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ARE THE ^{14}C DATES OF THE DEAD SEA SCROLLS AFFECTED BY CASTOR OIL CONTAMINATION?

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ABSTRACT. The paper "The effects of possible contamination on the radiocarbon dates of the Dead Sea Scrolls I: castor oil" by Rasmussen et al. (2001) is discussed. Detailed analysis of the extant dates of the Dead Sea Scrolls suggests that the pretreatment of the samples was adequate. Errors and omissions in the paper are discussed and the implications of the experiment of Rasmussen et al. (2001) are questioned.

INTRODUCTION

In the paper "The Effect of Possible Contamination on the Radiocarbon Dating of Dead Sea Scrolls I: Castor Oil", Rasmussen et al. (2001), state "that the two series of ^{14}C dating of the Dead Sea Scrolls that have been conducted up to the present (Bonani et al. 1992 and Jull et al. 1995) cannot be guaranteed to have removed all of the modern carbon in any samples if they had been contaminated with castor oil and hence could have produced some ^{14}C dates that were younger than the texts' true ages". Their conclusion is based on the results of an experiment in which they soaked a medieval parchment with castor oil (organic—modern) and with mineral oil (old—with no radiocarbon in it), applied a single step of AAA treatment and measured the ages and the $\delta^{13}C$ of the untreated and treated parchments and of the oils that they used in their experiments.

I have four comments on the Rasmussen et al. (2001) paper and my conclusion is that their experiment does not cast doubt on the validity of the dates of the Dead Sea Scrolls. My comments relate to:

1. The extant dates of the Dead Sea Scrolls do not suggest a major deviation from their paleographic or specific ages. There is thus no indication that the pretreatment was inadequate.
2. The authors miscalculated the efficiency of their AAA treatment from the ^{14}C data.
3. They have not used the $\delta^{13}C$ values of the samples in order to validate their ^{14}C calculations of the efficiency of the AAA procedure.
4. Their strategy of testing the validity of the dates of the Dead Sea Scrolls is wrong.

Evaluation of the Extant Dates of the Dead Sea Scrolls

It is important to note that the Dead Sea Scrolls were never *soaked* with castor oil: at most the oil had been applied superficially (Rasmussen et al. 2001). In *all* cases the samples for dating were taken from the margins of each parchment/papyrus, where there was no writing and hence no intentional smearing with castor oil (Magen Broshi, personal communication 2002). The radiocarbon experts were aware of a possible problem, took care to do just this in collecting the samples. Evaluating whether or not the AAA treatment of the Dead Sea Scrolls was adequate can be done by comparing ^{14}C dates of the scrolls with ages assigned to them using paleographic methods and with ages of explicitly dated scrolls. Indeed a significant part of the two dating projects was dedicated to such a comparison. Recently I have presented the extant dates of the Dead Sea Scrolls (Carmi 2000) and I reproduce here the data (Table 1) with two modifications:

1. In the first column of Table 1, scrolls that have *not* been treated with castor oil are marked with (*); those which most *probably* have *not* been treated with castor oil are marked ($^{\#}$), and those which *might* have been treated with castor oil are marked with ($^{!}$).
2. I recalibrated the conventional ages with Oxcal Version 3.3.

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Table 1 Compilation of the extant radiocarbon date of Dead Sea Scrolls

