1 Radiocarbon dating strategy for the Limmo peninsula clinker boat (XRW10)

1.1 Introduction

Here we present a strategy for dating a section of hull from a clinker built vessel uncovered on the Limmo peninsula (XRW10). On technological grounds the hull has been provisionally dated to the 11th to the 16th century (Damien Goodburn pers comm). Although some features suggest a date range of late 12th to 15th century or even 14th to 15th century, the broader date range is currently the most accurate interpretation.

Of the 5 samples sent for dendrochronological assessment, 3 (samples B, C and E) contained measurable tree-ring sequences (Table 1). However, a cross-match could not be found. It is therefore proposed that a wood sample from the boat could be sent for radiocarbon dating to improve the precision of the technological date. Below are presented priced options for radiocarbon dating. Dates are simulated using OxCal 4.1 (Bronk Ramsey 2009) using the IntCal calibration curve (Reimer *et al* 2009).

Sample No	Plank ID No	Rings	Sap rings
79	A	~25	
	B	79	21
	C	58	22
	D	~20	
	E	114	

Table 1 Details of the Limmo clinker oak samples after dendrochronologial assessment

1.2 Radiocarbon dating proposal

1.2.1 OPTION 1 – single date

The overlapping planks were waterproofed with rolls of tarred animal hair. Although tar contains 'old carbon' the sample can be treated with organic solvent extraction apparatus (soxhlet) to rinse through the sample and dissolve the tar. Subsequent washes with more polar (water soluble) solvents remove the organic solvent.

A single date on the hair would provide a date that is most closely related to the date of last use of the boat, as may represent the last stages of construction or subsequent repair. It is for this reason that in the literature that fastenings and strake seams are considered the best samples to date by this method (Krąpiec and Ossowski, 2000). Option 1 would also provide a result at the lowest cost. Single dates are simulated (using the R_simulate function in OxCal 4.1) at 50 year intervals with precisions of ±20, ±25 and ±30 years (Figure 1). The multiplots show that it is likely that a radiocarbon date on the animal hair would narrow the result to a time span of just over 100 years, or less than 70 years if the date falls in the mid 15th century.

1.2.2 OPTION 2 – multiple dates

Radiocarbon dating several samples from individual tree rings on the planks could significantly improve the precision of the felling date. This would be achieved by sampling and dating single tree rings at known locations on a sap wood sample (i.e. 79 B or C) and, by using the number of years between dated samples, match the results to the calibration curve. This is called wiggle match dating. It uses the non-linear relationship between the radiocarbon determination and calendar age to match the shape of a series of dates with the calibration curve. The OxCal programme uses the radiocarbon dates and the 'gap' in years (counted tree rings) between dates and matches this information to the wiggles in the calibration curve to tighten the timespan of the results (Bronk Ramsey *et al* 2001). The technique works best with closely spaced sequential samples, but can be used with 2 or more dates. Here we simulate results with 2, 3 and 5 radiocarbon dates (options 2a, 2b and 2c respectively). Results for options 2a, 2b and 2c are shown below in Figure 2, Figure 3 and Figure 4. As with any radiocarbon date, due to the variable shape of the calibration curve over time, wiggle matching may be more successful at certain periods, so simulations are made at 50 year intervals across the time frame AD 1200-1600. As stated above, OxCal takes the information it is given by the user and attempts to narrow the calibrated date ranges. The refined dates are shown by the darker distributions imposed on the calibrated dates in the multiplots.

To simulate felling at a calendar date of e.g. 1200 years, we assume a 7 year 'gap' from the felling date and the radiocarbon date on a sapwood tree ring towards the outer edge of the plank sample. The first calendar age to simulate is therefore AD 1193. Subsequent dates in the simulated sequence are placed at intervals spanning 70 years. Where 2 radiocarbon dates are wiggle-matched (option 2a) calendar dates are simulated at 7 and 70 years from the felling date of 1200 (i.e. at 1193 and 1123). Where 3 radiocarbon dates are simulated (option 2b) calendar dates are placed at intervals of 7, 40 and 30 years from 1200 (at AD 1193, 1153 and 1123) and for option 2c dates are simulated at intervals of 10, 20, 20 and 20 (at AD 1193, 1183, 1163, 1143 and 1123). An example of the code for option 2c is shown below (Table 2). It must be noted that all option 2 prices will include MOLA time for re-sampling plank 79 B or C (*c* £100 + p&p) and time for dendrochronology (Ian Tyers) for sub-sampling individual or multiple rings for radiocarbon dating (*c* £50).

```
Plot()
 {
  D_Sequence( "Wiggle-match 1200")
  {
   R_Simulate( "1", 1123, 30);
   Gap( 20);
   R_Simulate( "2", 1143, 30);
   Gap( 20);
   R_Simulate( "3", 1163, 30);
   Gap( 20);
   R_Simulate( "4", 1183, 30);
   Gap( 10);
   R_Simulate( "5", 1193, 30);
   Gap( 7);
   Date("Felling date");
  };
 };
```

Table 2 showing code for option 2c when simulating a felling date of cal AD 1200

1.3 Discussion and Conclusions

In general the multiplots show that the precision on simulated radiocarbon dates is tightest in the mid 15th century but rather poor at the end of the 16th century. Simulations suggest that a single date on the horse hair waterproofing between the boat's planks would significantly improve the precision of the current style-based date from a time span of 400 years to *c* 70-150 years. This option would provide a date most closely associated with construction or recent boat renovation, whereas a plank may have been incorporated into the boat some time after felling, making the date less precise. Option 1 incurs the lowest charge, costing under £300 as opposed to the next cheapest option (2a) that would be *c* £820 (£570+£150).

