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Reviewing the Mid-First Millennium BC ^{14}C "warp" using ^{14}C/bristlecone pine data

R.E. Taylor [a,b,c,*], John Southon [c]

[a] Department of Anthropology, University of California, Riverside, Riverside, CA, United States
[b] Cotsen Institute of Archaeology, University of California, Los Angeles, CA, United States
[c] Keck Carbon Cycle Accelerator Mass Spectrometry Laboratory, University of California, Irvine, CA, United States

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ABSTRACT

AMS-based ^{14}C measurements have been obtained on 53 dendrochronologically-dated Bristlecone pine (*Pinus longaeva*) wood samples in decadal increments spanning 2300–2750 cal BP with particular interest focused on the decades centered on 2405 cal BP and 2625 cal BP. In general, there is overall agreement with the current IntCal04/09 consensus calibration curve for this period. For the 2400–2410 cal BP interval, our Bristlecone-based ^{14}C value is consistent with the ^{14}C value obtained by Belfast on Irish oak for that decade but not on German oak values obtained by Seattle. Our ^{14}C value for the 2620–2630 cal BP interval is consistent with the German oak (Heidelberg)-based ^{14}C decadal value. The ^{10}Be-based reconstruction of ^{14}C variations over the 2620–2630 cal BP interval also supports the Heidelberg data although clearly additional clarifications are required before the current tree ring-based ^{14}C and ice core-based ^{10}Be data for this interval can be accurately interpreted and valid inferences obtained.

1. Introduction

The current IntCal09 calibration data set for the period 2360–2740 cal BP documents the longest ^{14}C "warp/wiggle" of the middle and late Holocene, the deVries effect III b ^{14}C time scale excursion [1]. The values currently used for this time interval are based on ^{14}C measurements obtained at the University of Washington (Seattle), Queen's University (Belfast), and Heidelberger Akademie der Wissen-shaften (Heidelberg) on dendrochronologically-(tree ring-) dated wood. For this period, the tree-ring data used for IntCal09 is identical to that used in IntCal04 [2,3].

The study being reported here is a progress report on the first set of bristlecone pine measurements originally undertaken, in part, to address questions that had been raised about two decadal episodes within the III b period. These two episodes are centered on 2405 cal BP and 2625 cal BP. The immediate general context for our interest in this period is based on results of ^{14}C measurements obtained on human skeletons associated with a 612 BCE event at the archaeological site of Nineveh in ancient Mesopotamia. Nine ^{14}C values obtained on three skeletons directly associated with an historically-documented event which occurred in 612 BCE yielded calibration values ~150 years too old. One explanation offered to explain at least part of this result was the existence of a regional Δ^{14}C offset [4]. To provide a baseline against which to compare possible regional data, we wished to reexamine calibration data for the III b interval which included obtaining new ^{14}C data on tree ring-dated bristlecone pine (*Pinus longaeva*).

2. Materials and methods

AMS-based ^{14}C measurements have been obtained on 53 tree-ring dated Bristlecone pine (*P. longaeva*) wood samples in decadal increments spanning 2300 to 2750 cal BP. In 7 instances, we undertook duplicate measurements of the same decadal wood sample. The tree ring-dated ages of these samples had been determined in the 1960s by the late C. Wesley Ferguson of the Laboratory of Tree Ring Research (LTRR), University of Arizona [5,6]. All of these samples had been collected at an elevation above 3000 meters in the White Mountains of east central California (USA). Dr. Paul Creasman of the LTRR kindly made these samples available to us.

After physically cleaning the surface by abrasion and sizing to ~1 × 3 mm segments making sure that multiple annual ring increments in each decadal sample was represented, each sample was chemically pretreated by heating at 90 °C for at least 30 min each in 1 N HCl, 1 N NaOH, 1 N HCl, and milli-Q H_2O followed by drying for at least 8 h at 90 °C. The same pretreatment was applied simultaneously to infinite ^{14}C age wood blanks and known-age wood standards. We are not aware of any data which supports the view that the isolation of alpha cellulose from bristlecone pine wood samples used for dendrochronological purposes results in more accurate ^{14}C age determinations than the chemical pretreatment

* Corresponding author at: Department of Anthropology, University of California, Riverside, Riverside, CA, United States.
E-mail address: retaylor@ucr.edu (R.E. Taylor).

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Table 1
Decadal bristlecone pine ^{14}C measurements: 360–800 BC.

