

THE SCIENCES AND
THE RECONSTRUCTION OF THE ANCIENT SCROLLS:
POSSIBILITIES AND IMPOSSIBILITIES

EMANUEL TOV
The Hebrew University of Jerusalem

The study of the Qumran scrolls is the study of fragments and sheets rather than that of complete scrolls. For example, 4QJer^a consists of fifty fragments covering parts, sometimes very minute, of sixteen chapters. 4Q509 consists of 313 fragments, and 4QSam^a has 346 fragments covering parts of fifty chapters. I have no idea how many fragments altogether have been found in the Qumran caves, but it must be a large number. Some scholars speak of 15,000 fragments for cave 4 alone,¹ while others estimate the total number of fragments as 10,000² or as many as 100,000.³ If we set the *average* number of fragments per scroll randomly at forty, we are dealing with 37,000 fragments covering 930 fragmentary scrolls. The actual number will remain unknown unless one dedicates many weeks to counting.

When dealing with a topic like the sciences and the ancient scrolls, scientists often forget that these fragments are parts, however minute, of once complete sheets, and that each medium-sized scroll consisted of a number of sheets. A fragment does not constitute an independent unit for a material investigation, since the information about fragments needs to be supplemented by that in other fragments deriving from the same sheet. Each sheet forms an independent unit, not necessarily of the same nature as the sheet that is now stitched to it. Therefore, in the material analysis of the fragments it is necessary to know more about each sheet or the scroll as a whole. The scroll is the overriding unit, but since many scrolls are composed of different sheets, we have to base our remarks on these sheets. Single-column sheets like 4QTest

¹ R. de Vaux, quoted by P. Benoit in *DJD* VI (1977): v.

² Thus S.R. Woodward et al., "Analysis of Parchment Fragments from the Judean Desert Using DNA Techniques," in *Current Research and Technological Developments in the Dead Sea Scrolls—Conference on the Texts from the Judean Desert, Jerusalem, 30 April 1995* (ed. D.W. Parry and S.D. Ricks; STDJ 20; Leiden: Brill, 1996), 215–238 (222).

³ J.T. Milik, oral communication.

(4Q175) and single-sheet scrolls are rare in Qumran. Most scrolls are composed of a number of sheets, seventeen in the case of the large Isaiah scroll.

Over the past five decades, the sciences have come to our aid in examining several material aspects of scroll fragments, their coverings, stitching material, etc. The first such study was that included in *DJD* I (1955), viz., examinations by Crowfoot of the linen textiles, some of which must have covered scrolls.⁴ Further, according to investigations made in 1958 and the early 1960s by Ryder on the one hand and Poole and Reed on the other,⁵ the leather scrolls found at Qumran were made mainly from skins of sheep and goats.⁶ A more detailed study of the scroll material mentioned the following four species: calf, fine-wooled sheep, medium-wooled sheep, and a hairy animal that was either a sheep or a goat.⁷

There are many ways in which the sciences helped or *could* help us to gain a better understanding of the scroll fragments and aid us in their reconstruction. The main areas are: (1) determining the date of the scrolls (based on the age of the leather and ink [?]), (2) determining whether fragments derive from the same sheet (Carbon-14, DNA research, the chemical composition of the leather and ink; follicle patterns in leather, and fibers in papyrus), (3) retrieving previously unreadable letters with the aid of advanced photographic techniques, (4) and identifying fragments and determining the relation between fragments with the aid of computer-assisted research. At the same time, we should also be able to determine where these sciences are *unable* to help us.⁸

⁴ G.M. Crowfoot in *DJD* I (1955): 18–38. The tests themselves were carried out under the direction of W.F. Libby at the University of Chicago in 1950.

⁵ M.L. Ryder, “Follicle Arrangement in Skin from Wild Sheep, Primitive Domestic Sheep and in Parchment,” *Nature* 182 (1958): 1–6; J. Poole and R. Reed, “The Preparation of Leather and Parchment by the Dead Sea Scrolls Community,” *Technology and Culture* 3 (1962): 1–26; repr. in *Technology and Culture: An Anthology* (ed. M. Kranzberg and W.H. Davenport; New York: Schocken, 1972), 143–168; idem, “A Study of Some Dead Sea Scrolls and Leather Fragments from Cave 4 at Qumran: Part I, Physical Examination; Part II, Chemical Examination,” *Proceedings of the Leeds Philosophical and Literary Society, Scientific Section* 9/1 (1962): 1–13; 9/6 (1964): 171–182.

⁶ *Ibid.*, “Part I, Physical Examination,” 1–13, especially 8.

⁷ M.L. Ryder, “Remains Derived from Skin,” in *Science in Archaeology: A Comprehensive Survey of Progress and Research* (ed. D. Brothwell and E.S. Higgs; London: Thames & Hudson, 1963), 539–554.

⁸ For an earlier survey, see M. Broshi, “The Dead Sea Scrolls, the Sciences and New Technologies,” *DSD* 11 (2004): 133–142.

This study refers solely to the scientific examination of the fragments, and not to the identification and reconstruction on the basis of content. Further, it refers only to scientific aid in the reconstruction and understanding of the scrolls, and not to the contribution of these examinations to the archeology of Qumran or the understanding of life at Qumran. Thus, we do not deal with ground-penetrating radar locating caves, examination of parasites in combs, Qumran skeletons, or pottery, nor do we deal with the study of metals, wood, glass, etc. The latter list of examinations is very important for many aspects of Qumran archeology and Qumran research, and sometimes also of scroll research, but does not contribute directly to the reading and reconstruction of scroll fragments, which is our immediate aim.

Over the past four decades, many types of scientific investigation have been carried out, providing help for the research of the scrolls.

This paper focuses on the following areas:

1. Topics examined and results reached with the aid of the sciences
2. Some technical data about the scrolls
3. Scientific aid in the reconstruction of ancient scrolls: possibilities and impossibilities.

1. TOPICS EXAMINED AND RESULTS REACHED WITH THE AID OF THE SCIENCES

Individual scholars as well as groups of scholars⁹ advanced the scientific investigation of the scrolls in individual and collective publications dealing with the sciences.¹⁰ Progress has been made in the following areas.

⁹ Note especially the Jerusalem “Taskforce for science and the scrolls” on behalf of the Orion Center at the Hebrew University.

¹⁰ Parry and Ricks, *Current Research*; J.-B. Humbert and J. Gunneweg, eds., *Khirbet Qumrân et ‘Ain Feshkha: Études d’anthropologie, de physique et de chimie* (NTOA.SA 3; Fribourg: Academic Press, 2003); K. Galor, J.-B. Humbert, and J. Zangenberg, eds., *Qumran, the Site of the Dead Sea Scrolls: Archaeological Interpretations and Debates: Proceedings of a Conference Held at Brown University, November 17–19, 2002* (STD) 57; Leiden: Brill, 2006); J. Gunneweg, C. Greenblatt, and A. Adriaens, eds., *Bio- and Material Cultures at Qumran: Papers from a COST Action G8 Working Group Meeting Held in Jerusalem, Israel on 22–23 May 2005* (Stuttgart: Fraunhofer IRB, 2006).

a. *Dating the Scrolls*(1) *Carbon-14*

The first system used for dating scrolls was that of *paleography* (dating on the basis of the type of handwriting), and this is still our major resource for dating.¹¹ At the same time, at an early stage in the study of the scrolls, C-14 examinations¹² of the leather and papyrus fragments became instrumental in determining their dates,¹³ usually corroborating paleographical dating.¹⁴ These examinations have been applied only to a small number of scrolls.¹⁵

The paleographical dates applied to the documents range from the fourth century B.C.E. to the first century C.E. for the Jericho documents, from 250 B.C.E. to 68 C.E. for the Qumran texts, from 150 B.C.E. to 70 C.E. for the Masada texts, and from 75 B.C.E. to 135 C.E. for the texts from Wadi Murabba'at, Naḥal Ḥever, and Naḥal Şeelim.

