Radiocarbon Dating the Gospel of John and the Gospel of Jesus Wife Papyri: protocols, stable isotope measurements, and discussion of the validity of the radiocarbon measurements.

Greg Hodgins, NSF-Arizona AMS Laboratory

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1. Introduction

Two papyrus samples were sent to the University of Arizona AMS Laboratory on 5/29/2013. One sample, 7.90 mg (figure 1), was identified as from the Coptic Gospel of John. The sampling location could not be identified based upon available photographs. The other (figure 2a-b) weighed 2.27 mg, and was identified as from the Coptic Gospel of Jesus Wife. Sampling locations for some of the fragments were identified from published photographs of the Gospel of Jesus Wife (Figure 3a-b).

2. Sample Cleaning

The papyrus cleaning protocol typically involves a series of solvents, whose chemistries progress from the pure hydrocarbon hexane back to pure water. These solvent washes are followed by a sequence of washes with mineral acids and bases (known as ABA or acid-base-acid treatment). The protocol is designed to remove oily contaminants that might accumulate during burial or handling, mineral carbonates that might have precipitated within the structure through sequences of wetting and drying with carbonate-containing water, and base-soluble organic compounds collectively known as humic acids, that can be transported into buried objects via aqueous transport.

Data from the cleaning steps are presented in Table 1. As shown, the Gospel of John sample was carried through the solvent series followed by ABA, but the Gospel of Jesus Wife was cleaned by the solvent series followed by only a short acid extraction. Mass losses during the solvent cleaning necessitated an abbreviated protocol for the Gospel of Jesus Wife. The full ABA portion of the treatment removed 5% of the mass of the Gospel of John sample, and the abbreviated acid-only extraction removed 13% of the mass of the Gospel of Jesus wife. Both samples showed typical fragmentation and disaggregation during cleaning. 1.12 mg of pure carbon was extracted from the Gospel of John sample, and 0.45 mgs of carbon from the Gospel of Jesus Wife.

Previous experience dating ancient papyri indicated that 70 to 80% loss of sample mass is typical during the chemical cleaning steps. Precise estimates of loss are not possible ahead of time as it depends upon the preservation of each document. The laboratory aims to produce a minimum of 0.5 mg of pure carbon from each sample for radiocarbon measurement, so a minimum sample size for papyrus is typically in the range 4.2 to 6.2 mg. The Gospel of John sample was sufficient but the Gospel of Jesus Wife sample was below this threshold.

3. Carbon Stable Isotope Measurements

Carbon stable isotope measurements were carried out on both samples in preparation for radiocarbon dating. The Gospel of John measurement was -9.0±0.1‰. This value is typical of a broad category of plants known as C4 plants. C4 plants are typically grasses and sedges, and include *Cyperus papyrus*. The range of C4 plant carbon stable isotope values is typically -8 to -12 but can span -7 to -15 (e.g. see Ambrose, 1986 figure 1). Another broad plant category is called C3. C3 stable isotope values are typically in the range -21 to -28‰.

The Gospel of Jesus Wife measurement was -14.3±0.1‰. This value is within the total range of C4 plants but low compared to values derived from other papyrus documents dated in this laboratory. Canvasing other AMS laboratories for papyrus carbon stable isotope measurements bore this observation out. Table 2 shows that the Gospel of Jesus Wife $\delta^{13}C$ value was the lowest of 42 documented old and ancient papyri measurements.

4. Radiocarbon Measurements

Radiocarbon measurements were carried out by accelerator mass spectrometry. This instrument quantifies the amount of radiocarbon (^{14}C) in a sample relative to its carbon stable isotope content (^{13}C or ^{12}C). This ratio is compared to the same ratio within modern standard materials and the result expressed as the Fraction Modern, or FM. Small differences in radiocarbon content between samples of the same age are accounted for based upon differences encountered in stable isotope content. This process is known as isotope fractionation correction.

The isotope fractionation corrected radiocarbon measurement of the Gospel of John fragment was 0.8568±0.0033 Fraction Modern. The Gospel of Jesus Wife radiocarbon measurement was 0.7526±0.0035 Fraction modern.

