

# Writing and Correcting a Torah Scroll in Germany of the Thirteenth and Fourteenth Centuries\*

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Ms Erfurt 7 (Berlin, Staatsbibliothek Preussischer Kulturbesitz, Ms. Or. fol. 1216) is a thirteenth-century Torah scroll from the famous Erfurt collection kept at the Berlin State Library. Multiple corrections, reinking, and three replacement sheets testify to intense ritual use of the scroll. A previous study has already investigated the different nature of the inks used for the original and replacement sheets and identified a two-stage process of writing, in which the names of God were sometimes added in the second state. The present article broadens the previous study, investigating the relationship between the inks used for the different corrections, reinking, and names of God on both the original and replacement sheets, using a scanning micro-XRF spectrometer. Scientific material analysis confirms and supplements palaeographical observations, identifying the work of a scribe who filled God's name into blank spaces in replacement sheets and performed corrections on both the original sheets and the replacement sheets. It is suggested that this scribe was a master scribe working alongside an apprentice, a practice with parallels in the Dead Sea Scrolls and medieval Hebrew Bible codices.

## **Introduction**

Scientific material analysis of the elemental composition of inks from different strata of a manuscript has the potential to complement scholarly observations using palaeography and philology in reconstructing the history of the manuscript's production, correction and repair.<sup>1</sup> There are three typologically different classes of black writing inks: soot inks consist of carbon particles

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1 See for example Hahn et al. 2008 on the reconstruction of the history of a manuscript from the same collection as the one studied in this article.

suspended in a water-soluble binder; plant inks made of tannin extracts with or without a binder; and iron-gall inks produced by chemical reaction between ferrous iron (Fe II) and gallic or tannic acid. In the Western world, iron-gall inks dominated writing materials in the Middle Ages. Historical records indicate that the most common source of iron for iron-gall inks was a water-soluble mineral, ferrous sulphate, commonly known as vitriol since late Middle Ages.<sup>2</sup> However, sometimes ink makers used other sources of iron for the production of iron gall inks.<sup>3</sup> To distinguish between iron-gall inks based on vitriol and those based on metallic iron, we refer to them as vitriolic or non-vitriolic, respectively. The present study contributes to a study of the history of Erfurt 7 by combining material analysis of inks with scholarly investigation.

### ***Background***

Torah scrolls, containing the five Books of Moses (Genesis, Exodus, Leviticus, Numbers, Deuteronomy), have maintained a central place in Jewish liturgy down to modern times. As the book-form codex swept across the Roman world and was adopted by Christians, Jews continued to utilize the Torah scroll as an intentionally archaic, and to some extent archaizing, ritual artefact for use in public liturgy.<sup>4</sup>

The Torah was, and still is, read publicly three times a week in synagogues every Monday, Thursday, and Saturday.<sup>5</sup> In order to be used in this public liturgy, a Torah scroll had to be written according to exacting standards. These standards required a precise reproduction of every letter of the biblical text.<sup>6</sup> This also included certain paratextual details such as specific types of spacing between sections of text and the layout of poetic passages.<sup>7</sup> Some requirements pertained to the thoughts active in the mind of the artisan or scribe during various stages of production of a Torah scroll. For example, there was a requirement that the skins needed to be prepared with the specific intent

2 Karpenko and Norris 2002.

3 Hahn et al. 2019 (publ. 2021).

4 Haran 1982, 347; according to Beit-Arié 2020a, 39, ‘The Jews ... adopted the codex ... not before the Muslim period and the beginning of the Geonic literary activity, and presumably no earlier than the eighth century.’

5 Jacobs 2007, 46, where the thrice weekly public Torah reading is attributed to the biblical Ezra.

6 To some extent this was an ideal, rather than a reality, in the Middle Ages, cf. Ofer 2019, 46–57. On the typologies of medieval Pentateuch texts in different geocultural regions, see Penkower 2002, 237–264. On the typology of Ashkenazic Pentateuch texts, see Peretz 2008, 92–175; Peretz 2019, 217–256.

7 On the layout of the songs, see Peretz 2019, 257–317; Penkower 2015, 131–137.

of being used for a Torah scroll.<sup>8</sup> Failure to adhere to these specifications, whether textual, technical, or mental, could make a scroll unfit for use in the public reading.<sup>9</sup>

According to the Babylonian Talmud, a scribe needed to write each and every instance of God's name with the proper intent.<sup>10</sup> This applied first and foremost to the personal name of God, 'Yehovah' (often rendered as Yahweh or Jehovah), consisting of the four Hebrew letters *yôḏ hē wāw hē* (יהוה). Writing the Tetragrammaton with 'proper intent' originally meant that as the scribe was writing, he had to form the thought in his mind that he was writing the name of the God of the Hebrew Bible. If the scribe intended to write a graphically similar word (e.g., 'Judah,' in Hebrew יהודה) but accidentally wrote the Tetragrammaton (יהוה), then that instance of God's name was invalid. This in turn invalidated the entire Torah scroll.<sup>11</sup> The requirement for a scribe to write with proper intent was extended to also include other 'names' (or titles) of God, such as *'ēlohîm* ('God').<sup>12</sup>

### **Dating Torah scrolls**

Hebrew codicology and palaeography extrapolate the approximate date of undated manuscripts based on comparison with dated manuscripts. The manuscripts that provide the basis for such comparisons generally contain a date recorded in a colophon, dedication inscription, or ownership inscription. This poses immense methodological challenges for the study of Torah scrolls. Firstly, some aspects of codicology, such as dating Hebrew codices based on the characteristics and construction of quires, naturally have limited application when it comes to the study of scrolls.<sup>13</sup> Secondly, Torah scrolls, as a rule, do not contain any writing other than the consonantal text of the Bible and precisely prescribed paratextual features. Hence, authentic colophons and dedication inscriptions are extremely rare in Torah scrolls.<sup>14</sup> The result

8 Ganzfried 1871, 3b–4a (§2:2–6); for an English translation, see <[https://www.sefaria.org/Keset\\_HaSofer.2.2?lang=bi&with=all&lang2=en](https://www.sefaria.org/Keset_HaSofer.2.2?lang=bi&with=all&lang2=en)>.

