Supplementary Material

for “Absolutely dating the European Neolithic through a rapid 14C excursion”

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S1 – Dispilio oak chronology wiggle-matching OxCal CQL code and results

```
Options()
 {
  Resolution=1;
 };
 Plot()
 {
  D_Sequence("Disp-6001 QUSP")
  {
   R_Date("BE-12206.1.1 R.3-12", 6491, 24);
   Gap(1);
   R_Date("BE-12197.1.1 R.6-10", 6444, 23);
   Gap(4);
   R_Date("BE-12220.1.2 R.10-14", 6484, 28);
   Gap(31);
   R_Date("BE-12222.1.1 R.41-45", 6448, 23);
   Gap(9);
   R_Date("BE-12204.1.1 R.51-54", 6415, 24);
   Gap(16);
   R_Date("BE-12215.1.1 R.67-70", 6398, 23);
   Gap(1);
   R_Date("BE-12207.1.1 R.65-73", 6406, 24);
   Gap(14);
```

```
  R_Date("BE-12214.1.1 R.80-86", 6397, 23);
  Gap(26);
  R_Date("BE-12205.1.1 R.104-114", 6359, 24);
  Gap(0);
  R_Date("BE-12216.1.1 R.106-112", 6311, 24);
  Gap(5);
  R_Date("BE-12223.1.1 R.110-120", 6316, 23);
  Gap(1);
  Date("modelled end-date Dispilio oak chrono");
 };
};
```

