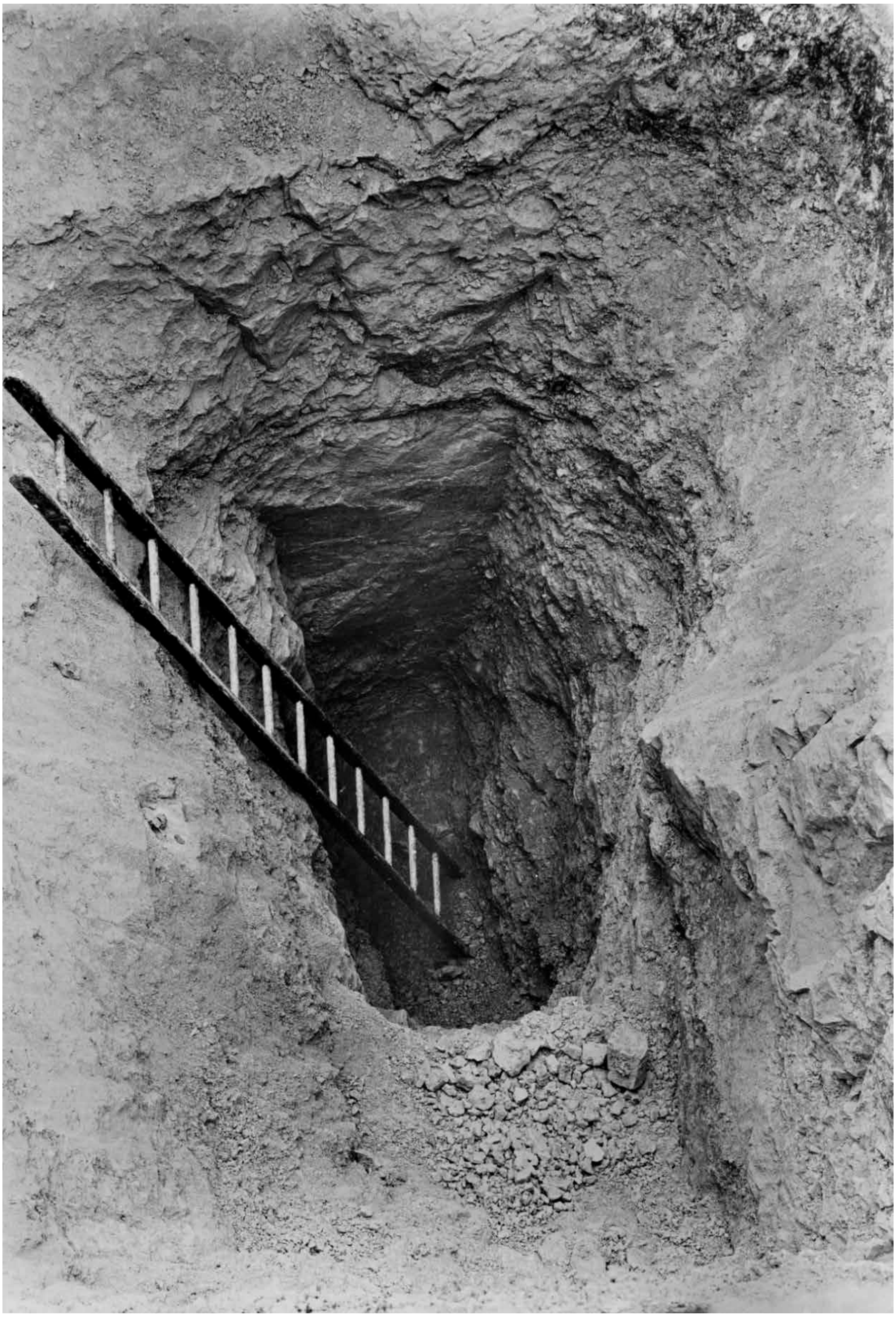

Figure 4: Cutting XXI. Bottom of Shaft XI from NNE at level of Roman floor. The south end only was excavated to the bottom due to time restrictions. Photographer: Harold St George Gray. [© Dorset Museum]

Radiocarbon dating and chronological modelling

Sampling

The new radiocarbon dating programme for Maumbury Rings was conceived within the framework of Bayesian chronological modelling (Buck et al. 1996). This allows the combination of calibrated radiocarbon dates with archaeological prior information using a formal statistical methodology. The objective of the programme was to provide a robust chronology for the construction of the monument.

Two measurements were obtained from the British Museum radiocarbon laboratory in 1984–5 on antlers submitted by Richard Bradley in 1983 (Ambers et al. 1987, 63–4)[1].

Sample selection was undertaken using the iterative process for implementing Bayesian chronological modelling on archaeological sites as outlined in Bayliss and Marshall (2022). At Maumbury Rings we targeted antler tools discarded at or near the base of negative features thought to be functionally related to the digging of them. This inference is more secure when use-wear such as battering on the posterior side of the beam/burr/coronet is identifiable (Bayliss and Marshall 2022: §3.2.2).

