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Building a Bridge from the Dead Sea Scrolls to Mediaeval Hebrew Manuscripts

Abstract: As part of the Qumran project conducted at the BAM Federal Institute for Materials Research and Testing in Berlin between 2007 and 2010, my colleagues and I developed a new, integrated methodology for determining the original and acquired properties of highly heterogeneous Dead Sea Scrolls. The purpose of this methodology is to help scholars determine the provenance of fragments of the scrolls and sort and compare them more easily than in the past. Since our measurements allowed us to differentiate between the minerals originating from the production processes and the sediments accrued during storage in the caves in Qumran, we were able to reconstruct the treatment of hides and discovered that at least two distinct parchment-production techniques co-existed at the beginning of the common era.

The reconstruction of workmanship on animal hides in Antiquity raised doubts about the validity of the current definition of parchment, which is based on a production technique known from the Middle Ages. We hope that our current work will also help researchers understand the characteristic properties of *gewil*, *qelaf* and *dukhsustos* better.[1]

The evolution and socio-geographic distribution of writing inks in Late Antiquity and the early Middle Ages are the second focus of our investigative work at BAM. We use X-ray fluorescence analysis (XRF) to determine the chemical composition of inks and NIR reflectography for their typology. We are amply assisted in our ambitious enterprise by codicologists and palaeographers who have adopted our methodology and conduct field studies of their own.

1 Introduction

The International Qumran Project was conducted at BAM Bundesanstalt für Materialforschung und -prüfung (Federal Institute for Materials Research and Testing) between 2007 and 2010 and aimed at establishing the best methodology

1 These three Hebrew/Aramaic terms all relate to different forms of treated leather intended to serve as writing material; the terminological differentiation in rabbinic literature is not totally clear, however. Cf. Blau 1902, 22ff., and for a more recent discussion, see Haran 1991, 37ff. and Olszowy-Schlanger's contribution to this volume, p. 64–68.

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for achieving an accurate characterisation of the Dead Sea Scrolls Collection to address such questions as the archaeological provenance, origin and attribution of fragments to a specific sheet of a scroll.[2] This project was followed by a field study of scrolls now belonging to the Schøyen Collection[3], which contains fragments of the *Great Isaiah Scroll* (1QIsa[a]), *Community Rule* (1QS[a]) and *Genesis Apocryphon* (1QapGen. Combining the results from the Qumran project with those of the untreated fragments from the Schøyen Collection, we were able to show the co-existence of multiple techniques for producing parchment in Antiquity as opposed to the uniform technique characteristically employed in the Middle Ages.[4]

2 Technical aspects of parchment production in Antiquity

Unlike parchment production in the Middle Ages,[5] the production of the majority of the hide-based material used for the Dead Sea Scrolls, as reported in the first physical and chemical study, did not involve lime soaking, but enzymatic depilation. In Antiquity, this was usually carried out by applying dung or flour to the animal skin or immersing it in a solution containing warm water and vegetable matter. The treatment involved drying the hide under tension, a stage that supplied the material with properties similar to those of common parchment. However, vegetable tannins that were sometimes applied to the surface of the hide during the last stage of the treatment produced an interesting hybrid between leather and parchment that was never tanned conventionally.[6] Extremely thin pieces of parchment from the time before lime was employed for depilation testify to production processes in which an animal skin could be separated into two usable parts now known as grain and flesh splits. In my opinion, the rather confused Talmudic discussion with regard to the rules of inscribing grain and flesh splits indicates that this technique was neither common nor in use when the Talmudic description was written.[7] The art of splitting skins manually disappeared with the introduction of lime. Furthermore, aluminium sulphate salts, which are also

2 Rabin/Hahn 2013.

3 See *The Schøyen Collection: Manuscripts from around the World Spanning 5000 Years of Human Culture & Civilisation*, http://www.schoyencollection.com/ (last accessed 12 March 2017).

