COMPOSITION ANALYSIS OF WRITING MATERIALS IN CAIRO GENIZAH DOCUMENTS

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By

ZINA COHEN

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Composition Analysis of Writing Materials in Cairo Genizah Documents

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Abbreviations

Institutions

CUL	Cambridge University Library
CSMC	Centre for the Study of Manuscript Cultures
BAM	Bundesanstalt für Materialforschung und -prüfung (Federal Institute for Materials Research and Testing)
EPHE	École Pratique des Hautes Études

Collections

Ar.	Arabic, Taylor-Schechter Genizah Research Unit, Cambridge University Library
AS	Additional Series, Taylor-Schechter Genizah Research Unit, Cambridge University Library
BL	British Library
BnF	Bibliothèque Nationale Française
Bodl.	Bodleian Library
CUL	Cambridge University Library
ENA	Elkan Nathan Adler collection at the Jewish Theological Seminary of America, New York
Misc.	Miscellaneous, Taylor-Schechter Genizah Research Unit, Cambridge University Library
Mosseri	Jacques Mosseri collection, Taylor-Schechter Genizah Research Unit, Cambridge University Library
NS	New Series, Taylor-Schechter Genizah Research Unit, Cambridge University Library
Or.	Oriental (acquired before Schechter's visit to Cairo), Cambridge University Library
T-S	Taylor-Schechter Genizah Research Unit, Cambridge University Library

Techniques

EDX	Energy-dispersive X-Ray analysis
FTIR	Fourier-transform infrared spectrometry
IR	Infrared

MS	Mass spectrometry
NIR	Near-infrared
PIXE	Particle-induced X-Ray emission
XRF	X-Ray fluorescence

Résumé [Francais]

Durant ce projet, nous nous sommes intéressées à l'analyse des matériaux d'écriture d'un corpus composé d'ouvrages retrouvés dans la Génizah du Caire et rédigés essentiellement pendant la première moitié du XIe siècle.

L'objectif premier a été l'identification et la caractérisation des matériaux d'écriture (supports et encres) qui ont permis la rédaction des documents de ce corpus, puis dans un second temps, l'identification des motifs derrière l'utilisation des différents matériaux d'écriture. L'ensemble des documents que nous avons étudiés sont aujourd'hui conservés dans la Bibliothèque Universitaire de Cambridge.

1 Contexte historique et corpus étudié

Dans le judaïsme, il est interdit de jeter ou de détruire les textes qui pourraient contenir le nom divin (*Siphrei Torah, Téfilines, mezouzot* ...). Ces textes, dont l'usure empêchait l'utilisation, sont réunis, stockés ensemble, puis enterrés dans un cimetière. En attendant leur enfouissement, les documents sont entreposés pour éviter leur profanation, dans un lieu désigné par le mot de *génizah* (גניזה) au pluriel *génizoth*.

À partir de l'époque talmudique[1] et durant le Moyen-Âge, le lieu (Génizah) destiné à recevoir les manuscrits en attendant leur enterrement est le plus souvent une pièce ou un bâtiment attenant à la synagogue[2].

En Égypte, la synagogue Ben Ezra du quartier de Fusṭāṭ dans le vieux Caire (sud du Caire actuel), disposait d'une Génizah, désormais célèbre, et connue aujourd'hui sous le nom de « Génizah du Caire ». Les documents trouvés dans la Génizah du Caire ont une portée chronologique assez vaste qui s'étend de la fin du IXe jusqu'au XIXe siècle, et proviennent pour la plupart d'Égypte, d'Israël et de Sicile actuelles. Ces documents ont été rédigés dans de nombreuses langues, comme l'hébreu, l'arabe ou l'araméen et sur des supports variés comme le papier, le parchemin, le papyrus ou le tissu.

La diversité et l'ancienneté de ces textes, ainsi que leur très grand nombre, ont contribués à en faire l'ensemble le plus riche mis au jour. D'autant plus que

1 L'époque talmudique fait référence au IIIe-VIe siècle, où le Talmud a été écrit. Le Talmud est le texte central du judaïsme rabbinique et la source première de la halakha, la loi religieuse juive. Elle est séparée en deux traditions : un recueil d'écrits appelé le Talmud de Babylone ou Talmud Bavli et un autre appelé le Talmud de Jérusalem ou Talmud Yerushalmi.

2 Abraham Meir Habermann, Fred Skolnik, and Michael Berenbaum, 'Genizah', in *Encyclopaedia Judaica* (Detroit: Macmillan Reference USA, 2007).

les fragments extraits de la Génizah du Caire portent non seulement sur des questions juridiques, mais aussi sociales, médicales, économiques, culturelles, littéraires et évidemment religieuses.

L'abondance des sujets abordés dans ces documents nous permet de mieux comprendre l'histoire et le fonctionnement des communautés qui les ont produits en nous révélant des micro-faits historiques sur le système légal, le système d'archives, les conflits privés ou légaux, les disputes religieuses ou communales entre individus mais aussi entre communautés.

Ces textes d'une grande richesse nous laissent entrevoir la vie quotidienne des juifs, mais aussi des non-juifs, musulmans et chrétiens, à l'époque médiévale dans le monde musulman.

Le patrimoine découvert dans cette Génizah est non seulement un témoignage unique de l'histoire médiévale de la population du Caire, juive ou non-juive, mais nous donne aussi, au-delà de son contenu (des textes et histoires relatées), la possibilité d'obtenir une vision continue des matériaux (support et encres) employés par les scribes durant une large période chronologique.

La matérialité des documents écrits reste une question encore trop peu étudiée alors que cette question est fondamentale, puisqu'elle constitue un marqueur économique, technologique et sociologique. Le scribe, celui qui écrit, est soumis aux nécessités techniques et au contexte de production.

L'analyse des matériaux employés devient donc une source d'informations. Évaluer les procédés de l'écriture d'une société, c'est réfléchir aux interactions qui ont pu exister entre des individus, comprendre la transmission du savoir, et envisager les routes commerciales qui ont pu permettre ces échanges. Toutes ces questions pourraient se résumer en une seule : quelles raisons poussent un scribe à utiliser certains matériaux d'écriture et à en délaisser d'autres pour rédiger son texte ?

Nous avons disposé d'un corpus formé de 391 côtes, divisé en 498 documents, qui rassemble principalement cinq scribes auxquels sont venus s'ajouter des documents comparatifs.

Les scribes sur lesquels s'est attachée notre étude appartenaient à des communautés juives aux contextes historiques différents : la communauté dite Palestinienne, la communauté dite Babylonienne et la communauté Karaïte de Fusṭāṭ. Cette diversité nous permet de définir si la notion d'identité – et donc de l'appartenance à une communauté – peut être un paramètre qui joue ou non un rôle clé dans le choix des matériaux adoptés par les scribes.

Notre première étape a consisté à déterminer et étudier les représentants de ces communautés. En effet, les dirigeants des communautés présentaient l'avantage d'une affiliation claire à leur communauté ainsi qu'un large nombre de documents, signés, datés et disponibles ; mais aussi d'avoir été préalablement largement étudiés lors de différentes études académiques, sur lesquelles nous nous sommes appuyés, nous permettant ainsi une meilleure connaissance et identification des manuscrits à analyser.

Pour la communauté dite Palestinienne, nous avons analysé les productions écrites d'Éphraïm b. Shemariah et de son secrétaire Yefet b. David. Pour la communauté dite Babylonienne, nous avons étudié celles de Elḥanan b. Shemariah, Abraham b. Sahlān et de son fils Sahlān b. Abraham.

Pour nous permettre d'apprécier l'influence du paramètre géographique, il nous fallait compléter notre étude en ajoutant à notre corpus, des documents rédigés par des scribes issus d'autres espaces géographiques que Fusṭāṭ, mais aux parcours culturels comparables. Nous avons donc opté pour les productions écrites du chef de la *yeshiva* palestinienne, le *Ga'on* Solomon b. Judah. Un dernier point, et non des moindres, a été apporté par les nombreux documents légaux, que nous avons trouvé revêtus par la signature d'un ou plusieurs témoins. Comme certains des noms de ces témoins ont été retrouvés à plusieurs reprises dans le corpus, cela nous a permis d'élargir le nombre d'individus ainsi examinés.

2 Les matériaux d'écriture

Dans le monde musulman médiéval, les recettes de préparations des encres noires sont nombreuses et se sont propagées avec succès, notamment à travers aux manuels rédigés à l'intention des scribes que nous citerons par ordre chronologique : le *Zīnat al-kataba* (*Les décorations du scribe*) par ar-Razi (Xᵉ siècle)[3], *ʿUmdat al-kuttāb wa-ʿuddat ḏawī al-albāb* (*Support du scribe et outils pour les hommes sages*)[4] d'Ibn Bādis (XIᵉ siècle)[5], *Kitāb al-Azhār fī*

3 Mahmoud Zaki, 'Early Arabic Bookmaking Techniques as Described by Al-Rāzī in His Recently Rediscovered Zīnat al-Katabah', *Journal of Islamic Manuscripts* 2, no. 2 (2011): 223-34.

4 La traduction du titre est basée sur celle donnée par Colini qui est *The support of the scribes and the tool for the wise men* dans Claudia Colini, 'From Recipes to Material Analysis the Arabic Tradition of Black Inks and Paper Coatings (9th-20th Century)' (PhD Thesis, Hamburg, Universität Hamburg, 2018), 35. qui utilise la traduction donnée par Sara Fani, 'Le arti del libro secondo le fonti arabe originali. I ricettari arabi per la fabbricazione degli inchiostri (sec. IX-XIII): loro importanza per una corretta valutazione e conservazione del patrimonio manoscritto' (PhD Thesis, Naples, Università L'Orientale, 2013), 50. Comme le fait remarquer Colini, Martin Levey, 'Mediaeval Arabic Bookmaking and Its Relation to Early Chemistry and Pharmacology', *Transactions of the American Philosophical Society* 52, no. 4 (1962): 13. traduit le titre du traité d'Ibn Bādis très différemment en *Staff of the scribes and implement of the discerning*.

5 Levey, 'Mediaeval Arabic Bookmaking and Its Relation to Early Chemistry and Pharmacology'.

ʿamal al-aḥbār (*Florilège pour la fabrication des encres*) par al-Marrākushi (XIII^{e} siècle)[6] ou *Tuḥaf al-Ḫawāṣṣ fī Ṭuraf al-Ḫawāṣṣ* (*Délectation des sens avec les anecdotes des initiés*) d'al-Qalalusi (XIII^{e} siècle)[7].