Radiocarbon dating

A total of fifteen radiocarbon measurements, all from antler, are now available relating to activity at Maumbury Rings. Details of the dated samples, radiocarbon ages, and associated stable isotopic measurements are provided in Table 1. Antler numbers are those given by Gray; a full list is available in the site archive in Dorset Museum.

The results are conventional radiocarbon ages, corrected for fractionation using $\delta^{13}C$ values measured by Accelerator Mass Spectrometry (Stuiver and Polach 1977; Table 1). The quoted $\delta^{13}C$ and $\delta^{15}N$ values were measured by Isotope Ratio Mass Spectrometry.

At the Laboratory of Ion Beam Physics, ETH Zürich the eight antler samples were gelatinised and ultrafiltered as described by Hajdas et al. (2007; 2009). They were then combusted in an elemental analyser and graphitised using the fully automated system

[1] The dates were obtained by liquid scintillation counting of benzene using the procedures described in Baker et al. (1971). A technical problem in the laboratory between 1980–84 meant that results were systematically too young (Bowman et al. 1990) and samples either remeasured as in the case of the antler from Shaft 1 (denoted with the laboratory suffix ‘N’), eg BM-2282N or recalculated as in the case of the antler from Shaft 3 (denoted with the laboratory suffix ‘R’), eg BM-2281R.

described by Wacker et al. (2010a). Graphite targets were dated using a 200kV, MICADAS Accelerator Mass Spectrometer as described by Wacker et al. (2010b).

Table 1: Maumbury Rings, Dorset: radiocarbon and stable isotope measurements. Replicate measurements have been tested for statistical consistency and combined by taking a weighted mean before calibration as described by Ward and Wilson (1978; T'(5%)=3.8, v=1).

Laboratory number	**Sample reference, material & context**	**$\delta^{13}C_{IRMS}$ (‰)**	**$\delta^{15}N_{IRMS}$ (‰)**	**C/N ratio**	**Radiocarbon age (BP)**
Shafts					
BM-2282N	Antler 60 (1) Red deer antler pick (H St George Gray). Cutting X, from bottom of Shaft 1 (depth of 36ft below modern ground surface; Bradley 1976, 16) (Ambers et al. 1987, 64; Bowman et al. 1990, 65; Bradley and Thomas 1984, 133)	–22.3		3.4	3970±50
ETH-86727	Antler 59. Red deer antler pick. Cutting X, from depth of 24.8ft below modern ground surface within Shaft 1 (Gray excavation diary; Bradley 1976, 16). This antler pick has a tine that is smoothed and polished from use, making it likely to be functionally related to the digging of the shaft.	−23.5±0.1	6.1±0.1	3.4	3985±22
BM-2281R	Antler 160 (4) Red deer antler pick (H St George Gray). Cutting XV, from uppermost Neolithic fill of Shaft 3 (Ambers et al. 1987, 64; Bowman et al. 1990, 71; Bradley and Thomas 1984, 133)	−23.3			3940±130
ETH-86728	Antler 245. Red deer antler pick. Cutting XX, from bottom of Shaft 6 at a depth of 20.7ft below modern ground surface (Gray 1910, 262; Gray excavation diary; Bradley 1976, 16). This antler pick has a polished and partly burnt tine, making it likely to	−23.4±0.1	6.0±0.1	3.3	3961±23

Laboratory number	Sample reference, material & context	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{15}N_{IRMS}$ (‰)	C/N ratio	Radiocarbon age (BP)
	be functionally related to the digging of the shaft.				
ETH-86729	Antler 293. Red deer antler pick. Cutting XX, from depth of 27ft below modern ground surface within Shaft 9 (Gray 1913, 102; Gray excavation diary; Bradley 1976, 16). This antler pick has a tine that is smoothed and polished from use, making it likely to be functionally related to the digging of the shaft.	−22.7±0.1	5.5±0.1	3.4	4064±22
ETH-86730	Antler 311. Red deer antler pick. Cutting XXI, from depth of 22ft below modern ground surface within Shaft 10 (Gray 1913, 102; Gray excavation diary; Bradley 1976, 16). This antler pick has a tine that is smoothed and polished from use, making it likely to be functionally related to the digging of the shaft.	−22.9±0.1	5.3±0.1	3.4	4011±23
GrM-13227	Antler 332. Red deer antler pick. Cutting XXI, from the bottom of Shaft 11 at a depth of 28ft below modern ground level (Gray excavation diary; Bradley 1976, 16). This antler pick has a highly polished shaft from use, making it likely to be functionally related to the digging of the shaft.	−22.6±0.05	3.2±0.1	3.2	3889±16
ETH-96043	Antler 332.b. Replicate of GrM-13227	−22.8±0.1	3.3±0.1	3.4	4002±24
^{14}C: 3924±14 BP, T'=15.4; $\delta^{13}C$: −22.6±0.05‰, T'=3.2 $\delta^{15}N$: 3.3±0.1‰, T'=0.5					
GrM-13230	Antler 399. Red deer antler pick. Cutting XXX, from 4.7ft from the bottom of Shaft 15 (Gray 1914, 111).	−22.9±0.05	4.6±0.1	3.2	3917±16
ETH-96044	Antler 399.b. Replicate of GrM-13230	−22.7±0.1	4.8±0.1	3.5	3963±24