The radiocarbon content of a sample is translated into a calendar date range by the process of calibration. It is accomplished using a dataset comprised of a large number of radiocarbon measurements on known-age samples. Throughout the Holocene, the calibration samples are known-age tree rings. The Gospel of John measurement was calibrated to the range of 681 to 781 CalAD, and 787 to 877 CalAD at 95.4% confidence (figure 4). The Gospel of Jesus Wife measurement generated calibrated date ranges of 405 to 350 CalBC and 307 to 209 CalBC at 95.4% Confidence (figure 5).

5. Discussion and Conclusion

The reliability of the Gospel of Jesus Wife radiocarbon measurement is questionable. Three things are at play in the assessment of the current measurement: 1, the abbreviated cleaning protocol; 2, the odd carbon stable isotope measurement; and 3, the early GJW papyrus radiocarbon date.

The abbreviated cleaning protocol might be significant. The stable isotope measurement and the early date might be explained by the presence of a contaminant that was not completely removed during cleaning. For example, a brownish residue was visible on one of the GJW fragments submitted for measurement (figure 3). This might be original to the papyrus (for example, see Wiedemann and Bayer 1983), or a later addition. Contaminating carbon might also have been introduced in the recent past as part of a treatment to preserve the piece, or in this laboratory, for example, in the form of traces of organic solvent not completely removed in the abbreviated cleaning protocol. The presence of a contaminant, either a natural product or a modern petroleum-derived synthetic material, could alter the carbon stable isotope value and the measured radiocarbon age. This could result in either an erroneously old or an erroneously young date.

The carbon stable isotope value of the GJW (-14.3 ‰) is odd. Although modern living papyri have documented stable isotope values in this range (Gichuki et al. 2005), their relevance to the ancient writing media is debatable. A survey of carbon stable isotope measurements from other papyrus document dating projects suggests that a range of heavier values is typical (Table 2). The odd measured value is strong evidence for the presence of a contaminant on the GJW sample. If this is the case, the contaminant has a low carbon stable isotope value.

The measured Gospel of Jesus Wife radiocarbon date is strange but not impossible. However, if a contaminant was present in the measured sample, and the true age of the papyrus is in fact younger, it would suggest that the contaminant is radiocarbon depleted. Further sampling of the document and additional measurements would be required to sort this out.

6. References

Ambrose, S. (1986) Stable carbon and nitrogen isotope analysis of human and animal diet in Africa. *Journal of Human Evolution* 15:707-731.

Gichuki, J. W., Triest, L., Dehairs, F. (2005) The fate of organic matter in a papyrus (*Cyperus papyrus* L.) dominated tropical wetland ecosystem in Nyanza Gulf (Lake Victoria, Kenya) inferred from $\delta^{13}C$ and $\delta^{15}N$ analysis. *Isotopes and Environmental Health Studies* 41(4):379-390.

Wiedemann, H. G., Bayer, G. (1983) Papyrus: the paper of ancient Egypt. *Analytical Chemistry* 55(12):1220A-1230A.

7. Tables

Table 1: Summary of Chemical Pretreatment protocols and sample recovery data.

Papyrus Sample Pretreatments		
Lab number: *Protocol*/Data	AA101793 Gospel of John	AA101794 JWG
Starting Mass after Freeze Drying (mg)	7.90	2.27
Soxhlet extraction hexane *Ethanol* *Methanol* *Type 1 dH2O washes (4x)*	*6.5 hrs* *11 hrs* *8 hrs* *2 hrs*	*6.5 hrs* *11 hrs* *8 hrs* *2 hrs*
Mass after Freeze Drying (mg) mass % recovery	3.49 44	1.44 63
ABA, 1.0 N HCl *0.1 N NaOH* *0.1N HCl* *Type 1 dH2O washes (4x)*	*16 hrs RT* *2 hrs RT* *1 hr RT* *2 hrs*	*30 min RT* *not done* *not done* *2 hrs*
Mass after Freeze Drying (mg) % recovery	3.07 39	1.14 50
Combusted mass (mg) Carbon recovered (mg) % carbon recovery	2.44 1.12 45.9	1.14 0.45 39.5

Table 2: Comparison of $\delta^{13}C$ measurements from papyrus documents and specimens from the Oxford, VERA, LABEC, CIRCE and Arizona AMS Laboratories.