¹¹ For a summary of the paleographical dates given to the scrolls, see B. Webster, "Chronological Index of the Texts from the Judaean Desert," in *DJD XXXIX* (2002): 351–446.

¹² C-14 analysis is based on the fact that the animal hides contained carbon-14 atoms when the animal was alive, and that the number of these atoms decreased at a measurable rate after its death, when they became carbon-12 atoms, all compared with the C-14 atoms in tree rings.

¹³ The best non-technical explanation of C-14 is probably by G. Doudna, "Dating the Scrolls on the Basis of Radiocarbon Analysis," in *The Dead Sea Scrolls after Fifty Years: A Comprehensive Assessment* (ed. P.W. Flint and J.C. VanderKam; 2 vols.; Leiden: Brill, 1998–1999), 1:430–471. See also *Methods of Investigation of the Dead Sea Scrolls and the Khirbet Qumran Site: Present Realities and Future Prospects* (ed. M.O. Wise et al.; Annals of the New York Academy of Sciences 722; New York: New York Academy of Sciences, 1994), 441–453 ("Report and Discussion Concerning Radiocarbon Dating of Fourteen Dead Sea Scrolls").

¹⁴ For comparative tables recording the paleographical and C-14 data, see Webster, "Chronological Index" (362–368). 1QIsa^a was tested in the laboratories of Zurich and Tucson with similar results (see n. 15).

¹⁵ The report of the first C-14 tests (14 texts) carried out in Zurich is that of G. Bonani et al., "Radiocarbon Dating of the Dead Sea Scrolls," *Atiqot* 20 (1991): 27–32 = *Radiocarbon* 34 (1992): 843–849. The second group of carbon-tests was carried out on 28 texts, of which one (1QIsa^a) had also been sampled by Bonani et al.: A.J.T. Jull et al., "Radiocarbon Dating of Scrolls and Linen Fragments from the Judean Desert," *Radiocarbon* 37 (1995): 11–19 = *Atiqot* 28 (1996): 85–91. Some individual texts were examined as well: M. Broshi and H. Eshel, "Radiocarbon Dating and 'The Messiah Before Jesus,'" *RevQ* 20 (2001): 310–317 (4Q427 and 4Q491) = *Tarbiz* 70 (2001): 133–138; J. Charlesworth in his publications of XJoshua (MS Schøyen 2713) in *DJD XXXVIII* (2000): 231–239 and XJudges (MS Schøyen 2861) in *DJD XXVIII* (2001): 231–233.

With the aid of a C-14 test, 1QIsa^a was dated to between 250 and 103 B.C.E. (paleographical date: 125–100 B.C.E.)¹⁶ and 11QT^a between 97 B.C.E. and 1 C.E. (paleographical date: late first century B.C.E. to early first century C.E.).¹⁷ However, there are also a few texts for which the paleographical and C-14 dates differ greatly. This pertains to 4QTQahat, C-14 dated to 385–349 B.C.E. This date is earlier than the dates of all other Qumran scrolls.¹⁸ By the same token, one of the fragments of 4QS^d (4Q258) dated to 134–230 C.E. at the one-sigma range, after the destruction of Qumran, is later than expected.¹⁹ Some scholars ascribe the deviating dates of these documents—either too early or too late according to the common view about Qumran—to the applying of castor oil to the leather in the 1950s in order to improve the clarity of the written text.²⁰ This claim is made especially by G. Doudna; Doudna's own view is that all the scrolls date from the period before 40 B.C.E.²¹ On the other hand, according to Broshi, the possible influence of such

¹⁶ Jull et al., "Radiocarbon Dating"; Bonani et al., "Radiocarbon Dating": 202–107 B.C.E.

¹⁷ Ibid.

¹⁸ Ibid. The fragment was probably contaminated, offsetting the precision of the C-14 analysis.

¹⁹ Jull et al., "Radiocarbon Dating." Another fragment of the same scroll was dated to 11 B.C.E.–78 C.E.

²⁰ See J. Strugnell, "On the History of the Photographing of the Discoveries in the Judean Desert for the International Group of Editors," in E. Tov with the collaboration of S.J. Pfann, *Companion Volume to The Dead Sea Scrolls Microfiche Edition* (2nd rev. ed.; Leiden: Brill, 1995), 125: "Next came some cleaning of the darker patches with oil, to bring out the writing—something chemically harmless, I am told, but some of us used it too generously in the early days."

²¹ "Dating the Scrolls on the Basis of Radiocarbon Analysis," 430–465; idem, *Redating the Dead Sea Scrolls Found at Qumran* (QC 8.4; Cracow: Enigma Press, 1999); idem, "The Legacy of an Error in Archaeological Interpretation: The Dating of the Qumran Cave Scroll Deposits," in Galor, Humbert, and Zangenberg, *Qumran, the Site of the Dead Sea Scrolls*, 147–157. See also K.L. Rasmussen et al., "Cleaning and Radiocarbon Dating of Material from Khirbet Qumran," in Gunneweg, Greenblatt, and Adriaens, *Bio- and Material Cultures*, 139–163; idem et al., "The Effects of Possible Contamination on the Radiocarbon Dating of the Dead Sea Scrolls I: Castor Oil," *Radiocarbon* 43 (2001): 127–132 (note that the great majority of the samples taken are not from parchments); R. van der Water, "Reconsidering Palaeographic and Radiocarbon Dating of the Dead Sea Scrolls," *RevQ* 19 (1999–2000): 213–216; J. Atwill and S. Braunheim, "Redating the Radiocarbon Dating of the Dead Sea Scrolls," *DSD* 11 (2004): 143–157; see also the reactions to this paper by J. van der Plicht, "Radiocarbon Dating and the Dead Sea Scrolls: A Comment on 'Redating,'" *DSD* 14 (2007): 77–89; T. Higham, J.E. Taylor, and D. Green, "New Radiocarbon Determination," in Humbert and Gunneweg, *Khirbet Qumrân*, 197–200; S. Pfann, "Relative Agreement and Systematic Error of Radiocarbon Tests Applied to the Dead Sea Scrolls," *Radiocarbon*, forthcoming.

oil is negligible.²² The last word has not been said on this issue, and the presence of castor oil on the margins of the leather (from which samples were taken) as opposed to the inscribed surface itself, has yet to be proven. This discussion is important, since C-14 examinations are very significant for scroll research. A. Masic has developed a new technique to identify such oil.²³

(2) *Ink Research*

So far ink has not been dated.