9 Some paratextual features, such as large and small letters, were deemed by Maimonides desirable (מצוה מן המבחר) but their absence did not invalidate a scroll's use in public liturgy, see *Mishneh Torah, Tefillin, Mezuzahs, and the Torah Scroll* 7:9–11 (for an English translation, see <[https://www.sefaria.org/Mishneh\\_Torah%2C\\_Tefillin%2C\\_Mezuzah\\_and\\_the\\_Torah\\_Scroll.7.9?lang=bi&with=all&lang2=en](https://www.sefaria.org/Mishneh_Torah%2C_Tefillin%2C_Mezuzah_and_the_Torah_Scroll.7.9?lang=bi&with=all&lang2=en)>).

10 *Babylonian Talmud*, Gittin 54b.

11 *Babylonian Talmud*, Gittin 54b (cf. *Soferim* 5:4).

12 *Soferim* 4:1–2.

13 For an example, see Iakerson 2014, 69–70.

14 The First Firkovich collection at the Russian National Library in St. Petersburg contains several Torah scrolls with forged inscriptions (Harkavy and Strack 1875, 173–221; Beit-Arié 2020b, 195–205). Other examples of forged inscriptions in

is a lack of firmly dated scrolls from which to extrapolate to undated scrolls. Thirdly, Torah scrolls by their very nature are archaizing ritual artefacts. Even in the Middle Ages, there is a possibility that scribes intentionally used what they considered to be archaic-looking scripts when writing Torah scrolls, in order to imbue them with more of a perceived sanctity. This has the potential to skew dates extrapolated from palaeographical comparison with dated codices. Fourthly, the study of Hebrew codicology and palaeography carried out by *The Hebrew Palaeography Committee* only studied Hebrew manuscripts up until the year 1540.<sup>15</sup> This was an arbitrary endpoint chosen because it was the end of a Hebrew century (5300 *anno mundi*) about one hundred years after the start of printing in Europe. However, the vast majority of surviving Torah scrolls (not even including those still in use in synagogues around the world) are later than 1540. Torah scrolls tend to become increasingly homogenous over time, especially following the printing revolution (lending special importance to the study of medieval scrolls). The above underscores the importance of employing radiometric dating, specifically, Carbon 14.

Other methodological challenges stem from the ritual performative function of Torah scrolls. The abrasive act of rolling a Torah scroll from one end and back again throughout a reading cycle (either, one year or three years) naturally damaged the writing.<sup>16</sup> A scroll would be retired when enough of the ink was rubbed off, although reinking faded letters could delay this process. The browning of some types of skin over time, which reduced the contrast be-

Torah scrolls include MSS Jerusalem, National Library of Israel, Ms. Heb. 5935 (which attributes the scroll to Rabbi Nissim Gerondi; Zucker 2012, 623–633), Jerusalem, The National Library of Israel, Ms. Heb. 6100<sup>4</sup> (which attributes the scroll to Anan ben David; Zucker 2012, 633–636), and Washington DC, Museum of the Bible, SCR.4676 (which attributes the scroll to Jewish survivors of the Spanish Inquisition). Examples of genuine inscriptions in Torah scrolls are MSS Cambridge, Trinity College, Wren Library, F.18.1 (Crimea, c.1320–1350; Chwolson 1882, 232–233), St. Petersburg, Russian National Library, Evr. IA 35 (Crimea, 1363; Harkavy and Strack 1875, 220–221; Beit-Arié 2020a, 105–106) and New York, Columbia University, Ms. General 61 (1690). These genuine examples were produced by Karaite Jews who did not consider themselves bound by rabbinic strictures that prohibited writing anything other than the consonantal text of the Bible (and specific paratextual elements) in Torah scrolls. Beit-Arié 2020a, 480, n. 31 cites an example of a (presumably) non-Karaite Torah scroll with a colophon from southern Italy dated 1091–1092 in a private collection.

15 See MMch I–III.

16 The triennial cycle was the custom of Eretz Israel (*Babylonian Talmud*, Megillah 29b) and was still being used in the synagogue of Jews following the traditions of Eretz Israel in Fustat as late as the beginning of the thirteenth century (Naeh 1998, 167).

tween the ink and the background, could also bring about the end of life for a scroll.<sup>17</sup> When scrolls were retired, they were often placed in a grave or tomb, allowing them to decay naturally.<sup>18</sup> The result is a paucity of surviving Torah scrolls from the fourteenth century and earlier.

Similarly, as objects with a performative function, Torah scrolls had to comply perfectly with the standards of halakhah (Jewish ritual law).<sup>19</sup> Since no text on the scale of the Torah (approximately 80,000 words) could ever be reproduced perfectly by human hands, scrolls were corrected on an ongoing basis as errors were found. Medieval scrolls also needed to be corrected (or rather updated to new standards) as scribal praxis and halakhah evolved.<sup>20</sup> As a result, surviving examples of medieval Torah scrolls tend to contain successive corrections and modifications.

All of these factors make the study of the four Torah scrolls from the Erfurt collection an important contribution to Hebrew codicology and palaeography, to Jewish scribal culture, and to the transmission of the biblical text in the Middle Ages. It is generally assumed that these scrolls were seized from the Jewish community in a massacre that took place in March 1349.<sup>21</sup> If this is correct, then the *terminus ad quem* for any Jewish scribal interventions in these scrolls would be March 1349.

### **Erfurt 7**

Erfurt 7, one of fifteen Hebrew manuscripts purported to have been seized from the Jewish community of Erfurt in the 1349 massacre, is a thirteenth-century Torah scroll housed in Berlin, at the Staatsbibliothek Preussischer Kulturbesitz, Orientabteilung, where it is designated Ms. Or. fol. 1216. The scroll consists of fifty sheets containing three columns each, with sixty lines per column. The sheets measure in height between 64 and 68 cm (with an average of 66 cm) and in width between 51 and 62 cm (with an average of 58 cm) for an overall length of the scroll of 28.85 m. The scroll was copied from a codex now preserved at the Bayerische Staatsbibliothek in Munich (Cod. heb. 212 [IMHM F 25964]) or from a source in common with that codex.<sup>22</sup> A date of

17 Rabin 2017, 309–322.

18 Stern 2017, 223, n. 170.

19 For examples of conflicts between scribal praxis and halakhah, see Ofer 2019, 271; Penkower 2019, 138–166; Penkower 2020, 33–49; Gordon 2021, 208–236.

20 Penkower 2015, 125–140.

21 Penkower 2015, 122–123; Caspi 2014, 240–241.

22 For further codicological and textual characteristics, see Jaraczewsky 1868, 116; Steinschneider 1897, 3; Thimme 2009, 64; Caspi 2014, 234–236; Penkower 2015, 118–119, 123–140; Gordon et al. 2020, 163–171.