Laboratory number	**Sample reference, material & context**	**$\delta^{13}C_{IRMS}$ (‰)**	**$\delta^{15}N_{IRMS}$ (‰)**	**C/N ratio**	**Radiocarbon age (BP)**
^{14}C: 3931±14 BP, T'=2.5; $\delta^{13}C$: −22.9±0.05‰, T'=3.2 $\delta^{15}N$: 4.7±0.1‰, T'=2.0					
ETH-86731	Antler 400A. Red deer antler pick. Cutting XXX, from 1.2ft above the bottom of Shaft 15 (Gray 1914, 111). This antler pick has a tine that is smoothed and polished from use, making it likely to be functionally related to the digging of the shaft.	−22.6±0.1	6.3±0.1	3.3	3973±23
GrM-13231	Antler 400B. Red deer antler pick. Cutting XXX, from 1.2ft above the bottom of Shaft 15 (Gray 1914, 111). This antler pick has a tine that is smoothed and polished from use, making it likely to be functionally related to the digging of the shaft.	−22.4±0.05	5.9±0.1	3.2	3951±16
^{14}C: 3958±14 BP, T'=0.6; $\delta^{13}C$: −22.4±0.05‰, T'=3.2 $\delta^{15}N$: 6.1±0.1‰, T'=8.0					
GrM-13232	Antler 401. Red deer antler crown. Cutting XXX, from within 2in of bottom of Shaft 15 (Gray 1914, 111). This antler pick has a tine that is highly smoothed and polished from use, making it likely to be functionally related to the digging of the shaft.	−23.8±0.05	4.1±0.1	3.2	3856±16
ETH-96045	Antler 401.b. Replicate of GrM-13232	−23.8±0.1	4.3±0.1	3.4	3936±24
^{14}C: 3881±14 BP, T'=7.7; $\delta^{13}C$: −23.8±0.05‰, T'=0.0; $\delta^{15}N$: 4.4±0.1‰, T'=0.5					
Henge bank					
GrM-13228	Antler 398. Red deer antler tine. Cutting XXXII, found 'just below the brown mould rise in the body of the henge bank', 4.75ft down from the surface, i.e. within the secondary henge bank (Gray excavation diary; Gray 1914, 116). This broken antler tine is highly polished, making it	−21.8±0.05	6.2±0.1	3.2	3908±16

Laboratory number	Sample reference, material & context	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{15}N_{IRMS}$ (‰)	C/N ratio	Radiocarbon age (BP)
	likely to be functionally related to the digging of the shafts or henge ditch.				

Stable isotopic ratios were obtained on sub-samples of the pretreated material using a ThermoFischer Flash-EA 1112 elemental analyzer coupled through a Conflo IV interface to a ThermoFisher Delta V Isotope Ratio Mass Spectrometer.

Five antler samples were dated at Centre for Isotope Research, University of Groningen in 2018. The samples were pretreated using an acid-base-acid protocol, before being gelatinised, and filtered (50µm) (Dee et al. 2019). They were then combusted in an elemental analyser (IsotopeCube NCS), coupled to an Isotope Ratio Mass Spectrometer (Isoprime 100) for measurement of %C, %N, C/N, $\delta^{13}C$ and $\delta^{15}N$. The resultant CO_2 was graphitised by hydrogen reduction in the presence of an iron catalyst. The graphite was then pressed into aluminium cathodes and dated by AMS (Synal et al. 2007; Salehpour et al. 2016).

Data reduction was undertaken at both laboratories as described by Wacker et al. (2010c). Both facilities maintain continual programmes of quality assurance procedures, in addition to participation in international inter-comparison exercises (Scott et al. 2017). Details of quality assurance data and error calculation at Groningen are provided by Aerts-Bijma et al. (2021), and similar details for ETH are provided in Sookdeo et al. (2020).

Replicate radiocarbon measurements are available on four samples, of which two pairs are statistically consistent at the 5% significance level, but the other two pairs are statistically significantly different at the 1% significance level. This reproducibility is not within statistical expectation, and so the accuracy of these measurements has been assessed during the modelling process by their compatibility with related radiocarbon results.