L'étude de ces manuels de scribes nous apprennent qu'en Égypte médiévale différents types d'encres existaient. Ces encres noires, peuvent être classées en quatre grandes catégories : l'encre dite carbonique, l'encre végétale, l'encre ferrogallique et une quatrième appelée encre mixte. L'encre carbonique est le produit d'une fine dispersion de pigments de carbone dans un liant soluble dans l'eau. L'encre végétale est réalisée à base de tannins[8]. L'encre ferrogallique est le produit d'une réaction entre de l'acide gallique (obtenue à partir de noix de galle[9]), et du fer (II), que l'on peut retrouver sous différente forme mais principalement sous la forme de vitriol[10] dans les recettes contemporaines. Enfin, les encres mixtes proviennent de l'association de deux encres noires différentes : un mélange d'encre carbonique avec soit une encre végétale, soit avec de l'encre ferrogallique.

Le livre d'ar-Razi mentionne la première recette arabe d'encre ferrogallique, dès le X^{e} siècle[11] (à titre indicatif, la plus ancienne recette européenne connue à ce jour est datée du XII^{e} siècle)[12]. Notons aussi que le Talmud qui ne consigne, *per se*, aucune recette, mentionne les différents types d'encres (en particulier, carbonique, ferrogallique et mixte) et en discute leurs différentes propriétés[13].

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6 Ibrahim Chabbouh, 'Two New Sources on the Art of the Mixing Ink', in *Proceedings of the Second Conference of Al-Furqān Islamic Heritage Foundation 4-5 December 1993*, ed. Yasin Dutton (The Codicology of Islamic Manuscripts, London: Al-Furqān Islamic Heritage Foundation, 1995), 59-76.

7 Chabbouh.

8 Tanin ou tannin : Substance organique contenue dans de nombreux végétaux (…) qui est utilisée à des usages divers notamment dans le tannage des peaux, la fabrication des encres ou en pharmacologie. 'Définition de TANIN', in *Trésor de la Langue Française informatisé*, 2002, https://www.cnrtl.fr/definition/Tanin.

9 Excroissance du chêne produite par les piqûres d'un insecte.

10 Mélange de sulfates métalliques hydratés contenant du fer, manganèse, cuivre, zinc et d'autres sulfates métalliques. Les proportions de chaque élément varient en fonction de la source géologique du vitriol. Vladimír Karpenko and John A. Norris, 'Vitriol in the History of Chemistry', *Chemicke Listy* 96 (2002): 997-1005.

11 Lucia Raggetti, 'Cum Grano Salis. Some Arabic Ink Recipes in Their Historical and Literary Context', *Journal of Islamic Manuscripts* 7, no. 3 (2016): 294-338, https://doi.org/10.1163/1878464X-00703002.

12 Monique Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge* (*jusqu'à 1600*) (Paris: Centre National de la Recherche Scientifique, 1983).

13 Les références sont nombreuses, mais à titre d'exemple, nous pouvons citer le Talmud de Babylone, traité Eruvin 13a:8-12, l'histoire de Rabbi Meïr qui ajoute du vitriol (kankantum, קנקנתום) dans une encre (probablement) carbonique pour permettre une meilleure fixation de l'encre sur le support et qui crée ainsi une encre mixte). Cette histoire est

Bien qu'un intérêt tout particulier ait été porté aux encres, l'analyse des matériaux d'écriture incluent bien évidemment celle des supports. En effet, les surfaces d'écriture jouent un rôle important dans le processus de rédaction et dans l'histoire des documents. De plus, du point de vue de la conservation, l'interaction entre le support et l'encre est d'une importance primordiale pour comprendre le vieillissement du document. L'étude des surfaces d'écriture a été abordée selon deux problématiques : la question de leur utilisation à part entière (quel type de matériau d'écriture est utilisé, dans quelle proportion et par qui) et ensuite celle de leur possible interaction avec les encres. Et enfin, il nous a fallu soulever une dernière question afin de déterminer si un type de support était préférentiellement associé à un type d'encre, et inversement.

Dans la Génizah du Caire, si les supports d'écritures retrouvés incluent le papyrus, le papier, le cuir[14], le parchemin, et même le textile, seuls trois d'entre eux font partie de notre corpus d'étude : papier, parchemin et cuir. En effet, les autres supports ont été abandonnés avant le XIe siècle, date de début de notre corpus.

3 Protocole d'analyse

Le domaine des sciences du patrimoine a recours à de nombreuses techniques et de nombreux instruments empruntés à la chimie analytique, la physique, voire la médecine. L'étude des encres noires n'en est plus à ses prémices et de nombreux travaux, qui utilisent différentes méthodologies ont fait leurs preuves[15]. Dans le cadre de l'étude des documents de la Génizah du Caire, le

retranscrite par Zerdoun : Par ailleurs, le traité Shabbat 23a:5 rapporte un débat entre plusieurs sages qui discutent de la meilleure façon de préparer de l'encre carbonique.

14 Bien que le cuir et le parchemin proviennent du même matériau d'origine, de la peau animale, ils sont le résultat de traitements différents. Au contraire du cuir, le parchemin n'est pas tanné, mais tendu sur un support où la peau est nettoyée et séchée. Bien que la différence *per se* entre le cuir et le parchemin ne réside pas dans le tannage mais dans le séchage sous tension, il est intéressant de noter qu'il n'existe, à notre connaissance, des exemples de parchemin tanné que dans le monde juif.

15 Roger L. Easton and William Noel, 'Infinite Possibilities: Ten Years of Study of the Archimedes Palimpsest', *Proceedings of the American Philosophical Society* 154, no. 1 (2010): 50-76, https://doi.org/10.2307/20721527; Maurizio Aceto et al., 'The Vercelli Gospels Laid Open: An Investigation into the Inks Used to Write the Oldest Gospels in Latin', *X-Ray Spectrometry* 37, no. 4 (2008): 286-92, https://doi.org/10.1002/xrs.1047; Andrea Gambaro et al., 'Study of 19th Century Inks from Archives in the Palazzo Ducale (Venice, Italy) Using Various Analytical Techniques', *Microchemical Journal* 91 (2009): 202-8; Oliver Hahn, 'Charakterisierung historischer Eisengallustinten mittels mikro-RFA und mikro-XANES', *ZfP-Zeitung* 84 (2003): 31-35; Emmanuel Brun et al., 'Revealing

choix du protocole analytique a dû se plier à un certain nombre d'impératifs. En premier lieu, il n'était pas envisageable de porter atteinte à l'intégrité des documents par la réalisation de micro-prélèvements, et puisque les manuscrits ne pouvaient voyager jusqu'à notre laboratoire, il était donc nécessaire d'utiliser un équipement portable non-destructif et non-invasif permettant des analyses *in-situ*.

Pour identifier les types d'encres, il a été utilisé, une technique d'imagerie scientifique, la réflectographie[16]. Alors que l'encre carbonique absorbe la lumière à toutes les longueurs d'onde, l'encre ferrogallique perd de son opacité sous lumière infrarouge (entre 750 jusqu'à 1.000 nm) et devient transparente autour de 1.400 nm[17]. L'encre végétale en revanche, disparait entièrement

Metallic Ink in Herculaneum Papyri', *Proceedings of the National Academy of Sciences* 113, no. 14 (21 March 2016): 3751-54, https://doi.org/10.1073/pnas.1519958113; Irena Nastova et al., 'Spectroscopic Analysis of Pigments and Inks in Manuscripts: I. Byzantine and Post-Byzantine Manuscripts (10-18th Century)', *Vibrational Spectroscopy* 68 (2013): 11-19, https://doi.org/10.1016/j.vibspec.2013.05.006; Denis Nosnitsin et al., 'A "Study Manuscript" from Qäqäma (Tagray, Ethiopia): Attempts at Ink and Parchment Analysis', *Comparative Oriental Manuscript Studies Newsletter*, 2014, 28-31; Vinka Tanevska et al., 'Spectroscopic Analysis of Pigments and Inks in Manuscripts: II. Islamic Illuminated Manuscripts (16th–18th Century)', *Vibrational Spectroscopy* 73 (2014): 127-37, https://doi.org/10.1016/j.vibspec.2014.05.008; Thomas Christiansen et al., 'Chemical Characterization of Black and Red Inks Inscribed on Ancient Egyptian Papyri: The Tebtunis Temple Library', *Journal of Archaeological Science: Reports* 14 (2017): 208-19, https://doi.org/10.1016/j.jasrep.2017.05.042; Nasser M. Hamdan, Hussain Alawadhi, and Najeh Jisrawi, 'Integration of μ-XRF, and u-Raman Techniques to Study Ancient Islamic Manuscripts', *IOP Conference Series: Materials Science and Engineering* 37, no. 1 (2012), https://doi.org/10.1088/1757-899X/37/1/012006; Marina Bicchieri et al., 'Non-Destructive Spectroscopic Investigation on Historic Yemenite Scriptorial Fragments: Evidence of Different Degradation and Recipes for Iron Tannic Inks', *Analytical and Bioanalytical Chemistry* 405, no. 8 (1 March 2013): 2713-21, https://doi.org/10.1007/s00216-012-6681-4; Seyed Sadra Zekrgoo, 'Methods of Creating, Testing and Identifying Traditional Black Persian Inks', *Restaurator*, International Journal for the Preservation of Library and Archival Material, 35, no. 2 (2014): 133-58, https://doi.org/10.1515/rest-2014-1001; Gianpiero Adami et al., 'Micro-XRF and FT-IR/ATR Analyses of an Optically Degraded Ancient Document of the Trieste (Italy) Cadastral System (1893): A Novel and Surprising Iron Gall Ink Protective Action', *Microchemical Journal*, no. 124 (2016): 96-103, https://10.1016/j.microc.2015.07.020; Sarah Goler et al., 'Characterizing the Age of Ancient Egyptian Manuscripts through Micro-Raman Spectroscopy', *Journal of Raman Spectroscopy* 47, no. 10 (2016): 1185-93, https://doi.org/10.1002/jrs.4945; Vito Mocella et al., 'Revealing Letters in Rolled Herculaneum Papyri by X-Ray Phase-Contrast Imaging', *Nature Communications* 6, no. 1 (2015): 1-6, https://doi.org/10.1038/ncomms6895.