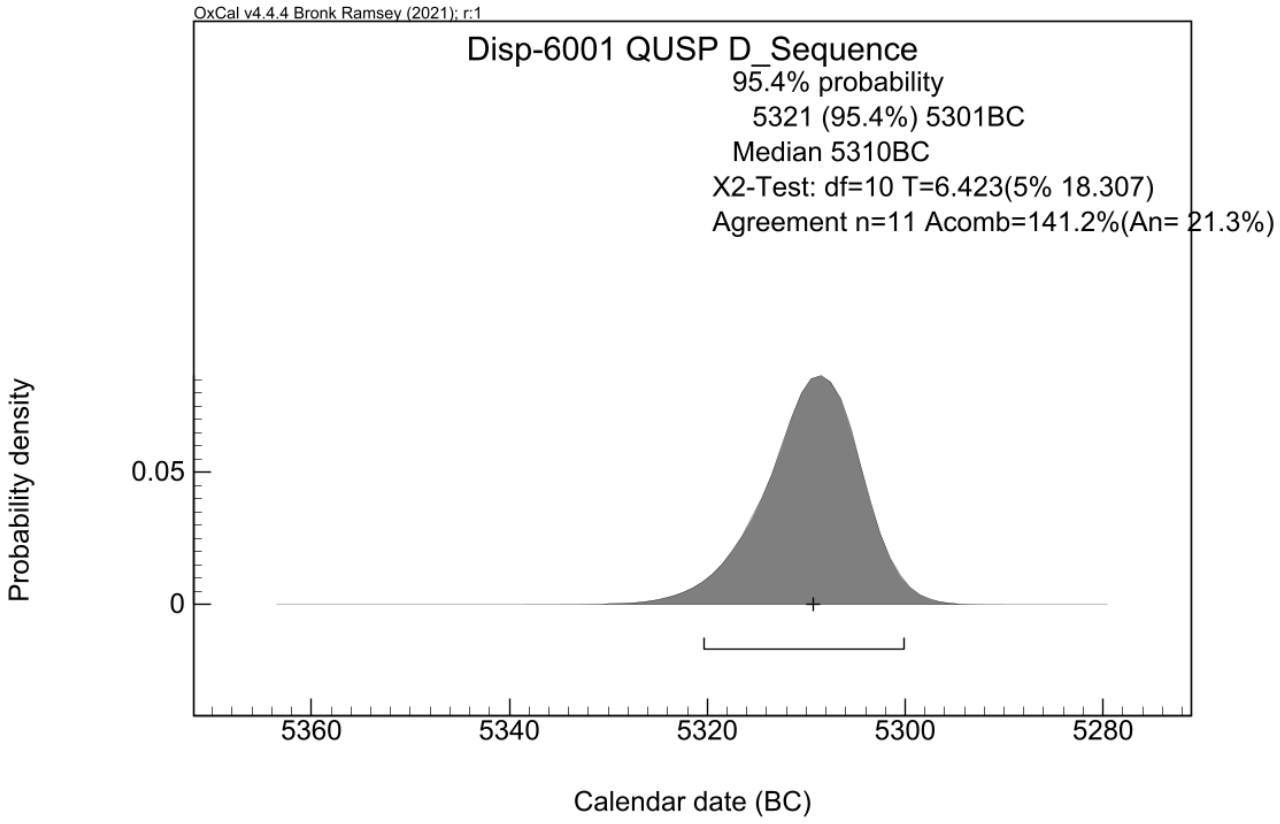

Figure S1.1 *Dispilio oak chronology modelled end-date through wiggle-matching in OxCal 4.4* [1,2]