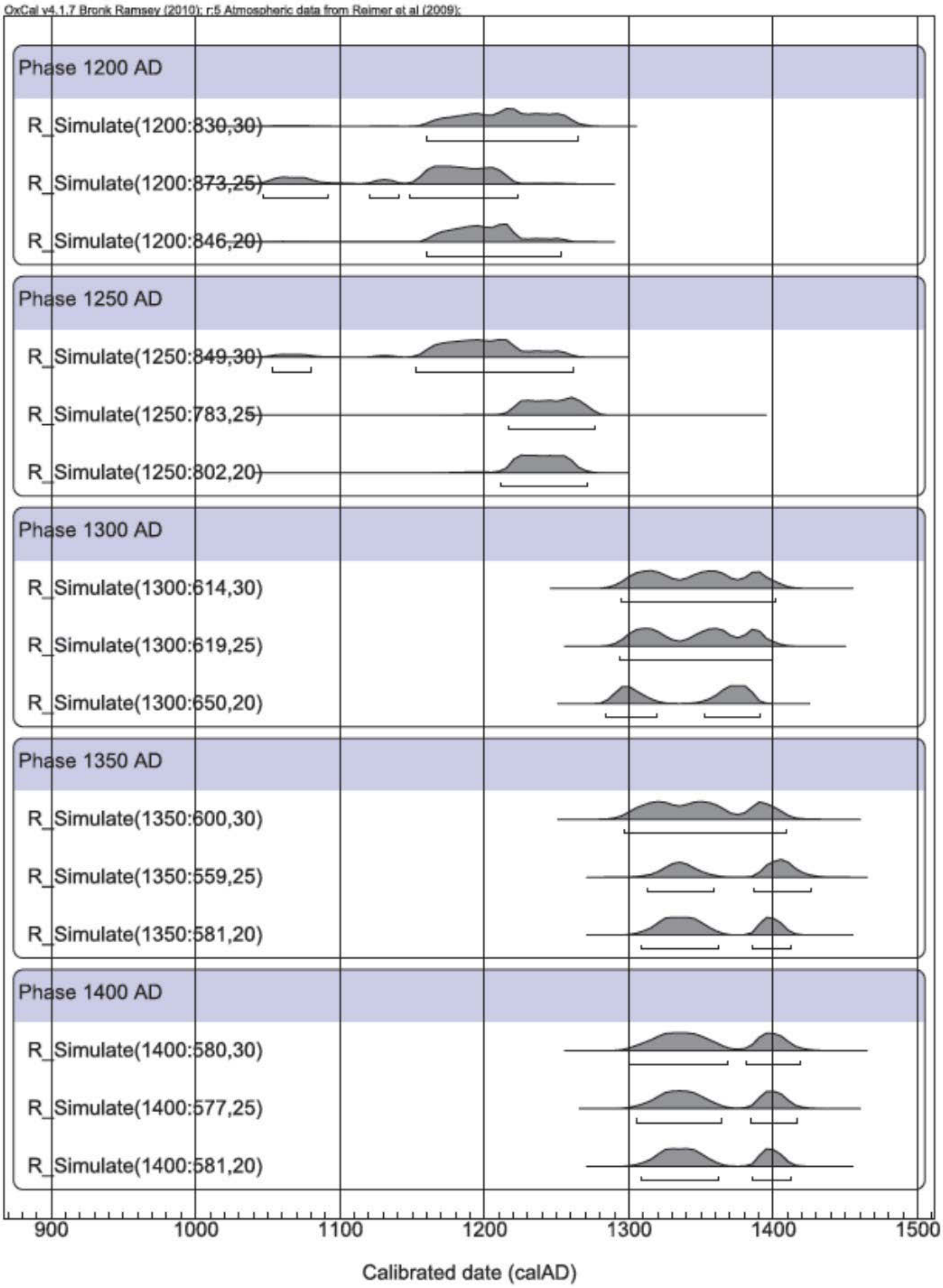
Option 2a is similar to, or marginally improves on, option 1 precision between cal AD 1200-1300. Both plots show precision in the order of 50 to 100 years. Between 1300-1400 and 1500-1600, option 2a refines option 1 calibrated dates from two ranges spanning *c* 120-150 years, to one dominant 25-90 year range. Where precision is good in option 1, in the early part of the 15th century, option 2a does not narrow the calibrated date range. Option 2b simulated precision on the felling date differs little from the previous options at around 150 years for cal AD 1200 and 1600, but improves to 30-50 years for the major part of the 4 centuries in question (from cal AD 1250-1550). If option 2c were to be employed, precisions of 20-60 years could be expected across nearly the entire date range, with the exception of the late 16th century where precision widens to 70-140 years.

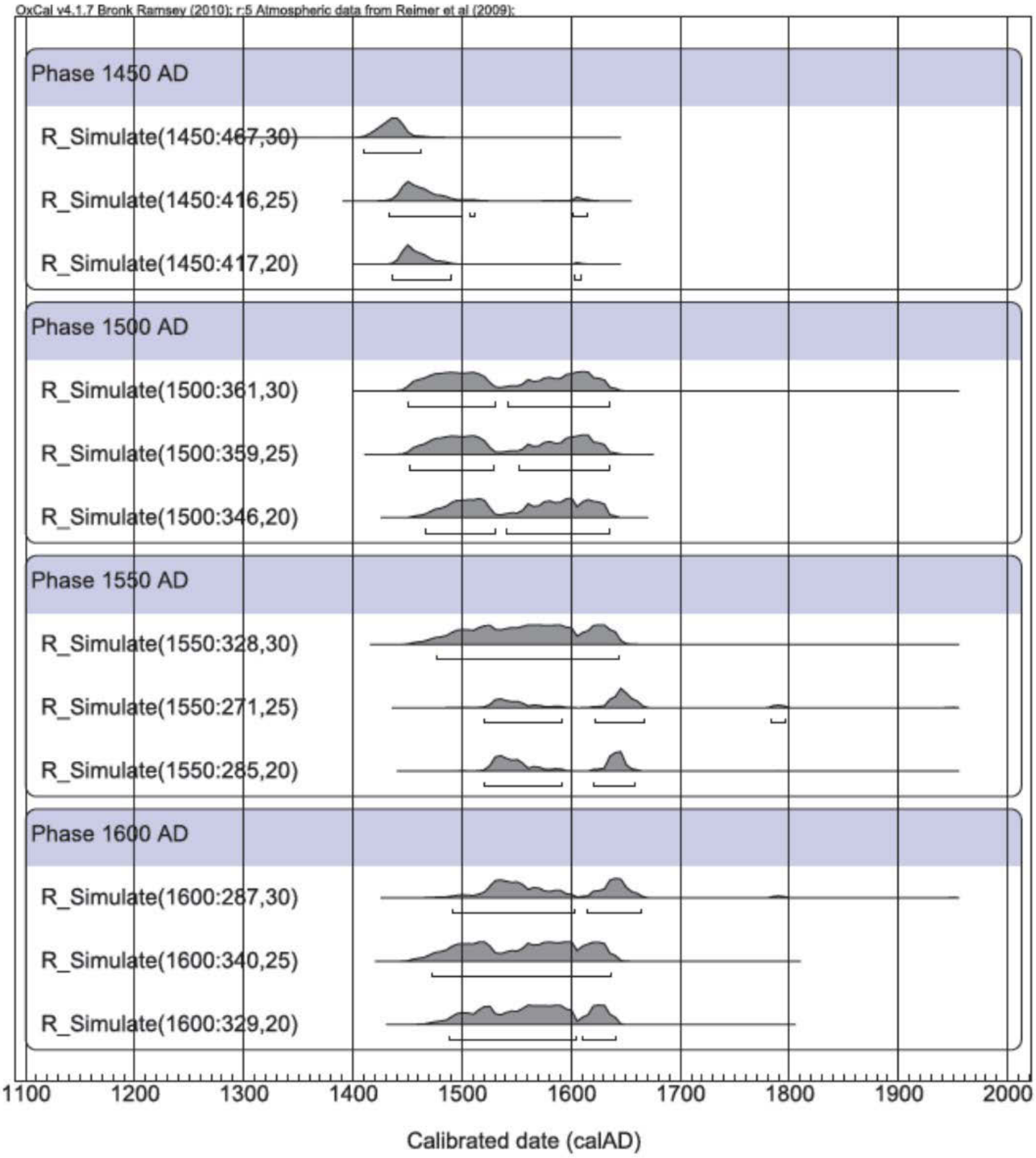
Given that the Limmo boat is of local rather than regional or national importance, option 1 is the recommended choice, winning on accuracy of dating the event and showing comparable precision to option 2a. If accuracy and precision are to be enhanced, a series of radiocarbon dates could predict the felling date with a precision of *c* 20-60 years (options 2b and 2c) and, as wiggle matching is rarely used in archaeology, this would provide an example of novel method used for Crossrail. If money were no object, a dating programme combining option 1 and option 2c would provide an interesting comparison between the date of tree felling and boat construction or repair.