All four pairs of $\delta^{13}C$ values measured by Isotope Ratio Mass Spectrometry (IRMS), and three pairs of replicate $\delta^{15}N$ values are statistically consistent at the 5% significance level, but the other pair $\delta^{15}N$ values are statistically significantly different at the 1% significance level (Ward and Wilson 1978; Table 1). The quoted errors derive from the uncertainty in the IRMS combustion and measurement, and the observed reproducibility on repeat sample preparations. The measurements provided also demonstrate it is appropriate to employ a fully terrestrial calibration curve for the results on these samples.

Chronological modelling

The chronological modelling presented here has been undertaken using OxCal 4.4 (Bronk Ramsey 2009), and the internationally agreed calibration curve for the northern hemisphere (IntCal20; Reimer et al. 2020). The models are defined by the OxCal CQL2 keywords and by the brackets on the left-hand side of Figures 5–6 (the full code is given in Appendix 1). In the figures, calibrated radiocarbon dates are shown in outline, and the posterior density estimates produced by the chronological modelling are shown in solid black. The other distributions correspond to aspects of the model. For example, the distribution *BuildMaumburyRings* (Fig. 6) is the posterior density estimate for the date when Maumbury Rings was built. In the text and tables highest posterior density intervals, which describe the posterior distributions, are given in italics.

We consider the elements of these models using Harold St. George Gray's shaft numbers starting with Shaft 1.

Shaft 1 was one of the largest shafts to be sectioned to its base at a depth of 30ft (9m) from the modern ground surface (mgs) and an original estimated depth of 36.4ft (11m). Its lower half had been filled by a coarse rubble fill of such uniformity that Gray suggested 'it had been filled in at one time' was sealed by three lenses of humic material and subsequently an upper fill of fine rain-washed marl (Bradley 1976, 8, fig 4). Radiocarbon determinations on antlers from the bottom (BM-2282N) and the lower fill (ETH-86727) are statistically consistent at the 5% significance level (T'=0.1, T'(5%)=3.8, v=1) and could be of the same actual age.

The almost vertically sided Shaft 3 was sectioned to a depth of 11.4ft (3.5m) and a single antler pick dated (BM-2281R) from its uppermost chalk rubble fill (Bradley 1976, 11). Shaft 6 was excavated to a depth of 25.5ft (8m below mgs) and a single antler pick (ETH-86728) dated from the pure chalk rubble fill close to its base at 20.7ft (6.3m below mgs). Shaft 9 was excavated to a depth of 28.5ft (9.3m below mgs) and a single antler pick (ETH-86729) dated from near to its base at 27ft (8.2m below mgs). Shaft 10, likely representing two separate shafts (Bradley 1976, 10) was filled with chalk rubble including large blocks, to its double base at a depth of 25.5ft (7.8m below mgs). A single antler pick (ETH-86730) was dated from close to the base at a depth of 22ft (6.7m below mgs).

Shaft 11 was sectioned to its base at 28ft (8.6m below mgs) (Bradley 1976, 10). Two measurements from an antler pick (GrM-13227 and ETH-96043) from its base are statistically significantly different at the 1% significance level (T'=15.4; T' (5%)=3.8; v=1). Initially, both measurements were included separately in the chronological model (see below).