(3) *Parchment Shrinkage*

In a little-known study, Burton, Poole, and Reed suggested dating the scroll fragments according to the pattern of the shrinkage temperature of the collagen fibers in the leather (1959).²⁴ To the best of my knowledge, this method has not been applied to the Qumran fragments.

b. *Relation between Fragments*

When reconstructing scrolls there are many unknowns. The question of whether two or more fragments should be joined as adjacent fragments or designated as belonging to the same column or sheet, remains a major issue in scrolls research. Information about the content is usually insufficient in fragmentary scrolls. The analysis of script is often equally unsatisfying when analyzing small fragments. We would appreciate some help from the sciences in either linking fragments or excluding such a connection, but such help is still being developed. In short, we would like to have objective criteria for making a connection between any two fragments or excluding such a possibility. The first steps in exploring some possibilities have been made, but scholars are in need of a database incorporating

²² Broshi, "The Dead Sea Scrolls," 135: "To 16 of the 34 samples no castor oil was applied; in the other, samples were taken from margins never touched by castor oil. Even if there were traces of oil they would have been eliminated by the pre-treatment." See also I. Carmi, "Are the 14C Dates of the Dead Sea Scrolls Affected by Castor Oil Contamination," *Radiocarbon* 44 (2002): 127-132.

²³ "Dead Sea Scrolls: Non-Invasive Characterisation of Conservation Treatment Materials by Means of IR-ERS," in *Israeli-Italian Bi-national Workshop*, Ramat-Gan, 2007 (unpublished in the meantime).

²⁴ D. Burton, J.B. Poole, and R. Reed, "A New Approach to the Dating of the Dead Sea Scrolls," *Nature* 184 (1959): 533-534.

alternative scientific data referring to a large number of fragments. The techniques that come to mind relating to the possible joining of fragments are DNA research, ink research, research of leather follicles and papyrus fibers, and elemental composition analysis. However, it should be remembered that these examinations can only determine whether or not two fragments belong to the same sheet. A fragment is not a unit. The real unit is the sheet, because the information gathered by the aforementioned examinations pertains to the sheet as a whole. This examination is further complicated by the fact that skins of different animals were used as writing material for one scroll (see below). To the best of my knowledge, all these techniques would produce the same results for fragments taken from any part of the sheet (C-14, DNA, research of leather follicles, ink research²⁵), with the exception of the examination of fibers in papyri, a technique that is not yet developed.

In all these cases, the sciences may help us in determining whether a frg. a and frg. b derive from the same sheet or of the same animal, no more and no less. If they derived from the same sheet, the exact relation between these fragments cannot be determined with the aid of the sciences. Since the fragments could be three columns apart, multiple possibilities should be envisaged. Furthermore, if two completely different compositions were written on skins deriving from the same animal, wrong conclusions could be drawn if we were to be guided solely by the scientific examinations.

(1) DNA

DNA research of ancient texts is still in its infancy. Scholars have succeeded in extracting aDNA (ancient DNA) from ancient sources such as mummies, scrolls, and ancient animal bones. The main research in this area was carried out by Kahila Bar-Gal in her Hebrew University dissertation supervised by P. Smith, E. Tchernov, and S. Woodward.²⁶ The technique has been applied to fragments of several scrolls

²⁵ The results of ink research, as yet unexplored, would be less compelling, since two different scribes could have used the same ink in different compositions.

²⁶ "Genetic Change in the *Capra* Species of Southern Levant over the Past 10,000 Years as Studied by DNA Analysis of Ancient and Modern Populations" (Ph.D. diss., The Hebrew University of Jerusalem, 2000). See further Kahila Bar-Gal's paper "What Can Fragments of the Dead Sea Scrolls Teach Us of Ancient Animal Husbandry?" (abstract of paper presented at the Symposium on the Role of Analytical Methods in the Study, Restoration, and Conservation of Ancient Manuscripts, with Emphasis on the Dead

that have been mentioned by name: 4QS^b (4Q256), 4QS^d (4Q258), 4QS^e (4Q259), 4QIsa^a (4Q161), 11QT^a (fragments from six different sheets as well as stitching material)²⁷ together with a host of uninscribed fragments from caves 3 and 4. Examinations of 1QH^a and 4QpHos^b (4Q167) did not yield DNA.²⁸ The techniques used were described by Woodward.²⁹

This type of investigation can (1) determine the species of animal from which the leather derived, (2) distinguish between the DNA signature of individual animals, and (3) determine groups of animals (herds) from which the hides derived.³⁰ Ideally, these herds should be linked with bones of individual animals or herds, ancient or modern, since the DNA signature has not changed from antiquity to modern times. These links between hides and herds have hardly been made,³¹ and researchers are still waiting for the construction of databases that link specific fragments and bones.

(2) Ink Research

The study of the composition of ink could give us some clues regarding the relationship between scroll fragments. So far, ink has not been dated but its composition has been analyzed, to a limited extent, by Nir-El

Sea Scrolls, Prague, 14 April 1999; online: <http://orion.mscc.huji.ac.il/orion/programs/taskforce.shtml>); eadem et al., "The Genetic Signature of the Dead Sea Scrolls," in *Historical Perspectives: From the Hasmoneans to Bar Kokhba in Light of the Dead Sea Scrolls: Proceedings of the Fourth International Symposium of the Orion Center for the Study of the Dead Sea Scrolls and Associated Literature, 27–31 January 1999* (ed. D. Goodblatt, A. Pinnick, and D.R. Schwartz; STDJ 37; Leiden: Brill, 2001) 165–171.

²⁷ More precise data on the texts sampled are listed in Bar-Gal, "Genetic Change," 70.

²⁸ As implied by the discussion of the results *ibid.*, 71–76.

²⁹ Woodward et al., "Analysis of Parchment Fragments"; *idem* in D.W. Parry et al., "New Technological Advances: DNA, Databases, Imaging Radar," in *The Dead Sea Scrolls after Fifty Years*, 1:496–515; *idem*, "DNA Analysis of Ancient Parchment" (abstract of paper presented at the Symposium on the Role of Analytical Methods in the Study, Restoration, and Conservation of Ancient Manuscripts, with Emphasis on the Dead Sea Scrolls, Prague, 14 April 1999; online: <http://orion.mscc.huji.ac.il/orion/programs/taskforce.shtml>).

³⁰ See the summary by Woodward et al., "Analysis of Parchment Fragments," 216: "The precision of the DNA analysis will allow us to identify at least three levels of hierarchy: the species, population, and individual animal from which the parchment was produced."

³¹ Thus Bar-Gal, "Genetic Change," 75, noting that the Qumran bones cannot be traced. The existence of such bones, including those of goats, is mentioned in Y. Magen and Y. Peleg, "The Qumran Excavations 1993–2004, Preliminary Report," *Judea and Samaria Publications* 6 (2007): 1–74 (42–43).

and Broshi³² (pertaining to both inscribed papyrus and leather) and a German research group (I. Rabin, O. Hahn et al.).³³ On the basis of examinations carried out in 1995 at the Soreq Nuclear Research Centre on fragments from caves 1 and 4, Nir-El and Broshi concluded that no metal ink was used in writing the Qumran scrolls under investigation.³⁴ The examinations were made with the EDXRF (Energy Dispersive X-Ray Fluorescence) procedure. These scholars assumed that the copper elements in the ink derived from copper inkwells used by scribes, and that the ink used was carbon-based.³⁵ A similar suggestion had been made earlier by H.J. Plenderleith,³⁶ Steckoll (see n. 32), and Haran,³⁷ mainly for the texts from cave 1.