16 Ralf Mrusek, Robert Fuchs, and Doris Oltrogge, 'Spektrale Fenster zur Vergangenheit: Ein neues Reflektographieverfahren zur Untersuchung von Buchmalerei und historischem Schriftgut', *Naturwissenschaften* 82, no. 2 (1995): 68-79.

17 Dans l'article cité précédemment, Mrusek, Fuchs, and Oltrogge., il est indiqué que l'encre ferrogallique devient transparent à 1.200 nm. Néanmoins, des tests plus récents, faits à

autour de 750 nm[18]. Dans ce travail, un microscope portable (Dino-Lite AD4113T-I2V USB) avec des illuminations dans l'ultraviolet (UV, 390 nm), dans le visible (VIS), et dans le proche infrarouge (NIR, 940nm) a été utilisé.

Afin de comparer les différentes encres, et en particulier les encres ferrogalliques, un tiers du corpus a été analysé en utilisant de la spectrométrie de fluorescence de rayons X (XRF). L'interaction du faisceau de rayons X avec la matière conduit à des émissions de photons dont l'énergie est caractéristique des éléments chimiques présents. Comme l'intensité des raies de fluorescence dépend également de la concentration de l'élément, il devient possible de comparer semi-quantitativement les teneurs en fer, zinc et cuivre, c'est-à-dire les éléments généralement présents comme impuretés dans le vitriol. La proportion de ces éléments change en fonction du produit brut ou du processus de purification[19]. Cette variation des proportions des espèces métalliques présentes sous la forme de sulfates permet une comparaison des différentes encres via l'application d'un modèle qu'on appellera en français « Signature » (traduction abusive basée sur le nom du modèle en anglais « *Fingerprint model* », qui ne rend pas justice à l'idée d'empreintes digitales). Ce modèle est donc basé sur la détection qualitative et semi-quantitative des composants inorganiques des encres ferrogalliques (et mixtes, le cas échéant) normalisé au fer, composant principal de l'encre, qui est également responsable de sa couleur noire[20]. Ce modèle, tout comme une empreinte digitale ou une signature, ne permet pas de révéler l'aspect de l'individu analysé, mais permet de déterminer si les échantillons analysés appartiennent ou non au même individu, c'est-à-dire ici si les encres ont la même composition. Malheureusement, ce procédé ne fonctionne ni pour les encres carboniques ni pour les encres végétales. Le laboratoire du BAM et du CSMC disposent de différents spectromètres XRF, mais le

l'aide d'une caméra infrarouge ont montré que l'encre ferrogallique disparait plutôt aux environs de 1.400 nm.

18 Ira Rabin, Oliver Hahn, and Marcello Binetti, 'Tintenarten in mittelalterlichen hebräischen Manuskripten: eine typologische Studie / Inks Used in Medieval Hebrew Manuscripts: A Typological Study', *Manuscript Cultures* 6 (2014): 119-31; Ira Rabin and Marcello Binetti, 'NIR Reflectography Reveals Ink Type: Pilot Study of 12 Armenian Manuscripts of the Staatsbibliothek Zu Berlin', *Բանբեր Մատենադարանի* (*Banber Matenadaran*) 21 (2014): 465-70.

19 Christoph Krekel, 'The Chemistry of Historical Iron Gall Inks: Understanding the Chemistry of Writing Inks Used to Prepare Historical Documents', *International Journal of Forensic Document Examiners* 5 (1999): 54-58.

20 Oliver Hahn et al., 'Characterization of Iron-Gall Inks in Historical Manuscripts and Music Compositions Using X-Ray Fluorescence Spectrometry', *X-Ray Spectrometry* 33, no. 4 (2004): 234-39, https://doi.org/10.1002/xrs.677.

choix s'est porté sur le modèle ArtTAX (Bruker Nano GmbH) un spectromètre utilisé déjà routinement dans l'analyse des œuvres culturelles.

Le nombre d'encres examinées pour cette étude est conséquent, à la fois pour les résultats de la réflectographie et pour les données rassemblées lors de la composition élémentaire. En effet, la réflectographie a été effectuée sur l'ensemble du corpus et l'analyse XRF sur 181 manuscrits. Afin de découvrir les raisons derrière l'utilisation d'un type d'encre ou d'un type de support plutôt qu'un autre, il a été nécessaire de non seulement comparer les encres utilisées au sein d'un même manuscrit, mais aussi celles utilisées au cours de la production d'un scribe, et enfin à toutes les observations rassemblées lors des analyses. Du fait du grand nombre d'individus examinés, il a été nécessaire de faire appel à des techniques statistiques. Une base de données a donc été construite pour y rassembler les descriptions des manuscrits, et plus particulièrement les critères susceptibles de motiver un changement dans le type de matériau d'écriture (tel que le type de document, le scribe, sa communauté, l'espace géographique de copie du document).

Différents modèles ont été essayés, avec plus ou moins de succès. Il a été tenté d'utiliser une analyse en composantes principales (ACP), une technique d'analyse statistique déjà utilisée largement en archéométrie[21], mais ici sans succès. Nous nous sommes donc tournés vers un modèle de régression multinomiale. La version simple de ce modèle est appelée régression logistique mais implique l'attente d'un résultat binaire (oui/non, perte/gain, encre ferrogallique/encre carbonique) et leur comparaison avec des variables explicatives. Malheureusement ici, le résultat n'était pas binaire, mais multiple. En effet, le modèle a été appliqué à la fois à l'utilisation du support (c'est-à-dire papier, parchemin, cuir) et à l'utilisation des encres (c'est-à-dire encre ferrogallique, encre carbonique, encre mixte, puisque le nombre d'observations pour les encres végétales étaient trop réduits pour permettre un résultat fiable). Le modèle forme alors un arbre de décision appelé « arbre d'inférence

21 Maurizio Aceto et al., 'Characterisation of the Different Hands in the Composition of a 14th Century Breviary by Means of Portable XRF Analysis and Complementary Techniques', *X-Ray Spectrometry* 46, no. 4 (2017): 259-70, https://doi.org/10.1002/xrs.2768; Lisa Marie Zimmerman, 'Brick by Brick: A Comparative PXRF Analysis of Brickworks and Structures in the Belgian-American Community of the Door Peninsula' (Master Thesis, University of Wisconsin-Milwaukee, 2013); Michael J. Baxter, 'Standardization and Transformation in Principal Component Analysis, with Applications to Archaeometry', *Journal of the Royal Statistical Society: Series C* (*Applied Statistics*) 44, no. 4 (1995): 513-27; Sonia Ostaptchouk, 'L'économie Des Matières Premières de La Pierre Taillée d'Anatolie Centrale Au Chalcolithique Ancien (6000-5500 Cal. BC/ECA IV): L'étude de Cas de Çatalhöyük-Ouest' (PhD Thesis, Paris, Muséum National d'Histoire Naturelle (MNHN), 2012).

conditionnel »[22]. L'algorithme teste la relation entre les variables explicatives et le résultat, c'est-à-dire le type de matériau d'écriture utilisé.

Toutes les analyses statistiques ont été faites sous le logiciel R (ver. 3.2.4)[23] développé par le CRAN (Comprehensive R Archive Network).

4 Les résultats

L'analyse des encres de ce corpus a ainsi démontré l'utilisation, dans un cadre temporel et géographique restreint, des quatre types d'encres mentionnées précédemment : encre carbonique, encre ferrogallique, encre végétale et encres mixtes (mélange des caractéristiques des encres carboniques et des encres ferrogalliques). Le protocole d'analyse mis en place ne permet malheureusement pas de détecter les encres mixtes résultant du mélange d'encre carbonique avec des encres végétales.

Ces quatre types d'encres apparaissent comme étant présents dans des proportions variables dans le corpus analysé. De plus, l'utilisation de notre modèle a montré combien les concentrations des éléments métalliques vitrioliques (manganèse, cuivre et zinc) varient largement d'une encre à une autre, mais a également dévoilé l'existence d'encres ferrogalliques ne contenant aucun de ces métaux.

Nous nous sommes donc interrogés sur la raison de cette variabilité : les résultats obtenus ont été comparés aux critères descriptifs des manuscrits pour rechercher ce qui avait pu provoquer un changement de matériel d'écriture. L'utilisation des différents types d'encres ont ainsi été mis en regards des différents scribes étudiés, mais aussi à la communauté à laquelle ils appartenaient (communauté dite Palestinienne, dite Babylonienne, Karaïtes), au type de document (légal, privé, religieux), ainsi qu'au support utilisé.

L'évaluation de ces 498 documents a démontré que bien qu'il existait une forme d'utilisation préférentielle personnelle concernant le type d'encre utilisée, il semble que pour l'usage privé et pour les documents juridiques les scribes ont utilisé les matériaux disponibles et à leur portée. Cette préférence personnelle n'était motivée ni par la communauté ni corrélée au type de

22 Torsten Hothorn, Kurt Hornik, and Achim Zeileis, 'Unbiased Recursive Partitioning: A Conditional Inference Framework', *Journal of Computational and Graphical Statistics* 15, no. 3 (2006): 651-74; Torsten Hothorn et al., 'A Lego System for Conditional Inference', *The American Statistician* 60, no. 3 (2006): 257-63.

23 R Core Team, 'R: The R Project for Statistical Computing', R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, 2008, https://www.r-project.org/.

support. Aucune encre, sur la base de sa signature chimique, n'a pu être associée à un seul scribe ou uniquement à un sujet spécifique de document.

Les deux communautés rabbiniques étudiées dans le cadre de ce projet ne montrent aucune préférence, tant qu'il s'agit de documents non religieux, pour un type d'encre spécifique. Un petit nombre de documents attribués à la communauté karaïte ont cependant montré l'utilisation quasi systématique d'encre ferrogallique.

Le type de support choisi a été principalement dicté par le type de document à écrire et donc très probablement par le prix que le scribe était prêt à payer pour la copie du document[24]. Il a été démontré qu'une large partie des documents religieux étaient copiés préférentiellement sur des supports en peau (ceux qui étaient copiés sur papier étant principalement des *responsa* (décisions et réglementations en réponse à des questions données) religieuses, et des poèmes, *piyyutim*) alors que la majorité des documents juridiques étaient écrits sur du papier, à l'exception des *Ketubot* (contrats de mariages) qui doivent être conservés longtemps et les documents impliquant de larges sommes d'argent, qui étaient, eux, rédigés sur parchemin. Pour les rouleaux religieux étudiés dans le cadre de cette thèse, la tendance, pour la communauté palestinienne, est à l'utilisation de parchemin et d'encres ferrogalliques, alors que pour la communauté babylonienne le choix se porte vers le cuir et tout type d'encres.