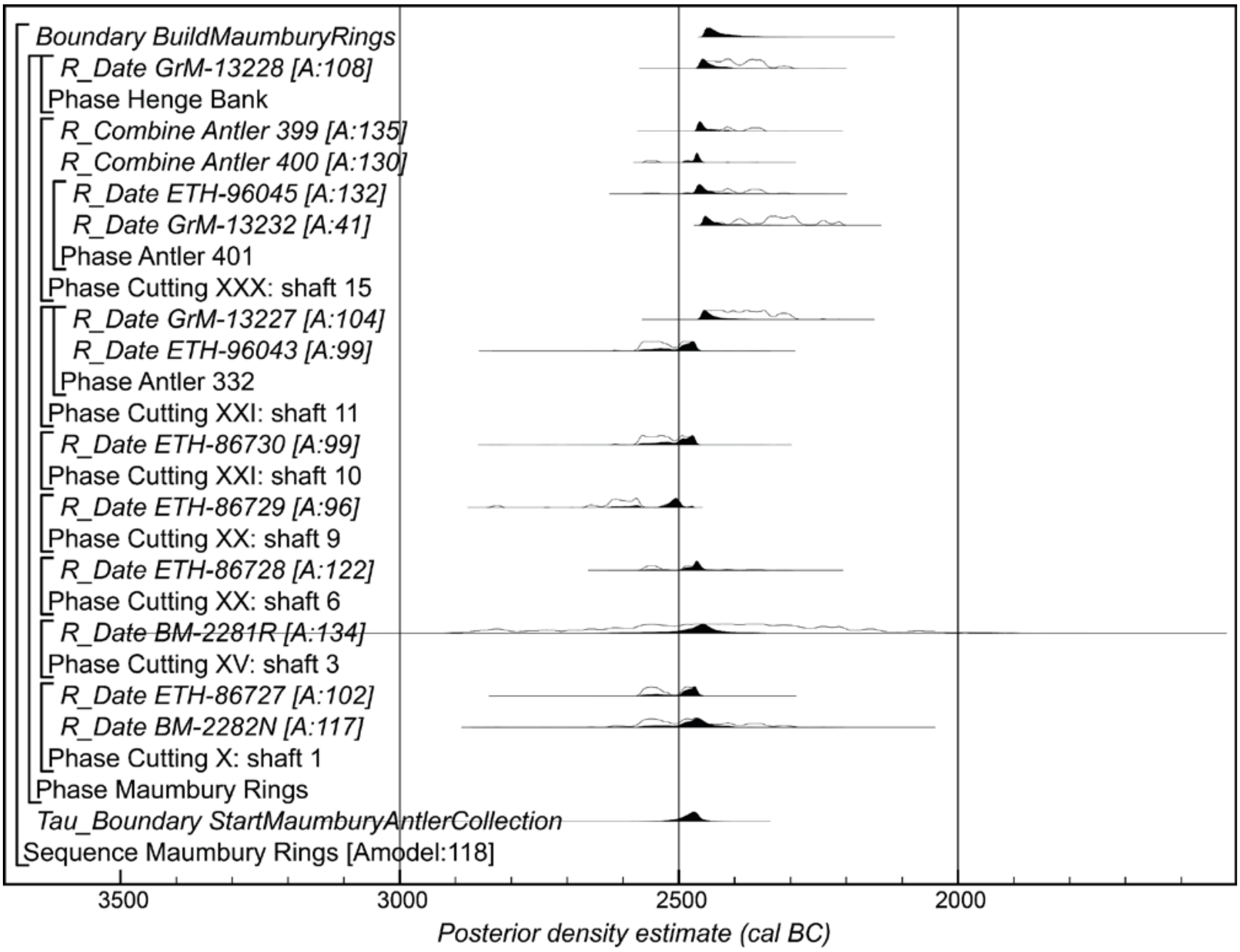

Figure 5: Probability distributions of dates from Maumbury Rings. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the result of simple radiocarbon calibration, and a solid one, based on the chronological model used. Distributions other than those relating to particular samples correspond to aspects of the model. For example, the distribution '*BuildMaumburyRings*' is the estimated date when the monument was constructed. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly. [© Historic England]

Replicate measurements were obtained on three antler picks, 399, 400, and 401 from close to the base of Shaft 15. Excavated to its base (26.7ft, 8.2m below mgs) the bottom contained a large number of antler tools. Both pairs of measurements on antlers 399 and 400 are statistically consistent at the 5% significance level (Table 1) and weighted means (Antler 399; 3931±14 BP and Antler 400; 3958±14 BP) provide the best estimates for the ages of the antlers. Two measurements from antler 401 (GrM-13232 and ETH-96045) are statistically significantly different at the 1% significance level (T'=7.7; T' (5%)=3.8; v=1). Initially, both measurements were included separately in the chronological model (see below).