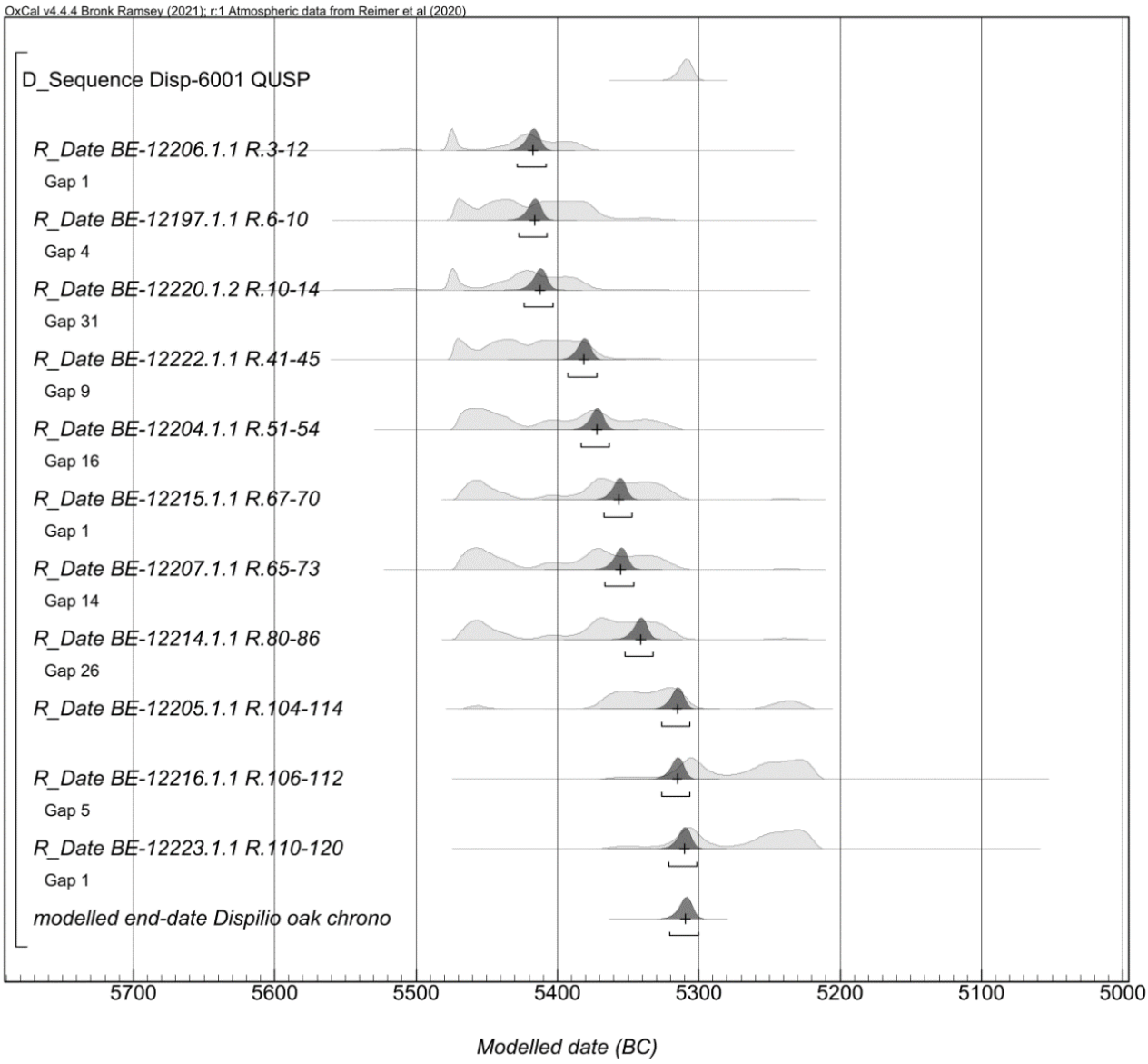

Figure S1.2 *Dispilio oak chronology wiggle-matching, same as Fig. S1.1, but including all the 14C dates; OxCal 4.4* [1,2]

S2 – Supplementary figures

Figure S2.1 *Wood sample DISP-10206*

Figure S2.2 *Wood sample DISP-10611; inset: close-up of the samples' waney-edge (last growth ring), tracheids filled with chalk to enhance contrast.*