Option	Sample No	Sample type	Number of dates	Cost	Turnaround time
1	79	animal hair waterproofing	1	£285	10-12 weeks
				£385	3 weeks
2a	79B	Oak plank of hull	2	£570	10-12 weeks
				£770	3 weeks
2b			3	£855	10-12 weeks
				£1,155	3 weeks
2c			5	£1,425	10-12 weeks
				£1,925	3 weeks

Table 3 Lab costs for AMS dates for options 1 and 2 sent to Queen's University Belfast radiocarbon lab 'Chrono' (http://chrono.qub.ac.uk/)

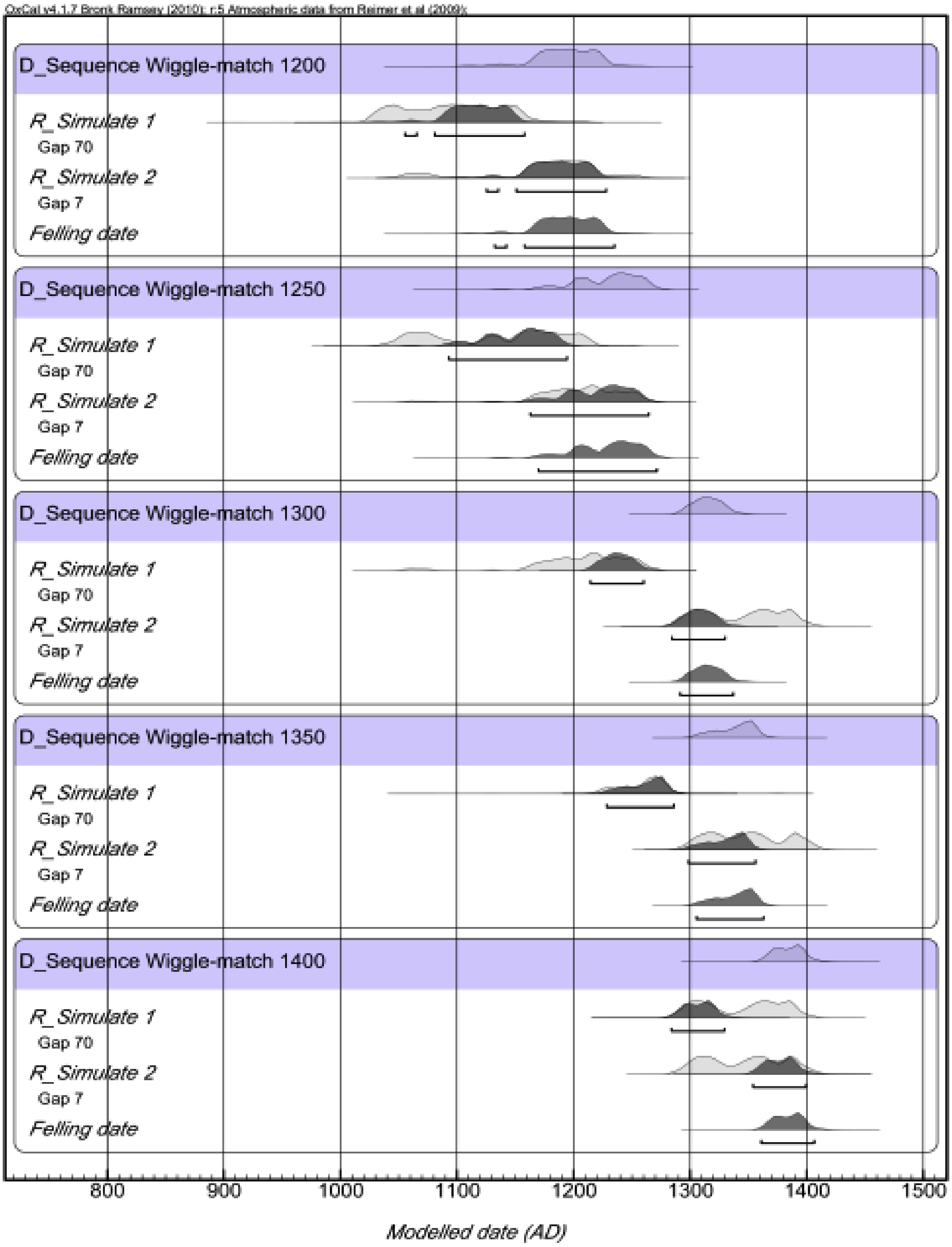
Figure 1 OxCal multiplots showing simulated dates for option 1 covering the period 1200 to 1600. Three dates with varying precision (±20, ±25 and ±30 years) are simulated at 50 year intervals across the four centuries.