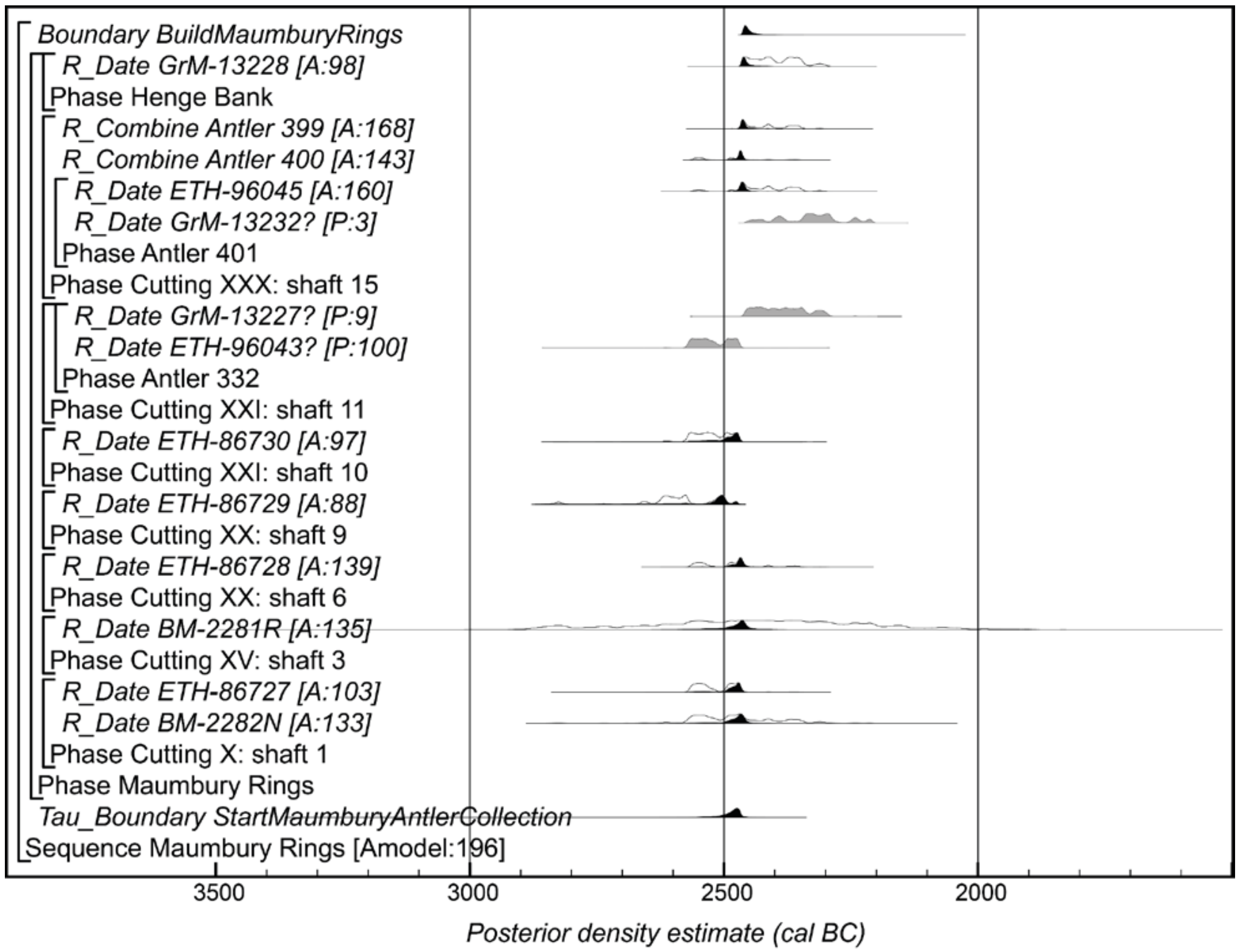

Figure 6: Probability distributions of dates from Maumbury Rings. The overall format is identical to Figure 5. Distributions from samples excluded from the model are shown in grey. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly. [© Historic England]

A summary of the prior information included in the model (Fig. 5) is shown in Figure 7, with all the dated samples deriving from an exponential distribution rising to the greatest numbers being found from the end of the constructional activity. This is based on the suggestion that it is most likely that the antlers found in the base of the features come from the last stages of their digging, with a few older antlers being mixed in (Bronk Ramsey 2009, fig 5c).

Both measurements from the antler pick in Shaft 11 (GrM-13227 and ETH-96043) have good individual agreement in this reading (A: 104 and A: 99 respectively; Fig. 5). Since these measurements are replicates on a single object, they cannot both be accurate. In the absence of independent information determining, which is correct, we have chosen to exclude both from the final model. However, one of the measurements from the antler pick 401 (Shaft 15), GrM-13232 does have poor individual agreement in this reading (A:41; Fig.

5) while ETH-96044 has good individual agreement (A:132; Fig. 5). We have thus excluded GrM-13232 from the final model and included ETH-96044.

Our preferred model (Fig. 6) has good overall agreement (Amodel: 196; Bronk Ramsey 1995) and provides an estimate for the construction of Maumbury Rings of *2470–2405 cal BC* (*95% probability*; *BuildMaumburyRings*; Fig. 6) and probably of *2465–2445 cal BC* (*68% probability).* The antler used in the construction of the monument is estimated to have been collected over a period of *10–185 years* (*95% probability;* Fig. 8) and probably over *30–115 years* (*68% probability)* and this thus potentially provides a proxy for the length of time it took to build.