Figure S2.3 *Wood sample DISP-10070*

Figure S2.4 *Wood sample DISP-10063*

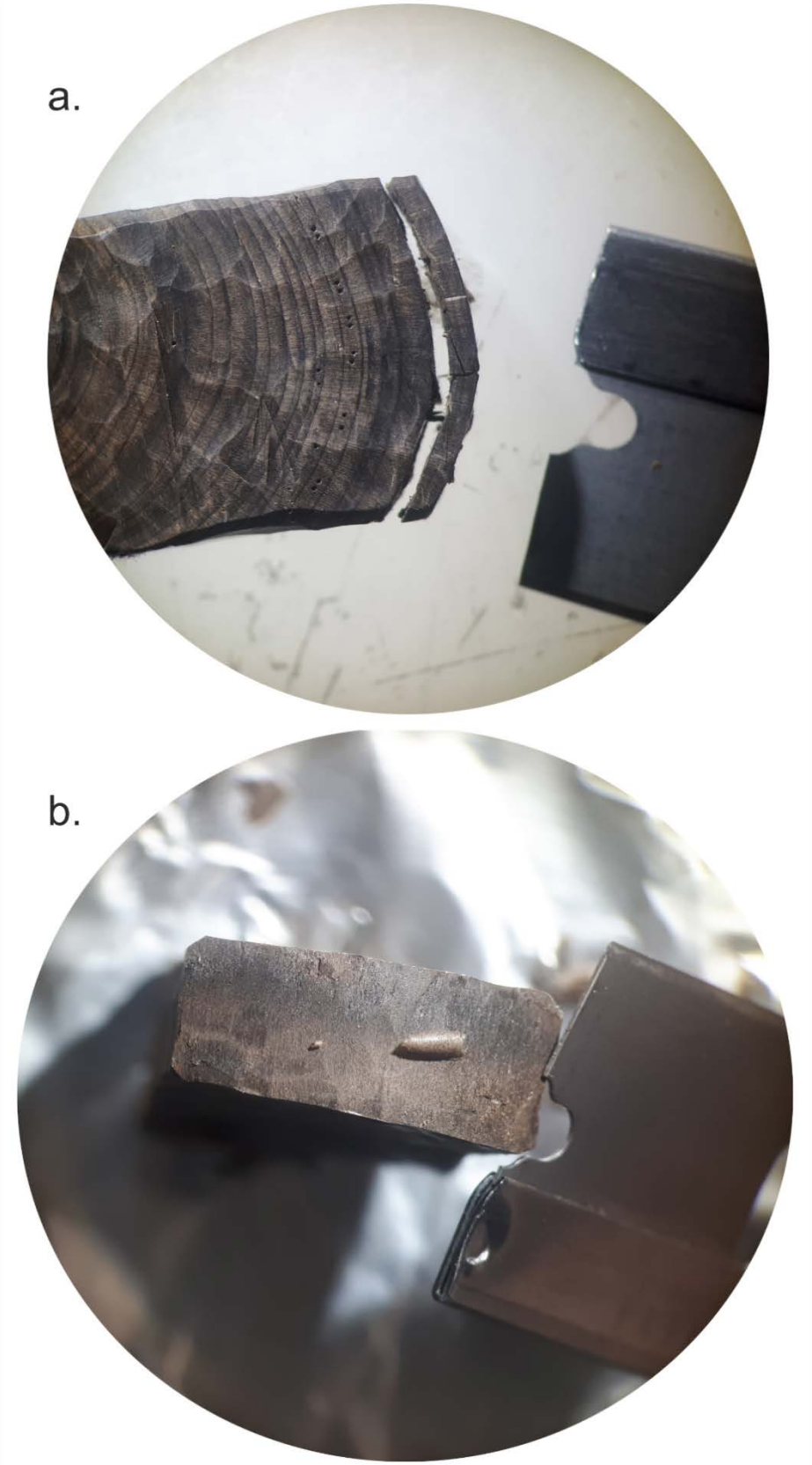

Figure S2.5 *Details from the ring sampling of DISP-10611: **a**.: sampling an individual ring. The "event ring" is ring number 19, located just below the ring 20 which is marked with a series of double pins; **b**.: scraping off last bits of earlywood, tangetial view of the wood block in **a**.; width of razor side 1.8 cm.*