Enfin, l'étude des différentes encres utilisées dans un même document légal a permis de dégager un nouvel élément important qui n'avait pour l'heure pas été envisagé. En effet, nous avons pu constater que certains documents légaux portaient plusieurs encres différentes, utilisées pour copier et signer le document ; le nombre d'encres utilisées pouvant varier d'un document à un autre.

Si nous n'avons pas pu expliquer jusqu'à présent cette diversité, il nous semble cependant que l'importance du document en constitue au moins un

24 Bien que de nombreux travaux Eliyahu Ashtor, 'Le coût de la vie dans l'Égypte médiévale', *Journal of the Economic and Social History of the Orient* 3, no. 1 (1960): 56, https://doi.org/10.2307/3596029; Eliyahu Ashtor, *Histoire des prix et des salaires dans l'Orient médiéval* (Paris: S.E.V.P.E.N., 1969); 'MMIE – Western University', accessed 26 January 2018, http://www.medievalislamiceconomy.uwo.ca/., nous permettent d'obtenir une idée des prix en cours à l'époque médiévale, aucun prix concernant les différentes encres ou les différents supports n'a pu être observé à ce jour. Néanmoins, des récits de voyageurs nous indiquent que le papier était très peu cher au XIe siècle. Nasir-i Khosrau dit, par exemple, en 1046 qu'au Caire le papier pour envelopper les marchandises étaient fournis aux clients par les commerçants, indiquant probablement par là même, un produit bon marché et facile d'accès Au contraire, nous savons que le parchemin était un produit coûteux – à cause du matériau d'origine et de son long traitement. Bien que rien n'ait été fait sur les différentes encres, nous aimerions dans le futur, nous pencher sur cette question.

des enjeux. En effet, plus le texte est important, plus le nombre de signatures des témoins est grand, et plus les témoins sont en général prestigieux. Dans au moins un des cas, celui du document T-S 16.124 un document légal concernant le prêt d'une forte somme d'argent, il est probable que la réunion de tous ces témoins prestigieux ayant été impossible, il a fallu se résoudre à leur envoyer le document pour le leur faire signer, et chaque témoin aurait alors utilisé son encre pour le parapher. Ce seul exemple montre ainsi au-delà de la variété des documents, l'existence d'une grande variété de procédures que nous avons du prendre en compte lors de l'interprétation de nos données.

Les résultats obtenus nous ont néanmoins permis de reconstituer la chronologie de la production de certains documents juridiques, en identifiant différentes étapes d'écriture.

Des données similaires ont été collectées dans un corpus assez limité constitué de documents juridiques arabes. Dans ces documents, il a été possible d'observer l'utilisation occasionnelle d'une même encre pour copier et signer le document et dans d'autres cas, l'utilisation de différentes encres, l'une pour copier le document et une ou plusieurs autres pour le signer.

La variation dans le nombre d'encres utilisées au sein des mêmes documents légaux permet d'affiner notre connaissance du système légal (juif et non-juif) en cours à l'époque médiévale à Fusṭāṭ en recherchant la raison derrière ces différentes phases d'écriture.

Bien que nous ayons pu répondre à nos questions initiales, et à d'autres ajoutées en cours de route, de nouvelles interrogations se dessinent devant nous. Et nous pensons qu'il serait intéressant d'élargir le corpus en intégrant une plus grande période chronologique, afin d'étudier l'évolution de l'usage de ces matériaux d'écriture. Le suivi de l'ensemble de la production d'un seul scribe serait également intéressant afin de mesurer l'évolution de ses pratiques personnelles au cours du temps. Enfin, nous aimerions beaucoup nous pencher sur la question du coût de ces matériaux d'écriture et résoudre la question de ce paramètre dans le choix de du matériau d'écriture.

Kurzfassung [Deutsch]

Das Thema dieser Promotion ist die Analyse des in der Kairoer Geniza verwendeten Schreibmaterials anhand eines Korpus von Texten, welche hauptsächlich in der ersten Hälfte des 11. Jhds. verfasst wurden. Alle Dokumente dieses Korpus werden heute in der Universitätsbibliothek im Cambridge aufbewahrt.

Es ist im Judaismus verboten, Texte wegzuwerfen oder zu zerstören, die den göttlichen Namen (*Siphrei Torah, Téfilines, mezouzot …*) enthalten können. Die Schriftträger, die durch Abnutzung nicht mehr gebraucht werden können, wurden gesammelt, aufbewahrt, und in einem Friedhof begraben. Der Ort, wo diese Dokumente hinterlegt werden, damit sie nicht geschändet werden können, wird *genizah* (גניזה) (im Plural *genizoth*) genannt. Seit der talmudischen Ära und dem Mittelalter befinden sich die Geniza (als Raum oder Anbau) angrenzend an oder innerhalb einer Synagoge.[1] In Ägypten besaß die Ben-Esra-Synagoge in Fostat, heute ein Teil der Altstadt im Süden des heutigen Kairo, eine solche Geniza, die als „Kairoer Geniza“ bekannt ist. Die Schriften, die in dieser Geniza gefunden wurden, stammen aus Zeit vom Ende des 9. Jhds. bis zum 19. Jhd. und stammen hauptsächlich vom heutigen Ägypten, Israel und Sizilien. Die Handschriften wurden in unterschiedlichen Sprachen verfasst, unter anderem in hebräisch, in arabisch und in aramäisch, und auf unterschiedliche Beschreibstoffe, wie zum Beispiel Papier, Pergament, Papyrus oder Textilien geschrieben. Die Vielfalt und das Alter der Fragmente machen aus dem Bestand der „Kairoer Geniza“ einen der mannigfaltigsten und reichesten Funde unterschiedlicher Handschriftfragmente, der jemals entdeckt wurde. Von besonderen Interesse ist, dass die Texte aus dem Kairoer Geniza nicht nur religiöser, sondern auch juridischer, sozialer, medizinischer, ökonomischer, kultureller und literarischer Natur sind.

Die Vielfalt der in den Fragmenten behandelten Themen bietet eine grundsätzliche Möglichkeit, ihre Verfasser und deren soziokulturelles Umfeld besser zu verstehen. Dank ihnen haben wir nicht nur ein besseres Verständnis über die Geschichte der Jüdischen Gemeinden, sondern entdecken auch Fakten der Mikrogeschichte über das Rechtssystem, das private und rechtliche Archivierungssystem, über die religiösen, zwischenmenschlichen und zwischen-gemeinschaftlichen Auseinandersetzungen und über den mittelalterlichen Alltag der Juden und nicht-Juden im arabischen Kulturraum.

1 Habermann, Skolnik, and Berenbaum, ‘Genizah’.

Materialwissenschaftliche Untersuchungen der Manuskriptfragmente standen bislang weniger im Vordergrund. Diese sind jedoch zentral, denn sie sind eng mit dem Herstellungskontext, mit dem technischen und technologischen Wissen der Gesellschaft, mit der Wissensvermittlung und mit Handelsrouten verbunden. Diese Aspekte können wir in einer einzigen Frage zusammenfassen: Welche Gründe führen dazu, dass ein Schreiber gewisse Schreibmaterialien nutzte und andere nicht, um ein Text zu verfassen, bzw. kopieren?

Aus Tinten-Rezepturen in Handbüchern für Schreiber erfahren wir zum Beispiel, dass im Mittelalter im Reich der Fatimiden unterschiedliche Arten von schwarzen Schreibstoffen vorhanden waren. Rußtusche, Pflanzen- und Eisengallustinten bilden verschiedene typologische Gruppen von historischen schwarzen Schreibmaterialien, die für die Anfertigung von Manuskripten verwendet wurden. Rußtusche ist eine feine Dispersion von Kohlenstoffpigmenten in einem wasserlöslichen Bindemittel; für Pflanzentinte werden die extrahierten Gerbstoffe von Baumrinden in Flüssigkeit gelöst; Eisengallustinte, hergestellt durch Vermischen von gelösten Eisen(II)verbindungen mit einem aus Galläpfeln gewonnenen Gerbstoffextrakt, stellt einen Grenzfall zwischen Rußtusche und Pflanzentinte dar: Eine wasserlösliche Vorstufe (ähnlich den Tinten der zweiten Gruppe) oxidiert nach dem Verschreiben an der Luft und entwickelt sich zu einem schwarzen, unlöslichen Material. Jede Tintengruppe besitzt spezifische Eigenschaften, anhand diese bequem zu differenzieren sind, wenn es sich um reine Tinten handelt. Da oftmals auch Mischungen Verwendung fanden, sind aufwendigere Methoden erforderlich, um eine umfassende Charakterisierung vorzunehmen. Unterschiedliche Techniken stehen der Wissenschaftlerin zu Verfügung, um schwarze Schreibmaterialien zu untersuchen.[2]

2 Hahn et al., 'Characterization of Iron-Gall Inks in Historical Manuscripts and Music Compositions Using X-Ray Fluorescence Spectrometry'; Alana S. Lee, Peter J. Mahon, and Dudley C. Creagh, 'Raman Analysis of Iron Gall Inks on Parchment', *Vibrational Spectroscopy*, 6th Australian Conference on Vibrational Spectroscopy, 41, no. 2 (30 August 2006): 170–75, https://doi.org/10.1016/j.vibspec.2005.11.006; Aceto et al., 'The Vercelli Gospels Laid Open'; Andrea Gambaro et al., 'Chemical and Statistical Characterization of Selected Documents from the Archives of the Palazzo Ducale (Venice, Italy)', *Analytica Chimica Acta* 651, no. 2 (2009): 139–48, https://doi.org/10.1016/j.aca.2009.08.023; Easton and Noel, 'Infinite Possibilities'; Nastova et al., 'Spectroscopic Analysis of Pigments and Inks in Manuscripts'; Tanevska et al., 'Spectroscopic Analysis of Pigments and Inks in Manuscripts'; Mocella et al., 'Revealing Letters in Rolled Herculaneum Papyri by X-Ray Phase-Contrast Imaging'; Ira Rabin, 'Digital and Scientific Approaches to Oriental Manuscript Studies: Instrumental Analysis in Manuscript Studies', in *Comparative Oriental Manuscript Studies: An Introduction*, ed. Alessandro Bausi et al. (Hamburg: Tredition, 2015), 27–30.

