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RADIOCARBON DATING OF SCROLLS AND LINEN FRAGMENTS FROM THE JUDEAN DESERT

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ABSTRACT. We report on new ^{14}C measurements of samples of 18 texts (scrolls) and 2 linen fragments from Qumran Caves 1, 2, and 4 and from Naḥal Ḥever, both in the Dead Sea region. The radiocarbon results are in good agreement with estimates of age based on paleography.

INTRODUCTION

Various parchment and papyrus manuscripts found in caves in the area of Qumran and at other sites in the Judean Desert are known generally as the Dead Sea Scrolls. The Qumran scrolls are generally considered to have been hidden by the Qumran Community, identified by most scholars as the Essenes. The documents are usually regarded to have been copied between the mid-third century BC and AD 68, when the Qumran settlement was destroyed by the Romans.

Bonani *et al.* (1991, 1992) dated 14 texts, 8 of which came from Qumran. We present here new radiocarbon dates of 18 texts, including 3 date-bearing texts (3 from Qumran Cave 1, 12 from Cave 4, and 3 from other sites in the Judean Desert). We consider the importance of the ^{14}C dates in relation to other age estimates and we also report on ^{14}C examinations of linen fragments from the Judean Desert.

METHODS

All except three of the scroll samples were taken on 21 and 22 March 1994 by museum staff in the presence of the authors at either the Rockefeller or Israel Museums (see Table 1). Three additional samples (DSS-50, -52 and -53) were taken later at the Shrine of the Book and sent to Tucson for analysis. All samples were taken from ragged edges of top or bottom margins of the scrolls. No samples were taken that would have caused any significant damage to the scrolls themselves. The sizes of the samples are listed in Table 1. Most of the documents from the Judean Desert had been suggested to us by colleagues who had special interests in ^{14}C analysis of particular texts.

Some samples from date-bearing documents were added as control texts (DSS-25, -52 and -53), and the identity and ages of these materials were unknown to the Arizona AMS laboratory at the time of measurement. One control sample had been dated previously at ETH-Zürich in 1990–1991 (DSS-50). The identity of this sample was also unknown to the Arizona laboratory at the time of measurement. Photographic records were made of the exact locations of the pieces subjected to examination. In some cases, scrolls suggested as important for dating had insufficient material available in the margins or the margins were too beautiful to be harmed. These samples were not taken and they account for the missing numbers in the lists (*e.g.,* DSS-2).

Sample Types and Treatment

Small samples of 5–15 mg of material were removed. Samples were studied under a binocular microscope and were divided into three types:

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[2]Shrine of the Book, Israel Museum, Jerusalem 91710 Israel
[3]Dead Sea Scrolls Publication Project, Department of the Bible, Hebrew University, Jerusalem, Israel

TABLE 1. Description and Weights of Dead Sea Scroll Samples and Related Materials

Sample	Q no.	Description	Museum no.*	Weight (mg)
DSS-1	4Q266 (D^a)	Damascus Document, a	706	23.35
DSS-3	1QpHab	Commentary on Habakkuk	Shrine†	31.00
DSS-4	1QS	Community Rule	Shrine	14.20
DSS-5	4Q258	Community Rule, d	140	14.90
DSS-7	4Q171 (pPs^a)	Commentary on Psalms, a	600	11.70
DSS-8	4Q521	Messianic Apocalypse	330	4.90
DSS-9	4Q267 (D^b)	Damascus Document, b	107	7.80
DSS-10	4Q249	Midrash Sepher Moshe	590	6.20
DSS-11	4Q317	Phases of the Moon	899	19.30
DSS-13	4Q208	Astronomical Enoch^a	823	19.20
DSS-19	4Q22	PaleoExodus^m	661	6.75
DSS-19P	4Q22 patch	Patch on 4Q22	661-P	10.70
DSS-22	4Q342	Letter	602	23.70
DSS-23	4Q344	Debt acknowledgment	602	9.56
DSS-24	4Q345	Sale of land	602	14.40
DSS-25	Pap Yadin 21	Papyrus, AD 130	Shrine	5.24
DSS-26	Cave 4	Linen	1041	30.70
DSS-27	Cave 2	Linen	749	21.70
DSS-50	1QIsa^a	Book of Isaiah^a	Shrine	56.50
DSS-52	Kefar Bebayou	Papyrus	Shrine	20.20
DSS-53	Pap Yadin 19	Papyrus, AD 128	Shrine	18.20