4 Rabin, 2016

5 See de Groot 2012; Rück 1991.

6 Poole/Reed 1962.

7 Cf. Haran 1991, 39ff.; he is of a different opinion than I, though.

known as alum [$MAl(SO_4)_2x12H_20$, M=Na, K, NH_4], have been used to produce soft, white leather of excellent quality ever since Antiquity.[8] This material, however, differs greatly from the usual tanned leather in that it is not resistant to water. In the Middle Ages, leather goods manufactured by a technique called alum thawing included pieces of parchment for writing that were more flexible than the rigid mediaeval parchment so common at the time (and better suited for codices).[9]

Reed's description of the manufacture of the parchment used for the Dead Sea Scrolls lacks detail regarding the treatment provided after flaying a hide, the use of materials to assist drying, and finishing steps. From the detailed descriptions of parchment-making in the Middle Ages that still exist, we know that chalk and powdered pumice were applied to the flesh side to assist in the cleaning and drying of the de-haired skin.[10] Our discovery of calcium distributed on the grain and flesh surfaces of the *Great Isaiah Scroll* and the *Community Scroll* strongly indicates that similar steps existed in Antiquity as well.[11] There are no records in early Hebrew literature that mention the composition of de-hairing liquors. Similarly, we do not know whether treatment with tannins could be a general finishing step in the manufacture of hide-based material or whether tannins were only applied directly before the parchment was inscribed. In their independent studies, Reed and Wallert[12] found evidence that tannins were applied to the surface of a skin. Reed, however, mentions that he found no difference between the treatment of the hair and flesh sides, and concludes that de-hairing steps could also have involved tannins.

Ideally, reconstruction of the techniques used to treat hides – depilation, drying and finishing procedures – should determine every step in the process of transforming a flayed skin into writing material (see Fig. 1). In the absence of detailed written records, we have to rely on analyses of the end products, i.e. historical, skin-based writing material. With few exceptions, the end products have reached us in a rather degraded state, so our analysis obviously needs to take the effects of this degradation into consideration. In view of the current stage of our technology, precise elucidation of all the production steps could only be achieved with techniques that require physical samples to be taken and then analysed. Nevertheless, non-destructive testing of a large number of scrolls and sorting them according to their similarities can still provide us with some precious information. In addition to this, NDT considerably reduces the need for destructive analysis.

8 Reed 1972, 50.
9 Reed 1972, 62.
10 See Gullick 1991, 148; Ryder 1991, 26ff.
11 Rabin 2016.
12 Reed/Poole 1964; Wallert 1996.

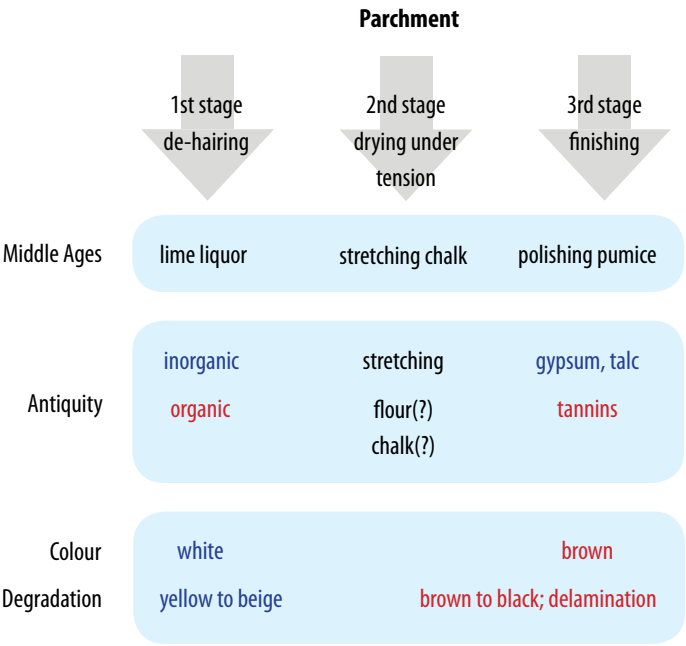

Fig. 1: Parchment preparation.