Das Protokoll für die Analyse war an selbstverständlich an verfügbare Techniken gebunden, allerdings waren grundsätzlich zwei Voraussetzungen zu erfüllen. Zunächst einmal war es zwingend notwendig, tragbare, mobile Geräte zu benutzen, um die Manuskripte *in situ* vor Ort zu analysieren. Darüber hinaus durfte nur zerstörungsfrei gearbeitet werden, d.h.: die Analyse sollte das Manuskript weder berühren noch beschädigen, damit die untersuchten Objekte intakt bleiben. Wir haben in diesem Fall die nah-Infrarotreflektografie benutzt (940nm), um die unterschiedlichen schwarzen Schreibmaterialien zu klassifizieren. Eisengallustinten lassen sich am besten mithilfe der Röntgenfluoreszenzanalyse (RFA) untersuchen. Natürliches Vitriol, Hauptbestandteil vieler historischer Eisengallustinten, besteht aus einer Mischung von Metallsulfaten (Eisensulfat, Kupfersulfat, Mangansulfat und Zinksulfat), deren relativer Massenanteil charakteristisch für das jeweilige Rohprodukt oder Reinigungsverfahren ist.[3] Diese Eigenschaft von Eisengallustinten kann herangezogen werden, um sie zu vergleichen bzw. voneinander zu unterscheiden. Genauer gesagt, ermöglicht die Anwendung des Fingerprint-Modells, das auf einer qualitativen und quantitativen Erfassung der anorganischen Bestandteile von Eisengallustinten basiert, deren verlässliche Klassifizierung.[4]

Die Analyse der schwarzen Schreibmaterialien in unserem Korpus bezeugt, dass die oben zitierten Arten von schwarzen Schreibmaterialien in einem beschränkten zeitlichen und räumlichen Bereich Verwendung fanden, und beweist darüber hinaus, dass Mischungen aus Rußtuschen und Eisengallustinten benutzt worden sind. Eisengallustinten wurden nicht durch Mischen von Vitriol und Gallussäure sondern durch Mischen anderer eisenhaltiger Komponenten mit Gallussäure hergestellt.

Die Analyseergebnisse haben wir mit weiteren Attributen verglichen, die die Manuskripte kennzeichnen, um herausfinden, welche Gründe die Wahl für einen bestimmten schwarzen Schreibstoff beeinflussen: wir haben unterschiedliche Schreiber (soweit nachweisbar), Schreibergemeinde (die sog. palästinensische Gemeinde, die sog. babylonische Gemeinde, die Karäer), in denen die Schriften hergestellt worden sind, die Art der Manuskripte (rechtlich, privat, religiös), die Beschreibstoffe, usw. miteinander verglichen.

Dafür haben wir ein Korpus von 393 Signaturen gesammelt, gegliedert in 498 Fragmente. Im Zentrum dieses Korpus stehen fünf Schreiber; Manuskripte von anderen Schreibern wurden zu Vergleichszwecken hinzugefügt. Die Untersuchung dieser 498 Fragmente bezeugt, dass, obwohl eine gewisse subjektive

3 Krekel, 'The Chemistry of Historical Iron Gall Inks'.

4 Hahn et al., 'Characterization of Iron-Gall Inks in Historical Manuscripts and Music Compositions Using X-Ray Fluorescence Spectrometry'.

Bevorzugung für bestimmte Materialien zu beobachten ist, die Schreiber anscheinend alle vorhandenen Schreibmaterialien für ihre Tätigkeit benutzt haben. Insgesamt ist wohl bemerkenswert, dass Schreiber, unabhängig von ihren jeweiligen Gemeinden, eine gewisse Bevorzugung für bestimmte Schreibmaterialien zeigen. Die Ergebnisse erlauben es nicht, eine Eisengallustinte (basierend auf dem Fingerprint) einem singulären Schreiber zuzuordnen.

In diesem Projekt haben wir Manuskripte untersucht, die in zwei rabbinischen Gemeinden verfasst wurden. Die Ergebnisse zeigen keine Bevorzugung für einem bestimmten Typ von Schreibmaterialien, solange die Manuskripte nicht religiöser Natur sind. Eine kleine Sammlung von Schriften die der karaitischen Gemeinde zugeschrieben wird und ein ähnliches Korpus beinhaltet, wurde nur mit Eisengallustinten verfasst.

Insgesamt lässt sich konstatieren, dass die Wahl des Beschreibstoffes hauptsächlich von der Art des Manuskriptes, höchstwahrscheinlich vom Preis, den der Schreiber bereit war, für die Kopie auszugeben, abhängt. Es gibt eine Korrelation zwischen religiösen Dokumenten und Beschreibstoff aus Tierhaut, während fast alle rechtlichen Dokumente (äußer Ehevertrag und Schriften, in denen viel Geld involviert war) auf Papier geschrieben wurden. Für die im Rahmen dieser Dissertation untersuchten nichtbiblischen Schriftrollen lässt sich die Tendenz, Pergament und Eisengallustinte in der palästinensischen Gemeinde zu benutzen, mit dem Gebrauch von Leder und von einer Vielfalt an schwarzen Schreibmaterialien in der babylonische Gemeinde bestätigen.

Schließlich konnte mit der Untersuchung der unterschiedlichen Tinten in juristischen Manuskripten eine weitere Besonderheit entdeckt werden. Die Befunde der Tintenanalysen weisen darauf hin, dass es offenbar eine Korrelation zwischen der Anzahl an Unterschriften, der Wichtigkeit der Unterschrift und dem Typ der Tinte zu geben scheint. Weiterhin konnten anhand der Analyse der Tuschen und Tinten die Schreibgeschichte von einzelnen Handschriften rekonstruiert werden. Ähnliche Ergebnisse wurden in einem einigermaßen kleinen Korpus von arabischen rechtlichen Schriften erzielt.

Introduction

The manuscripts preserved in the Cairo Genizah have attracted considerable scholarly attention since their discovery by Europeans in the 19th century, and they have changed the face of research on Mediterranean societies in the Middle Ages; in particular, research on both Jewish and non-Jewish history, daily life and documentary practices. The documents found in the various Genizah collections cover a range of subjects: there are legal, social, medical, economic, cultural, literary and religious documents.

Prior to the discovery of the Genizah, the study of Jewish communities in the Middle Ages focused mainly on the central leadership in Palestine and Babylonia, with very little being done on the particularities of local communities. The Genizah treasure trove and associated research, especially since the monumental work of S. D. Goitein, has addressed an array of issues of daily life, family matters and internal communal organisation. However, the history of the writing materials of that time is still underresearched. In this work, I study the materials used in the day-to-day life of the scribes in these communities, understanding the logic behind their use of writing material and the relationship of this to the different functions of writing and different practices and beliefs, such as the prescriptions of the Talmud and issues of trade, technique and social interaction.

The main overall aim of this study is to understand better the writing materials used for the documents in the Genizah, which in turn will offer a different perspective and shed new light on the production of manuscripts in the Middle Ages. Indeed, the application of scientific methods of analysis may contribute to a fresh understanding of the materials and techniques used for the production of these manuscripts and thus furnish new information regarding their date and the historical context of their copying.

The first goal of this project is to conduct a systematic study of the medieval black inks used in the Genizah fragments, based on their composition and any possible interaction with the writing medium. In addition to the intrinsic value of this data for the history of writing techniques, the ink analysis also has a practical use: it gathers necessary information for the efficient conservation of manuscripts, the reconstruction of the history of the documents and an examination of the practices of their scribes.

The second objective is to compare the results of the analysis of the writing materials to other available information on the manuscripts, using both paleographical and textual methods. The intent is to study the change from one material (writing surface, type of ink) to another and the reasons why specific

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combinations are or are not used together, and to uncover any patterns that may exist in the use of specific types of writing material during certain periods. If any are found, this information could serve as an additional argument for a typology of and the dating of Hebrew script in other documents. The main research questions here thus relate to whether there was a preference for a certain type of ink depending on specific criteria such as the community within which the document was produced, the individual scribe who wrote the document, the type of document or the type of writing support. This set of questions was applied to a pragmatic corpus of documents limited to those written within a short time span (fifty years, i.e. a lifetime) and a small geographical area (a specific town). On this micro-level, I try to assess whether there was communication between different communities in a town, and what the relationship was between a given scribe and the writing materials he used, the tools of his work. This project also attempts to compare the results of the ink analysis with ink preparations discussed in literary sources to highlight links between recipes and specific type of documents.

My project is part of a larger study of historical inks conducted in Division 4.5 of the Bundesanstalt für Materialforschung und -prüfung (BAM) together with the Centre for the Study of Manuscript Cultures (CSMC). This has allowed me to compare the inks in the present analysis with those used in other Jewish documents studied in the broader project (e.g. scrolls) and also more globally with inks from other places and periods.

The corpus used to answer the questions of this study consists of 391 manuscripts (based on shelfmarks; this corresponds to 498 documents) written primarily by different leaders of the Jewish community of Fusṭāṭ between 994 (the earliest document of Elḥanan b. Shemariah) to 1057 (a document of Yefet b. David). All the documents of the corpus were found in the Cairo Genizah, but are specifically conserved today in the different collections of the Cambridge University Library (CUL), which gave me access to the manuscripts and authorised the use of the scientific equipment for the analysis. The documents largely emanate from three different contemporary communities in Fusṭāṭ – the Karaites, the Jerusalemites and the Babylonians – but in order to validate various hypotheses that I was able to formulate while studying the documents from Fusṭāṭ, I have also carried out comparisons with a number of documents that were included in the corpus but which were written outside Fusṭāṭ and indeed outside Egypt. Most of the documents in the corpus are written in Judeo-Arabic (that is, Arabic written in Hebrew letters), but some are written in Hebrew, Aramaic or Arabic. The preliminary dataset for this research was mainly gathered using the website of the CUL.

I have chosen to focus on documents from the 11th century in the main corpus because this period has been very well studied from historical and philological points of view: considerable research has been carried out on the main scribes of the documents studied here, and the documents themselves have been edited and are consequently well-known. In addition, the differences between the three Jewish communities in Fusṭāṭ are well marked in the 11th century and the documents reflect a rich panoply of subjects (legal, private and religious). The large number and diversity of documents allow us to have a more representative sample of the written production of 11th-century society in Fusṭāṭ.