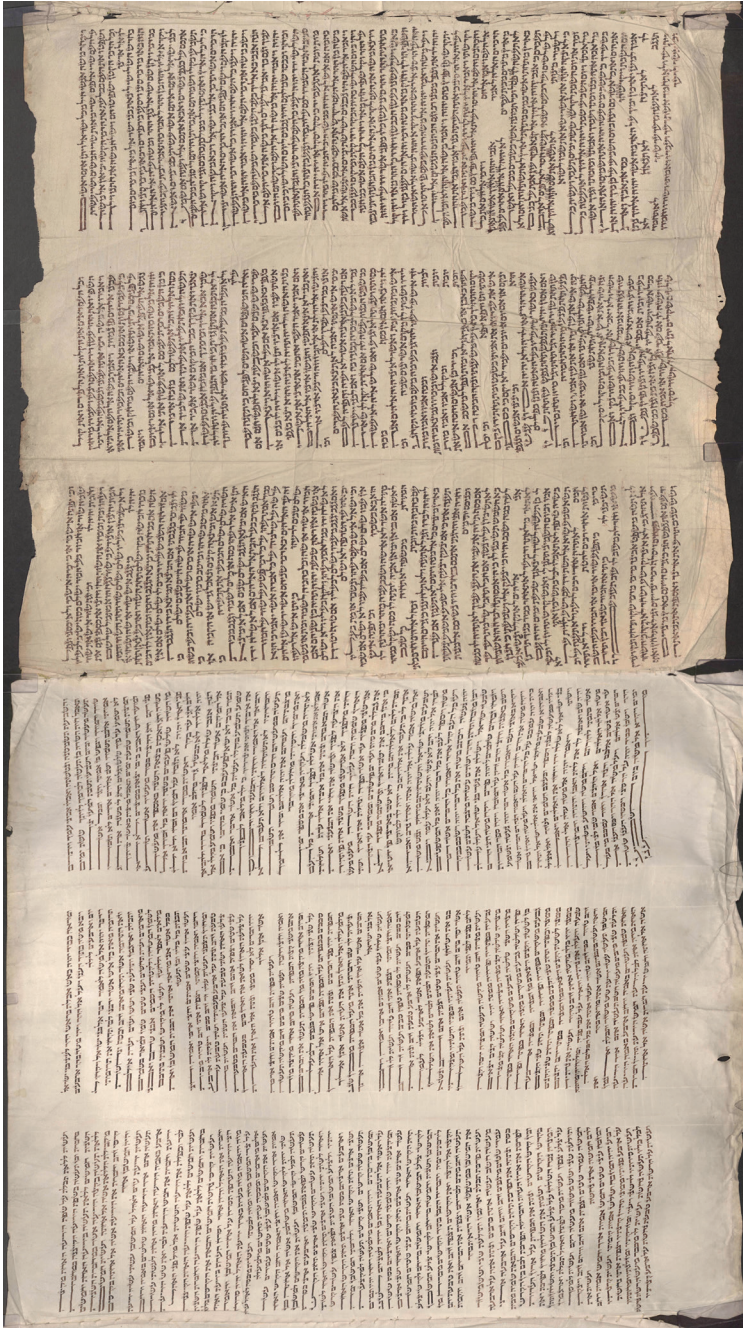


Fig. 1. The Torah scroll Erfurt 7 contains the Five Books of Moses (Genesis, Exodus, Leviticus, Numbers, and Deuteronomy) written on fifty 'sheets' (Hebrew: *yeri* אַף יָרֵי) sewn together end to end. Each sheet has 3 columns of text with sixty lines per column. In the photo, the sheet on the right (18) is one of forty-seven original sheets (1–18, 21–25, 27–50) presumably dating to the thirteenth century. The sheet on the left (19) is one of three replacement sheets (19–20, 26) presumably dating to the early fourteenth century. © Staatsbibliothek zu Berlin - Preussischer Kulturbesitz, Orientabteilung, Ms. or. fol. 1216.

the thirteenth century has been suggested for the 47 original sheets of Erfurt 7, with three replacement sheets added in the fourteenth century.<sup>23</sup>

Erfurt 7 contains successive corrections in the hands of multiple scribes. Corrections can usually be identified by the damage done to the parchment by an erasure through abrasion (scratching ink off the parchment with a sharp object). Another sign of correction can be a change in the appearance of the handwriting and ink. The hands of later scribes can often be identified based on palaeographical grounds such as the shapes of the letters and the density of the writing. When only a few letters were modified, it can be difficult to determine the relationship between various scribal interventions. Some corrections, especially the addition of missing words, can affect aspects of the script (e.g. size, density) making it difficult to determine the relationship of the corrector and the original scribe.

Our first study of Erfurt 7 explored the relationship between the names of God (יהוה 'YHWH' and יהוה אלהים 'YHWH God') in the first 1.5 columns of the first sheet and that of the surrounding text.<sup>24</sup> The names of God were in a distinctly darker shade of brown ink than that of the surrounding text. Despite the difference in colour, from a palaeographical perspective, these names of God appeared to have been written by the same scribe who wrote the surrounding text. However, prior research has shown there can be a lack of correlation between the appearance of inks and their elemental composition.<sup>25</sup> Nevertheless, in this specific case, through X-Ray Fluorescence (XRF) analysis, a small, although detectable difference in the signal of potassium relative to iron was observed between the lighter and darker shades of inks (respectively called OS.LT and OS.DK in the previous study). OS.LT and OS.DK were tentatively determined to be from two different batches of iron gall ink, suggesting that the divine appellations were not inscribed at the same time as the main text. This result fits well with a special procedure employed in liturgical scrolls, described in medieval Jewish sources and found in other scrolls.<sup>26</sup> The procedure involved initially leaving blank spaces for the names of God, which were filled in during a second stage of writing by the same scribe or a different scribe. The XRF results along with palaeographical observations suggested this two-stage procedure was performed by a single scribe. The same study also showed that the main ink used on the original sheets was non-vitriolic iron gall ink, which differed from the ink used on the replacement sheets,

23 Penkower 2015, 118–119; Caspi 2014, 234–236. On the characteristics of thirteenth and fourteenth century German Ashkenazic square script, see Engel 2017, xxii–xxxii.