UCIAMS sample No.	Bristlecone tree ring age[a] (BC yrs)	$\delta^{13}C$[b] (‰)	$\Delta^{14}C$ (‰)	^{14}C age (yrs BP)
87267	360-350	−21.8	3.1 ± 2.0	2215 ± 20
87300	370-360	−22.4	−2.4 ± 1.9	2270 ± 15
87268	380-370	−22.1	−4 ± 2.1	2290 ± 20
87301	390-380	−22.4	−3.4 ± 1.9	2295 ± 15
87269	400-390	−20.6	−1 ± 2.1	2285 ± 20
87302	410-400	−22.2	−8.7 ± 1.9	2360 ± 15
87270	420-410	−22.2	−14.3 ± 2.0	2415 ± 20
87303	430-420	−22.1	−9.3 ± 1.3	2385 ± 15
87271	440-430	−22.0	−12 ± 1.9	2415 ± 20
87304	450-440	−22.5	−10.7 ± 1.9	2415 ± 15
87272	460-450	−22.2	−7.1 ± 2.1	2395 ± 20
87305	470-460	−22.1	−7.6 ± 1.9	2410 ± 15
87273	480-470	−22.2	−9.7 ± 2.0	2435 ± 20
87306	490-480	−22.3	−6.2 ± 1.9	2415 ± 15
63349	500-490	–	−7.4 ± 1.9	2440 ± 20
87274	500-490	−19.9	−7.6 ± 1.9	2435 ± 20
87307	510-500	−21.9	−4 ± 2.0	2420 ± 15
87275	520-510	−21.6	−7 ± 1.9	2450 ± 20
87308	530-520	−22.1	−2 ± 1.9	2420 ± 15
87276	540-530	−22.1	0.2 ± 2.2	2410 ± 20
87309	550-540	−22.2	−5.4 ± 2.0	2470 ± 15
87277	560-550	−22.0	−6 ± 2.0	2485 ± 20
87310	570-560	−22.2	−5.8 ± 1.9	2490 ± 15
87278	580-570	−22.4	−4.4 ± 2.2	2490 ± 20
63350	590-580	–	−1.9 ± 2.0	2495 ± 20
87311	590-580	−22.3	−3.9 ± 2.4	2480 ± 15
87279	600-590	−22.1	−5.6 ± 1.9	2520 ± 20
63351	610-600	–	−2.3 ± 2.0	2495 ± 15
87312	610-600	−22.4	−1.2 ± 2.2	2500 ± 15
87280	620-610	−22.0	−0.3 ± 1.9	2495 ± 20
63352	630-620	–	0.3 ± 2.0	2470 ± 15
87313	630-620	−21.7	3.9 ± 2.1	2500 ± 15
87281	640-630	−21.7	2.2 ± 2.0	2495 ± 20
87314	650-640	−22.9	8.1 ± 1.9	2455 ± 15
87282	660-650	−20.0	10.1 ± 2.0	2450 ± 20
63353	670-660	–	6.1 ± 1.9	2490 ± 15
87315	670-660	−22.7	6.1 ± 2.1	2490 ± 15
87283	680-670	−22.7	4.5 ± 2.0	2515 ± 20
87316	690-680	−2.0	7.7 ± 1.9	2500 ± 15
63356	690-680	−22.0	14.7 ± 2.1	2445 ± 15
87284	700-690	−21.0	14 ± 1.9	2460 ± 20
87317	710-700	−22.6	15.9 ± 1.9	2455 ± 15
87285	720-710	−22.4	14.5 ± 2.0	2475 ± 20
63354	720-730	–	17.1 ± 1.9	2425 ± 15
87318	730-720	−22.2.	21.7 ± 2.4	2465 ± 15
87286	740-730	−22.0	16.9 ± 2.0	2475 ± 20
87319	750-740	−22.3	17.2 ± 1.9	2480 ± 15
87287	760-750	−21.8	15.6 ± 2.0	2505 ± 20
63355	770-760	–	16.5 ± 1.9	2500 ± 20
87320	770-760	−22.2	17.2 ± 2.1	2505 ± 15
87288	780-770	−21.9	14.2 ± 2.0	2535 ± 20
87321	790-780	−22.2	15.3 ± 1.9	2535 ± 15
87289	800-790	−22.2	13.3 ± 2.0	2560 ± 20

[a] Tree-ring ages of these samples were determined by the late C. Wesley Fergusson, Laboratory of Tree Ring Research (LTRR), University of Arizona, retained in LTRR collections, and provided from those collections by Dr. Paul Creasman of the LTRR.
[b] $\delta^{12}C$ measurements were obtained by IRMS instrumentation using a Thermo Finnigan Delta Plus spectrometer with a Fisons NA 1500 elemental analyzer input.

technique we have employed. For example, Stuiver and Quay [7] noted that the measured differences were limited to 2 or 3 years.

About 2.5 mg of each sample of pretreated wood was placed in an evacuated tube along with CuO and Ag, sealed, and combusted at 900 °C for 3 h. CO_2 resulting from sample combustions was converted to catalytically-condensed carbon with H_2 using iron as the catalyst. Measurement of the ^{14}C concentration in each sample was obtained by accelerator mass spectrometry utilizing the instrument of the Keck Carbon Cycle AMS Laboratory, Department of Earth System Science, University of California, Irvine [8]. Measurements were calculated as conventional ^{14}C ages as defined by Stuiver and Polach [9]. Table 1 lists the results of this study.