Ronald Reed divided the fragments at his disposal into three groups: (a) leather, (b) parchment-like and (c) *gewil*-like. According to him, the last group, which was pale yellow in colour, differed from the parchment-like group in its suppleness and similarity to the modern *gewil*. He concluded that various preparation processes were probably responsible for this difference since all the other properties tested appeared to be quite similar, including tanning on the surface of the hide. In his original interpretation of the results, Reed relied heavily on rabbinic sources about the preparation of writing materials. Later, however, he revised his conclusions, acknowledging that the *gewil*-like parchments at his disposal had never been tanned.[13] Since the *gewil* described in the Talmud requires dressing with vegetable tannins, he tentatively concluded that this type of material, with a pale colour and soft, velvety touch, cannot correspond to the *gewil* described in the Talmud.

Similarly, our studies have shown that the Dead Sea Scrolls material can roughly be divided into three groups: leather, light coloured parchment and parchment of various shades of brown. The latter ones are invariably tanned, whereas the

13 Reed 1972, 262.

first parchment group is characterised by the presence of various sulphate salts. The colour of some of the pale parchments, among them well-preserved portions of the *Temple Scroll* (11QT[a]), is remarkably similar to that of mediaeval European parchment. We therefore formulated the working theory that in Hellenistic-period Judaea, two different parchment-making traditions must have existed side by side: an 'eastern' one (represented by the tanned parchments of Qumran, closely resembling Aramaic documents from the 5[th] century BCE)[14] and a 'western' one (represented by the non-tanned/lightly tanned ones, similar to early Christian Greek parchments). Comparing Reed's classification with ours, we concluded that his '*gewil*-like' parchment coincides with our 'western' type. Usually, one can see a striking difference in the elemental composition of the two types. Sulphur (S) from the sulphates used in de-hairing liquors only corresponds to the most abundant element in the second group, whereas potassium (K), which is present in plant extracts, is mostly evident on the scrolls that have undergone vegetable tanning. It is worth noting that in the lightly tanned parchments, the levels of potassium are not necessarily very high. Unfortunately, potassium and sulphur may result from more than one source. Therefore, when only minute amounts are detected with a single non-destructive method such as XRF, no precise attribution is possible. Luckily, the presence of tannins can be tested by other methods, such as Raman and FTIR spectroscopy or fluorescence analysis. The fact that tannins effectively quench the fluorescence of parchment is well known and routinely used for enhancing the contrast between a text written in iron-gall ink and a mediaeval parchment. Reed applied fluorescence analysis in his own assessment of scroll fragments: the observation that his '*gewil*' group fluoresced strongly under UV light served as the final argument against tanning. In our laboratory at BAM, we performed all four tests for tannin identification and came to the conclusion that the fluorescence test was the quickest and easiest way of answering this question.

3 Parchment production in the Middle Ages

In Fig. 1, the main steps of parchment production in Antiquity are being compared with the common techniques we know of from the Middle Ages (and which are still in use today in some places). As we can see, the main innovation in mediaeval times (which was actually introduced at an unknown time and place in the early Middle Ages) was treating hides with lime liquor for quick and efficient

14 Driver 1954.

removal of hair at the first stage of production. It is also this stage that allows us to differentiate between 'eastern' and 'western' methods in Antiquity, marked in red and blue respectively in the Figure. During the second stage, drying the skin while it was under tension and then cleaning it conferred a two-dimensional structure to the skin, turning it into parchment. This central stage in the production process has not changed since Antiquity, although different powdered materials are now used to assist drying. The last stage, finishing, has many different features that depended strongly on the locality, time and the intended final use of the hide in the Middle Ages. The third stage was also distinctly different for the 'eastern' and 'western' treatment of hides in Antiquity: heavy surface tanning vs. gypsum and talc detected on some of the untanned scrolls.