Lab Ref	Origin	Dynastic Period or Name	Sample ID	Date	Error	$\delta^{13}C$
OxA-15313	Illahun	Senusret III	10009	3503	30	-9.4
VERA-3726	Illahun	Senusret III	10009	3543	29	-11.0
OxA-15315	Illahun	Senusret III	10041	3513	31	-8.9
VERA-3728	Illahun	Senusret III	10041	3565	29	-11.3
VERA-3735	Illahun	Amenemhet III	10044	3550	29	-10.8
OxA-15316	Illahun	Amenemhet III	10053	3542	30	-9.3
VERA-3729	Illahun	Amenemhet III	10053	3563	29	-10.8
VERA-3732	Illahun	Senusret III	10077	3563	29	-9.6
VERA-3733	Illahun	Amenemhet III	10091	3568	28	-7.8
OxA-15317	Illahun	Senusret III	10092	3532	31	-8.7
VERA-3730	Illahun	Senusret III	10092	3529	29	-10.2
OxA-15311	Illahun	Senusret III	10248	3532	31	-9.4
OxA-15310	Illahun	Amenemhet III	10018Bd	3560	33	-8.9
OxA-15314	Illahun	Amenemhet III	10038 b+c	3755	33	-10.1
VERA-3727	Illahun	Amenemhet III	10038 b+c	3522	29	-10.0
VERA-3734	Illahun	Amenemhet III	10038a	3512	29	-9.0
OxA-15309	Illahun	Amenemhet III	10081c	3626	33	-9.7
OxA-15318	Illahun	Senusret III	10345d	3518	31	-9.2
VERA-3731	Illahun	Senusret III	10345d	3513	29	-11.5
OxA-15312	Illahun	Amenemhet III	10419a	3485	31	-8.8
OxA-14993	Illahun	Senusret II	Fragment B2	3551	32	-9.4
OxA-14994	Illahun	Senusret II	Fragment B2	3483	32	-9.0
OxA-18052	Saqqara	Djoser	MMA 30948	2421	28	-8.1
OxA-20212	Abusir	Djedkare	BM10735/10	3911	31	-9.1
OxA-16838	Thebes	Amenemhat I or Senusret I	MMA 22.3.5239	3620	32	-9.8
VERA-4075	Thebes	Amenemhat I or Senusret I	MMA 22.3.5239	3679	29	-11
OxA-20189	Thebes	Ramesses IV	BM9999/97	2972	27	-9.1
OxA-20213	Thebes	Ramesses IX-XI	BM10326	2771	28	-10.8
OxA-20214	Thebes	Ramesses IX-XI	BM75018	2946	29	-9.2
LABEC/CIRCE	Alexandria?	Artimedorus Papyrus	Arte 1	1974	80	-11.5
LABEC/CIRCE	Alexandria?	Artimedorus Papyrus	Arte 2	1906	67	-11.5
LABEC/CIRCE	Alexandria?	Artimedorus Papyrus	Arte 3	1958	33	-11.5
OxA-16346	Nile River Bank	C. alopucuroides Rottb.	2a[1]	141	27	-9.0
OxA-16342	Alexandria	C. dives Del.	25a[1]	112	26	-8.3
OxA-16344	Alexandria	C. longus L.	27[1]	126	27	-8.2
AA-62452	unknown	Codex Chaco	page 9	1739	48	-10.0
AA-62453	unknown	Codex Chaco	page 39	1726	47	-9.9
AA85363	Memphis	Early 18th Dyn., Book of the Dead	#371777E	3249	42	-9.3
AA99528	Medinet Madi	Manichaean Codex	cartonnage	1572	38	-10.0
AA101793	unknown	Gospel of John Coptic	fragment	1242	31	-9.2
AA101794	unknown	Gospel of Jesus Wife	fragment	2283	37	-14.3

1. botanical specimen

OxA and VERA data graciously provided by Michael Dee, University of Oxford, and Ezra Marcus, University of Haifa, previously published in Bronk Ramsey C *et al.* (2010) *Science* 328:1554-1557 and Dee M *et al.* (2010) *J Arch Sci* 37:687-693. LABEC/CIRCE data courtesy Marialena Fedi, dates previously published in Fedi M *et al.* (2009) *Radiocarbon* 52(2):356-363. AA85363 data courtesy Paul O'Rourke and Edward Bleiberg, Brooklyn Museum. AA99528 data courtesy Jason BeDuhn, Northern Arizona University. Other AA data courtesy Greg Hodgins and Tim Jull, University of Arizona.