N[a]	Lab[b]	Description	^{14}C age (yr BP)	Calibrated age[c]	p[d]	Paleographic or specified age
1[#]	Z	Daliyeh	2289 ± 55	410–210 BCE	1.00	352 BCE
2[!]	Z	Testament of Kahat	2240 ± 39	390–200 BCE	1.00	100–75 BCE
3[!]	T	Sale of Land	2185 ± 60	360–170 BCE	1.00	
4[*]	T	Book of Isaiah	2141 ± 32	210–110 BCE	0.82	125–100 BCE
5[!]	Z	Pentateuchal paraphrase	2139 ± 32	210–110 BCE	0.85	125–100 BCE
6[*]	Z	Book of Isaiah	2128 ± 38	210–90 BCE	0.97	125–100 BCE
7[!]	Z	Testament of Levi	2125 ± 24	200–105 BCE	1.00	Late 2nd early 1st c. BCE
8[!]	T	Midrash Sefer Moshe	2097 ± 50	180–40 BCE	1.00	
9[!]	T	Astronomical Enoch	2095 ± 20	170–50 BCE	0.91	200 BCE
10[!]	Z	Book of Samuel	2095 ± 49	180–40 BCE	1.00	100–75 BCE
11[!]	T	Damascus Document[b]	2094 ± 29	170–50 BCE	1.00	50–0 BCE
12[*]	Z	Joshua (Masada)	2086 ± 28	160–50 BCE	1.00	30–1 BCE
13[!]	T	Phases of the Moon	2084 ± 30	160–40 BCE	1.00	
14[*]	T	Commentary on Habakkuk	2054 ± 22	95–0 BCE	1.00	30–1 BCE
15[!]	T	Paleo Exodus	2044 ± 65	160 BCE–CE 30	1.00	100–25 BCE
16[*]	T	Community Rule[d]	2041 ± 68	160 BCE–CE 50	1.00	100 BC–25 CE
17[*]	Z	Temple Scroll	2030 ± 40	100 BCE–CE 50	1.00	Late 1st BCE early 1st CE
18[!]	T	Paleo Exodus patch	2024 ± 39	90 BCE–CE 50	1.00	50 BCE–50 CE
19[*]	Z	Genesis Apocryphon	2013 ± 32	45 BCE–CE 50	1.00	Late 1st BCE early 1st CE
20[!]	T	Messianic Apocalypse	1984 ± 33	40 BCE–CE 60	1.00	
21[*]	Z	Thanksgiving Scroll	1979 ± 32	40 BCE–CE 70	1.00	50–0 BC
22[*]	Z	Sectarian (Masada)	1971 ± 46	40 BCE–CE 80	1.00	30–1 BCE
23[!]	T	Community Rule[d]	1964 ± 45	40 BCE–CE 90	1.00	100 BCE
24[!]	T	Damascus Document[a]	1954 ± 38	CE 0–120	1.00	100–5 BCE
25[!]	T	Commentary in Psalms[a]	1944 ± 23	CE 25–115	1.00	
26[!]	T	Letter	1934 ± 47	CE 20–130	1.00	
27[#]	Z	Wadi Seyal	1917 ± 42	CE 20–140	1.00	CE 130–131
28[!]	T	Debt Acknowledgement	1902 ± 39	CE 30–210	1.00	
29[#]	Z	Murba'at	1892 ± 32	CE 60–210	1.00	CE 134
30[*]	T	Pap Yadin 19	1827 ± 36	CE 130–240	1.00	CE 128
31[*]	T	Community Rule	1823 ± 24	CE 130–240	1.00	100 BCE
32[*]	T	Pap Yadin 21	1799 ± 57	CE 130–330	1.00	CE 130
33[*]	T	Kefar Bebayu	1758 ± 36	CE 230–350	1.00	CE 135
34[#]	Z	Khirbet Mird	1289 ± 36	CE 680–775	1.00	CE 744

[a]Scrolls not treated with castor oil are marked with (*), scrolls most probably not treated with castor oil are marked with (#), scrolls possibly treated with castor oil are marked with (!).
[b]T is the Tucson AMS lab, Z is the Zürich AMS lab
[c]Calibrated with OXCAL version 3.3
[d]In cases that there is more then one possible calendar age the probability of each age is given. If the difference between the ranges is less than 1σ the two possibilities are lumped together. In some cases only the age with the highest probability is given.

I first examine the 18 samples that have not been treated ([*]), or most probably have not been treated ([#]) with castor oil. The younger age of (31[*]) was an outlier, and a reanalysis by duplicate preparation and measurement, (23[*]), deviates from the expected age by $-2\,\sigma$. Two dates are older than the expected age: (12[*]) by <0.5 σ and (33[*]) by about 1 σ. These deviations are reasonable by present-day ^{14}C standards and there is no indication of contamination of the scrolls by castor oil because the ages came out older than expected.

Of the 16 samples that might have been treated with castor oil, the calibrated ages of 13 agree with the expected ages. One date (2[!]), verified by quadruplicate preparation and measurement, was too

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old—this surely cannot be due to castor oil contamination. A second one ($24^{!}$) was younger than expected, by 2.5 σ. This deviation is acceptable, but not desirable, by current standards of ^{14}C dating. By contrast, the remnant contamination in Rasmussen's et al. (2001) experiment deviates from the true age of their scroll by 6.6 σ and 20 σ, respectively, for castor oil and mineral oil. For the extant dates of the Dead Sea Scrolls (excluding ($2^{!}$) and (31^{*})) the statistical nature of ^{14}C dating suggests that four deviations in a sample of 32 dates are very reasonable as well as expected.