This study is at the intersection between different disciplines: it belongs to humanities in terms of its paleographical and textual analyses, and to physics with its reliance on the methods of reflectographic and X-ray fluorescence.

The type of analysis used during this research provides some characterisation of the components of the inks under study, but not a "recipe", in the sense of "a set of instructions telling you how to prepare and cook food, including a list of what food is needed for this", to use the definition of the Cambridge Dictionary of English.[1] A recipe is an explanatory text, and this kind of text existed during the Middle Ages and before.[2] A scientific analysis like the one carried out here can identify the ingredients of the recipe and provide the relative proportions of some of the components, but it does not provide a description of the process. However, the proportions of the components can be compared – using the same instruments and parameters – with the relative proportions of those components in another ink from another set of documents. Such a comparison of the elementary composition of the inks of different documents allows us to check whether inks used by the same scribe, the same community, within the same document, or across a larger corpus, are identical or not. This ink identification can, in turn, shed light on the scribes, their work and their milieu.

The methodology utilised in this research classifies black inks into different groups, depending on the main colouring material used in their production:

1 Definition of « recipe », from the Cambridge Academic Content Dictionary, accessed November 2017, through https://dictionary.cambridge.org/dictionary/english/recipe.

2 Armin Schopen, *Tinten und Tuschen des arabisch-islamischen Mittelalters: Dokumentation, Analyse, Rekonstruktion: ein Beitrag zur materiellen Kultur des vorderen Orients* (Göttingen: Vandenhoeck & Ruprecht, 2006); Raggetti, 'Cum Grano Salis. Some Arabic Ink Recipes in Their Historical and Literary Context'; Jamâl Abarrou, *L'art du livre et sa fabrication au XI^e^ siècle en Occident musulman et en Europe du sud : encres, papier, colles, enluminure, reliure et calligraphie*, 1 vols (Reims: J. Abarrou, 2015).

iron, plant, carbon and mixed inks, with different proportions. This classification into distinct groups is a marker of different ink production.

The identification of the ink types is the first stage of this study. This typology is then compared with the writing surface on which the different inks are used, and also with their specific and identifiable users. Indeed, the broader purpose here is to reach beyond the manuscripts' materiality and consider the results about the materials within the content of the texts they carry and the scribes who copied them. This comparison will allow us to conclude whether the choice of ink and writing support is guided by codes relating to the field of the document, or just by practical or personal aspects of the work of the scribes themselves.

In the first chapter, the context of the corpus will be discussed (its discovery, its production and its limits), before we move on to consider the different writing materials used (chapter 2), the methodology of the experimental analysis (chapter 3), the results of the study (chapter 4) and some of the implications (chapter 5).

CHAPTER 1

The Cairo Genizah

1 Historical Background

Egypt, like Babylonia, formed a part of the Jewish Diaspora well before the rise of Islam. According to the early sources of Ibn Abd al-Hakam, there were about 40,000 Jews in Alexandria alone in 642, though Stillman believes this to be a great overestimation and suggests the much lower figure of 4,000 Jews.[1] Whatever the case before Islam, however, the two first centuries of the Islamic era formed a period of social, economic and political change for the whole of the Middle East and its inhabitants, including Jews.

The new empire ruled over a vast territory with common communication routes and a unified set of relationships, and this produced a rich environment for the development of local communities. The local population, after the Muslim conquest, was divided into three: Muslims, monotheistic non-Muslims and polytheistic non-Muslims. Monotheistic non-Muslims were given the status of *dhimmi*, or 'protected person'.[2] This status was primarily reserved for Christians and Jews, but sometimes extended to other groups, as Islam included Zoroastrians and Hindus in this category.[3] While the origin of the status of *dhimmi* is based on Qur'anic verses, the legal forms and conditions attached to the status are based on the covenant of Umar.[4] The origins of this pact are slightly unclear, since they are based on the records of probably

1 Norman A. Stillman, 'The Non-Muslim Communities: The Jewish Community', in *Islamic Egypt 640-1517*, ed. Carl F. Petry (Cambridge: Cambridge University Press, 1998), 198, https://doi.org/10.1017/CHOL9780521471374.009.

2 Marina Rustow, 'The Legal Status of Dhimmis in the Fatimid East: A View from the Palace in Cairo', in *The Legal Status of Ḏimmī-s in the Islamic West* (*Second/Eighth-Ninth/Fifteenth Centuries*), ed. Maribel Fierro and John Tolan, Religion and Law in Medieval Christian and Muslim Societies (RELMIN) 1 (Turnhout: Brepols Publishers, 2013), 307–32, https://doi.org/10.1484/M.RELMIN-EB.1.101823; Paul B. Fenton, 'Jewish-Muslim Relations in the Medieval Mediterranean Area', in *The Cambridge Genizah Collections: Their Contents and Significance*, ed. Stefan C. Reif and Shulamit Reif (Cambridge University Press, 2002), 152–59.

3 Mark R. Cohen, 'Medieval Jewry in the World of Islam', in *The Oxford Handbook of Jewish Studies*, ed. Martin Goodman (Oxford & New York: Oxford University Press, 2002), 198, https://doi.org/10.1093/oxfordhb/9780199280322.013.0009.

4 Phillip Isaac Ackerman-Lieberman, 'The Muhammadan Stipulations: Dhimmī Versions of the Pact of 'Umar', ed. Arnold E. Franklin et al., *Jews, Christians and Muslims in Medieval and Early Modern Times: A Festschrift in Honor of Mark R. Cohen*, 2014, 195–206; Mark R. Cohen, 'What Was the Pact of 'Umar? A Literary-Historical Study', *Jerusalem Studies in Arabic and*

apocryphal events in the 7th century during the rule of the Umayyad Caliph Umar b. al Khattab.[5] However, research at the end of the 20th century has suggested that there was some truth in the legend, but that the relevant events should be dated to the rule of Caliph Umar b. Abd al-Aziz, at the end of the 8th century.

The pact takes the form of a letter from non-Muslims to the caliph and contains a list of duties and conditions that *dhimmi*s agreed to respect as a guarantee for their protection.[6] *Dhimmi*s were allowed to regulate their own communal life and were requested to pay taxes that were different from those paid by Muslims,[7] including a poll tax, the *jizya*, in exchange for their protection. The enforcement of the taxes and the rights and obligations of *dhimmi*s, as well as a dress code, were not constant but depended on the rulers. However, despite various limitations, *dhimmi*s were rather well integrated into general society and could conduct negotiations with the authorities and institutions to define their status.[8] The judiciary system of *dhimmi*s was supported and authorised by the Muslim government. Though a member of a minority group was free to seek a Muslim judge instead of the courts of their own denomination, issues were more commonly settled inside their own communities.[9] The Jewish community could even impose punishments for seeking help outside of it. Indeed, turning to a Muslim court instead of the Jewish one could even be punished by excommunication.[10]

Following the Muslim conquest, Jews in the Middle East not only spoke Arabic but also used it for nearly every type of writing, even religious works that had in the past been written in either Hebrew or Aramaic. This whole period is marked both by a relative religious tolerance and by a multilingual cosmopolitan society of Muslims, Jews, Christians and other travellers from all around the Mediterranean Sea.

Islam, no. 23 (1999): 100–157; Antoine Fattal, *Le statut légal des non-musulmans en pays d'Islam* (Beyrouth: Impr. catholique, 1958), 60–69.

5 Cohen, 'What Was the Pact of 'Umar?', 101.

6 Yohanan Friedmann, 'Dhimma', in *Encyclopaedia of Islam, Three*, ed. Kate Fleet et al. (Brill, 2012), http://referenceworks.brillonline.com/entries/encyclopaedia-of-islam-3/dhimma-COM_26005.

7 Mark R. Cohen, *Under Crescent and Cross: The Jews in the Middle Ages* (Princeton University Press, 1994), 68–72; Oded Zinger, 'Introduction to the Legal Arena', in *The Jews of Medieval Egypt*, ed. Miriam Frenkel, The Lands and Ages of the Jewish People (Boston: Academic Studies Press, 2021), 86–123.

8 Rustow, 'The Legal Status of Ḏimmī-s in the Islamic West'.

9 Moshe Gil, *A History of Palestine, 634-1099* (Cambridge University Press, 1997), 165.

10 Gil, para. 738.

In 969, General Jawhar al-Siqili conquered Egypt for the fourth Fatimid caliph, Caliph al-Mu'izz; this event established the rule of the Fatimid dynasty in Egypt, which lasted for nearly two centuries, until 1171.[11] By that time, Jews had been already playing an important role in trade and commerce in the Muslim world,[12] and in the Fatimid caliphate, Jews were able to rise as high as being appointed by the Fatimid government to occupy official posts in the Fatimid bureaucracy.[13]

However, one period during Fatimid times shows that there were government persecutions of the *dhimmi*s. During the summer of 1007, Caliph al-Hakim, the sixth Fatimid caliph, began to destroy the prayer houses of Christians and Jews,[14] with the destruction of synagogues apparently following the destruction of churches. Persecutions and acts of destruction lasted until around 1020. These events are mentioned in several letters, such as the letter written by Elḥanan b. Shemarya around 1013 (e.g., Oxford MS Heb. a.3/21) or in several other private documents (e.g., T-S 13J26.16), but more information about them can be found in the "Egyptian scroll", preserved in several versions (e.g., T-S Misc. 35.5 and T-S 8K10), that describes the beginning of these events.

The life of the Jewish community relied on three academic centres: a Palestinian one in the Land of Israel, and two Babylonian ones, in Sura and Pumbedita; both Babylonian centres moved to Baghdad at the end of the 10th century, although they retained their names after moving. These academic centres or *yeshivot* (sg. *yeshiva*) represented the highest spiritual authority in

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11 Paula A. Sanders, 'The Fāṭimid State, 969–1171', in *Islamic Egypt 640-1517*, ed. Carl F. Petry (Cambridge: Cambridge University Press, 1998), 151–74, https://doi.org/10.1017/CHOL9780521471374.007.