*All items derive from the Rockefeller Museum, Jerusalem, unless otherwise indicated.
†Items from the Shrine of the Book, Israel Museum

Type 1. Parchment samples that appeared to be relatively clean

Pieces of *ca.* 2–10 mg were pretreated using procedures based on those reported by Bonani *et al.* (1991, 1992) with some modifications. Samples were washed in ~1N HCl for 10 min, rinsed in distilled water, washed in 0.1% NaOH for up to 10 min, rinsed again in distilled water, and finally re-acidified with HCl, and cleaned with distilled water. Samples were dried in a vacuum oven and were removed as soon as they were dry. We found that some partially gelatinized samples were very easily dissolved by NaOH solutions (as previously reported by Bonani *et al.* 1991 and 1992), and all samples were monitored during this process. Samples that started to dissolve in NaOH were removed from the solution as quickly as possible.

Type 2. Parchment samples with glue contamination

These samples were contaminated with perspex glue, as they had been stuck to rice paper as a backing material. They included DSS-1, -5, -11, -22, -23 and -24. DSS-4 was difficult to clean, as it had been attached to a silk backing material and also appeared to be impregnated with a glue-like material. Pieces of 2–8 mg with adhering glue were washed in acetone in an ultrasonic bath for 30 min. This procedure worked well for most samples, but in the case of two sample pieces (DSS-23 and -24), this process had to be repeated for three hours. The samples were then subjected to the same pretreatment routine as the first batch.

Type 3. Papyri

Papyrus samples (DSS-10, -25, -52, -53) were generally very clean. Pretreatment was carried out easily using the standard methods of Type 1, above.

Dried samples were combusted with CuO to make CO_2 using the standard techniques at Arizona (Donahue, Jull and Toolin 1990). For most samples, sufficient CO_2 sample was available, and a split of up to 0.2 ml was taken for stable-isotope analysis of the $\delta^{13}C$ of the carbon. This parameter is important to make accurate corrections to the ^{14}C age, which are all quoted as normalized to –25‰ (Stuiver and Polach 1977). The remaining CO_2 was converted to graphite using standard procedures. The graphite powder so produced was pressed into an accelerator target holder, and the target was then analyzed by accelerator mass spectrometry (AMS). We loaded 24 sample targets with 8 standard targets (consisting of 4 standard graphites made from NIST HOxI and 4 of HOxII). In most cases, several separate preparations of samples were performed. A general description of the AMS measurements is given by Donahue, Jull and Toolin (1990). ^{14}C results were calculated using the procedures reported by Donahue, Linick and Jull (1990).

Results and Discussion

Written Texts

Table 2 presents the results of the ^{14}C and $\delta^{13}C$ measurements. The results are reported as conventional ^{14}C ages in years before present (AD 1950), with errors on one standard deviation (1 σ), and calibrated ages obtained using both 1-σ and 2-σ confidence intervals, using the calibration of Stuiver and Pearson (1986). For samples with insufficient material for both ^{14}C and $\delta^{13}C$ measurements, an average value of $\delta^{13}C$ was estimated from results of other scrolls, and this value is given in parentheses. Also included in Table 2 are ages determined by paleographic analysis. In Appendix 1, we present further information about the sources of the paleographic age estimates.