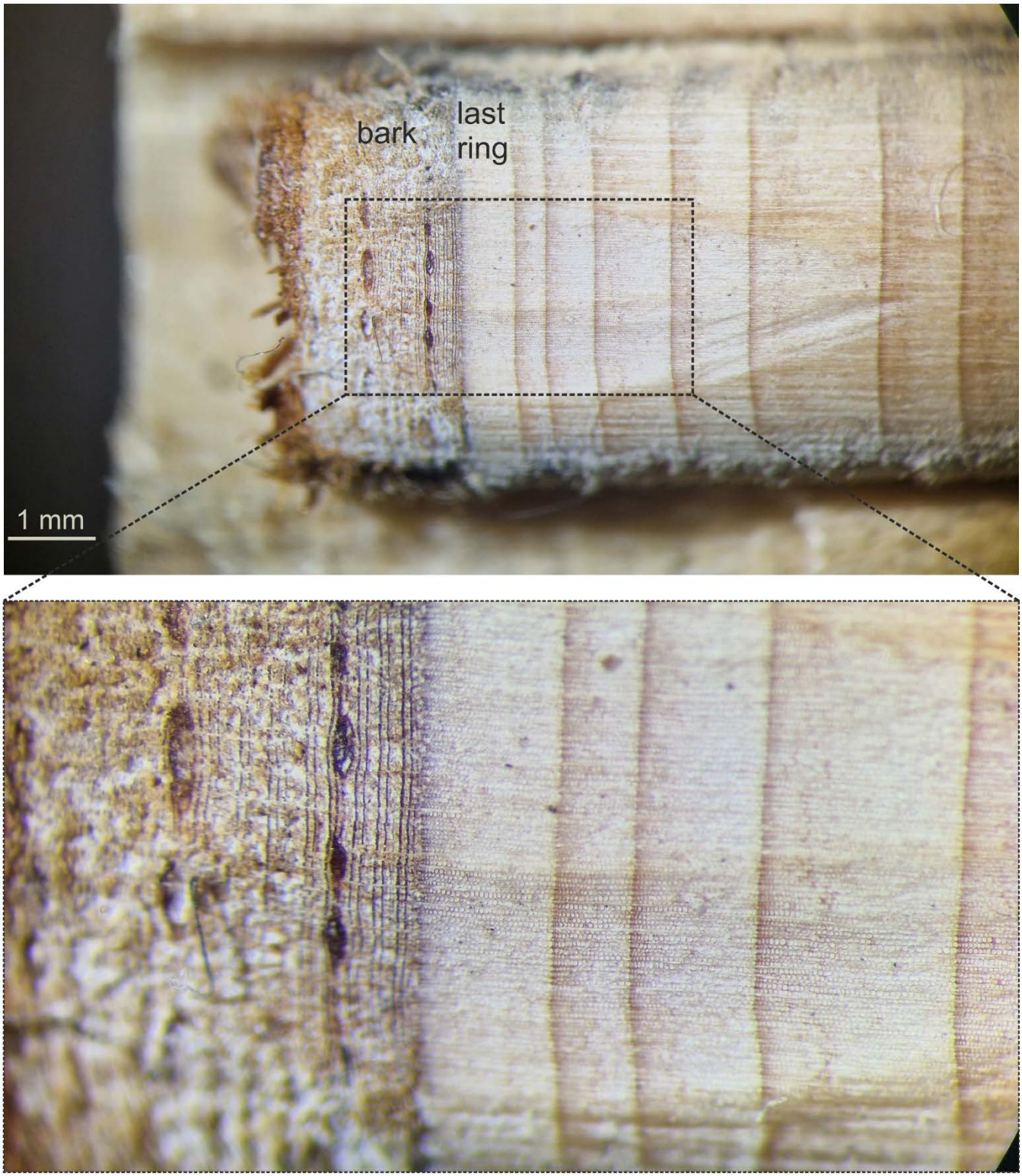

Figure S2.6 *Cross-section of a modern Juniperus excelsa from Mt. Galichica, ca. 60 km northwest of Dispilio. Latewood of last ring is almost fully developed, same as in the oaks in the area, indicating similar timing of ring formation. Core taken between 5-7 September 2021.*