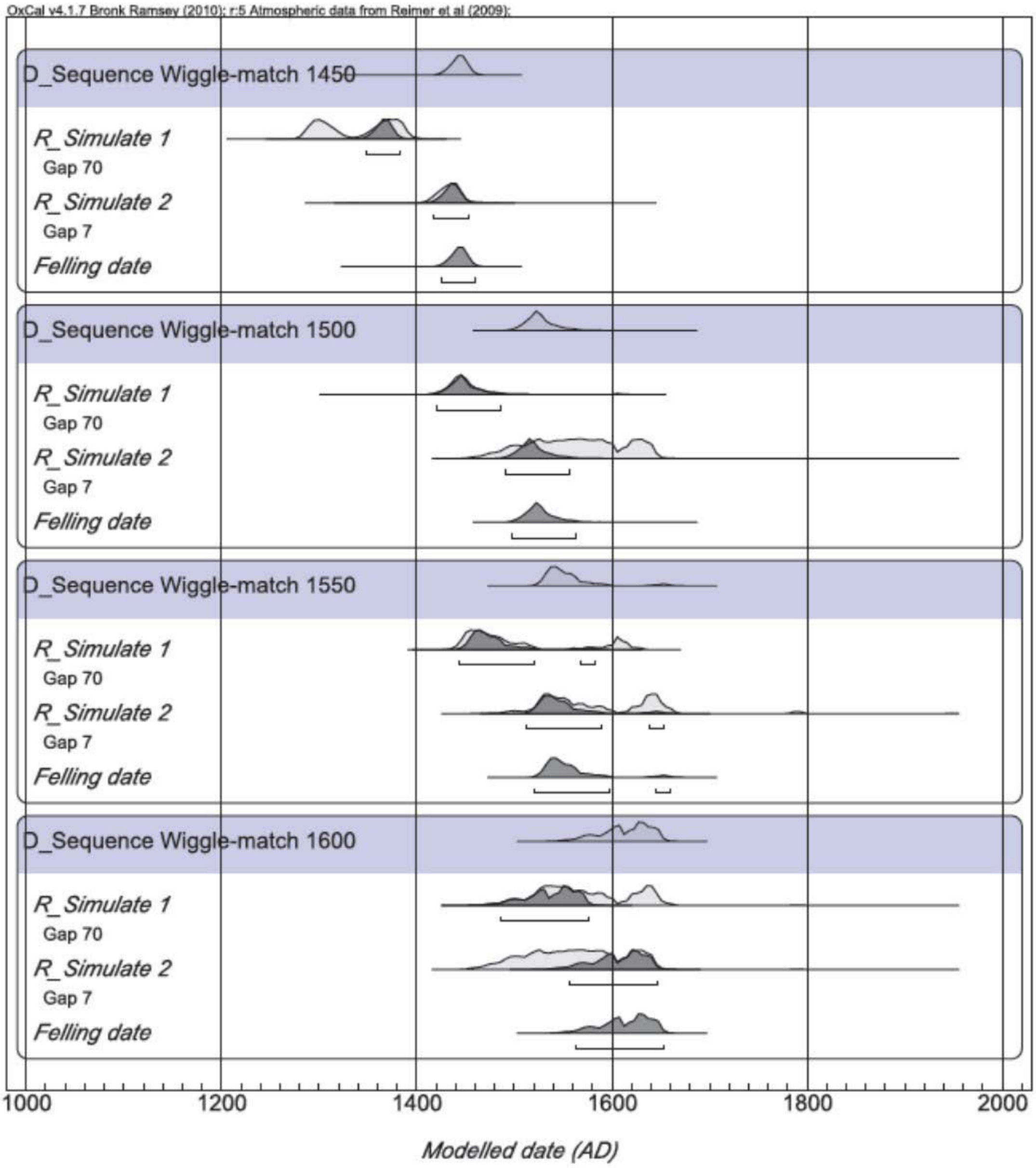




OxCal v4.1.7 Bronk Ramsey (2010); r:5 Atmospheric data from Reimer et al (2009);
Phase 1450 AD
R_Simulate(1450:467,30)
R_Simulate(1450:416,25)
R_Simulate(1450:417,20)
Phase 1500 AD
R_Simulate(1500:361,30)
R_Simulate(1500:359,25)
R_Simulate(1500:346,20)
Phase 1550 AD
R_Simulate(1550:328,30)
R_Simulate(1550:271,25)
R_Simulate(1550:285,20)
Phase 1600 AD
R_Simulate(1600:287,30)
R_Simulate(1600:340,25)
R_Simulate(1600:329,20)
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Calibrated date (calAD)