Turning to the Jewish mediaeval scrolls now, I would like to investigate whether our east/west hypothesis concerning the differences in the production of scrolls actually does reflect the practices common in Western and Oriental Jewish communities. There are, indeed, some indications that different traditions have been preserved to this today. Regarding the Middle Ages, we studied four mediaeval Tora scrolls from the Erfurt Collection kept at the Staatsbibliothek zu Berlin (Ms. or. fol. 1215–Ms. or. fol. 1218). Our analysis revealed that none of them was written on *gewil*; rather than that material, they were written on conventionally prepared mediaeval parchment with no detectable traces of any tanning. To follow up the development of the writing materials, it was necessary to identify a representative and accessible corpus for our investigation. Judith Olszowy-Schlanger's suggestion that different book forms (i.e. the scroll and codex) co-existed in the Middle Ages provides us with a corpus that actually goes well beyond Tora scrolls.[15] Her discovery that the Cairo Geniza collection contains fragments of scrolls that can be attributed to the Babylonian and Palestinian communities narrowed the choice down to a manageable number of manuscripts.[16] Moreover, the distribution of the writing material (leather or parchment) between these two communities not only supports our east/west hypothesis, i.e. the co-existence of two different processing techniques at the end of the Second Temple period, but it also indicates the continuity of these traditions into the Middle Ages. Our pilot material analysis of the Cairo Geniza fragments conducted in September 2015 included nine leather scroll fragments and a single fragment made of parchment.[17] All the fragments

15 Olszowy-Schlanger 2017.

16 For a detailed discussion of the attribution, see Judith Olszowy-Schlanger's article in the present volume.

17 *Cairo Genizah Palimpsests Project* conducted at the University Library Cambridge and co-ordinated by Judith Olszowy-Schlanger (EPHE, Paris) and Ben Outhwaite (Cambridge).

were subjected to reflectographic analysis, i.e. we obtained micrographs under UV, VIS and near-infrared illumination (NIR). X-ray fluorescence measurements of eight scrolls – seven made of leather and one of parchment – revealed such a high amount of calcium in the leather scrolls that it seems the leather must have undergone treatment with lime rather than dung. Furthermore, the elevated amount of iron also detected may indicate that the tanning was not entirely vegetable. An interesting question as to whether the non-biblical scroll parchments of the Geniza collection were indeed tanned will be addressed in studies that are planned for 2018. Our preliminary observations based on the UV micrographs tentatively suggest that no such practice was in use.

4 Inks

In her excellent study on the written sources of ink recipes, Monique Zerdoun covers more than 1,000 years of history.[18] Starting with soot inks from Late Antiquity, she moves on to the common iron-gall inks of the mediaeval period. Among the inks mentioned in her review, we find pure soot inks, soot inks with different additives, in particular with a substance containing copper (χάλκανθον or *chalkanthon*; blue vitriol, copper sulphate, as mentioned by Dioscorides), tannin inks produced from oak galls or tree bark, mixtures of soot ink and tannins, iron-gall inks and, finally, mixtures of iron-gall inks and soot or soot-based inks. Since we are mostly interested in the analysis of inks here, let us start by describing their properties and the methods used to identify them.

Soot, plant and iron-gall inks belong to different typological classes of black ink: soot ink is a fine dispersion of carbon pigments in a water-soluble binding agent, while plant-based ink consists of a solution of tannin extracts with a binding agent. Iron-gall ink combines water-soluble components (iron sulphate and tannin extract from gall nuts) with insoluble black material that is produced when the components undergo a chemical reaction. Each ink class has distinct properties that would readily permit their differentiation if only historical inks belonged to just one of the classes above. In reality, however, inks often contain additives that obscure the picture and make the full elucidation of the ink composition a challenging task. Table 1 lists all known inks together with their characteristic features and means of identification:

18 Zerdoun 1983.

Table 1: Black inks detected in various documents ranging from Antiquity to the Middle Ages