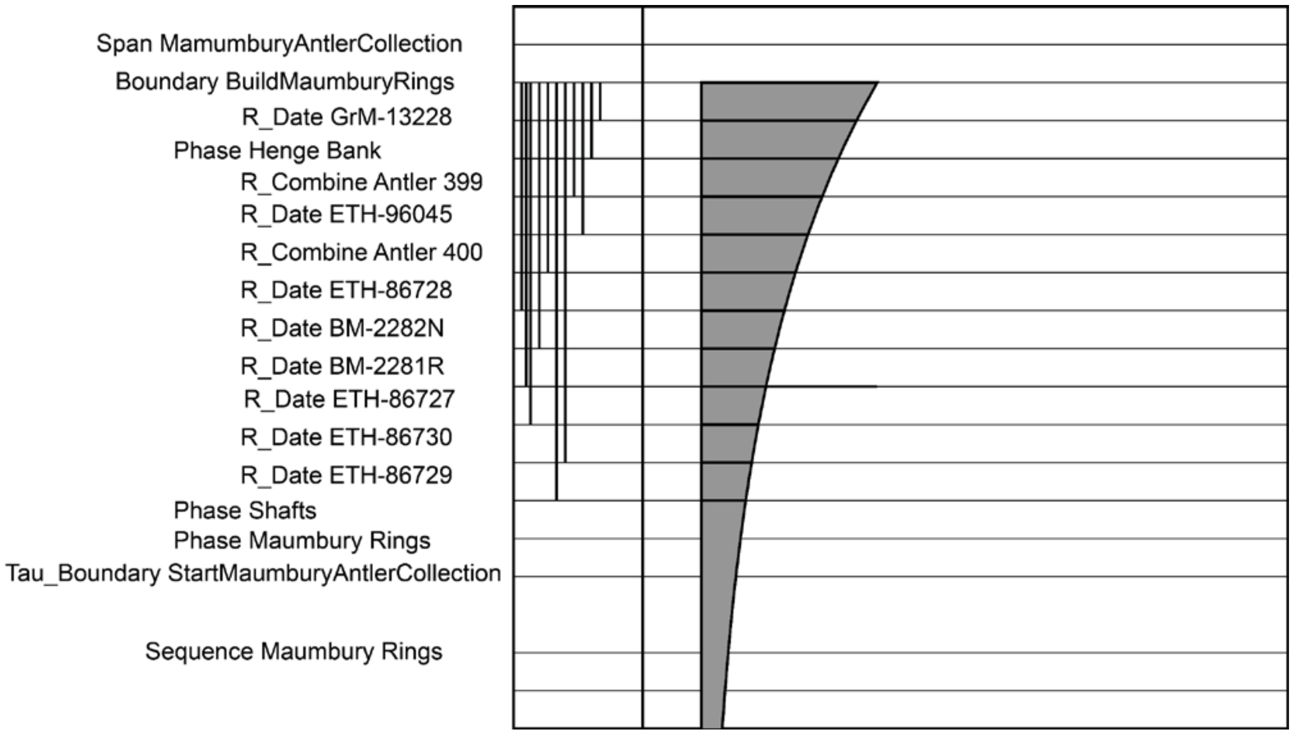

Figure 7: Schematic diagram showing the prior information which has been included in the chronological model defined in Figure 5. [© Historic England]

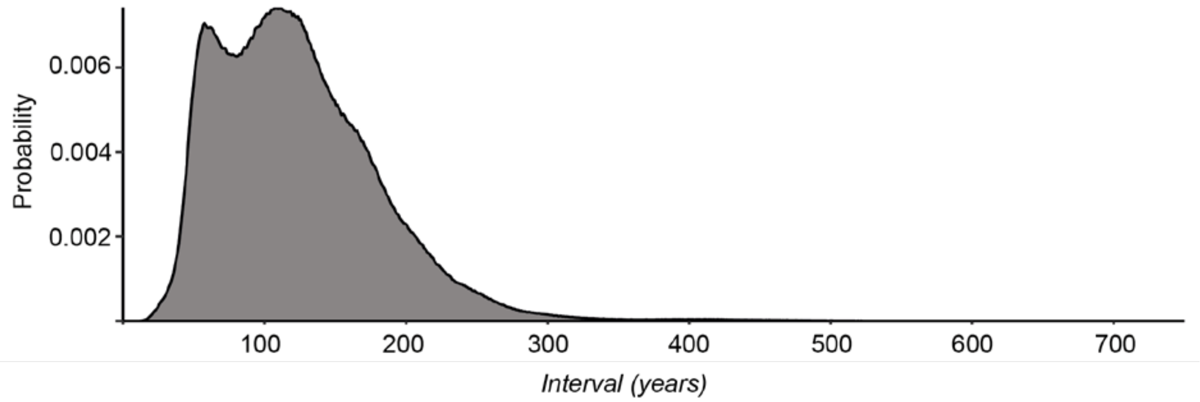

Figure 8: Duration of antler collection, derived from the model defined in Figure 6. [© Historic England]

Summary

Maumbury Rings is estimated to have been completed in *2470–2405 cal BC* (*95% probability*; Fig. 9) and probably in *2465–2445 cal BC* (*68% probability*).