In the future, study of the components of ink may help us to pinpoint different types of ink. Rabin believes that a basic distinction can be made between ink prepared at Qumran and ink prepared elsewhere because of an analysis of the water component in ink.³⁸ In particular, she points out that the chlorium/bromium ratio is lower in places near

³² Y. Nir-El and M. Broshi, "The Black Ink of the Qumran Scrolls," *DSD* 3 (1996): 157–167. For earlier studies, see among others S.H. Steckoll, "Investigations of the Inks Used in Writing the Dead Sea Scrolls," *Nature* 220 (1968): 91–92. Other examinations are mentioned by Nir-El and Broshi. See also the discussion in my *Scribal Practices and Approaches Reflected in the Texts Found in the Judean Desert* (STDJ 54; Leiden: Brill, 2004), 53–55.

³³ See the summary by I. Rabin et al., "Characterization of the Writing Media of the Dead Sea Scrolls," in *Holistic Qumran: Trans-disciplinary Research of Qumran and the Dead Sea Scrolls* (ed. J. Gunnweg, A. Adriaens, and J. Dik; STDJ 87; Leiden: Brill, 2010), 123–134. The techniques used are micro X-ray fluorescence, FT-IR spectroscopy, mass spectrometry, and scanning electron microscopy. See also O. Hahn et al., "Non-destructive Investigation of the Scroll Material: 4QComposition Concerning Divine Providence (4Q413)," *DSD* 15 (2007): 359–364 (described below).

³⁴ The sources sampled are listed in Nir-El and Broshi, "Black Ink," 157 n. 1. See further Y. Nir-El, "מקורו של הצבען בדיו שחורה בכתיבת ספרים, תפילין ומוזות," *Sinai* 57 (1993–1994): 261–268 (Hebrew).

³⁵ On the other hand, according to the editors of 4QpaleoExod^m, the ink used in that manuscript contained iron: P.W. Skehan, E. Ulrich, and J.E. Sanderson in *DJD* IX (1992): 18.

³⁶ "Technical Note on Unwrapping of Dead Sea Scroll Fragments," in *DJD* I (1955): 39.

³⁷ M. Haran, "Scribal Workmanship in Biblical Times: The Scrolls and Writing Implements," *Tarbiz* 50 (1980–1981): 65–87 (81–84) (Hebrew with English summary). According to Haran, metal-based ink was used only from the second century C.E. onwards.

³⁸ I. Rabin et al., "Non-Destructive Methods in the Study of the Dead Sea Scrolls" (paper presented at the Israeli-Italian Bi-national Workshop on Materials, Time, and Stability: Applications in Archaeology and Conservation, Bar-Ilan University, Ramat-Gan, 2007). Thanks are due to the author for showing me the material ahead of its publication.

the Dead Sea than in other localities. Studies like this could help us differentiate between groups of scrolls penned at different locations, even if the locations themselves cannot be named. Other areas of investigation are the ink of corrections in the text as opposed to that of the main text as well as possible distinctions between the scrolls found in the different caves.

(3) *Elemental Composition Analysis*

A study by Hahn et al. based on the contaminants present in the parchment and ink showed how two fragments cannot have belonged to the same sheet.³⁹ According to these scholars, “Scroll and ink are organic materials, consisting mainly of carbon, hydrogen, oxygen and nitrogen. In addition to these main elements a variety of contaminants are found. Their kind, type and quantity depend on the details of the preparation process and storage conditions. For example, minerals dissolved in the water used for the preparation of the scroll material and inks are a source of a specific contamination that would normally be distributed evenly throughout the material. On the other hand, the contaminants deposited on a scroll surface, due to its storage, (e.g., on the floor of a cave), would be mainly restricted to the surface areas and more likely to appear as patches.” This examination makes use of a micro X-ray fluorescence spectrometer (XRF) as well as a micro-focus confocal XRF. The authors use this approach in an examination of two small fragments published as 4Q413 that belong to the top of the same column of a sheet.⁴⁰ They were separated and renamed 4Q413 and 4Q413a by T. Elgvin on the basis of paleography and microscopic parchment analysis.⁴¹ Elgvin’s microscopic analysis showed that the surface of 4Q413a “is more scraped than that of 4Q413, so that the hair structure is not visible, while it is clearly seen on 4Q413.” The *elemental composition analysis* of the leather and ink executed by Hahn et al. now confirmed these findings, demonstrating that the two fragments could not have belonged to the same sheet.⁴² This type of analysis may well be better

³⁹ O. Hahn et al., “Non-Destructive Investigation of the Scroll Material: 4QComposition Concerning Divine Providence (4Q413),” *DSD* 15 (2007): 359–364.

⁴⁰ E. Qimron in *DJD XX* (1997): 169–171.

⁴¹ T. Elgvin, “4Q413—A Hymn and a Wisdom Instruction,” in *Emanuel: Studies in Hebrew Bible, Septuagint, and Dead Sea Scrolls in Honor of Emanuel Tov* (ed. S.M. Paul et al.; VTSup 94; Leiden: Brill, 2003) 205–214.

⁴² Hahn et al., “Non-Destructive Investigation.”

suited for negative than positive conclusions, but the authors do not say this in their paper. In any event, a similar approach followed by Rabin et al. in the study mentioned in n. 38 provides much promise for positive results. These authors study the composition analysis of the surface and inner layers of the leather, and we wait for more specific results.

Scribes probably prepared their own ink. It is not known whether ink prepared from the same components deposited in different inkwells would produce a different type of chemical signature. On the whole, the identification of scribes or compositions on the basis of the ink used has not even begun.

(4) *Stitching Material*

Sheets in parchment scrolls were joined with different stitching materials. DNA and C-14 analysis of the stitching materials may aid us in understanding the background of the different scrolls. So far, one such examination has been carried out (see n. 46).

According to rabbinic prescriptions, scroll sheets are to be joined with sinews from the same ritually clean cattle or wild animals from which the scroll itself was prepared.⁴³ The evidence suggests that most of the stitching material used in the scrolls from Qumran indeed consists of sinews. Further investigation should help us to determine which threads were made of animal sinews and which, contrary to rabbinic ruling, were of flax. In their 1962 research, Poole and Reed claimed that the stitching material examined was of vegetable origin and most probably flax.⁴⁴ It is not known, however, which specific scrolls were examined for this purpose. At the same time, more recent examinations have been applied to four specific scrolls.⁴⁵ Further research is needed regarding

⁴³ See *b. Menah.* 31b “only with sinews, but not with thread”; *y. Meg.* 1.71d “It is also an oral prescription delivered to Moses at Sinai that (scrolls) shall be written on the skins of ritually clean cattle or ritually clean wild animals, and be sewn together with their sinews.” This was indeed the case with the stitch material and the sheets of 11QT^a (domestic goat), see n. 45 below.

⁴⁴ Poole and Reed, “The Preparation of Leather,” 22.