12 Jessica L. Goldberg, 'Geographies of Trade and Traders in the Eleventh-Century Mediterranean: A Study Based on Documents from the Cairo Geniza' (PhD Thesis, Columbia University, 2005); Jessica L. Goldberg, *Trade and Institutions in the Medieval Mediterranean: The Geniza Merchants and Their Business World* (Cambridge University Press, 2012); Shlomo Dov Goitein, *Letters of Medieval Jewish Traders* (Princeton University Press, 1973); Norman A. Stillman, 'The Eleventh Century Merchant House of Ibn 'Awkal (a Geniza Study)', *Journal of the Economic and Social History of the Orient* 16, no. 1 (1973): 15–88, https://doi.org/10.2307/3596145; Moshe Gil, 'The Jewish Merchants in the Light of Eleventh-Century Geniza Documents', *Journal of the Economic and Social History of the Orient* 46, no. 3 (2003): 273–319; Jeremy Edwards and Sheilagh Ogilvie, 'Contract Enforcement, Institutions, and Social Capital: The Maghribi Traders Reappraised', *The Economic History Review* 65, no. 2 (2012): 421–44, http://dx.doi.org/10.1111/j.1468-0289.2011.00635.x.

13 Stillman, 'The Non-Muslim Communities'.

14 Moshe Gil, 'Institutions and Events of the Eleventh Century Mirrored in Geniza Letters (Part I)', *Bulletin of the School of Oriental and African Studies* 67, no. 2 (2004): 165; Stillman, 'The Non-Muslim Communities', 201; Rustow, 'The Legal Status of Ḏimmī-s in the Islamic West'.

Judaism. Each was led by a *Ga'on* (pl. *Ge'onim*) and was in constant contact with the local leaders of its respective community.[15] The *yeshivot* were considered to be a direct continuation of the Sanhedrin – the word *yeshiva* (from the Hebrew for "sitting") is itself a translation of Sanhedrin (the Greek word *synedrion* meaning "sitting together").

Before the Islamic conquest, these academic centres had been under different rules: the Palestine centre was under Byzantine control, while the Babylonian ones were under Persian rule. As a result, some rites and traditions had drifted from each other in the Babylonian and Palestinian communities; these differences mostly concerned *halakhot* (laws, sg. *halakha*) and the recitation of the Torah in the synagogue. The four first centuries following the Islamic conquest were marked by several fights between the Babylonian and the Palestinian centres for pre-eminence. The Babylonian centres claimed to be more important as the Torah had been continuously studied there since the destruction of the First Temple in 587 BCE, making their knowledge of the Talmud[16] and the *halakha* much deeper than anywhere else. Therefore, the leaders of the Babylonian *yeshivot* believed that the Palestinian leaders should give up their traditions, arguing that the practices of the latter had been developed under persecution and, thus, resulted from compromises.

The position as the leader of the *yeshiva*, the position of *Ga'on*, was often hereditary, passing to a member of the *Ga'on*'s family – usually his son – who would be trained for the position from a very early age. The *Ga'on* himself stood at the centre of a complicated power structure. On one hand, he was responsible for filling all available positions within the *yeshiva*. On the other hand, he also had the power to appoint a person of his choice to be the leader in every community that recognised his supremacy. These community leaders were responsible for organising community life on a local level; for example, they appointed specific people to perform religious and legal acts and they collected fees. From these revenues, a fraction was sent to the *Ga'on* to support him and his *yeshiva*.

In the first centuries following the conquest, the Jewish Diaspora in Islamic lands was led by the *yeshivot* of both the Land of Israel and Babylonia, and was organised in smaller territorial units within which the *yeshivot* were fighting for pre-eminence. Fusṭāṭ, the city with the largest Jewish community in Egypt,

15 Moshe Gil, *Jews in Islamic Countries in the Middle Ages*, ed. David Strassler, Études Sur Le Judaïsme Médiéval 28 (Leiden & Boston: Brill, 2004), 120.

16 The Talmud is the central text of Rabbinic Judaism and the primary source of the *halakha*, Jewish religious law. It is separated into two traditions: one collection of writing called the Babylonian Talmud or Talmud Bavli and another called the Jerusalem Talmud or Talmud Yerushalmi.

presented an example of such a struggle, as the members of the congregation could choose between two different communities. Each community in the city had its own synagogue and its own rites and the community leader of each was in constant contact with the *Ga'on* recognised by his community. The synagogue was the principal place of gathering for the Jewish inhabitants of the city, for religious, communal, and legal life: it served not only as a place of prayer but also as the seat of the Jewish court and the centre of communal activities. It is important to note that only in the larger cities were there two congregations; smaller towns rarely had more than one.

1.1 *History of the Cairo Genizah and Its Discovery by Scholars*[17]

Since at least talmudic times, and continuing through the Middle Ages, Judaism had the institution of the genizah (pl. genizoth): a storage place, often a room in a synagogue, for manuscripts that had gone out of use. This tradition developed because it was forbidden to destroy writings (mainly *Sifrei Torah, tefillin* and *ketubot*) liable to contain the divine name. These documents are stored instead in a genizah, awaiting burial to prevent their desecration,[18] following the prescription found in Mishnah Shabbat 16:1.[19]

Such a genizah was attached to one of the synagogues in Fusṭāṭ, which is today a district in Old Cairo, located south of the centre of modern Cairo. By the 19th century, when travellers came to Cairo and to this synagogue, it was known as the Ben Ezra Synagogue,[20] although it had a variety of other names during its history, including al-Fusṭāṭ, Fusṭāṭ-Misr and *kanīsat al-shāmiyyīn* "the synagogue of the Palestinians". It was the synagogue used by the Rabbanite community using the Palestinian rite. For many years, the Ben Ezra Synagogue was described as being a former Coptic church called St Michael's, which had been converted to a synagogue at the beginning of the Muslim conquest of

17 For more details on this story, see especially Stefan C. Reif, *A Jewish Archive from Old Cairo: The History of Cambridge University's Genizah Collection* (London: Routledge, 2000); Simon Anthony Hopkins, 'The Discovery of the Cairo Geniza', in *Bibliophilia Africana IV : Being the Proceedings of the Fourth South African Conference of Bibliophiles Held at the South African Library, Cape Town, 7-10 September 1981* (Fourth South African Conference of Bibliophiles Held at the South African Library, Cape Town: Friends of the South African Library, 1981), 137–78; Rebecca J. W. Jefferson, 'Deconstructing "the Cairo Genizah": A Fresh Look at Genizah Manuscript Discoveries in Cairo before 1897', *The Jewish Quarterly Review* 108, no. 4 (2018): 422–48, https://doi.org/10.1353/jqr.2018.0028.; and the literature cited in those works.

18 Habermann, Skolnik, and Berenbaum, 'Genizah'.

19 http://www.sefaria.org/Mishnah_Shabbat.16.1 (accessed 3 June 2019).

20 Hopkins, 'The Discovery of the Cairo Geniza', 146.

Egypt.[21] However, scholars now agree that it was probably not this Palestinian synagogue, but rather the Babylonian synagogue, which was built over that church.[22] The Ben Ezra Synagogue – then known as the Elijah Synagogue – was destroyed in 1014–1015 by order of the Caliph al-Hakim,[23] in the period of destruction mentioned earlier, and was rebuilt about ten years later. During the whole Fatimid period (969 to 1171), Fusṭāṭ remained the principal city of Egypt and the Ben Ezra Synagogue never went out of use.

The story of "discovery" of the genizah[24] of the Ben Ezra Synagogue and how it was emptied of its contents has been told several times.[25] About this "discovery", Glickman writes in his book: One of the most puzzling aspects of the "discovery" of the Cairo Genizah is that it wasn't a discovery at all. By the time Western scholars became aware of its documents, the existence of Ben Ezra's Genizah was a widely known – if largely ignored – fact. Indeed, over the years, a few Western visitors had even glimpsed the Genizah and written of its massive heap of crumbling paper and parchment. But no one much cared.[26]

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21 Solomon Schechter, 'A Hoard of Hebrew Manuscripts I', in *Studies in Judaism*, Second Series (London: Adam and Charles Black, 1908), 5.

22 Reif, *A Jewish Archive from Old Cairo*, 10.

23 Fenton, 'Jewish-Muslim Relations in the Medieval Mediterranean Area', 154; Sami Awad Aldeeb Abu-Sahlieh, *L'impact de La Religion Sur l'ordre Juridique : Cas de l'Égypte. Non-Musulmans En Pays d'Islam* (Friburg: Éditions Universitaires, 1979), 104.

24 Mark R. Cohen and Yedida Kalfon Stillman, 'The Cairo Geniza and the Custom of the Geniza among Oriental Jewry: An Historical and Ethnographic Study [Hebrew]', *Pe'amim* 24 (1985): 3–35.

25 Stefan C. Reif et al., 'Cairo Geniza', in *Encyclopedia of Jews in the Islamic World* (Leiden & Boston: Brill, 2010), https://referenceworks.brillonline.com/entries/encyclopedia-of-jews-in-the-islamic-world/cairo-geniza-COM_0004800; Rebecca J. W. Jefferson, 'A Genizah Secret: The Count d'Hulst and Letters Revealing the Race to Recover the Lost Leaves of the Original Ecclesiasticus', *Journal of the History of Collections* 21, no. 1 (2009): 125–42, https://doi.org/10.1093/jhc/fhp003; Hopkins, 'The Discovery of the Cairo Geniza'; Reif, *A Jewish Archive from Old Cairo*; Adina Hoffman and Peter Cole, *Sacred Trash: The Lost and Found World of the Cairo Geniza*, First edition, Jewish Encounters Series (New York: Schocken Books, 2011); Rebecca J. W. Jefferson, 'The Cairo Genizah Unearthed: The Excavations Conducted by the Count d'Hulst on Behalf of the Bodleian Library and Their Significance for Genizah History', in *From a Sacred Source*, ed. Ben Outhwaite and Siam Bhayro, Études Sur Le Judaïsme Médiéval 42 (Leiden: Brill, 2011), 171–200, https://doi.org/10.1163/ej.9789004190580.i-420.51; Mark Glickman, *Sacred Treasure – The Cairo Genizah: The Amazing Discoveries of Forgotten Jewish History in an Egyptian Synagogue Attic* (Woodstock: Jewish Lights Publishing, 2011).