Type of ink	Precursors	Colourant	Colour	Properties	Detection[a]
carbon[b]	wood, oil	carbon (soot or charcoal)	black	pigment; stays on the surface; solid black colour from UV to IR spectral regions	IR photography, Raman[c]
copper[d]	blue vitriol (CuSO4), gall nuts	not identified	brown	not studied	PIXE[e]
iron-gall	green vitriol[f] (FeSO4), gall nuts	iron gallate	black (brown when deteriorated)	pigment & solution; penetrates substrate; loses opacity towards IR; becomes transparent at 1200nm	IR photography, Raman, XRF, PIXE
plant[g]	bark, gall nuts	tannin	brown	solution; readily penetrates substrates; becomes invisible in NIR	IR photography, FTIR
mixed	carbon & copper[h]	carbon	black	same as carbon; presence of copper can only be detected by X-rays	IR photography + XRF
mixed	carbon & lead[i]	carbon	black	same as carbon	IR photography + XRF
mixed	carbon & tannin[j]	carbon	black	same as carbon	extraction
mixed	carbon & iron-gall[k]	carbon & iron gallate	black	same as carbon	IR photography + XRF

a. A detailed description of the detection techniques is given elsewhere (Rabin 2014).
b. In addition to the multitude of recipes, there is a great deal of analytical work in progress that reflects a growing interest in historic inks.
c. It is now routinely detected by infrared reflectography and Raman spectroscopy.
d. Copper-tannin ink was identified in a number of documents from Egypt in the 1st–3rd centuries CE (Delange et al. 1990).
e. PIXE stands for Particle Induced X-ray Emission.
f. Natural vitriol consists of a mixture of metallic sulphates (iron sulphate, copper sulphate, manganese sulphate, and zinc sulphate) with relative weight contributions characteristic of the source. These contributions can be easily detected by X-Ray Fluorescence (XRF). We use this property of iron-gall inks for their comparison and identification (Hahn et al. 2004).
g. Plant inks can be easily recognised by their homogeneous brown colour as opposed to the heterogeneous brown of degraded iron-gall inks.
h. So far, carbon inks containing copper have only been found in inks from the first few centuries CE.
i. Like ink containing copper, carbon ink with lead (Pb) as an additive can only be identified by combining two techniques: IR photography and XRF. The recent identification of lead on a charred fragment of material from Herculaneum caused a great deal of excitement as there are no written records from this period that mention the use of lead in black inks (Burn et al. 2016). Curiously, one of the ink ingredients mentioned in the Babylonian Talmud is lead (*ʾavar*, *ʾavara*ʾ, e.g. bGittin 19a).
j. This ink presents a challenge for identification by non-invasive methods and has not been found in a historical manuscript yet.
k. As with carbon inks containing copper and lead, two techniques are required for unequivocal identification: IR photography and XRF.

In Late Antiquity, the main black writing ink used was based on soot or charcoal produced mostly from oils and wood respectively. The best-known descriptions are from Pliny the Elder[19] and Vitruvius[20] and suggest a mixture of two ingredients: soot or charcoal and gum. Although not sought intentionally, soot has been identified in the inks of many documents from this period. Infrared images of the documents that show clear writing in black as compared to those images taken in visible light invariably indicate the presence of soot. In a relatively small number of ancient documents studied with X-ray methods, including five manuscripts from the Dead Sea Scrolls collection, analysis revealed the presence of copper in a

19 *The Natural History* 35.25.
20 *The Ten Books on Architecture VII*, 10, 217.