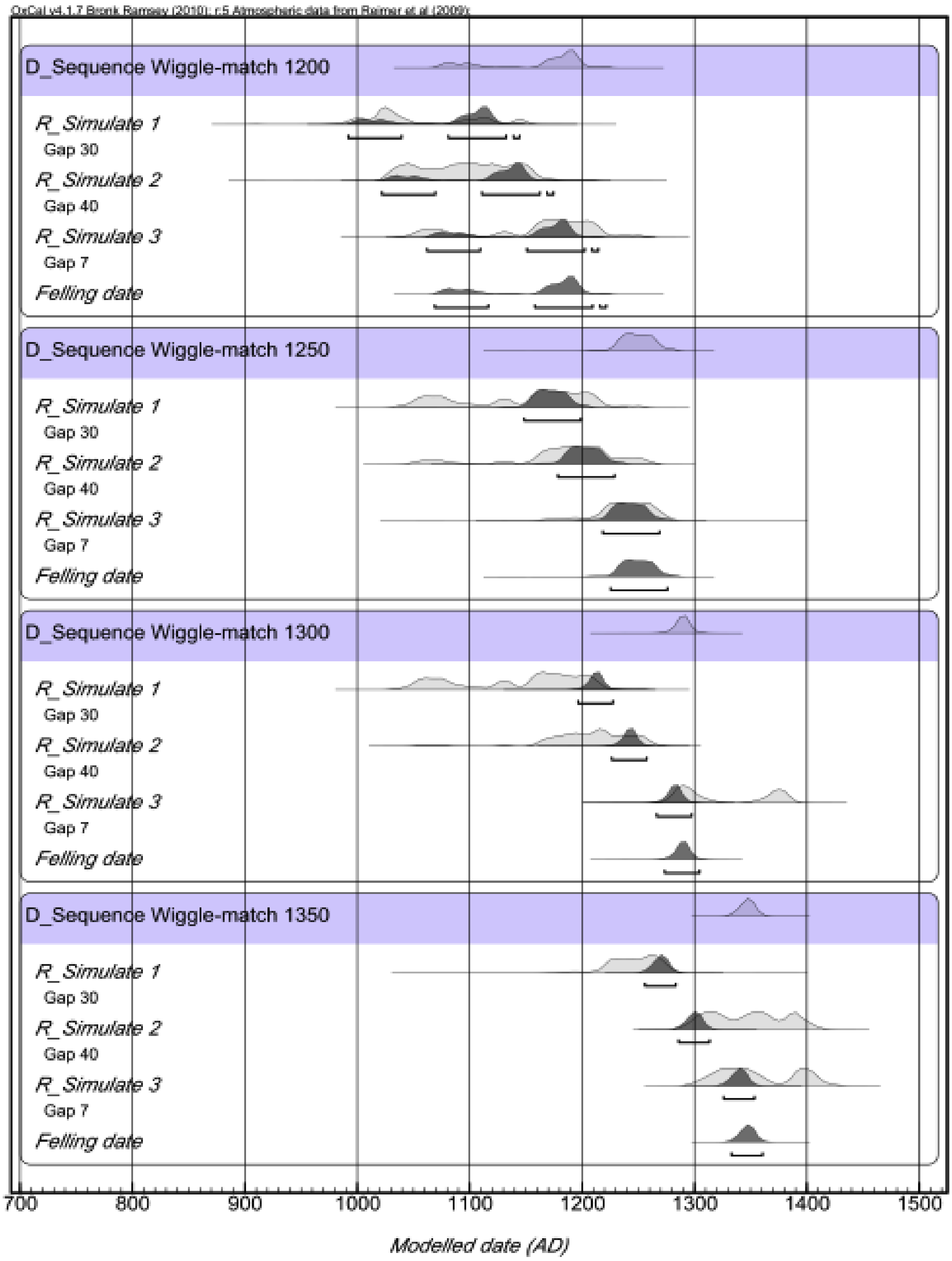
Figure 2 simulated wiggle matched dates (option 2a) for the period covering 1200 to 1600. Two dates are simulated at 50 year intervals across the four centuries.The precision is fixed at ±30 years.