24 Gordon et al. 2020.

25 See for example Rabin et al. 2012.

26 Gordon forthcoming.



Fig. 2. The Torah scroll Erfurt 7, mounted on a custom-built aluminium stage for non-destructive measurement with a high-resolution scanning micro-XRF M6Jetstream (Bruker Nano GmbH). The scroll is partially unrolled and opened to the first column of sheet 18 and the measurement is being conducted at approximately 10 mm distance. Some additional metallic weights (at the bottom of sheet 17, column 3 and sheet 18, column 2)—separated from the surface of the scroll by acid-free paper—are being used to keep (areas that are not being measured) flat. © Staatsbibliothek zu Berlin - Preussischer Kulturbesitz, Orientabteilung, Ms. or. fol. 1216.

which was vitriolic iron gall ink containing a large amount of zinc. Zinc-rich inks were also found in other manuscripts from Erfurt.<sup>27</sup>

Material analysis has the ability to identify the elemental composition of inks and their possible relationships. The participation of a scholar who

27 Hahn et al. 2008.



specialized in the text being studied (Gordon) allowed the material scientists (Nehring, Bonnerot, and Rabin) to focus their investigations on specific regions of interest in order to answer questions of scholarly interest related to the production and development of the text. In the case of Erfurt 7, the questions pertained to scribal interventions that produced and modified the text. This involved the scholar identifying elements that may have been added to the text during its initial production such as crowns (paratextual decorations), God's name (potentially written in a second phase), and corrections seemingly executed by the original scribe. Further questions considered the relationship between the original text, the added elements, and what appeared to be later corrections in multiple scribal hands (identified based on the shapes of the letters and the visual appearance of the parchment and the inks). These questions also applied to three replacement sheets, which had their own corrections as well as God's name, which seemed to have been written in a second stage of writing by a second scribe. Another question was the relationship of some of the inks used for corrections on the original sheets and those on the replacement sheets. The questions were refined iteratively during the experiment.

Usually, the correlations between different stages of writing are determined based on palaeographical grounds, such as 'morpholog[y] ... singling out similar shapes of individual letters, by dismantling the components of the script' and comparing 'the texture of the writing, its styles and general impressions.'<sup>28</sup> The use of a micro-X-ray fluorescence imaging spectrometer added a layer of material science to visual palaeographical comparisons. This required an ongoing and continuous interaction between the material scientists (Nehring, Bonnerot, and Rabin) and the textual scholar (Gordon).<sup>29</sup>

### ***Preparation of the object for the experiment***

To ensure the safety of the object during the measurements, we used a custom-built aluminium stage with a magnetic frame. The top part of the stage is made of plexiglass plates that can be slid open, leaving a space allowing measurements of an unrolled portion of the scroll without background interferences. Before each scan, the selected area was temporarily and non-invasively flattened using neodymium magnets wrapped in Tyvek<sup>30</sup> and placed on acid-free paper spacers and the magnetic frame on which the unrolled scroll

28 Beit-Arié 1987, iii.

29 On a practical level, this involved Nehring, Bonnerot, and Rabin operating the scientific equipment in Berlin, Germany, while Gordon was on-call over internet connection in Dallas, Texas. This allowed for real-time pragmatic adjustments of the experiment parameters based on philological and palaeographical considerations.

30 DuPont™ Tyvek® is a non-woven, conservation-grade material made of high-density polyethylene fibres.

was mounted. Due to the oversized nature of this precious object of cultural heritage, the scroll was handled by a group of three people and an art conservator coordinated the whole process.

### *Experiment*

The scroll was analysed according to a protocol described in detail elsewhere.<sup>31</sup> In short, the work protocol consisted in the initial reflectographic screening, followed by elemental analysis by X-ray fluorescence.

To verify that the inks belonged to the iron-gall type, we conducted the screening with a Dino-Lite USB microscope (model AD4113T-I2V). The device features magnification ranging from 20 to 200 and is equipped with built-in near-infrared (NIR) and ultraviolet (UV) lights at ~940 nm and ~395 nm, respectively, and an external LED white light source.

To obtain the elemental composition of inks, we used an M6 Jetstream (Bruker GmbH) imaging  $\mu$ -XRF spectrometer with an adjustable measuring spot ranging from 50 to 650  $\mu\text{m}$ , which is equipped with a low-power Rh X-ray tube, polycapillary X-ray focussing optics, a 50  $\text{mm}^2$  Xflash SDD detector, and two microscopes for positioning. Since scanning is conducted in air atmosphere, only elements heavier than magnesium (Mg,  $Z=12$ ) can be securely identified. We conducted a semi-quantitative comparison of the abundance of elements starting with potassium (K,  $Z=19$ ). All the measurements were performed at 50kV and 600 $\mu\text{A}$ , with a spot size of 100  $\mu\text{m}$ , an acquisition time of 10 ms/pixel, and a pixel (step) size of 200  $\mu\text{m}$ . The areas for the scans were carefully chosen to contain the maximum number of the relevant features (corrections, re-inking, changes of hands, etc.), under the constraints dictated by space and time. We focused our study on large portions of the text from both original sheets (14 and 17) and a replacement sheet (19). In total, we conducted 8 scans ranging in area from 30.2  $\text{cm}^2$  to 298.4  $\text{cm}^2$ .

We used a simplified version of the ‘fingerprint model’ initially introduced to compare the elemental composition of vitriolic iron-gall inks on paper.<sup>32</sup> For each given element, the intensity of the corresponding XRF signal is related to its quantity in the analysed material. However, the intensity also depends on the element itself, and on other factors (matrix effect, thickness etc.), making direct comparison of the measured intensities impossible. In the adaptation of the fingerprint model, we assumed:

- that the parchment composition in the inked and non-inked areas is the same;

31 See Nehring et al. 2021.

32 For the definition of the vitriolic and non-vitriolic inks see Hahn et al. 2021; for the fingerprint model see Hahn 2004.