soot-based ink.[21] This finding brings us to Dioscorides' recipe,[22] which contains a copper-based substance. Pliny the Elder equated this substance with atramentum sutorious, or 'shoemaker's black', and seemed to believe that it was used to blacken leather.[23] This is chemically implausible, though, as no copper substance produces a black pigment upon reaction with tannin; 'shoemaker's black' must therefore have contained an iron-based substance. The clear distinction between copper and iron sulphates probably marks the beginning of the era of iron-gall inks. Without joining the complicated debate on the inks described in various Talmudic tractates, I would like to point out that the list of possible ingredients from the earlier Mishna (e.g. mShabbat 12:4 / bShabbat 104b or mGittin 2:3 / bGittin 19a) contains *qanqantum*, which, despite slight distortion, remains easily recognisable as Dioscorides' *chalkanthon*, whereas the Gemara compiled later refers to the same substance (*ḥarta de-ʾushkafe*) as the 'shoemaker's black' mentioned by Pliny. Furthermore, the word *copperas*, which is actually sulphate of iron, or green vitriol, also testifies to the confusion regarding the technique used to produce iron-gall inks in the first few centuries of the Common Era.[24] By the 5th century CE, iron-gall ink seems to have become established, although the first written recipe did not appear for another 300–400 years in the Orient and for another 600–700 years in Europe (at least according to the written records known to us so far).

The chapter of Zerdoun's book dedicated to the inks used by Jews in different epochs and geographical zones is of particular interest to those of us who conduct material analyses and try to correlate the results with written records and existing traditions.[25] Comparing the inks proposed by Maimonides, who lived in 12th-century Egypt, with the considerations of Rashi, who lived in 11th-century northern France, we can see that they both advocated use of the inks commonly known and produced in their respective regions. It is Maimonides who proposes to add tannins to the soot inks, but rejects the metallic salt, both of which were practices that were well attested in contemporary Arabic recipes for making ink.[26] In contrast, Rashi was favourable to employing the plant inks in use in contemporary Northern Europe.[27]

21 Broshi 1996.
22 Dioscorides, *Materia Medica* V.181; Zerdoun 1983, 80.
23 *The Natural History* 34.32.
24 Karpenko/Norris 2002.
25 Zerdoun 1983, 97.
26 Zerdoun 1983, 124–126; Shoppen 2006, 141–144.
27 Dodwell 1961, 34–35.

It is very unfortunate that the sporadic material analysis of mediaeval inks lags far behind studies of written records at the moment. Given the fact that material analysis requires access to the original documents and involves transporting rather sophisticated equipment, it is no wonder that we do not possess statistically relevant data sets covering large geographic areas and periods of time. However, over the last five years, we have been collecting information about the inks used in Hebrew manuscripts in the Middle Ages. While no use of soot inks has been attested for Europe yet, iron-gall inks and carbon inks have been found in documents from the Orient[28] that are in accordance with the inks available in the respective regions. This finding supports the suspicion that theological debates responded to the common practices of ink preparation at a given geographic spot and time period. We plan to address the ink composition of biblical scrolls in the Geniza collection over the next few years.

5 Conclusion

The Qumran project in Berlin developed a methodology for the material study of the Dead Sea Scrolls that aimed at addressing archaeometric questions such as sorting the scrolls, their origin and archaeological provenance. In the course of examining the scroll material, we arrived at the conclusion that at least two different traditions of hide treatment co-existed towards the end of the Second Temple Era: heavily tanned parchments (the 'eastern' tradition) and non-tanned or lightly tanned parchments (the 'western' one). Preliminary observations regarding the nature of the writing material used for the non-biblical scrolls in the Cambridge Geniza collection supports the correlation of eastern and western traditions with the Babylonian and Palestinian communities, respectively.

Our ink studies tentatively suggest that inks found in profane Hebrew manuscripts generally correspond to the inks available at the time and location of writing rather than reflecting the isolated socio-cultural backgrounds of the respective Jewish communities. On the other hand, the preferential use of carbon inks for non-biblical scrolls from the Babylonian community may indicate that writing on the scrolls was subject to different rules. Planned study of a larger number of Tora scrolls from both communities will certainly clarify this question.

28 Rabin/Hahn/Binetti 2014; Cohen et al., current volume; and unpublished results.

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