Table 2
Duplicate ^{14}C measurements on the same decadal Bristlecone pine wood samples: 2470–2750 cal BP.

	Previous measurments[a]				UCIAMS measurements[b]	
	tree-ring age					
	mid-point[c]		Sample number	^{14}C age	^{14}C age	Sample number
	BC	BP		BP	BP	
1.	525	2475	LJ-3902	2348 ± 41	2420 ± 15	UCIAMS-87308
	525	2475	LJ-1575	2399 ± 56		
2.	535	2485	A-938	2417 ± 37	2410 ± 20	UCIAMS-87276
	535	2485	LJ-3900	2374 ± 42		
3.	545	2495	LJ-3889	2288 ± 42	2470 ± 15	UCIAMS-87309
	545	2495	LJ-1578	2432 ± 56		
4.	575	2525	LJ-3892	2397 ± 41	2490 ± 20	UCIAMS-87278
5.	585	2535	LJ-1575	2294 ± 55	2495 ± 20	UCIAMS-63350
6.	595	2545	A-936	2273 ± 58	2520 ± 20	UCIAMS-87279
	595	2545	LJ-3903	2441 ± 42	2480 ± 15	UCIAMS-87312
7.	605	2555	LJ-1577	2358 ± 83	2495 ± 15	UCIAMS-63351
	605	2555			2500 ± 15	UCIAMS-87312
8.	625	2575	LJ-1574	2517 ± 55	2470 ± 15	UCIAMS-63352
	625	2575			2500 ± 15	UCIAMS-87313
9.	645	2595	LJ-3909	2395 ± 42	2455 ± 15	UCIAMS-87314
	645	2595	LJ-1571	2508 ± 55		
10.	665	2615	LJ-1697	2418 ± 46	2490 ± 15	UCIAMS-63353
	665	2615			2490 ± 15	UCIAMS-87315
11.	685	2535	LJ-3906	2487 ± 42	2445 ± 15	UCIAMS-63356
	685	2535	LJ-1573	2439 ± 55	2500 ± 15	UCIAMS-87316
12.	695	2645	LJ-3908	2435 ± 41[d]	2460 ± 20	UCIAMS-87284
13.	705	2655	LJ-3910	2382 ± 41	2455 ± 15	UCIAMS-87317
	705	2655	LJ-1595	2444 ± 73		
14.	715	2665	A-937	2565 ± 27	2475 ± 20	UCIAMS-87285
15.	725	2675	LJ-1572	2423 ± 55	2465 ± 15	UCIAMS-87318
16.	735	2685	LJ-3914	2496 ± 41	2475 ± 20	UCIAMS-87286
17.	745	2695	LJ-3907	2414 ± 41	2480 ± 15	UCIAMS-87319
18.	755	2705	LJ-3912	2398 ± 41	2505 ± 20	UCIAMS-87287
19.	765	2715	LJ-3911	2465 ± 41	2505 ± 20	UCIAMS-87320
	765	2715			2500 ± 20	UCIAMS-63355
20.	775	2725	LJ-3915	2486 ± 41	2535 ± 20	UCIAMS-87288
21.	785	2735	LJ-3913	2454 ± 64	2535±15	UCIAMS-87321
	785	2735	LJ-1570	2584 ± 56		
22.	795	2745	A-938	2587 ± 26	2560 ± 20	UCIAMS-87289

[a] For University of Arizona (A-) ^{14}C values, see reference [10]. For University of California, San Diego [La Jolla] (LJ-) ^{14}C values, see references [11,12].
[b] This study, see Table 1.
[c] As determined by C. Wesley Ferguson, Tree Ring Laboratory, University of Arizona.
[d] In Appendix 1 of reference [11], the value of 3435 ± 41 cal BP is listed for LJ-3908. We assume this is a typographical error and that the correct value should be 2435 ± 41 cal BP.

In the 1960s, 22 tree-ring dated Bristlecone pine decadal samples which we have measured had also been analyzed by decay counting by the University of Arizona [10] and University of California, San Diego (Mt. Soladad, La Jolla) ^{14}C laboratories [11,12]. Table 2 lists the ^{14}C measurements obtained by these laboratories with our results for comparison. In six cases, the La Jolla laboratory carried out duplicate analysis of samples of the same age while in two instances, La Jolla and Arizona carried out measurements on the same age sample. In 10 instances, there is good concordance between the results obtained by the three laboratories on the same decadal interval. However, in a number of other cases, there are from minor to major discrepancies even when the larger statistical errors associated with the decay counting results are considered.

3. Discussion

Fig. 1 is a plot of our tree-ring dated bristlecone pine/^{14}C values. Also included in this figure are the ^{14}C measurements obtained on tree ring-dated Irish and German oak wood samples employed to