8. Figures

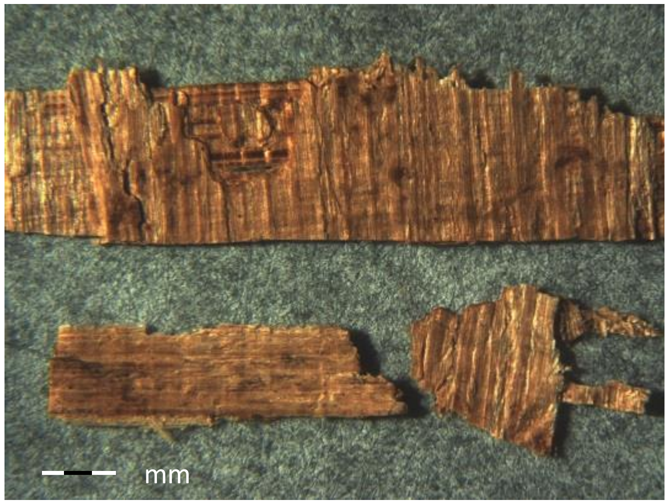

Figure 1: Gospel of John samples photographed at AMS Laboratory. Photo: G Hodgins 5/31/2013

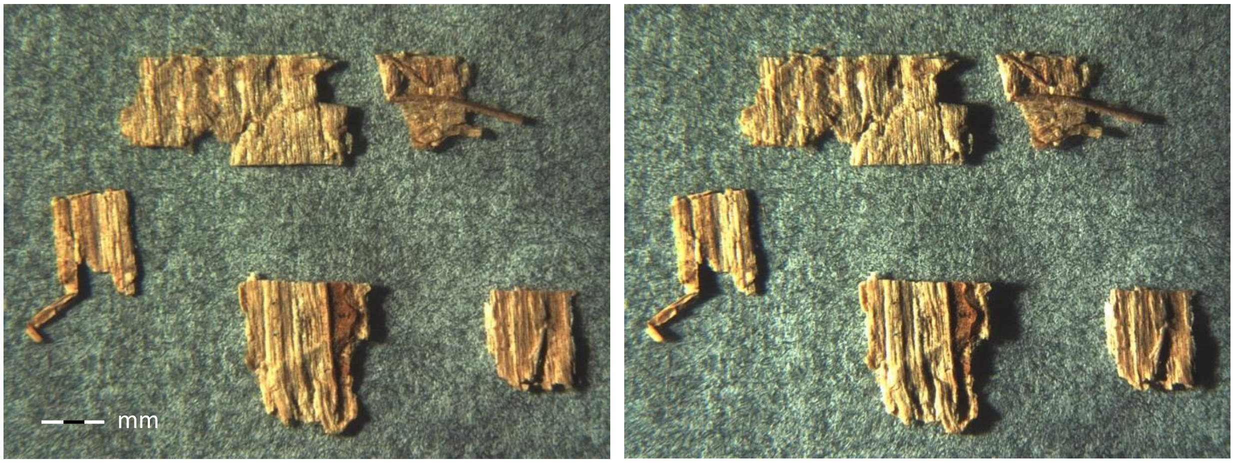

Figure 2: Gospel of Jesus Wife samples received at AMS Lab: normal (l) and raking (r) light. Note possible residue on bottom center fragment. Photos: G. Hodgins 5/31/2013

Figure 3: Identifying fragment locations from web site photographs of GJW, back (l) and front (r), http://www.hds.harvard.edu/sites/hds.harvard.edu/files/images/papyrus_back_lg.jpg, accessed 5/31/2013, http://www.hds.harvard.edu/sites/hds.harvard.edu/files/images/papyrus_front_lg.jpg, accessed 5/31/2013.