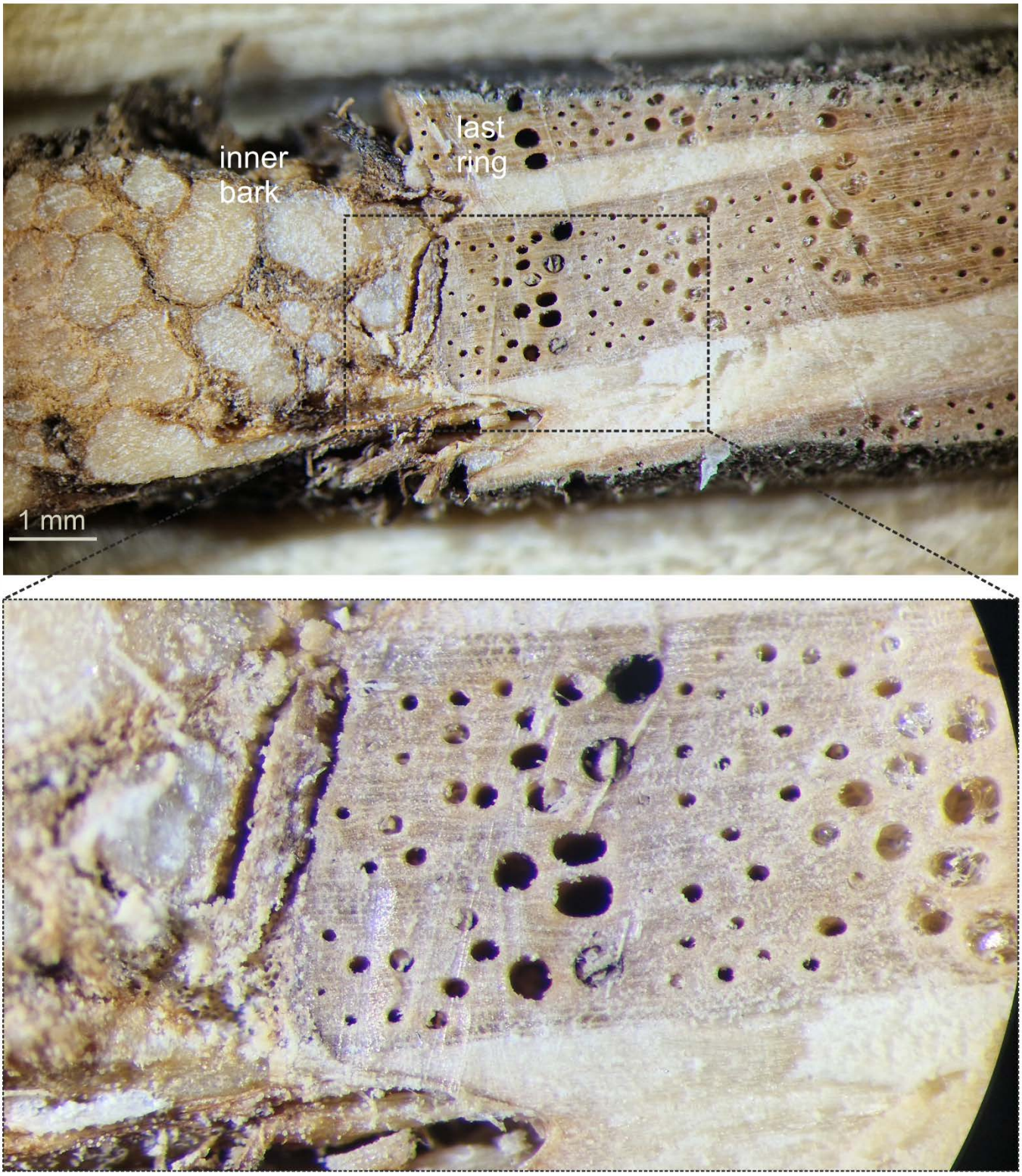

Figure S2.7 *Cross-section of a modern Quercus trojana from Mt. Galichica, ca. 60 km northwest of Dispilio. Latewood of last ring is fully developed, same as in junipers in the area, indicating similar timing of ring formation. Core taken between 5-7 September 2021.*