The dates reported in Table 2 were obtained in most cases by multiple measurements of several subsamples. All ^{14}C ages were corrected to a $\delta^{13}C$ value of –25‰, from the values indicated (Donahue, Linick and Jull 1990). This small isotope correction is a standard convention of ^{14}C measurements (Stuiver and Polach 1977). The best precisions are *ca.* ± 20 BP. For other samples where larger uncertainties are quoted, the precision was limited either by scatter in the individual measurements, or by the fact that only a few independent measurements were made, due to sample-size limitations. The calibration curve used to obtain the calendar age was the 20-yr average of Stuiver and Pearson (1986), although in some cases we also refer to the 10-yr average curve of Stuiver and Becker (1986). Calculations of probability are quoted for 2-σ ranges, where the calibration program (Stuiver and Reimer 1986) produces two ranges.

With one exception, the dates of the documents determined by the ^{14}C agree well with the dates previously suggested on the basis of paleographical analysis. These results are summarized in Figure 1, which shows the calibrated ^{14}C ages plotted against paleographic age estimates. The calibrated age ranges are derived by applying the ^{14}C age with uncertainties of 2 σ to the calibration curve of Stuiver and Pearson (1986). One exception was the first set of dates on 4Q258 (DSS-5), which was anomalously young and difficult to explain in terms of the expected age of the material. A second and cleaner sample of material was removed for dating. This second sample was subjected to an extensive acetone cleaning as described for Type 2 samples, as well as the acid-base-acid treatment, and gave a ^{14}C age comparable to the paleographic age.

Samples of Known Age

Samples in Table 2 listed as DSS-25, -52 and -53 are all papyri of precisely known age, since they bear written dates. For the two papyri, DSS-25 (pap Yadin 21) and -53 (pap Yadin 19), our results agree within 1 σ with known values. For DSS-52, the 2-σ range of our measurements fails by 10 yr

TABLE 2: Radiocarbon Dates on Dead Sea Scrolls and Related Materials Measured at The University of Arizona

Sample no.	Sample	No. of runs*	$\delta^{13}C$ (‰)†	^{14}C age (yr BP)	Calibrated age	Paleographic age
AA-13415	DSS-1 4Q266	5	−22.1	1954 ± 38	1σ: AD 5–80 2σ: 45 BC–AD 120	100–50 BC
AA-13417	DSS-3 1QpHab	8	−20.8	2054 ± 22	1σ: 104–43 BC 2σ 153–143 BC (3%) 120–5 BC (97%)	30–1 BC
AA-13418	DSS-4 1QS	3	(−21.2)	2041 ± 68	1σ: 159 BC–AD 20 2σ: 346 BC–317 BC (2%) 206 BC–AD 111 (98%)	100–75 BC
AA-13419 (first sample)	DSS-5A 4Q258	5	−22.6	1823 ± 24	1σ: AD 134–230 2σ: AD 119–245	~100 BC
AA-16060 (second sample)	DSS-5B 4Q258	4	−21.4	1964 ± 45	1σ: 11 BC–AD 78 2σ: 95 BC–AD 122	~100 BC
AA-13420	DSS-7 4Q171	7	(−21.2)	1944 ± 23	1σ: AD 22–78 2σ: AD 5–111	
AA-13421	DSS-8 4Q521	4	(−21.2)	1984 ± 33	1σ: 35 BC–AD 59 2σ: 93 BC–AD 80	100–80 BC
AA-13422	DSS-9 4Q267	5	−21.6	2094 ± 29	1σ: 172–98 BC 2σ: 194–45 BC	50–0 BC
AA-13423	DSS-10 4Q249	6	−10.8	2097 ± 50	1σ: 191–90 BC 2σ: 380–354 BC (8%) 242 BC–AD 6 (92%)	
AA-13244	DSS-11 4Q317	4	−20.9	2084 ± 30	1σ: 164–93 BC 2σ: 191–36 BC	
AA-13245	DSS-13 4Q208	9	−21.0	2095 ± 20	1σ: 166–102 BC 2σ: 186–92 BC	~200 BC
AA-13246	DSS-19 4Q22	2	(−21.2)	2044 ± 65	1σ: 159 BC–AD 16 2σ: 207 BC–AD 89	100–25 BC
AA-13426P	DSS-19a 4Q22 Patch	4	(−21.2)	2024 ± 39	1σ: 98 BC–AD 13 2σ: 120 BC–AD 63	50 BC–AD 50
AA-13430	DSS-22 4Q342‡	4	−20.8	1934 ± 47	1σ: AD 14–115 2σ: 43 BC–AD 141	
AA-13431	DSS-23 4Q344‡	3	−20.4	1902 ± 39	1σ: AD 72–127 2σ: AD 26–195	
AA-13432	DSS-24 4Q345	5	−19.7	2185 ± 60	1σ: 373–171 BC 2σ: 390–100 BC	
AA-13433	DSS-25 5/6 Hev 21 (pap Yadin 21)	3	−12.0	1799 ± 57	1σ: AD 130–321 2σ: AD 80–380	AD 130
AA-14984	DSS-50 1QIsa[a]	5	−20.4	2141 ± 32	1σ: 335–122 BC 2σ: 356–291 BC (24%) 250–103 BC (76%)	150–125 BC
AA-14986	DSS-52 Kefar Bebayou	4	−10.0	1758 ± 36	1σ: AD 231–332 2σ: AD 144–370§	AD 135
AA-14987	DSS-53 5/6 Hev 21	4	−10.8	1827 ± 36	1σ: AD 126–234 AD 86–314	AD 128