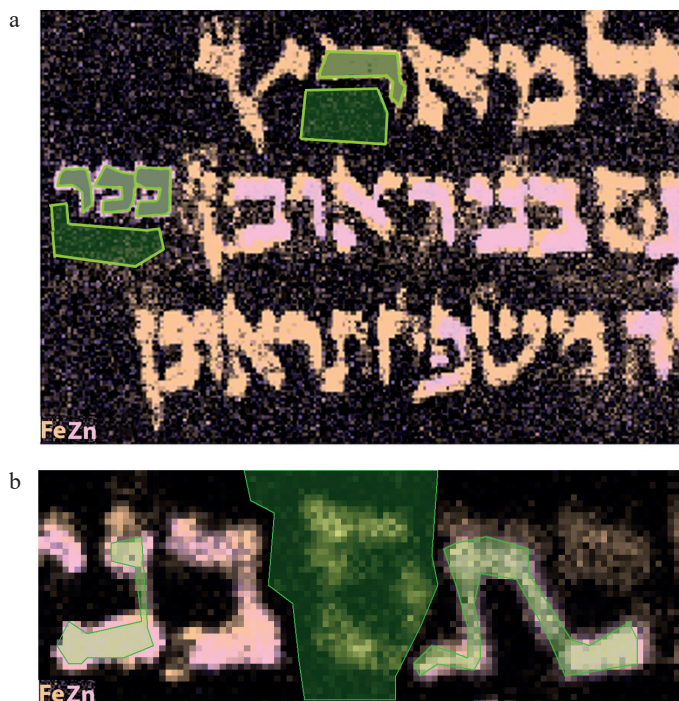


Fig. 3. Original and corrected text from sheet 14 col. 2 (Exodus 6:14). Superimposed maps of the elements iron (Fe, orange) and zinc (Zn, pink). The areas selected for semi-quantitative analysis are marked in green; (a) original text and correction in the margin; (b) reinked text.

- that the thickness of the inks is consistently smaller than that of the parchment;
- that if two areas were inked with the same batch of iron-gall ink, net peak intensities of a given element normalized to iron would be similar.

To estimate the contribution of the writing support to the element intensities measured in the inks, we selected regions of interest (ROIs) in the inked area and in the non-inscribed adjacent space as shown in fig. 3a. In one case, for which we investigated a reinked portion of the text, we had to choose a background area containing traces of the original ink in addition to virgin parchment (cf. fig. 3b). Since each pixel on the image of fig. 3 corresponds to a single XRF spectrum, each region of interest corresponds to a cumulative XRF spectrum, from which net peak intensities of the individual elements were calculated following an iterative fitting process using Gaussian deconvolution with the native software. To obtain net abundancies of the elements contained in the inks, the average net peak intensities from the background (non-inked) XRF spectrum are subtracted from those of the inked ones. Final-

ly, for each element, its net peak intensity ( $I_{Me}$ , where  $Me$  is the element) is divided by the net peak intensity of iron ( $I_{Fe}$ ) resulting in a relative contribution of the element  $Me$  to the ink.

### **Results and discussion**

We divided our work between the confirmation of the results of the previous survey for which we used the portable single spot measuring Elio XRF spectrometer,<sup>33</sup> and the investigation of questions which had remained unanswered. The primary survey indicated the presence of non-vitriolic inks in the main text of the original sheets (OS), while vitriolic zinc-rich iron-gall ink was used in the replacement sheets (RS). In addition, the results suggested that at least two batches of non-vitriolic ink were used on the original sheets. In the present survey, we were able to use a scanning micro-XRF spectrometer, which allowed us to delve further, investigating the relationship between the various corrections, reinking, and divine appellations present on the original sheets 14 and 17, and on the replacement sheet 19.

Fig. 4 summarizes the reflectographic survey of the different inks investigated in this work. All the inks reacted similarly to the tests: they appeared darker and more homogeneous under UV than under visible light testifying to the presence of tannins that quench the UV fluorescence of the parchment. By contrast, under NIR light, the letters become partly, but not totally transparent, indicating that they are penned with iron-gall ink.<sup>34</sup> No exact information on the ink composition can be extracted from the reflectographic analysis because the colour of the iron-gall ink and its transparency in the NIR light do not directly correlate with the presence or absence of impurities.<sup>35</sup>

It is the elemental composition of the inks determined by scanning XRF analysis that allowed us to immediately spot several differences between the inks. Maps of elements from the scanned areas allowed us to identify or confirm the presence of features such as corrections and re-inking of letters and suggest the succession of events that took place when the Torah scroll was written, repaired, and corrected. Fig. 5a shows a photograph of the three bottom lines from column 2 of the original sheet 14 (Exodus 6:14). About half of the second line (left-hand side) and most of the third line were erased and initially corrected with smaller letters than that of the surrounding text. The small letters of this initial correction were then reinked in a later stage. The seemingly bad state of preservation of these inks contrasts strongly with that of the word *beḵōr* (בכר) added in small letters in the margin of the second line,

33 Gordon et al. 2020.

34 Mrusek et al. 1995.

35 Rabin et al. 2012.

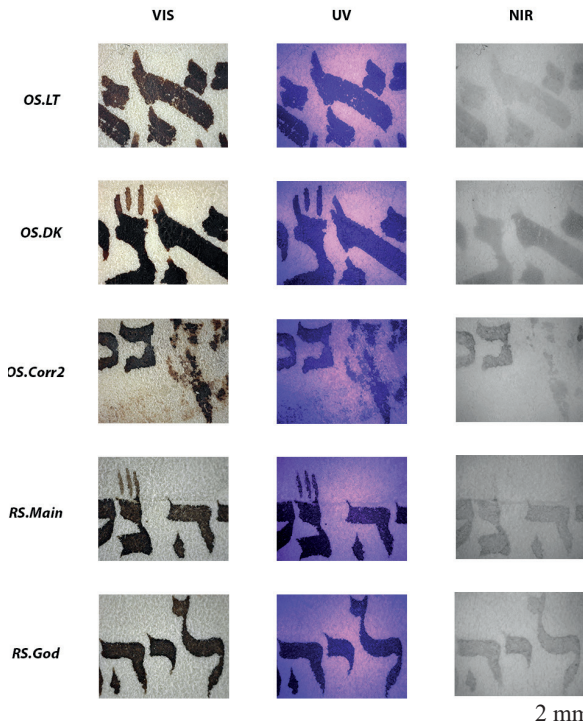


Fig. 4. Visible (left), UV (middle) and NIR (right) micrographs. *OS.LT* and *OS.DK* – inks of lighter or darker shades on original sheet 14 (column 2, line 40); *OS.Corr2* – addition of small letters on original sheet 14 (column 2, line 59), *RS.Main* – main ink of replacement sheet 19 (column 1, line 41); *RS.God* – God’s name on replacement sheet 19 (column 1, line 36).