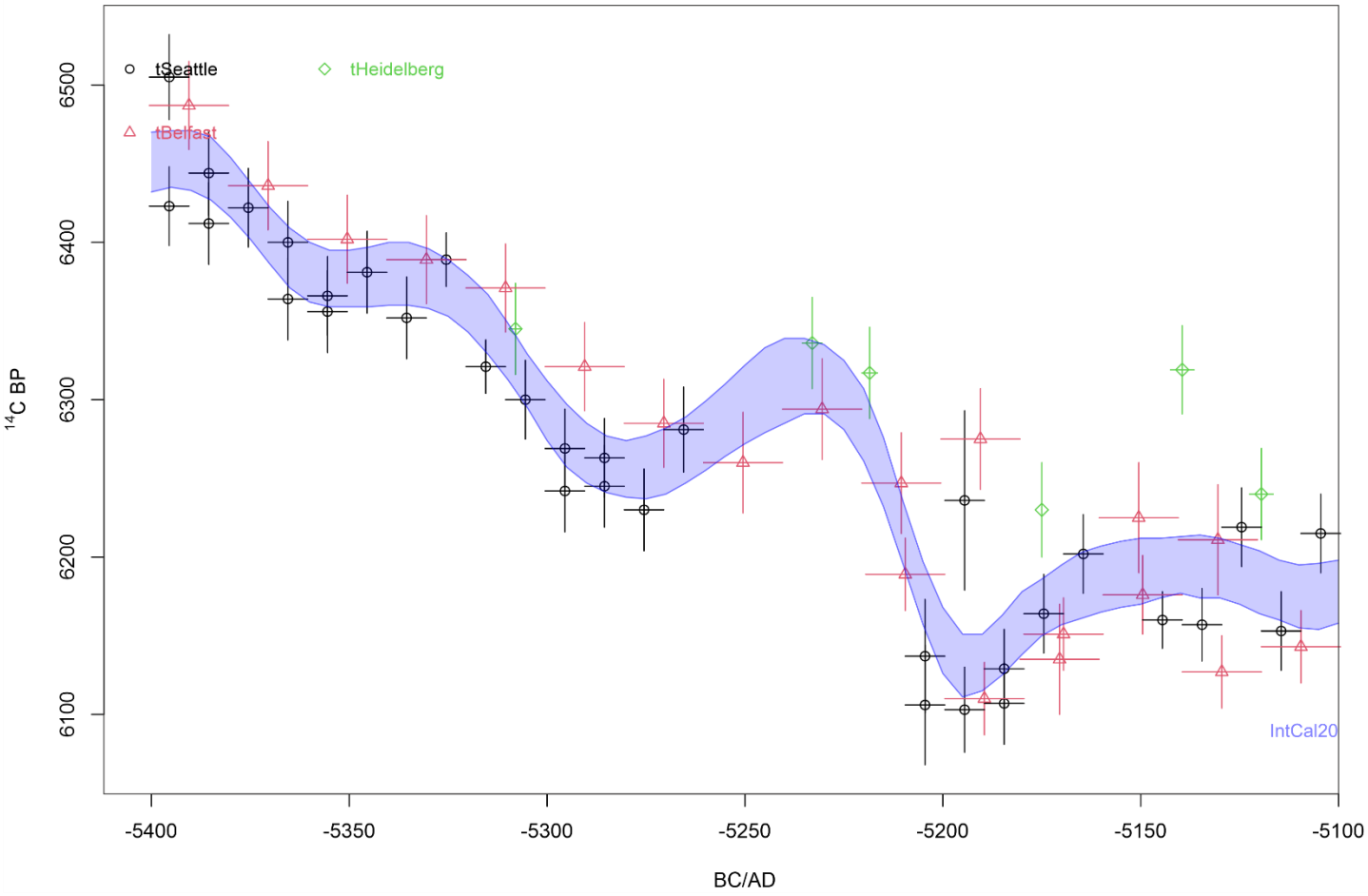

Figure S2.8 *Radiocarbon calibration curve IntCal20 (blue-shaded band) (Reimer et al., 2020) and individual data points that make up the curve for the period 5400-5100 BC. Vertical lines represent the measurement uncertainties, horizontal bars indicate the number of rings in the samples; in this period individual points of Belfast data represent 20-ring blocks, Seattle 10-ring blocks, and Heidelberg 4-5-ring blocks. Figure produced with the IntCal R package* [4].

S3 – Supplementary information on measurements and data

S3.1 Data handling at LARA 14C laboratory

Samples were measured using the LARA MICADAS AMS system. The tree-rings from wood samples DISP-10070, -10206 and a first run of -10611 were analysed in June – November 2022 together with three oxalic acid II (SRM 4990C, NIST) standards and three chemical blanks. In June 2023, DISP-10063 and a second run of -10611 were dated together with five oxalic acid II standards and four chemical blanks that were used for blank subtraction, standard normalization, and correction for isotope fractionations as well as two IAEA-C5, two IAEA-C7, two 1515 CE reference samples and two cellulose blanks as secondary standards and blanks, respectively. A total of ten samples from our first run of DISP-10611 were repeated within our second run which, gained an average negligible difference between both of our runs of 0.6‰ so that our DISP-10611 dataset that is shown Fig.3a represents the average of both LARA runs.

All initial results (Supplementary Table S1) were biased by an inappropriate batch of the oxalic acid II standard that was used for the measurements. By intercomparison with three other oxalic acid II batches (one of which was provided by ETHZ), an offset corresponding to a ^{14}C age of +30.9±3.2 yr was determined for the inappropriate batch, whereas the results of the oxalic acid II of the other three batches were identical within uncertainties. The initial results were corrected for this offset yielding a shift of ~+4.2‰ for the samples. The final (i.e. corrected) results are presented in Fig. 3a in the main article text.

S3.2 Note on 1 year correction of the Methuselah Walk Bristlecone Pine Chronology

Brehm et al., (2022) showed that the bristlecone pine 14C data preceded the 14C jump at 5259 BCE by 1 year relative to the other tree species used. At the time of publication, the authors had ruled out a dissection or labeling error. The remaining three explanations were that, 1; the rings, although correctly dissected may have been too narrow to achieve a full and perfect separation, 2; the response was caused due to a combination of the timing of the SEP event and the growth season of the tree, or 3; there was a dating error within the bristlecone master chronology.

Matthew Salzer and Christopher Basin conducted extensive testing of the portion of the master bristlecone pine chronology from which samples used in the study were taken. As reported in Brehm et al 2022, the statistics of the sample to the master chronology were excellent (correlation; r = 0.770), however Salzer and Baisan had previously discovered that two changes were required to the older portion of the record which could not be cross-checked against an independent sequence at a different growth location. A correction of 2 years was applied to Wes Ferguson's original 1966 CE dating of this part of the MWK chronology due to

an observation by Lamarche and Harlan in 1973 that Ferguson had incorrectly added what he thought were two likely missing rings to his chronology in -2141 and -2680. They suspected that something similar may have happened for the portion of the record between -2680 and -5075 (i.e. impacting the master but not the sample used in the study) as one wrongly inserted ring in this period would explain the off-set observed while still resulting in the strong statistical correlation for the sample. Checking this required physically checking a large number of samples and handwritten records from the 1970s and 1980s which used the skeleton plot method. This work is approaching completion and a candidate error has been identified and confirmed. The results will be published formally, however for the purpose of display in this study there is more than sufficient justification to now display the data in their correct position, especially as this does not impact the main conclusions of this study.