⁴⁵ The following conclusions have been reached:

1QIsa^a: M. Burrows with the assistance of J.C. Trever and W.H. Brownlee, *The Dead Sea Scrolls of St. Mark's Monastery*, vol. 1: *The Isaiah Manuscript and the Habakkuk Commentary* (New Haven: ASOR, 1950), xiv: “linen thread.”

4QNum^b: N. Jastram in *DJD* XII (1994 [repr. 1999]): 217: flax.

4QcryptA Words of the Maskil (4Q298): S.J. Pfann in *DJD* XX (1997): 2: flax.

the consistency of the use of the stitching material in the same scroll. The animal stitching material may also be used for DNA-examinations.⁴⁶

*c. Retrieving Previously Illegible Letters with the
Aid of Advanced Photographic Techniques⁴⁷*

For their time, the black/white infrared photographs taken by Najib Anton Albina, the photographer at the Palestine Archeological Museum (PAM) in the 1950s and 1960s, were extraordinarily good.⁴⁸ Other early photographs were equally good: the infrared black/white photographs by the Biberkrauts of the scrolls purchased by the State of Israel, and those of 1QIsa^a, 1QS, and 1QpHab by John Trever.⁴⁹ The three series of PAM photographs, more than the fragments themselves, formed the basis for the study and publication of the scrolls in *DJD*. Often, the photographs reveal more details than the fragments themselves, although the fragments need always to be consulted because only they reveal the distinctions between ink and shadow.

⁴⁴QApocryphal Pentateuch A (4Q368): J. VanderKam and M. Brady in *DJD* XXVIII (2001): 131: flax.

⁴⁶ In the meantime, see A. Gorski, "Analysis of Microscopic Material and the Stitching of the Dead Sea Scrolls: A Preliminary Study" (abstract of paper presented at the Symposium on the Role of Analytical Methods in the Study, Restoration, and Conservation of Ancient Manuscripts, with Emphasis on the Dead Sea Scrolls, Prague, 14 April 1999; online: <http://orion.mssc.huji.ac.il/orion/programs/taskforce.shtml>). This paper refers to the stitching of 1QpHab and 1QIsa^a (no conclusions). See also by the same author "Analysis of Microscopic Material and the Stitching of the Dead Sea Scrolls: A Preliminary Study," in *Historical Perspectives*, 173–178. Bar-Gal, "Genetic Change," 72 and Table 3.6 mentions the sampling of stitch material of the 11QT^a (domestic goat).

⁴⁷ For good summaries of all aspects relating to the imaging of the scrolls, see G. Bearman, S.J. Pfann, and S.A.I. Spiro, "Imaging the Scrolls: Photographic and Direct Digital Acquisition," in *The Dead Sea Scrolls after Fifty Years*, 1:472–495; B. and K. Zuckerman, "Photography and Computer Imaging," *Encyclopedia of the Dead Sea Scrolls* (ed. L.H. Schiffman and J.C. VanderKam; 2 vols.; Oxford: Oxford University Press, 2000) 2:669–675.

⁴⁸ See F.M. Cross, "On the History of the Photography," and J. Strugnell, "On the History of the Photographing of the Discoveries in the Judean Desert for the International Group of Editors," in Tov, *Companion Volume*, 121–122 and 123–134.

⁴⁹ Additional early photographs by David Shinhav, Ruth Yekutieli, Tsila Sagiv, and Robert Schlosser are described by J.C. VanderKam and P.W. Flint, *The Meaning of the Dead Sea Scrolls: Their Significance for Understanding the Bible, Judaism, Jesus, and Christianity* (San Francisco: HarperSanFrancisco, 2002), 69–70.

In later years, with the advancement of technology, better photographs were taken, revealing additional parts of letters, complete letters, and in rare cases complete words.⁵⁰ The following innovative techniques were used.

1. Use of filters in infrared photography (B. and K. Zuckerman).
2. High density digitization. This technique was applied to the *Genesis Apocryphon* in 1993 by Bearman and the Zuckermans using a “new tunable filter that could be set to any wavelength in the IR (the infrared spectrum) with a very narrow bandpass.”⁵¹ A second imaging expedition was launched by these scholars in 1997, producing new digital infrared images of approximately 900 fragments (not scrolls).⁵² Some of these photographs revealed additional letters in darkened areas.⁵³ Additional letters were revealed on the leather in separate projects by Bearman⁵⁴ and Zuckerman.⁵⁵ Likewise, Johnston also revealed additional letters,

⁵⁰ The collection as a whole has not been re-photographed although in 2008 plans were underway for such an enterprise.

⁵¹ Bearman, Pfann, and Spiro, “Imaging,” 488.

⁵² *Ibid.*

⁵³ See the photograph of 4QCant^b by G. Bearman and S. Spiro on behalf of the Ancient Biblical Manuscript Center as presented by E. Tov in *DJD XVI* (2000): 209 and pl. XXV.

⁵⁴ G.H. Bearman and S.I. Spiro, “Imaging: Clarifying the Issues,” *DSD* 3 (1996): 321–328; *idem*, “Archaeological Applications of Advanced Imaging Techniques. Reading Ancient Documents,” *BA* 59 (1996): 56–66; *idem*, “Imaging Clarified,” in *The Provo International Conference on the Dead Sea Scrolls: Technological Innovations, New Texts, and Reformulated Issues* (ed. D.W. Parry and E. Ulrich; STDJ 30; Leiden: Brill, 1999), 5–12; D.M. Cabries, S.W. Booras, and G.H. Bearman, “Imaging the Past: Recent Applications of Multispectral Imaging Technology to Deciphering Manuscripts,” *Antiquity: A Quarterly Review of Archaeology* 77 (2003): 359–372.

⁵⁵ B. Zuckerman in collaboration with S.A. Reed, “A Fragment of an Unstudied Column of 11QtgJob,” *The Comprehensive Aramaic Lexicon Newsletter* 10 (1993): 1–7 (online: <http://cal1.cn.huc.edu/newsletter/Zuckreed.html>); M.J. Lundberg and B. Zuckerman, “When Images Meet: The Potential of Photographic and Computer Imaging Technology for the Study of the Copper Scroll,” in *Copper Scroll Studies* (ed. G.J. Brooke and P.R. Davies; JSPPSup 40; London: Sheffield Academic Press, 2002), 45–55; B. Zuckerman, “Bringing the Dead Sea Scrolls Back to Life: A New Evaluation of Photographic and Electronic Imaging of the Dead Sea Scrolls,” *DSD* 3 (1996): 178–207. Lists of new readings revealed by Zuckerman’s techniques are included in “The Targums of Job (4QtgJob and 11QtgJob),” in *The Dead Sea Scrolls: Hebrew, Aramaic, and Greek Texts with English Translation* (ed. J. Charlesworth; The Princeton Theological Seminary Dead Sea Scrolls Project; Tübingen: Mohr Siebeck, forthcoming).

especially in 11QT^a.⁵⁶ Puech was able to improve the reading of the *Copper Scroll* with the aid of radiographs and photographs of the flattened replica of the scroll.⁵⁷

3. Lange's method of Computer Aided Text-Reconstruction and Transcription (CATT)⁵⁸ offers a new software option for the reconstruction of fragments based on digitized images of scrolls.⁵⁹ The author suggests that each scholar digitizes his or her own images of the scrolls, and he guides the reader in the use of software programs that can be used in order to improve the readability of these images.⁶⁰ The author also shows how to scan individual letters and combine them into units that can be electronically placed in *lacunae*, thus examining the correctness of reconstructions.

d. *Identifying Fragments and Determining the Relation between Fragments*

(1) *Computer-Assisted Identifications*

To the best of my knowledge, little use has been made of computer-assisted research in the identification of small fragments. Parry identified a number of minute fragments of 4QSam^a with the help of the Word-

⁵⁶ J.H. Charlesworth, "The Dead Sea Scrolls and Scientific Methodologies," in *Optics and Imaging in the Information Age* (IS&T: The Society for Imaging Science and Technology, 1997), 266–274; K. Knox, R. Johnston, and R.L. Easton, "Imaging the Dead Sea Scrolls," *Optics and Photonics News* 8 (1997): 30.