*The number of independent determinations of ^{14}C age

†Values in parentheses are estimated based on the mean values for Dead Sea Scroll parchments.

‡The documentary texts 4Q342 (letter in Judeo-Aramaic) and 4Q344 (debt acknowledgment) can be dated as late as the Bar-Kokhba period, and such a late date confirms doubts regarding the Qumranic origin of these texts. These fragments, bought from a Bedouin, were probably mixed up with the Qumran fragments by antiquity dealers (M. Broshi).

§The 10-yr average calibration curve of Stuiver and Becker (1986) gave AD 133–386 (2σ) for this sample.

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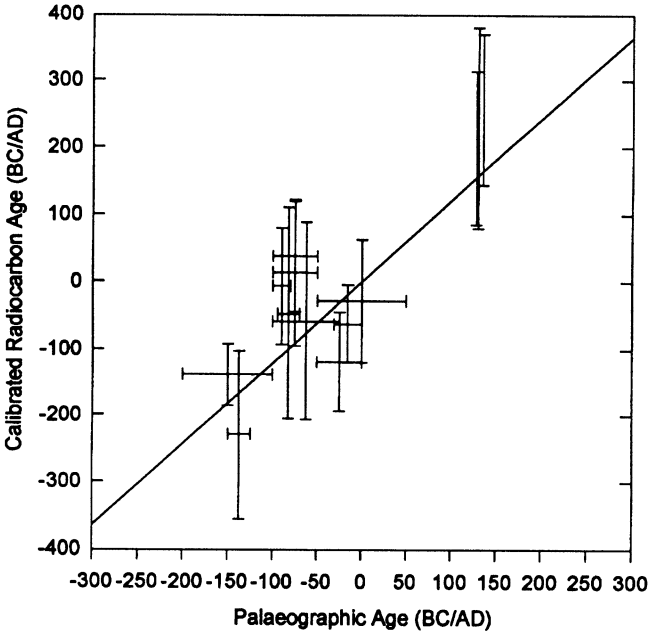

Fig. 1. Calibrated ^{14}C age ranges *vs.* estimated paleographic ages of scroll samples. The calibrated ranges were deduced from measured conventional ^{14}C ages, including 2 σ, using the tree-ring calibration curve of Stuiver and Pearson (1986). The ranges of paleographic estimates were chosen to include the range of the estimates reported in Appendix 1.

to include the known age. Interestingly, if the decadal tree-ring calibration curve of Stuiver and Becker (1986) is used, the 2-σ range of our measurement would be AD 133–386, and would include the known age. For a range produced by using the measured ^{14}C age and 1 σ, the expectation is that there is a 68% probability that the range encompasses the correct age of the document. If 2 σ are used, the probability is 95%. It is also true that, in comparing known ages with a possible range of ages obtained from ^{14}C measurements, the procedures for producing the calibrated age are such that the actual age can fall anywhere within the calculated limits.