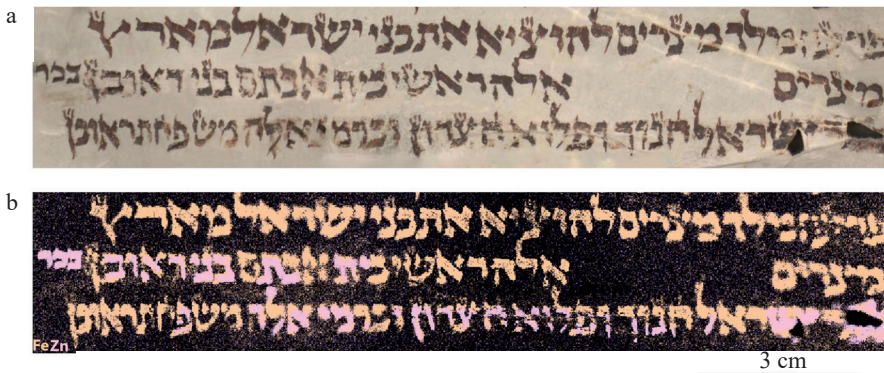


Fig. 5. Bottom lines of sheet 14 column 2 (Exodus 6.14); (a) image of the scanned area; (b) superimposed maps of iron (Fe, orange) and zinc (Zn, in pink colour).

visible on the left-hand side of the image. Note that the colour of this added word is not different from the original text of the top line. In fig. 5b one can see the superimposed maps of iron (Fe) and zinc (Zn) for the same area, which reflect the main difference in composition between the original ink and that of the initial correction, on the one hand, and the ink used by the reinker and the corrector who added the small letters in the left-hand margin, on the other hand. Since only the ink for some of the corrections contains zinc, the maps indicate the stratigraphy of the application of the ink, leading to the following tentative reconstruction of events: 1) The original scribe wrote Exodus 6:14 with some error. The error may have involved parablepsis, i.e. the scribe's eye jumping from one word to another after which he copied from the wrong place in his source text. The verse has the word *R<sup>e</sup> 'ûbēn* (רֵאוּבֵן) twice, which makes it a good candidate for this type of error, although the cause for the specific error is speculation; 2) a corrector (based on palaeography, probably the original scribe) erased 1.5 lines of text and replaced it with a correction. In the process of erasing, he made holes at the beginning of the last line; 3) another corrector decided that the first word in the last line was unsatisfactory because of the holes, so he put ink over the word (probably *beḵōr*) and rewrote it at the end of the previous line, in the margin. The earlier abrasion caused the ink of the initial correction to deteriorate, leading this later corrector to reink parts of some of the deteriorating letters (pink in fig. 5b). This corrector used a zinc-rich ink.

Another example of scientific material analysis corresponding to, and supplementing, palaeographical observations, concerns the two-stage procedure of leaving blank spaces for the names of God which were filled in during a second stage of writing. Fig. 6a shows a portion of column 1 from replacement sheet 19. God's name (cf. fig. 6a, white arrow) is significantly smaller with finer horizontal lines than that of the main text, even when ample room was left for it during the first stage of writing. The tops of the horizontal lines of the main text are aligned with the horizontal ruling line, whereas those of God's name are below and parallel to the horizontal ruling line. The vertical lines of God's name also descend lower than those of the main text.

As was already brought up by the previous XRF study, the main ink of the replacement sheets, contrary to the original sheets, contains elevated amount of zinc and small amounts of copper. The script from sheet 19 column 1 in fig. 6a has a uniform hue. The script also appears homogeneous in the elemental maps of iron and zinc in fig. 6b and fig. 6d, respectively, in contrast to the heterogeneity of the copper map in fig. 6c. A visible change in the intensity of copper precisely in the position of God's name (marked with a white ellipse) suggests that this word was not written together with the rest of the



Fig. 6. Portion of sheet 19 column 1 Exodus 23,19-20; (a) image of the scanned area; (b) map of iron (Fe); (c) map of copper (Cu), with God's name is marked with a white ellipse and with an arrow in the photograph; (d) map of zinc (Zn).

text. This unequivocally proves the validity of the scholarly hypothesis that God's name was filled into empty spaces left by the original scribe, apparently by a second scribe using different ink.

The two examples above show that distributions of specific elements such as iron, copper and zinc deliver important information regarding the succession of writing and correcting sessions of the scroll. Semi-quantitative

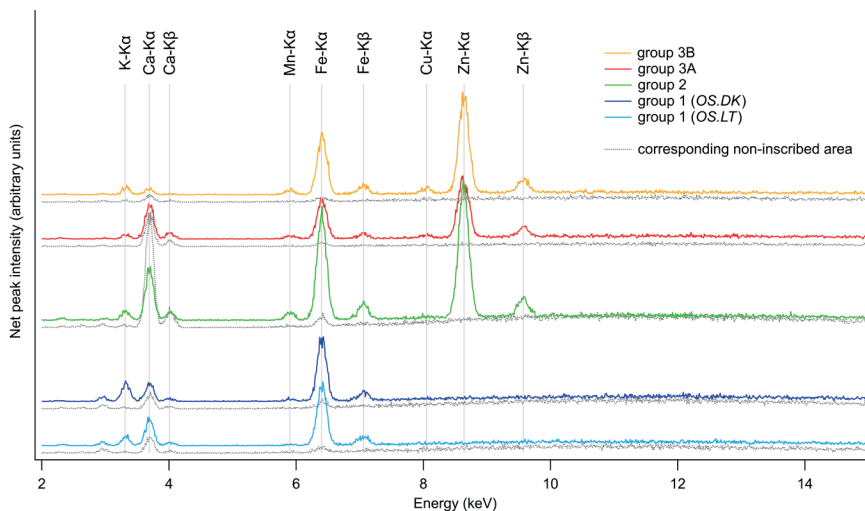


Fig. 7. XRF spectra of the different groups of inks. Group 1: OS.LT and OS.DK – dark and light inks from sheet 14 (column 2, line 40), respectively. Group 2: RS.Main – main ink of replacement sheets, sheet 19 (column 1 line 41). Group 3A: RS.God – God’s name, sample taken on sheet 19 (column 1 line 36). Groups 3B: OS.Corr2 – addition of small letters from sheet 14 (column 2 line 59).

evaluation of the data offers further insights into the history of writing and correcting Erfurt 7.