⁵⁷ É. Puech, "Some Results of the Restoration of the Copper Scroll by EDF Mécénat," in *The Dead Sea Scrolls Fifty Years After Their Discovery: Proceedings of the Jerusalem Congress, July 20–25, 1997* (ed. L.H. Schiffman et al.; Jerusalem: Israel Exploration Society, 2000), 889–894; D. Brizemeure, N. Lacoudre, and É. Puech, *Le Rouleau de cuivre de la grotte 3 de Qumrân: Expertise, Restauration, Epigraphie* (2 vols.; STDJ 55; Leiden: Brill, 2006).

⁵⁸ A. Lange, *Computer-Aided Text-Reconstruction and Transcription—CATT Manual* (Tübingen: Mohr Siebeck, 1993). For a review, see G. Bearman in *DSD* 1 (1994): 373–375.

⁵⁹ Lange describes his own technique as follows (p. 3): "... uses image editing software in dealing with the several different types of damage done to manuscripts and inscriptions. Image editing programs try to transfer the photographic darkroom into the desktop computer."

⁶⁰ When this book was written, digitized images were not yet available in commercial databases such as *The Dead Sea Scrolls Electronic Library* (rev. ed.; Brigham Young University, 2006), part of the *Dead Sea Scrolls Electronic Reference Library* of Brill Publishers (ed. E. Tov; Leiden: Brill, 2006).

cruncher program.⁶¹ Pike and Skinner recognized many of the hitherto unidentified fragments with the aid of the same program.⁶² Tigchelaar identified many fragments with the aid of the Accordance program.⁶³ Undoubtedly, the use of Accordance or Wordcruncher could produce many additional identifications. Optical Character Recognition (OCR) could have been employed for the analysis of script or the identification of partially preserved letters, but to the best of my knowledge, this technique has not been used.⁶⁴

(2) *Research of Hair Follicles in Leather and Fibers in Papyri*

The analysis of hair follicles and papyrus fibers could indicate that two or more scroll fragments derived from either the same or a different sheet. Barns provided the first description of the procedure followed for papyrus fragments,⁶⁵ described in greater detail by Pfann.⁶⁶ Pfann likewise briefly described the procedure followed for the study of hair follicles in leather.⁶⁷ In both cases, much more detailed research is needed.

⁶¹ See F.M. Cross, D.W. Parry, and R.J. Saley in *DJD* XVII (2005): 3.

⁶² D. Pike and A. Skinner, in consultation with J. VanderKam and M. Brady, *Qumran Cave 4. XXIII: Unidentified Fragments* (*DJD* XXXIII; Oxford: Clarendon, 2001).

⁶³ E.J.C. Tigchelaar, "4Q499 48 + 47 (par 4Q369 1 ii): A Forgotten Identification," *RevQ* 18 (1997): 303–306; idem, "Minuscule Qumranica I," *RevQ* 21 (2004): 643–648; idem, "On the Unidentified Fragments of *DJD* XXXIII and PAM 43.680: A New Manuscript of 4QNarrative and Poetic Composition, and Fragments of 4Q13, 4Q269, 4Q525 and 4Q5b (?)," *RevQ* 21 (2004): 477–485; idem, "A Cave 4 Fragment of *Divre Mosheh* (4QDM) and the Text of 1Q22 I:7–10 and Jubilees 1:9, 14," *DSD* 12 (2005): 303–312.

⁶⁴ One could teach the computer the various shapes of the letters of each scroll, so that the program would suggest readings for partially preserved letters.

⁶⁵ J.W.B. Barns, "Note on Papyrus Fibre Pattern," in *DJD* VI (1977): 29.

⁶⁶ S.J. Pfann in *DJD* XXXVI (2000): 517–523.

⁶⁷ S.J. Pfann, "Hair Follicle Analysis of Primitive Parchments: An Essential Tool for the Reconstruction of Fragmentary Dead Sea Scrolls" (abstract of paper presented at the Symposium on the Role of Analytical Methods in the Study, Restoration, and Conservation of Ancient Manuscripts, with Emphasis on the Dead Sea Scrolls, Prague, 14 April 1999; online: <http://orion.mscc.huji.ac.il/orion/programs/taskforce.shtml>): "The pattern, form, size and density of hair follicles which occur over the hides of various animals do so with a fair degree of consistency. Those hides which preserve their epidermis and are used in the preparation of scrolls maintain these hair follicle patterns. These same follicle patterns preserved on the surfaces of disjointed fragments of the Dead Sea Scrolls has proven to contain important clues aiding in their reconstruction (and thus their meaning and interpretation). This form of analysis was developed by the author while working with the edition of the various Dead Sea Scrolls assigned to him for publication over the past decade. With the aid of the binocular microscope many proposed links between disjointed fragments have been either confirmed or disproved based on this work."

The research of leather and papyrus sheets is promising, but at this stage it is unclear whether the various parameters identified in the fragments are distinctive enough in order to identify and differentiate between individual sheets. Research needs to proceed from the features of known sheets of complete scrolls to fragmentary texts, and such studies have not yet been written.

In the case of papyrus fragments, examining each papyrus strip involves the color, thickness, density, variability, and angle of the intersection between the horizontal and vertical strips of papyrus.

Research carried out so far by Pfann, focusing on fragmentary texts, shows the possibilities this research has in store. Pfann analyzed the papyrus texts in the cryptic script 4Qpap cryptA Midrash Sefer Moshe (4Q249)⁶⁸ and 4Q249a-z and 4Q250a-j,⁶⁹ focusing on the special features of each papyrus fragment. In the case of leather fragments, Pfann likewise analyzed the special hair follicle features of each individual fragment of 4QCryptA Words of the Maskil to All Sons of Dawn (4Q298).⁷⁰ This analysis enabled him to support the reconstruction of fragments belonging to the same sheet. The hair structure of 4Q413 and 4Q413a was found to be different by Elgvin (see n. 41 above).

Each single feature of the papyrus or leather, and definitely the combined features may give guidance regarding the placement of fragments in a particular sheet. However, this type of research is rather limited. Pfann examined the fragments that had been identified at an earlier stage as belonging to specific scrolls. Within those parameters, he separated the papyrus fragments into many different compositions based on the criteria mentioned above. This research enabled him to surmise that specific fragments belonged to the same sheet of papyrus, but no more than that. In the case of leather, the fragments could be placed anywhere in the sheet, either in the same column or one or two columns apart. In the case of papyrus, the guidance of the horizontal and vertical strips may aid in a more specific location alongside the horizontal or vertical strips, but further research on the known complete papyri has to consolidate the criteria used. Probably the strongest merit of this and any similar procedure is the ability to disprove that two fragments belonged to the same leather or papyrus sheet.