Comparison to Zürich ^{14}C Measurements

Sample DSS-50, which had been tested previously at the ETH Zürich Laboratory, was also measured in our study. This sample was taken from the same area of the scroll as the Zürich sample, from column XXXIX of the large Isaiah scroll from Cave 1. The ^{14}C results of Bonani *et al.* (1991, 1992) yielded the result of 2128 ± 38 BP (ETH-6651), which is in excellent agreement with our value, 2141 ± 32 BP (AA-14984). We report the calibrated age range in Table 2. The weighted mean of the two measurements is 2136 ± 24 BP.

Comparison of Results to the Calibration Curve

All of the results discussed are presented graphically in Figure 2. The individual points are obtained by plotting the measured conventional ^{14}C ages of the samples on the ordinate *vs.* the estimated paleographic ages of the samples on the abscissa. The fact that the individual points plot within 2 σ of the calibration curve indicates that the ^{14}C and paleographic ages are in reasonable agreement. It

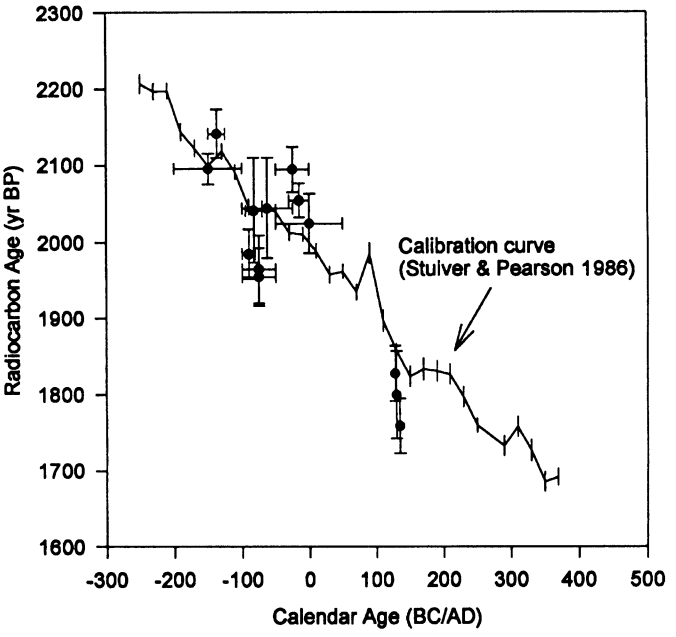

Fig. 2. Conventional ^{14}C age *vs.* calendar age. The solid curve shows the tree-ring calibration curve of Stuiver and Pearson (1986). The ordinate values for the data are conventional ^{14}C ages measured by AMS, as reported in Table 2. The error bars on the ^{14}C ages are 1 σ. The abscissa values for the data are estimates of paleographic age from Appendix 1.

is interesting that the three date-bearing papyri are all of approximately the same age, and there is a tendency for our measured age ranges to be on the younger side of these known ages. It is possible that the calibration curve for AD 135 should be slightly lowered, as its position appears to be determined by a single point in the 20-yr calibration curve (Stuiver and Pearson 1986).

Linen Fragments

Two samples of linen, tested by AMS, yielded results in line with their anticipated dates based on context. These results are presented in Table 3. DSS-26 was a sample of cloth from Qumran Cave 4, to which a leather thong was attached, of the kind used to fasten the scrolls at Qumran (Carswell 1977). Significantly, the ^{14}C date for this sample fell solidly within the dating period established for the scrolls by both paleography and ^{14}C dating. DSS-27, a linen fragment with silk embroidery, was dated to the 12th–13th centuries AD. This sample was bought from antiquity dealers who represented it as material "from Qumran cave 2"; it most probably originated from Wadi Murabba'at,

TABLE 3: Radiocarbon Dates on Linen Fragments from the Judean Desert

Sample no.	Sample identification	No. of runs	$\delta^{13}C$ (‰)	^{14}C age (yr BP)	Calibrated age
AA-13434	DSS-26, linen with leather thong Cave 4, inventory no. 1041	2	−26.5	2069 ± 40	160–41 BC (1σ) 193 BC–AD 11 (2σ)
AA-13435	DSS-27, linen, Cave 2 inventory no. 749	2	−26.3	664 ± 36	AD 1279–1376 (1σ) AD 1270–1392 (2σ)

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where similar textiles were found (Crowfoot and Crowfoot 1961). Descriptions of these fragments are given in Appendix 2.