Based on their relative elemental composition, the inks studied in this work, i.e., main texts, corrections, re-inking, and additions of God’s names fall roughly into three groups, whose representative XRF spectra are shown in fig. 7. All the inks contained potassium (K), manganese (Mn), and iron (Fe) in varying amounts. In addition, several inks contained zinc (Zn) in high amount, accompanied in some cases by traces of copper (Cu). Calcium (Ca) was found to originate mostly from the support. In the previous work, zinc (Zn) was found to be a key element in discriminating different groups of ink, but this time, the better statistics due to higher spatial resolution and scanning utility allowed us to add copper as a second discriminating element despite its extremely low abundance.

Group 1 encompasses inks which do not contain detectable amount of copper or zinc. It corresponds to the main inks found on the original sheets (‘OS.DK’ and ‘OS.LT’ from the previous survey belong to this group: OS.Main as well as some early corrections: OS.Corr1). We suggested in the previous publication that ‘OS.DK’ and ‘OS.LT’ may be indicative of two different batches of the same ink, based on small, but statistically significant differenc-



es in potassium to iron net peak intensities. This result was confirmed by this survey, with OS.DK inks having an average  $I_K/I_{Fe}$  value almost twice that of OS.LT (around 0.22 and 0.12, respectively). Inks from group 2 contain a significant amount of zinc ( $1.32 < I_{Zn}/I_{Fe} < 1.54$ ) but no detectable copper. They correspond to the main ink of the text in the replacement sheets (RS.Main). Inks from group 3 contain a higher amount of zinc than inks in group 2 ( $1.72 < I_{Zn}/I_{Fe} < 2.09$ ), and detectable traces of copper (though less than 0.1 net peak intensity relative to iron). They correspond to God's name on the replacement sheets (RS.God), two corrections on the replacement sheets (RS.Corr), some corrections on the original sheets (OS.Corr2, OS.Corr2.God, OS.Corr2.Prepare) and reinking on the original sheets (OS.Reink). Table 1 and fig. 8 present the results of the quantitative treatment of all the data collected in this work.

Table 1. Relative content of zinc and copper. Min-max: minimal and maximum measured values, : average value,  $\sigma$ : standard deviation. Group 3 (A&B) presents the results of group 3 as a whole. L.O.D.: Limit of detection.

Group	$I_{Cu}/I_{Fe}$			$I_{Zn}/I_{Fe}$		
	min-max		$\sigma$	min-max		$\sigma$
<b>1</b>	< L.O.D.	-	-	< L.O.D.	-	-
<b>2</b>	< L.O.D.	-	-	1.32 - 1.54	1.44	0.076
<b>3 (A &amp; B)</b>	0.02-0.09	0.06	0.021	1.72-2.09	1.91	0.115
<b>3A</b>	0.02-0.06	0.04	0.013	1.72-2.08	1.90	0.123
<b>3B</b>	0.07-0.09	0.08	0.009	1.89-2.09	1.95	0.088

The data evaluation clearly shows that the original script of the Torah did not contain such metallic impurities as zinc and copper tentatively leading to the suggestion that the original ink was not based on vitriol. Although we could confirm the differences in potassium concentration between 'OS.LT' and 'OS.DK' inks, we could not conclude whether corrections executed in this type of ink were conducted during the original production of the scroll. Indeed, such corrections were written over residues of the original ink which contains the same elements. Furthermore, they are characterized by a significantly worse preservation state than that of the remaining original script. By contrast, the Zn-rich ink of the replacement sheet is clearly of a vitriolic origin. Corrections conducted in vitriolic inks can be classified and compared in a more secure fashion. In this work, it was possible to tentatively divide group 3 into subcategories 3A and 3B. 3A consists of corrections and God's

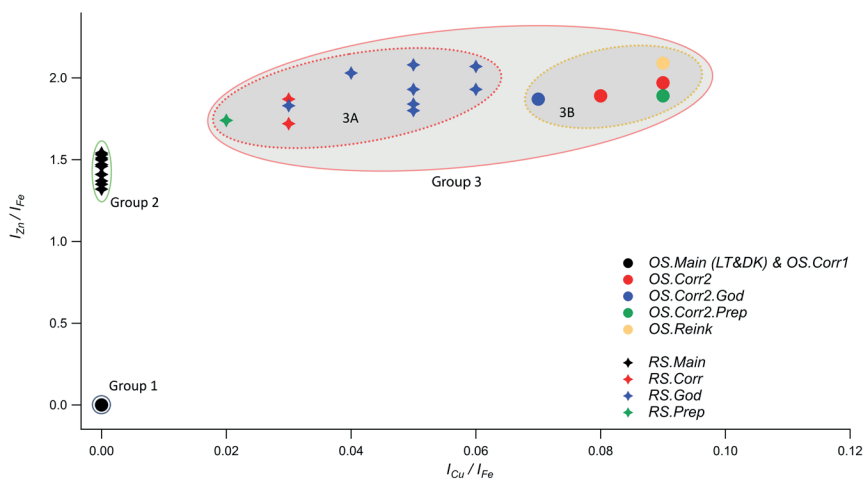


Fig. 8.  $I_{Zn}/I_{Fe}$  against  $I_{Cu}/I_{Fe}$  of the different inks sampled from the scans. Spots from the original sheets are represented as plain circles, while spots from the replacement sheets are plain diamonds. OS.main comprises both ‘OS.LT’ and ‘OS.DK’ from the previous study.

name on the replacement sheets. 3B consists of some corrections (including God’s name and an inseparable preposition) and re-inking on the original sheets. Zinc to iron ratios for both subgroups are indistinguishable, but there is a clear separation from the copper to iron net peak intensities (0.07-0.09 for 3B vs 0.02-0.06 for 3A). The difference in copper abundance, although small, clearly appears in fig. 8, which displays relative concentration of zinc ( $I_{Zn}/I_{Fe}$ ) versus that of copper ( $I_{Cu}/I_{Fe}$ ) for the different inked areas selected for semi-quantitative analysis.

We also tried to investigate the relationship between the inks used for the ‘crowns’ (*tagin*), the main text, and some other corrections. We observed no significant differences between the composition of the crowns and the corresponding letters in the examples we investigated. However, the crowns are extremely thin (~0.1 mm wide), and additional scans, centred around selected crowned letters, and with a much higher spatial resolution would be needed to unequivocally address this question. Because of time constraints, we could not perform these additional high-resolution scans this time.