S3.3 Tree-ring width measurements in Heidelberg format (.fh)

HEADER:

Keycode=10611.0

DateEnd=-5155

QualityCode=a

Species=JUSP

Length=123

SapWoodRings=44

Pith=p

WaldKante=3

Location=GRC/Kastoria Dispilio 2019

PersId=

ExcavNr=

CreationDate= 20210107

Dated=dated

DATA:Tree

30 65 74 88 102 95 117 171 108 94

121 58 77 55 75 63 47 46 79 80

92 78 111 129 69 46 40 52 61 38

31 42 35 16 18 36 44 37 23 50

60 67 90 105 88 112 92 78 62 71

76 52 59 96 45 70 71 54 43 67

64 71 68 78 71 54 69 42 42 43

58 57 42 48 43 49 77 36 30 42

18 21 17 21 22 23 26 22 24 29

42 47 29 21 17 17 33 38 27 16

36 44 38 21 14 26 18 10 32 33

24 46 48 46 39 41 20 17 31 23

20 43 53

HEADER:

Keycode=10206.0

DateEnd=-5153

QualityCode=a

Species=JUSP

Length=142

SapWoodRings=55

Pith=p

WaldKante=3

Location=GRC/Kastoria Dispilio 2019

PersId=

ExcavNr=.

CreationDate= 20210928

Dated=dated

DATA:Tree

66 65 55 54 69 77 106 100 106 101

47 54 15 23 33 41 39 64 68 52

73 58 48 51 57 50 36 41 31 40

39 53 52 50 43 41 44 42 28 34

52 34 43 25 37 46 43 60 66 52

38 50 52 51 46 32 50 56 49 58

66 64 56 52 46 42 44 41 38 51

36 34 47 54 46 40 32 38 39 48

40 53 56 48 34 30 28 44 45 56

56 53 60 69 50 26 14 15 28 37

36 40 28 43 23 23 35 37 45 22

17 21 26 27 51 21 20 50 67 91

55 31 48 35 17 29 31 29 42 56

61 61 66 47 41 42 42 31 55 66

38 48

HEADER:

Keycode=10070.0

DateEnd=-5240

QualityCode=a

Species=JUSP

Length=58

SapWoodRings=36

Pith=p

WaldKante=3

Location=GRC/Kastoria Dispilio 2019

PersId=

ExcavNr=

CreationDate= 20210928

Dated=dated

DATA:Tree

141 176 146 136 140 106 125 156 152 111

120 131 126 91 114 86 85 66 73 58

144 97 50 87 89 96 80 90 88 59

74 59 69 63 71 60 63 50 43 55

69 40 61 85 50 55 45 74 75 48

73 78 67 54 57 68 54 62

HEADER:

Keycode=10063.0

DateEnd=-5240

QualityCode=a

Species=JUSP

Length=125

SapWoodRings=81

Pith=p

WaldKante=3

Location=GRC/Kastoria Dispilio 2019

PersId=

ExcavNr=

CreationDate= 20210928

Dated=dated

DATA:Tree

90 91 48 102 91 97 61 62 46 62

82 77 91 84 76 60 103 123 97 53

61 70 68 103 80 93 88 116 106 101

112 97 66 94 95 144 103 57 70 69

58 80 71 67 86 65 80 72 70 75

51 33 73 84 82 57 91 62 76 72

66 59 69 83 101 76 79 68 88 65

96 75 91 88 118 142 107 89 61 74

25 39 23 20 26 31 31 97 66 52

83 69 84 77 95 76 44 74 59 63

43 46 35 39 28 57 44 56 25 46

52 35 41 35 66 47 37 50 56 59

63 46 60 69 49

Supplementary Material References

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

2. Reimer, P. J. *et al.* The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* **62**, 725–757 (2020).

3. Brehm, N. *et al.* Tree-rings reveal two strong solar proton events in 7176 and 5259 BCE. *Nat. Commun.* **13**, 1–8 (2022).

4. Blaauw, M. IntCal: Radiocarbon Calibration Curves. R package version 0.3.1. https://CRAN.R-project.org/package=IntCal. (2022).