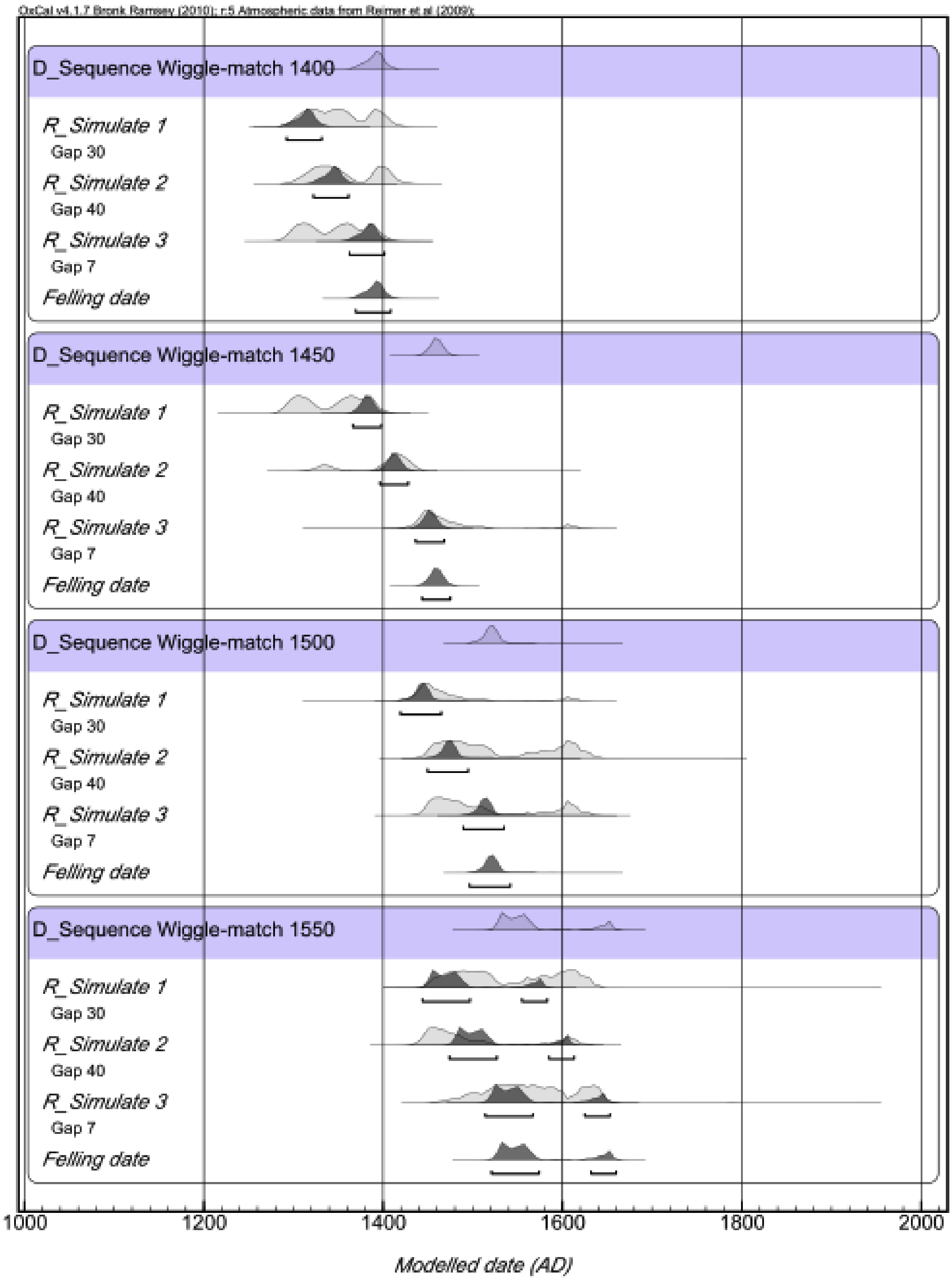




OxCal v4.1.7 Bronk Ramsey (2010); r:5 Atmospheric data from Reimer et al (2009);
D_Sequence Wiggle-match 1450
R_Simulate 1
Gap 70
R_Simulate 2
Gap 7
Felling date
D_Sequence Wiggle-match 1500
R_Simulate 1
Gap 70
R_Simulate 2
Gap 7
Felling date
D_Sequence Wiggle-match 1550
R_Simulate 1
Gap 70
R_Simulate 2
Gap 7
Felling date
D_Sequence Wiggle-match 1600
R_Simulate 1
Gap 70
R_Simulate 2
Gap 7
Felling date
1000
1200
1400
1600
1800
2000
Modelled date (AD)

Figure 3 simulated wiggle matched dates (option 2b) for the period covering 1200 to 1600. Three dates are simulated at 50 year intervals across the four centuries.The precision is fixed at ±30 years.




OxCal v4.1.7 Bronk Ramsey (2010); r:5 Atmospheric data from Reimer et al (2009);
D_Sequence Wiggle-match 1400
R_Simulate 1
Gap 30
R_Simulate 2
Gap 40
R_Simulate 3
Gap 7
Felling date
D_Sequence Wiggle-match 1450
R_Simulate 1
Gap 30
R_Simulate 2
Gap 40
R_Simulate 3
Gap 7
Felling date
D_Sequence Wiggle-match 1500
R_Simulate 1
Gap 30
R_Simulate 2
Gap 40
R_Simulate 3
Gap 7
Felling date
D_Sequence Wiggle-match 1550
R_Simulate 1
Gap 30
R_Simulate 2
Gap 40
R_Simulate 3
Gap 7
Felling date
1000
1200
1400
1600
1800
2000
Modelled date (AD)