⁶⁸ S.J. Pfann in *DJD XXXV* (1999): 1-24.

⁶⁹ S.J. Pfann in *DJD XXXVI* (2000): 515-701.

⁷⁰ S.J. Pfann and M. Kister, "4Q298: The Maskil's Address to All Sons of Dawn," *JQR* 85 (1994): 203-235; idem in *DJD XX* (1997): 1-30.

(3) *The Stegemann System of Reconstructing*

The so-called “Stegemann system of reconstructing fragmentary scrolls”⁷¹ belongs here only partially since it is based not on the sciences but on logical inference of destruction patterns of the leather or papyrus. Among other things, on the basis of the supposed measurements of the scroll and the increase in size between revolutions of the scroll starting with its innermost end, this system tries to establish the distance between the fragments (columns) based on identical destruction patterns, if any, repeated in each revolution of the scroll.

2. SOME TECHNICAL DATA ABOUT THE SCROLLS

When integrating data from the sciences into the reconstruction of the scrolls, we have to take into consideration the data known about them. Otherwise, we are in danger of applying the wrong types of conclusions. The following parameters relate to this reconstruction.⁷²

1. The first stage in the preparation of parchment was the slaughtering of an animal and the preparation of its hide for the production of the scroll material. Even the leftovers were used for writing: contrary to practice in later centuries, most of the *tefillin* found at Qumran were written on irregularly shaped pieces that were leftovers from the preparation of large skins. Upon preparation, most skins were inscribed on

⁷¹ H. Stegemann, “Methods for the Reconstruction of Scrolls from Scattered Fragments,” in *Archaeology and History in the Dead Sea Scrolls: The New York Conference in Memory of Yigael Yadin* (ed. L.H. Schiffman; JSPP 8; JSOT/ASOR Monograph Series 2; Sheffield: JSOT Press, 1990), 189–220; A. Steudel, “Assembling and Reconstructing Manuscripts,” in *The Dead Sea Scrolls after Fifty Years*, 1:516–534; E. Chazon, “The Qumran Community, The Dead Sea Scrolls and The Physical Method of Scrolls’ Reconstruction” (abstract of paper presented at the Symposium on the Role of Analytical Methods in the Study, Restoration, and Conservation of Ancient Manuscripts, with Emphasis on the Dead Sea Scrolls, Prague, 14 April 1999; online: <http://orion.mscc.huji.ac.il/orion/programs/taskforce.shtml>). See also D. Stoll, “Die Schriftrollen vom Toten Meer—mathematisch oder Wie kann man einer Rekonstruktion Gestalt verleihen?” in *Qumranstudien: Vorträge und Beiträge der Teilnehmer des Qumranseminars auf dem internationalen Treffen der Society of Biblical Literature, Münster, 25.–26. Juli 1993* (ed. H.-J. Fabry, A. Lange, and H. Lichtenberger; Göttingen: Vandenhoeck & Ruprecht, 1996), 205–217.

⁷² For a detailed description of each issue, see my *Scribal Practices*.

the (hairy) outside layer, while 11QT^a was inscribed on the inside of the skin (the flesh side).⁷³

2. The *length* of the composition was calculated approximately before commencing the writing, so that the required number of sheets could be ordered from a manufacturer or could be prepared to fit the size of the composition. Subsequently, the individual sheets were ruled and inscribed and only afterwards stitched together. The fact that some ruled sheets were used as uninscribed handle sheets (e.g. the last sheets of 11QT^a and 11QShirShabb) and that some uninscribed top margins were ruled (the second sheet of 1QpHab) shows that the ruling was sometimes executed without relation to the writing of a specific scroll. The numbering of a few sheets preserved in the Judean Desert probably indicates that some or most sheets were inscribed separately, and joined subsequently according to the sequence of these numbers (however, the great majority of the sheets were not numbered).

3. The first step in the preparation of scrolls for writing was the *ruling* (scoring), which facilitated the execution of the inscription in straight lines. The scroll was written by hanging the letters from the lines. This ruling provided graphical guidance for the writing, horizontal ruling for the lines, and vertical ruling for the beginning and/or end of the columns. In very few cases, the ruling was indicated by diluted ink.

4. Almost all Qumran and Masada texts written on leather in the square script had ruled horizontal lines in accordance with the practice for most literary texts written on parchment in Semitic languages and in Greek. On the other hand, texts written on papyrus were not ruled. The horizontal and vertical fibers of the papyrus probably provided some form of guidance for the writing.

5. The ruling was sometimes applied with the aid of guide dots/strokes, or with a grid-like device, while in other instances no device was used. These guide dots (“points jalons”), or sometimes strokes, were drawn in order to guide the drawing of dry lines. The ruling might have been executed by the scribes, but it is more likely that it was applied by the scroll manufacturers without reference to the text to be inscribed, as

⁷³ For parallels in rabbinic literature, see *y. Meg.* 1.71d: “One writes on the hairy side of the skin” (cf. *Massekhet Sefer Torah* 1.4).

indicated by several discrepancies between the inscribed text and the ruled lines, such as a larger number of ruled lines than inscribed text (see 4QDeutⁿ).

6. The preparation of the material for writing included not just the ruling, but also the preparation of the surface for writing in columns. The number of columns per sheet and their sizes differed from scroll to scroll, sometimes from sheet to sheet, and they depended much on the size of the sheets and the scroll.

7. The size of the scroll depended on the dimensions of the sheets. At Qumran, the length of most leather sheets varied between 21 and 90 cm, usually 30–40 cm.⁷⁴ The natural limitations of the sizes of animal hides determined the different lengths of these sheets, which varied more in some scrolls than in others.

8. The sizes of the hides derived from the different animals differ, but the animals that have been identified (calf, sheep, ibex, goat) would not yield more than one hide of 90 × 60 cm or two or three short ones. In some cases, more than one composition could be written on the material provided by a single animal, while in other cases several animals would be needed for a long composition, such as 11QT^a and the large Isaiah scroll.

9. There is a positive correlation between the length and width of columns: as a rule the higher the column, the wider the lines, and the longer the scroll.

10. The sizes of the columns differ in accordance with the number of columns per sheet, the scope of the sheets, and the conventions developed by the scroll manufacturers. The different parameters of the columns pertain to their width and length as well as to the top, bottom, and intercolumnar margins. In some Qumran scrolls, the height and width of the columns are fairly consistent, while in most scrolls these parameters varied from sheet to sheet as well as within each sheet, in accordance with the measurements of the sheets. The average number of lines per

⁷⁴ For example, 1QIsa^a consists of seventeen sheets (ten sheets measuring 35–47.7 cm, five 48.7–62.8 cm, and two 25.2–26.9 cm). 11QT^a is composed of nineteen sheets (eight measuring 37–43 cm, ten 47–61 cm, and the final sheet measuring 20 cm). For additional details, see my *Scribal Practices*, 79–81.

column in Qumran scrolls is probably 20, with a height of approximately 14–15 cm (including the top and bottom margins). Larger scrolls contained columns with between 25 and as many as 60 lines. Scrolls of the smallest dimensions contained merely 5–13 lines and their height was similarly small. Among the scrolls with a large writing block, one finds many texts from Qumran, as well as *all* the scrolls from Masada, Naḥal Ḥever, Sdeir, and Murabbaʿat that can be measured. The same compositions were often written on scrolls of differing sizes, although in some cases a degree of regularity is visible.