Palaeographic and material ink analysis firmly suggest that God’s name was added by a second scribe. Two corrections on the replacement sheets share the same palaeographical characteristics and that of God’s name. Corrections on sheets 14 and 17 (original sheets) also share these characteristics and appear to have been written in the same handwriting as both God’s name and the corrections on the replacement sheets. The results of the experiment

show that God's name on the replacement sheets, corrections on the replacement sheets, corrections on sheets 14 and 17, and the reinking that accompanies the correction on sheet 14 were all written with zinc-rich vitriolic ink containing copper. There is only a small difference in the copper amount between the ink used to write God's name and corrections in the replacement sheets (group 3A) and the ink used to write the corrections of sheets 14 and 17 and for the re-inking (group 3B). This difference, although minimal, tentatively suggests that the corrections and re-inking of sheets 14 and 17 were done during a separate writing session than the inscription of God's name and corrections on the replacement sheets. This difference might be due to contamination from a copper inkwell, in which the ink was laying during the correction session(s). These inks also have a similar visual appearance, and the handwriting appears to be the same (although one cannot determine the handwriting of the reinker). These material analysis results, combined with the palaeographical observations, suggest that a single scribe produced all these textual elements. Corrections performed in the same handwriting and bearing the same characteristics also appear on at least fifteen of the original sheets.<sup>36</sup> These corrections point to the work of a master scribe who filled God's name into blank spaces during a second stage of writing in the replacement sheets and made corrections throughout the scroll. It is possible that an apprentice was tasked with proofreading the forty-seven original sheets of the scroll and left the corrections to the master. Alternatively, the master may have proofread himself before making the corrections.

The Dead Sea Scrolls contain an early parallel to the practice of leaving blank spaces for God's name, which were filled in during a second stage of writing. In some instances, it has been determined on palaeographical grounds that God's name was filled in by a second scribe.<sup>37</sup> Hartmut Stegemann suggested that the community who produced the Dead Sea Scrolls employed a 'speziellen 'Gottesnamenschreiber'', who was perhaps qualified or authorized to write God's name in a way that the main scribe was not.<sup>38</sup> Stegemann suggested this based on palaeographical observations without the confirmation of material analysis. In the case of Erfurt 7, we can say based on material

36 The hand of the scribe who wrote God's name and the corrections on the replacement sheets, as well as corrections on sheets 14 and 17, is also evident on sheets 1 (col. 2, Gen 2:20), 2 (col. 2, Gen 7:11), 3 (col. 1, Gen 11:24), 7 (col. 1, Gen 27:44; col. 3, Gen 29:28), 8 (col. 1, Gen 30:38; col. 2, Gen 32:10), 10 (col. 3, Gen 41:21), 21 (col. 2, Exod 32:29–30), 28 (col. 2, Lev 17:13), 35 (col. 2, Num 14:8), 36 (col. 3, Num 19:6), 41 (col. 2, Num 36:3), 43 (col. 1, Deut 5:1), and 44 (col. 2, Deut 11:10). Our thanks to Nelson Calvillo for finding many of these examples.

37 Tov 2004, 218–221.

38 Stegemann 1969, 154; cf. Tov 2004, 240.

analysis that the God's-Name-Writer 1) filled in God's name in the replacement sheets, 2) made corrections on the replacement sheets, 3) made corrections on two (and based on palaeographical observations, possibly fifteen) of the original sheets, and 4) reinked part of sheet 14.

A medieval parallel of a master working with another scribe (although not an apprentice) can be found in some tenth-century Masoretic codices. An example of this is the Aleppo Codex, a copy of the Bible in Hebrew completed in Tiberias around the year 925 and prepared as a 'model codex' against which other scribes checked their copies.<sup>39</sup> According to the dedication inscription, the letters of the Aleppo Codex were written by Solomon Ben Buya'a, who is termed a *sofer mahir*, i.e., 'proficient scribe.' In a second stage, vowel points and accents were added by Aaron Ben Asher, who is referred to as *'adon ha-sofrim* 'Master of the Scribes.'<sup>40</sup> Maimonides later reported that, 'Ben Asher proofread it, precisely examining it for years, proofreading it many times, as has been related by tradition.'<sup>41</sup> Israel Yeivin found that the Aleppo Codex indeed contained numerous corrections on every page, consistent with the report of Maimonides.<sup>42</sup>

An Ashkenazic parallel, contemporary to the replacement sheets of Erfurt 7, is the Bible codex Hamburg, Staats- und Universitätsbibliothek, Levy 19 (Sfardata 0G132; IMHM F 1496), completed in Brussels in 1309. According to Judith Olszowy-Schlanger, one scribe wrote the main biblical text and the Rashi commentary, a second scribe wrote the Masorah parva, a third scribe wrote the Masorah magna, and a fourth scribe illuminated the manuscript and corrected the text throughout. The fourth scribe seems to have been the supervisor of the entire project; although he contributed quite little to the text, he states in the colophon (f. 625r): 'I completed the illumination and the writing together' (*š'yyūr wehakketibâ š'llamtî yaḥad*, ציור והכתיבה שילמתי יחד).

## Conclusions

Our findings confirmed the results from the previous publication but with better statistics. Non-vitriolic ink was used for writing the text of the original sheets of Erfurt 7 (inks from Group 1), while vitriolic ink was used for the replacement sheets (inks from Group 2). Furthermore, the original text was written with (at least) two batches of inks. Thanks to the high-resolution

39 Penkower 1981, 41.

40 Ofer 1989, 287.

41 *Mishneh Torah*, Tefillin, Mezuzahs, and the Torah Scroll 8:4; cf. Penkower 1981, 40–42.

42 Yeivin, *Erasures Apparatus*; our thanks to Michael Segal and Rafael Zer of the Hebrew University Bible Project for giving Gordon access to the handwritten unpublished manuscript.

area scans, we could investigate the relationship between corrections from the original sheets and the various inks found in the replacement sheets. The composition of the ink used for the corrections and the divine names written on the replacement sheets was found to be very similar to that of some corrections and re-inking on the original sheets. We showed that God's name was written in the second stage of preparing the replacement sheets. We suggest that the master scribe, who filled in the empty spaces left by the main scribe of the replacement sheets, executed various corrections and reinking on both the original and the replacement sheets.

We could only achieve these results due to the interdisciplinary character of our team and a close collaboration between the fields of material science and humanities.

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