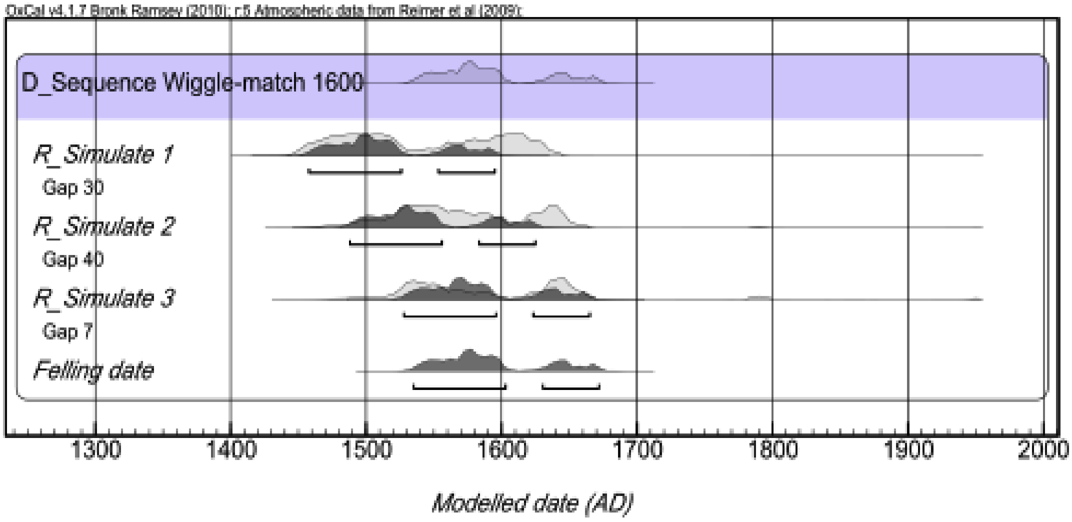
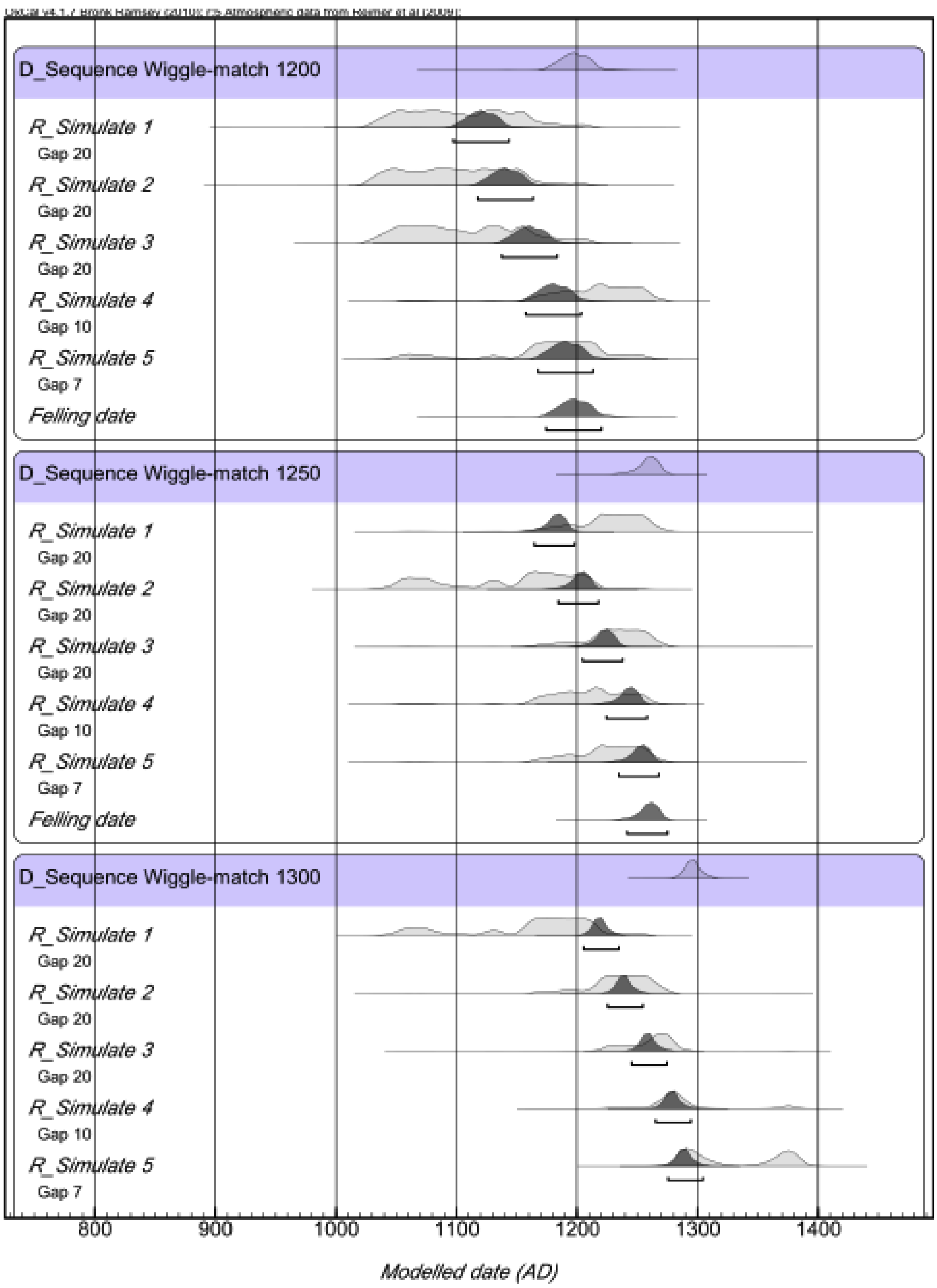
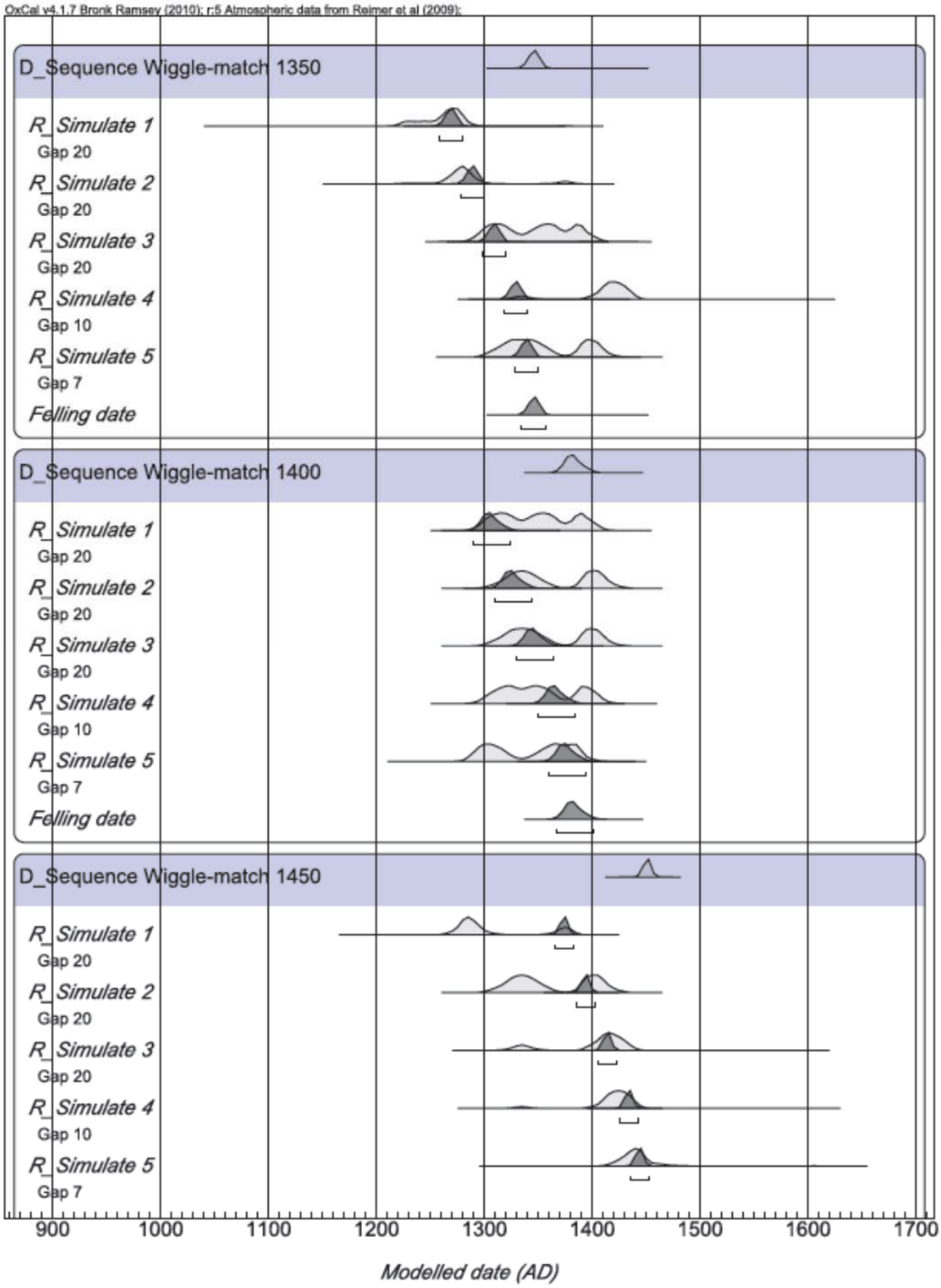
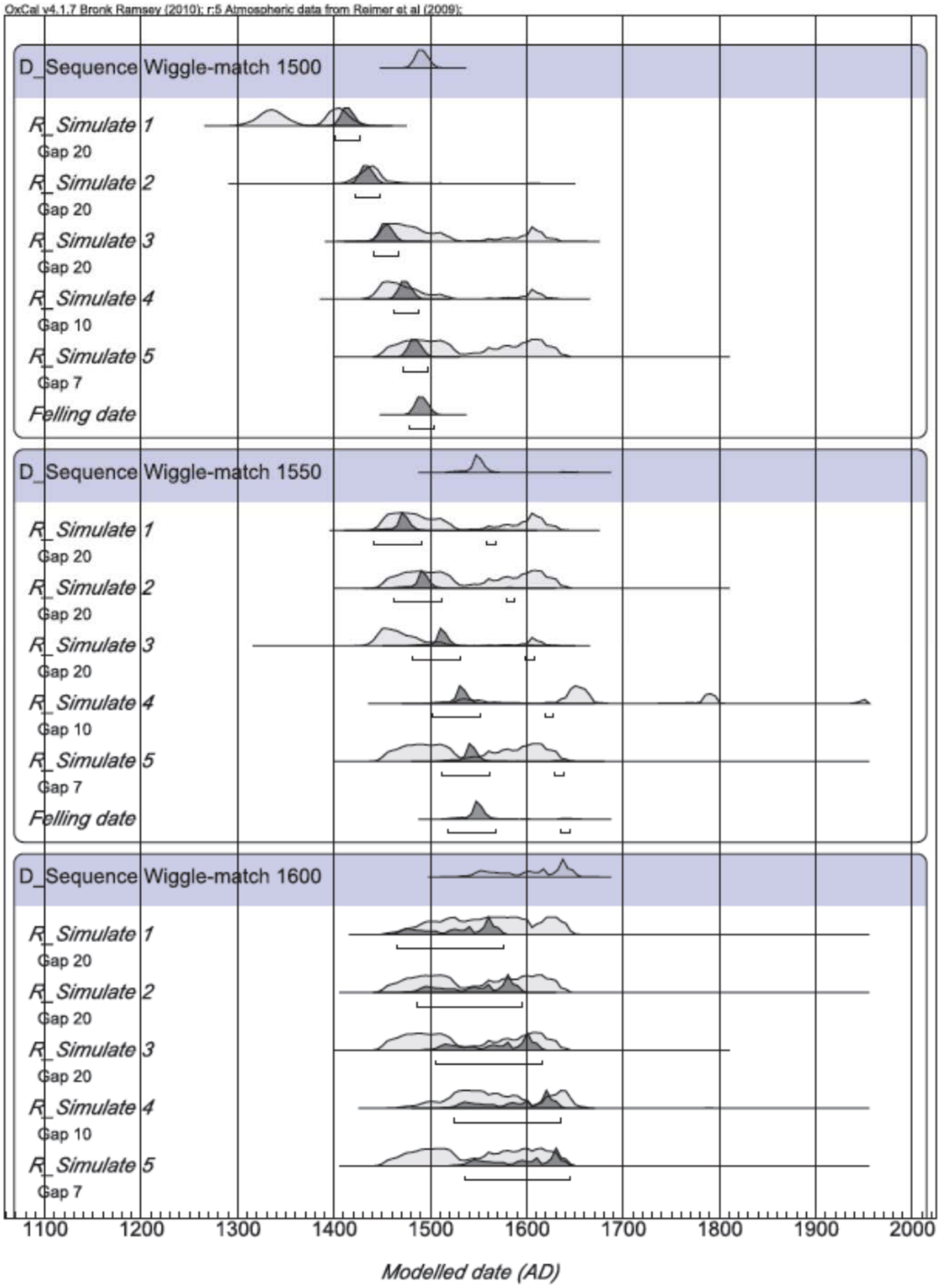