11. All biblical texts were inscribed on one side only, while several nonbiblical texts were inscribed on both sides (pisthographs).

12. With one possible exception, all compositions were written on separate scrolls. Some biblical scrolls contain more than one book (the Torah, Minor Prophets).

13. Some, mainly long, manuscripts were written by more than one scribe.

3. AID FROM THE SCIENCES FOR THE RECONSTRUCTION OF ANCIENT SCROLLS: POSSIBILITIES AND IMPOSSIBILITIES

In previous examinations, the reconstruction of the missing parts of the ancient scrolls was based mainly on content. In the case of biblical scrolls or other known compositions, content is our main guide, but even in these compositions small fragments with partial or frequently occurring words cannot be identified easily. In other cases, with fragmentary contents and the fertile minds of scholars, there are many possibilities and therefore it would be good to be aided by additional methods. Such aid may come from an exact or almost exact physical join, but such joins are rare. Some fragments of similar shape reflect subsequent layers or revolutions of a scroll (see n. 71), but such cases are also rare. In many cases, we would like to look to the sciences for help. Our main interest would be in proving or disproving a link already made between two fragments or in searching for a scroll to which a given fragment may have belonged. In such cases, we would like to resort to the sciences for objective criteria. The sciences have been invoked often, with high expectations, so it is time to be a little realistic.

It would not be feasible to send all the fragments to C-14 analysis only in order to know if their C-14 dates match. Ink analysis, if advanced sufficiently, would be easier and may be very relevant. In my view, the so-called elemental composition analysis sounds promising, and it is non-destructive, but we wait for the verdict of scientists. DNA will provide some answers, as will the follicle research on leather, and fiber research on papyri. It should be remembered that the maximum results we would receive refer to the identity of the complete sheet(s) from which the fragments derived, and not to the placing of individual fragments. These sheets were 21 to 90 cm long at Qumran, mostly 30–40 cm, and the placing of a fragment in such a large space would leave many options open. Most animals would not yield more than one hide of 90 × 60 cm.

On the other hand, in the descriptions of the DNA method, especially that of Woodward,⁷⁵ the expectations for DNA analysis have been very high. This scholar, who together with Kahila Bar-Gal was able to derive aDNA from ancient objects, was not sufficiently aware of the limitations of DNA in the case of the scrolls. In a programmatic paper published in 1998, he lists five questions for which DNA was supposed to provide answers.

1. “How many different manuscripts are represented in the collection of fragments at the Rockefeller and Israel Museums? . . . Obtaining DNA signatures unique to each manuscript will make it possible to sort out the physical relationships of scroll fragments.” At most, however, we would be able to list the individual animals, from whose skins the hides were derived. When naming these animals “animal 1,” “animal 2,” etc., we would have an important summary list, but that list would provide only a few clues for researchers. Thus, if two different compositions were written on the hide of animal 1, DNA alone would not suffice to distinguish between them. Further, multi-sheet compositions required more than one animal, sometimes ten or more, so that DNA signatures alone would not be able to distinguish between Qumran manuscripts.

2. “Which pieces can be grouped together as originating from the same scroll because they are from identical or related manuscripts? . . . This should assist both in the reconstruction of manuscripts and in the

⁷⁵ Woodward, “New Technological Advances.”

verification of assemblies that were previously already made.” It seems to me that all these are idle hopes as explained in my reply to item 1.

3. “Did more than one scribe work on a single document, or did different scribes use parchment that originated from the same source for different manuscripts?” In my view, neither question can be answered with DNA.

4. “Is the parchment for the patch from the same herd as the original manuscript? Does the patch represent a herd from a different region, reflecting mobility of either the original scroll or the herd?” These suggestions are helpful,⁷⁶ but impractical. Most importantly, the number of patches in the scrolls can be counted on one hand.

5. “Does the collection represent a library from a single locality, or is it a collection representing contributions from a wide region?” In general it is true that DNA analysis will help us to know more about the provenance of the hides, if only the connections between hides and bones can be made.

The expectations expressed in the Introduction to the Qumran scrolls by VanderKam and Flint, which run parallel to those of Woodward, are equally as utopian.⁷⁷

4. CONCLUSIONS

Summarizing the various types of expectations for scroll research, we note that they may help us with regard to some issues.

- a. C-14 examinations should be continued as a useful tool for dating in spite of the uncertainty regarding the contamination of castor oil.
- b. If performed on a large scale, C-14 examinations could also help us understand the relationship between many individual fragments. For example, two or more fragments assigned to the same column or sheet should not have different C-14 dates.

⁷⁶ The patch in 4Q22 and its main text were dated to different periods with C-14 analysis, see Jull et al., “Radiocarbon Dating,” 86.

⁷⁷ VanderKam and Flint, *The Meaning of the Dead Sea Scrolls*, 55–84 (57–58). 1. “Assembling scrolls in the Rockefeller and Israel Museums.” 2. “Making new reconstructions and assembling earlier ones.” 3. “Parchment used for patches.” 4. “Scrolls made from more than one animal.” 5. “The species of animals used for production.” 6. “Assembling the scope of the collection.” “Does the collection found at Qumran represent a library from one location or from a wider region?”

- c. Ink research, research of leather follicles and papyrus fibers, and elemental composition analysis such as the chlorine/bromine ratio should be encouraged as non-destructive examinations that may help us understand the relation between individual fragments. The merits of these examinations should be reviewed by scientists, since we humanists lack the means to review the methods used.
- d. The infrared color photographing of all the fragments with new techniques should be encouraged.

At the same time, expectations from these techniques should be realistic, taking into consideration the realities of scroll production such as described above, in particular the fact that the sheet and not the fragment is the unit of reference.

In an ideal world, we would have access to a database providing information of all the types described above about all the scroll fragments. Undoubtedly, this information would help us to solve some questions that face researchers. For example, by examining the technical data about the scrolls, we may be able to create clusters⁷⁸ of scrolls of a certain nature, such as Qumran scrolls as opposed to non-Qumran scrolls (based on elemental composition analysis). We may be able to find that scrolls written on a specific type of leather (DNA analysis) or with a specific type of ink have something in common, or that the Hebrew scrolls somehow differ from those written in Aramaic.

In the analysis of individual fragments, this database would help especially in negative aspects, namely the suggestion that two fragments that were joined in the past should not be ascribed to the same manuscript, as in the case of 4Q413 and 4Q413a discussed above.

In an ideal world we should have access to a database like this, but we are also realistic enough to realize that the keepers of the scrolls would have to agree to all these procedures, some of which are destructive. We keep our fingers crossed.

⁷⁸ The idea was expressed already by K. Bar-Gal, "Genetic Change," 76: "These findings show the ability of the aDNA method to contribute in matching and grouping together scroll fragments. These results also stress the possibility to solve the problem of the 10,000 unmatched fragments using genetic analysis."