Conclusion

^{14}C ages of 14 parchment and 4 papyrus samples found in caves in the Judean Desert have been measured by AMS. Measurements on samples of known ages are in good agreement with those known ages. Ages determined from ^{14}C measurements on the remainder of the Dead Sea Scroll samples are in reasonable agreement with paleographic estimates of such ages, in the cases where those estimates are available.

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Appendix 1. Dates suggested for the texts on the basis of paleographical analysis

The information given below for scroll samples includes the Q number, an abbreviated siglum following the name of the scroll, the PAM/Shrine photo number and the assigned paleographical date. The abbreviated sigla referring to the texts from the Judean Desert follow their conventional names. (For the most recent list, see Tov and Pfann (1995).) All photograph numbers are PAM (Palestine Archaeological Museum) numbers unless otherwise indicated.

DSS-1. 4Q266 Damascus document, D^a 43.277 100–50 BC
Comments: "The writing is in a semi-cursive Hasmonean hand which in Cross' paleographic sequence may be dated to the first half of the first century B.C.E." (Baumgarten 1992: 57). "The text is written in a semi-cursive Hasmonean hand which, in Cross's paleographic typology, may be assigned to the beginning of the first century B.C.E." (Baumgarten 1990: 153–165). 75–50 BC (Stegemann 1994: 166).

DSS-3. Commentary on Habakkuk, 1QpHab col. XIII Shrine 7203-4 30–1 BC
Comment: "The manuscript is written in an Early Herodian hand (*ca.* 30–1 B.C.), affecting the Palaeo-Hebrew script in a degenerate form when writing the Tetragrammaton" (Cross 1972: 4; Avigad 1965: 74).

DSS-4. Community Rule, 1QS col. XI Shrine 7111 100–75 BC
Comments: "As we have seen, it belongs to a special semi-formal tradition of the Jewish script, a Hasmonean exemplar of this style from about 100–75 B.C." (Cross 1972: 4). "[A] date somewhat later than $1QIsa^a$ is to be preferred" (Avigad 1965: 71).

DSS-5. 4Q258 Community Rule, S^d 43.244 Beginning of 1st century BC
Comment: "The script of the oldest copy is dated by F. M. Cross to the beginning of the first Century B.C." (Vermes 1991: 250; Cross 1956: 61).

DSS-7. 4Q171 pPsa 41.303

DSS-8. 4Q521 Mess. Apoc. 43.604 100–80 BC
Comment: "Cette écriture se placerait assez bien après celle de 1QIsa et 1QS, dans le premier quart de 1^{er} s., entre 100 et 80, plus ou moins contemporaire de SiraMas, mais après $4QDt^c$" (Puech 1992: 480). (This text is the focus of much debate in research, in particular with regard to its possible connection with early Christianity.)

DSS-9. 4Q267 Damascus Document, D[b] 43.294 Latter part of 1st century BC
Comment: "[A] formal hand of the latter part of the first Century B.C.E." (Baumgarten 1992: 60).