OxCal v4.1.7 Bronk Ramsey (2010); r:5 Atmospheric data from Reimer et al (2009);
D_Sequence Wiggle-match 1600
R_Simulate 1
Gap 30
R_Simulate 2
Gap 40
R_Simulate 3
Gap 7
Felling date
1300
1400
1500
1600
1700
1800
1900
2000
Modelled date (AD)

Figure 4 simulated wiggle matched dates (option 2c) for the period covering 1200 to 1600. Five dates are simulated at 50 year intervals across the four centuries. The precision is fixed at ±20 years.





OxCal v4.1.7 Bronk Ramsey (2010); r:5 Atmospheric data from Reimer et al (2009);
D_Sequence Wiggle-match 1350
R_Simulate 1
Gap 20
R_Simulate 2
Gap 20
R_Simulate 3
Gap 20
R_Simulate 4
Gap 10
R_Simulate 5
Gap 7
Felling date
D_Sequence Wiggle-match 1400
R_Simulate 1
Gap 20
R_Simulate 2
Gap 20
R_Simulate 3
Gap 20
R_Simulate 4
Gap 10
R_Simulate 5
Gap 7
Felling date
D_Sequence Wiggle-match 1450
R_Simulate 1
Gap 20
R_Simulate 2
Gap 20
R_Simulate 3
Gap 20
R_Simulate 4
Gap 10
R_Simulate 5
Gap 7
900
1000
1100
1200
1300
1400
1500
1600
1700
Modelled date (AD)


OxCal v4.1.7 Bronk Ramsey (2010); r:5 Atmospheric data from Reimer et al (2009);
D_Sequence Wiggle-match 1500
R_Simulate 1
Gap 20
R_Simulate 2
Gap 20
R_Simulate 3
Gap 20
R_Simulate 4
Gap 10
R_Simulate 5
Gap 7
Felling date
D_Sequence Wiggle-match 1550
R_Simulate 1
Gap 20
R_Simulate 2
Gap 20
R_Simulate 3
Gap 20
R_Simulate 4
Gap 10
R_Simulate 5
Gap 7
Felling date
D_Sequence Wiggle-match 1600
R_Simulate 1
Gap 20
R_Simulate 2
Gap 20
R_Simulate 3
Gap 20
R_Simulate 4
Gap 10
R_Simulate 5
Gap 7
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Modelled date (AD)

1.4 Bibliography

Bronk Ramsey, C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon, 51*(1), 337-360.

Bronk Ramsey, C., van der Plicht, J., & Weninger, B., 2001. 'Wiggle matching' radiocarbon dates. *Radiocarbon, 43*(2A), 381-389.

Krąpiec, M., Ossowski, W., 2000. Problems of absolute tree-ring dating. Geochronometria 19, 27–32.

Reimer, P. J., Baillie, M. G. L., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Buck, C. E., Burr, G. S., Edwards, R. L., Friedrich, M., Grootes, P. M., Guilderson, T. P., Hajdas, I., Heaton, T. J., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., McCormac, F. G., Manning, S. W., Reimer, R. W., Richards, D. A., Southon, J. R., Talamo, S., Turney, C. S. M., van der Plicht, J., & Weyhenmeyer, C. E., 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0-50,000 years cal BP. *Radiocarbon, 51*(4), 1111-1150.