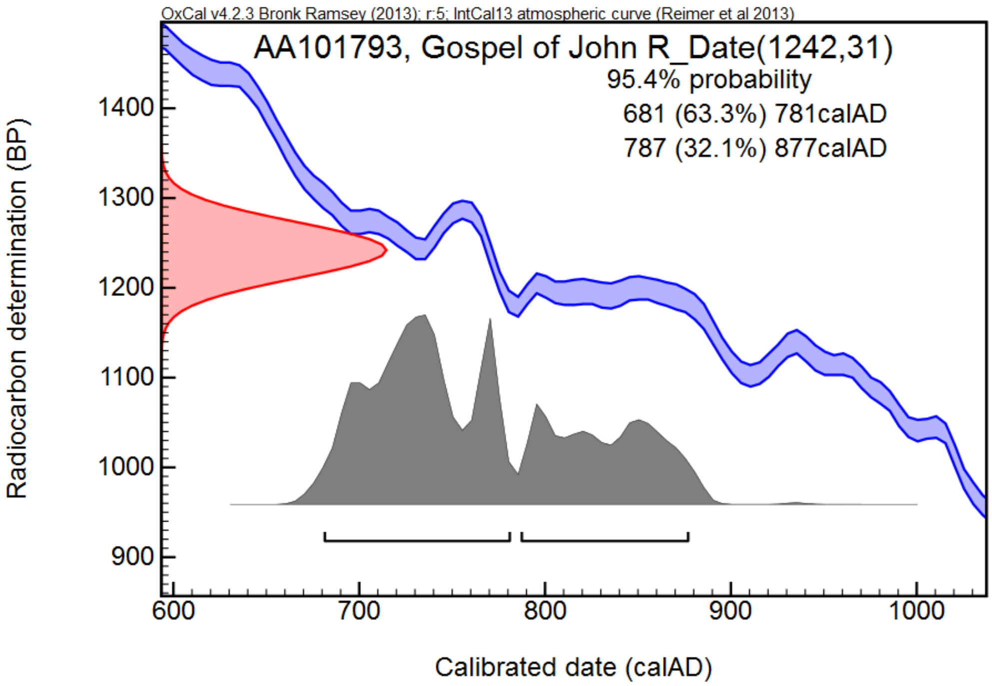

Figure 4: calibration plot for Gospel of John radiocarbon measurement

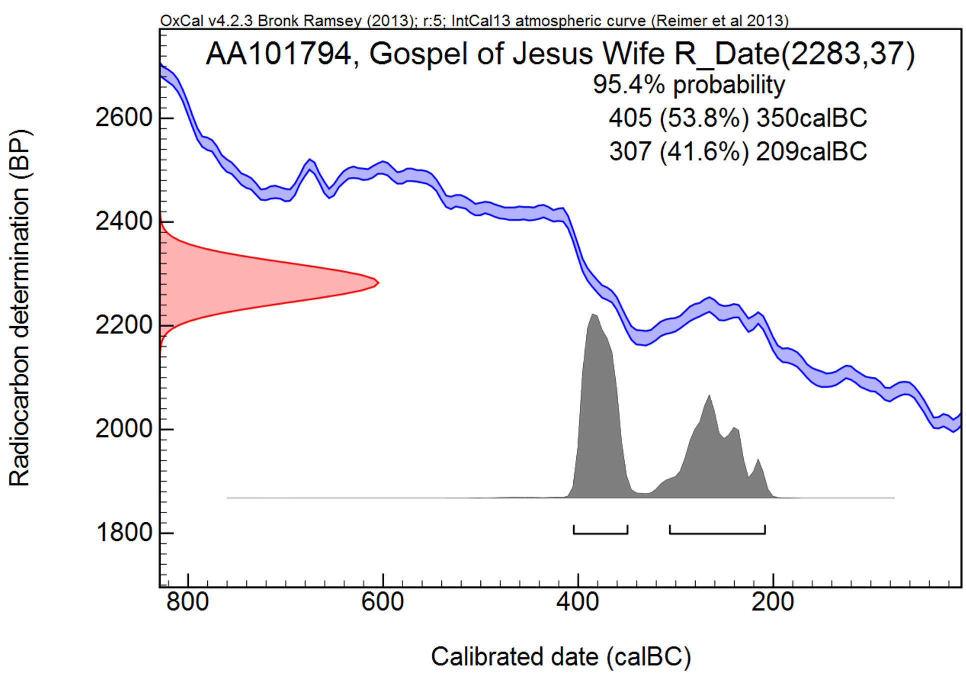

Figure 5: calibration plot for the Gospel of Jesus Wife radiocarbon measurement