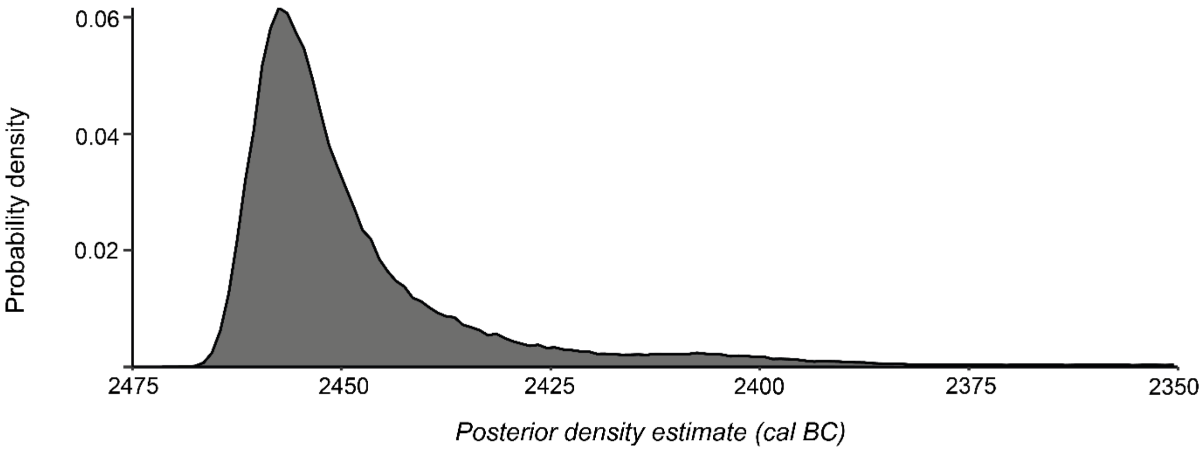

Figure 9: Probability distribution for the construction of Maumbury Rings (derived from the model shown in Figure 6). [© Historic England]

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Appendix 1: CQL2 code for the chronological models

Figure 5

```
Options()
 {
  Resolution=1;
  kIterations=20000;
 };
 Plot()
 {
  Sequence("Maumbury Rings")
  {
   Tau_Boundary("StartMaumburyAntlerCollection");
   Phase("Maumbury Rings")
   {
    Phase("Cutting X: shaft 1")
    {
     R_Date("BM-2282N", 3970, 50);
     R_Date("ETH-86727", 3985, 22);
    };
    Phase("Cutting XV: shaft 3")
    {
     R_Date("BM-2281R", 3940, 130);
    };
    Phase("Cutting XX: shaft 6")
    {
     R_Date("ETH-86728", 3961, 23);
    };
    Phase("Cutting XX: shaft 9")
    {
     R_Date("ETH-86729", 4064, 22);
    };
    Phase("Cutting XXI: shaft 10")
    {
     R_Date("ETH-86730", 4011, 23);
    };
    Phase("Cutting XXI: shaft 11")
    {
     Phase("Antler 332")
```

```
     {
      R_Date("ETH-96043", 4002, 24)
      {
      };
      R_Date("GrM-13227", 3889, 16)
      {
      };
     };
    };
    Phase("Cutting XXX: shaft 15")
    {
     Phase("Antler 401")
     {
      R_Date("GrM-13232", 3856, 16)
      {
      };
      R_Date("ETH-96045", 3936, 24);
     };
     R_Combine("Antler 400")
     {
      R_Date("ETH-86731", 3973, 23);
      R_Date("GrM-13231", 3951, 16);
     };
     R_Combine("Antler 399")
     {
      R_Date("GrM-13230", 3917, 16);
      R_Date("ETH-96044", 3963, 24);
     };
    };
    Phase("Henge Bank")
    {
     R_Date("GrM-13228", 3908, 16);
    };
    Span("MamumburyAntlerCollection");
   };
   Boundary("BuildMaumburyRings");
  };
 };
```

Figure 6

Options()

```
{
 Resolution=1;
 kIterations=20000;
};
Plot()
{
 Sequence("Maumbury Rings")
 {
  Tau_Boundary("StartMaumburyAntlerCollection");
  Phase("Maumbury Rings")
  {
   Phase("Cutting X: shaft 1")
   {
    R_Date("BM-2282N", 3970, 50);
    R_Date("ETH-86727", 3985, 22);
   };
   Phase("Cutting XV: shaft 3")
   {
    R_Date("BM-2281R", 3940, 130);
   };
   Phase("Cutting XX: shaft 6")
   {
    R_Date("ETH-86728", 3961, 23);
   };
   Phase("Cutting XX: shaft 9")
   {
    R_Date("ETH-86729", 4064, 22);
   };
   Phase("Cutting XXI: shaft 10")
   {
    R_Date("ETH-86730", 4011, 23);
   };
   Phase("Cutting XXI: shaft 11")
   {
    Phase("Antler 332")
    {
     R_Date("ETH-96043", 4002, 24)
     {
      Outlier();
     };
     R_Date("GrM-13227", 3889, 16)
     {
```

```
      Outlier();
     };
    };
   };
   Phase("Cutting XXX: shaft 15")
   {
    Phase("Antler 401")
    {
     R_Date("GrM-13232", 3856, 16)
     {
      Outlier();
     };
     R_Date("ETH-96045", 3936, 24);
    };
    R_Combine("Antler 400")
    {
     R_Date("ETH-86731", 3973, 23);
     R_Date("GrM-13231", 3951, 16);
    };
    R_Combine("Antler 399")
    {
     R_Date("GrM-13230", 3917, 16);
     R_Date("ETH-96044", 3963, 24);
    };
   };
   Phase("Henge Bank")
   {
    R_Date("GrM-13228", 3908, 16);
   };
   Span("MamumburyAntlerCollection");
  };
  Boundary("BuildMaumburyRings");
 };
};
```

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