Recalculation of the Efficiency of the AAA Pretreatment from the ^{14}a Data

Rasmussen et al. (2001) used the following formula for their calculations of the percent of retained oil in their experiment:

$$PCT = (X_{AAA}-X_{us})/(X_{oil}-X_{us}) \times 100 \tag{1}$$

PCT is the percent of retained oil in the sample and X is a concentration unit (^{14}a, $\delta^{13}C$ etc.). X_{AAA} is the sample after the AAA treatment, X_{us} is the un-treated parchment, X_{oil} is the castor oil or mineral oil in which the parchment was soaked.

For no retention, or perfect cleaning, one must have PCT=0 *i.e.* $X_{AAA}=X_{us}$. However, if the retention of the oil is 100%, *i.e.* a totally inefficient cleaning procedure, it is necessary to have $(X_{AAA}-X_{us})=(X_{oil}-X_{us})$ which is possible only if $X_{oil}=X_{AAA}$. This is incorrect because this implies that the parchment had been completely consumed in the AAA treatment and only the oil was retained. The comparison must rather be between parchments—the oil-soaked and AAA samples, and not between the oil and AAA samples. Thus, the condition for 100% retention of oil must be $X_{AAA}=X_{sk}$ (X_{sk} is the concentration of the sample soaked with oil).

The correct formula for the Rasmussen et al. (2001) calculations should be

$$PCT = (X_{AAA}-X_{us})/(X_{sk}-X_{us}) \times 100 \tag{2}$$

Rasmussen et al. (2001) did not report measurements of X_{sk}. In fact, they could not measure it in their experiment because they had subjected all their parchment samples to AAA treatment and X_{sk} is the concentration of the untreated oil-soaked parchment. This is a shortcoming in their strategy of the experiment. However, it is possible to reconstruct X_{sk} from the values of X_{us} and X_{oil} which are given by the authors, using the mass balance

$$m_{us} \times X_{us} + m_{oil} \times X_{oil} = m_{sk} \times X_{sk} \tag{3}$$

where m_{us} is the mass of the original scroll, $m_{oil}(=m_{sk}-m_{us})$ is the mass of the absorbed oil and m_{sk} is the mass of the soaked parchment. The data are from Tables 1 and 2 in the Rasmussen et al. (2001) paper. Table 2 compares the result of my calculations of the percent of oil retention, with the calculations of Rasmussen et al. (2001).

Table 2 Comparison between two estimates of AAA efficiency from the ^{14}C data, in retained % oil. Saturation percent is from Table 3 in Rasmussen et al. (2001).

Exp.	Contaminator	Saturation Percent	Retained (Rasmussen)	Retained (Carmi)
1	Old oil	22	7	67.9
	Castor oil	24	12	51.4
2	Old oil	17	6	63.2
	Castor oil	24	8	66.3

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The new results differ from those of Rasmussen et al. (2001) and suggest a lower efficiency (higher retention) in the AAA procedure. This retention means that some 27% of the mass of the oil in the soaked-parchment samples is present in the AAA samples. Such a quantity of oil, if present in the Dead Sea Scrolls, would make their ages several hundred years younger than their archaeological context.

Calculating the Efficiency of AAA Pretreatment from the $\delta^{13}C$ Data

Rasmussen et al. (2001) say "it is not safe to calculate the amount of oil left in the sample from the measured $\delta^{13}C$ values because it is uncertain precisely how the stable carbon isotope of the oil are fractionated by the cleaning procedure…". The same fractionation would have affected also the radiocarbon measurements. I used the ^{13}C data in Rasmussen et al. (2001) to estimate the efficiency of their AAA procedure on their samples. The results (Table 3) are quite similar to those of the ^{14}C calculation, but diverge significantly from the results of Rasmussen et al. (2001). From my calculations it is clear that the AAA treatment removed less than 50% of the castor oil and old oil from the soaked parchments.

Table 3 The retained oil in the scrolls after the AAA treatment, from $\delta^{13}C$ measurements, in % oil

Exp.	Contaminator	Retained %
1	Old oil	67.9
	Castor oil	71.3
2	Old oil	57.6
	Castor oil	62.3

CONCLUSIONS

1. The extant corpus of dates of the Dead Sea Scrolls is robust and does not indicate a problem with castor oil contamination.
2. The experiment of Rasmussen et al. (2001) has no relevance to the extant dates of the Dead Sea Scrolls.

Finally, a word of caution: The radiocarbon discipline has reached a state in which the pretreatment of samples is the limiting factor with respect to accuracy and precision. This pretreatment is no easy matter and a continuous search for better and more efficient cleaning procedures for parchments and other materials is appropriate.

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