DSS-10. 4Q249 pap Midrash Sefer Moshe 43.409

DSS-11. 4Q317 Phases of the Moon 42.424

DSS-13. 4Q208 Astronomical Enoch, Enastr[a] ar 43.210 End 3rd/beginning 2nd century BC
Comment: "The handwriting of Enastr[a] is rather unusual, but fairly archaic; it resembles 'an archaic or early Hasmonaean semi-formal script of *ca.* 175–125 B.C.' (Cross [1961], p. 137, fig. I, line 6; cf. ibid., line 7 and p. 138, fig. 2, line I). It seems to me, however, to be older than the alphabets discussed by Cross, and to be related, by many a detail, to the writings of fig. I, lines 2–5. As a result I would date 4QEnastr[a] to the end of the third century or else the beginning of the second Century B.C." (Milik 1976: 273)

DSS-19. 4Q22 paleoExodus, paleoExod[m] 42.582 100–25 BC
Comment: "[MacLean] has dated this scroll along with 4QpaleoGen-Exod[l] . . . and 4Q124 . . . within the period 100–50 or 100–25 BC, with this qualification: 'Of these three contemporary manuscripts, I believe 4QpaleoExod[m] to display the latest features and the greatest number of novel features which will see subsequent development' (MacLean [1982], 78). On the basis of the extensive nature of MacLean's study, as well as Cross's endorsement of his conclusions, we accept his dating" (Skehan, Ulrich and Sanderson 1992: 62).

DSS-19a. 4Q22 paleoExod[m] col. VIII (patch) 42.648 50 BC–AD 50
Comment: Skehan, Ulrich and Sanderson (1992: 85) state that "a patch was sewn from behind the leather to repair damage suffered by the MS after it had been inscribed." The patch thus had to be later than the manuscript itself; E. Ulrich (personal communication, 1995) dates it to 50 BC–AD 50.

DSS-25. 5/6Ḫev 21 (pap Yadin 21) purchase of crop in Greek Shrine 5195 11 September AD 130
(Lewis 1989: pl. 26)

DSS-50. Book of Isaiah, 1QIsa[a] col. XXXIX Shrine 7039 150–125 BC
Comments: "[T]he old Isaiah scroll . . . dates to c. 150–125 B.C.E." (Cross 1992: 5). "A date somewhere in the second half of the second century B.C.E. for Isa[a], somewhat later than Nash, seems to be most reasonable and in keeping with the opinion of most scholars" (Avigad 1965: 69).

DSS-52. XḪev /Se 8a pap sale of a house, Kefar Bebayou 40.996 AD 135
(Milik 1957; 1959: 138 and p. 25)

DSS-53. 5/6Ḫev 19 (pap Yadin 19) deed of gift Shrine 5185 16 April AD 128
(Lewis 1989: 83–87 and pl. 20)

Appendix 2. Linen Fragments

Description by A. Baginski, Israel Antiquities Authority, Jerusalem.

DSS-26. Linen fragment with leather thong attached from Qumran Cave 4
Size: 3.0 × 2.5 cm. Warp: linen, cream S M 12/cm. Weft: linen, cream S M 12/cm. Technique: balanced tabby sewing threads: linen Z_2 S. Description: small triangular linen fragment, on one side remains of a rolled hem. A leather strip is sewn to one corner (0.7 × 4.0 cm). The same box contains another small fragment of the leather thong (0.6 × 2.7 cm) and a larger square piece of leather which is folded and has two slits (2.7 × 3.0 cm), through which the thong was probably inserted. The linen fragment is very similar to some textiles from Qumran Cave 1; the leather thong and pieces are similar to those exhibited currently in the Israel Museum (Carswell 1977: 23–28; Crowfoot 1955: 37 no. 56, 38 no. 77, pl VII no. 26; Sussmann and Peled 1993: 114–115; Sheffer and Granger-Taylor 1994: 176 no. 102[A]).

DSS-27. Linen fragment with remains of silk embroidery from Qumran Cave 2
Size: 6.0 × 4.5 cm. Warp: linen, cream Z M 18/cm. Weft: linen, cream Z M 18/cm. Technique: balanced tabby weave. Decoration: embroidered, silk I, buff, darning stitches. Description: worn linen fragment with weaving faults; remains of silk embroidery, possibly of geometric pattern, but unrecognizable due to poor preservation. Fragment is most likely medieval or originating from Wadi Muraba'at, where similar textiles were found (Crowfoot and Crowfoot 1961: 51–63, pl. XVII no. 2; Lamm 1937: 65–76; Makie 1989: 81–101).