26 Glickman, *Sacred Treasure*, 19.

However in 1864 (after an earlier unsuccessful attempt to access the chamber in 1858), Jacob Saphir, passing through Cairo, entered the genizah and delivered a valuable description of it.[27] The same year, Abraham Firkovitch, a Russian Karaite scholar, visited the genizah of Ben Ezra and returned home with a large number of manuscripts. Firkovitch never officially revealed the source of his manuscripts, and today it is believed that he bought them from the Karaite synagogue in Cairo, rather than from the genizah attached to the Ben Ezra Synagogue.[28] Those manuscripts, the second Firkovitch collection, are today preserved in the National Library of Russia in St Petersburg. It is important to understand, then, that in Fusṭāṭ, other genizoth probably existed as well: one attached to the Karaite synagogue – the Dar Simha Synagogue[29] – and, in all probability, one attached to the synagogue of the Babylonian community, the Kanîsat al-'Îrâqiyîn. But, it is the genizah from the Ben Ezra Synagogue that is known today under the name of the Cairo Genizah, or often just "the Genizah".

In 1888, Elkan Nathan Adler went to Cairo and visited the Ben Ezra Synagogue.[30] He acquired a large amount of material from it (about 30,000 fragments),[31] which he brought with him to the United States, and today, these manuscripts constitute the ENA collection at the Jewish Theological Seminary of America in New York. In 1896 he returned to Cairo, and that time he was able to enter the Genizah itself, which had meanwhile undergone renovation.

Between 1889 and 1892, the synagogue and the Genizah chamber were restored. Unfortunately, it is not entirely clear what happened during and after

27 Jacob Saphir, *Iben Safir* [*Hebrew*] (M'kize Nirdamim, 1866), 21–22.

28 Reif et al., 'Cairo Geniza'; Menahem Ben-Sasson, 'Firkovich's Second Collection: Remarks on Historical and Halakhic Material', *Jewish Studies* 31 (1991): 47–67; Zeev Elkin and Menahem Ben-Sasson, 'Abraham Firkovich and the Cairo Genizas in the Light of His Personal Archive [Hebrew]', *Pe'amim* 90 (2002): 51–95; Hopkins, 'The Discovery of the Cairo Geniza', 153.

29 Marina Rustow, *Heresy and the Politics of Community: The Jews of the Fatimid Caliphate* (Ithaca: Cornell University Press, 2008); Haggai Ben-Shammai, 'Is "the Cairo Genizah" a Proper Name or a Generic Noun? On the Relationship between the Genizot of the Ben Ezra and the Dar Simha Synagogues', in *From a Sacred Source*, ed. Ben Outhwaite and Siam Bhayro, Études Sur Le Judaïsme Médiéval 42 (Leiden: Brill, 2011), 43–52, https://doi.org/10.1163/ej.9789004190580.i-420.23.

30 Elkan Nathan Adler, 'An Eleventh Century Introduction to the Hebrew Bible: Being a Fragment from the Sepher Ha-Ittim of Rabbi Judah Ben Barzilai of Barcelona', *The Jewish Quarterly Review* 9, no. 4 (1897): 669–716, https://doi.org/10.2307/1450786.

31 Mark R. Cohen, 'Geniza for Islamicists, Islamic Geniza, and the "New Cairo Geniza"', *Harvard Middle Eastern and Islamic Review* 7 (2006): 129–45.

the renovation.[32] Some documents seem to have been piled in the courtyard[33] and returned to the new Genizah room after the renovations. On the other hand, a number of manuscripts were buried in the cemetery near al-Bāsātin[34] or in the ground around the synagogue, or were thrown out with the rubbish from the construction site. It is impossible to even estimate what proportion of the documents went back to the new Genizah at the end of the construction work.[35]

During and after the renovation of the Ben Ezra Synagogue, some of the fragments from the Genizah were sold to different European collectors, among them Rabbi Solomon Wertheimer, a resident of Cairo and a seller of rare books. The famous "Sinai sisters", Agnes Smith Lewis and Margaret Dunlop Gibson, purchased several fragments in March 1896 during a visit to Cairo. Upon their return to Cambridge, they turned to a scholar of Hebrew scholar and asked for his expert advice on the fragments they had acquired.[36] This scholar was Solomon Schechter, and initially, he was not very interested in these fragments. However, after studying the Ben Sira fragments that were among them,[37] he felt so enthusiastic that he persuaded the Master of St John's College, Charles Taylor, to finance an immediate trip to Cairo. Between December 1896 and 1897,

32 Hoffman and Cole, *Sacred Trash*, 38–39.

33 Jefferson, 'The Cairo Genizah Unearthed', 171–72.

34 Jefferson, 'A Genizah Secret'; Jefferson, 'The Cairo Genizah Unearthed'.

35 Jefferson, 'The Cairo Genizah Unearthed', 177; Jefferson, 'Deconstructing "the Cairo Genizah"', 423.

36 These fragments now constitute the Lewis-Gibson collection, separated between the Bodleian Library in Oxford and Cambridge University Library.

37 Hopkins, 'The Discovery of the Cairo Geniza', 167; Menahem Ben-Sasson, 'Cairo Genizah Treasures and Their Contribution to Historiography', *Bulletin of the Israeli Academic Center in Cairo 21*, 1997, 3; Menahem Ben-Sasson, 'Genizah, Cairo', in *Encyclopaedia Judaica*, ed. Fred Skolnik and Michael Berenbaum (Detroit: Macmillan Reference USA, 2007), 462–63; I. Abrahams, 'Schechter and Taylor's Wisdom of Ben Sira', *The Jewish Quarterly Review* 12, no. 1 (1899): 171–76, https://doi.org/10.2307/1450585; Solomon Schechter and Charles Taylor, *The Wisdom of Ben Sira: Portions of the Books Ecclesiasticus. From the Hebrew Manuscripts in the Cairo Genizah Collection Presented to the University of Cambridge by the Editors* (Cambridge: Cambridge University Press, 1899); Schechter, 'A Hoard of Hebrew Manuscripts I', 3; Stefan C. Reif, 'Some First Editions of Genizah Manuscripts of Ben Sira: Approaches and Reproaches', in *Discovering, Deciphering and Dissenting: Ben Sira Manuscripts after 120 Years*, ed. James K. Aitken, Renate Egger-Wenzel, and Stefan C. Reif (Berlin: Walter de Gruyter, 2019), 39–65, https://doi.org/10.1515/9783110614473-005; Ben Outhwaite, 'Schechter's Eye for the Extraordinary', *Jewish Historical Studies* 48, no. 1 (2016): 36, https://doi.org/10.14324/111.444.jhs.2016v48.024; Solomon Schechter, 'The Quotations from Ecclesiasticus in Rabbinic Literature', *The Jewish Quarterly Review* 3 (1891): 682–706.

he purchased[38] all the remaining manuscript fragments in the Genizah, leaving behind only printed books.[39] In fact, it is not clear if he acquired the contents of a number of different genizoth,[40] or only of the Ben Ezra Synagogue.[41] In any case, he sent eight large boxes containing his purchases to Cambridge, estimating his shipment at the time to over 140,000 fragments – today it is estimated at 193,000 manuscripts. These fragments constitute the Taylor-Schechter collection (T-S) of the Cambridge University Library, the most substantial part of the whole Genizah collection.

Between 1910 and 1912, there were additionally some excavations in the al-Bāsātin cemetery, outside of Fusṭāṭ, where some material had been buried during the earlier renovations. The initial excavations were carried out by Count d'Hulst for the benefit of the Bodleian Library.[42] Other excavations in the same cemetery, carried out by Chapira and Israël Lévi in the name of the French Société des Études Juives, later found over 5,000 leaves, which now constitute the Mosseri collection.[43]

Today, the material from the Cairo Genizah is scattered throughout the world, though the greater part has found its way to England. According to Stefan Reif's evaluation, some 70% of the material is located now at the University of Cambridge.[44] The 75,000 fragments outside of the collections of the CUL are estimated to be spread among more than 72 collections. Among them are four other locations in England: the Bodleian Library and other locations at

38 Solomon Schechter, 'A Hoard of Hebrew Manuscripts II', in *Studies in Judaism*, Second Series (London: Adam and Charles Black, 1908), 12–30.

39 Shlomo Dov Goitein, *Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of the Cairo Geniza. Vol. I: Economic Foundations* (Berkley: University of California Press, 1978), 4; Schechter, 'A Hoard of Hebrew Manuscripts I', 7.

40 Ben-Shammai, 'Is "The Cairo Genizah" A Proper Name Or A Generic Noun?'.

41 Jefferson, 'Deconstructing "the Cairo Genizah"', 423.

42 Jefferson, 'A Genizah Secret'; Jefferson, 'The Cairo Genizah Unearthed'.

43 Judith Olszowy-Schlanger, 'Israël Lévi', in *École Pratique des Hautes Études : Invention, Érudition, Innovation. De 1868 à nos jours*, ed. Patrick Henriet (Paris: Somogy Éditions d'Art, 2018), 528; Rebecca J. W. Jefferson and Ngaio Vince-Dewerse, 'When Curator and Conservator Meet: Some Issues Arising from the Preservation and Conservation of the Jacques Mosseri Genizah Collection at Cambridge University Library', *Journal of the Society of Archivists* 29, no. 1 (2008): 42, https://doi.org/10.1080/00379810802499751; Rebecca J. W. Jefferson, 'The Mosseri Collection: The Challenges Associated with Acquiring a Large Manuscript Archive' (British Association of Jewish Studies Annual Conference, Wolfson College, Cambridge, 2006); Cohen, 'Geniza for Islamicists, Islamic Geniza, and the "New Cairo Geniza"', 130; Reif, 'Some First Editions of Genizah Manuscripts of Ben Sira: Approaches and Reproaches', 49–52; Shmuel Glick, *Seride Teshuvot: A Descriptive Catalogue of Responsa Fragments from the Jacques Mosseri Collection*, vol. 3, Cambridge Genizah Studies Series (Cambridge: Brill, 2012), XIII.

44 Reif et al., 'Cairo Geniza'.

the University of Oxford, the John Rylands University Library at the University of Manchester and the British Library in London. Some can also be found in Russia (at the National Library of Russia in St Petersburg), in France (at the Alliance Israélite Universelle in Paris) and in the United States (at the Jewish Theological Seminary in New York, and the University of Pennsylvania in Philadelphia).[45]

1.2 *Contents of the Cairo Genizah*

The Cairo Genizah is the most impressive collection of Jewish manuscripts, with more than 300,000 fragments. At this stage, the Friedberg Genizah Project,[46] attempting to gather digitized versions of all the fragments, has 254,405 shelfmarks in its inventory, but since one shelfmark might correspond to more than a single fragment, the project lists 326,967 fragments. Generally speaking, one would expect to find religious writings in a genizah, because those works are more likely to contain the divine name. The Cairo Genizah, however, includes both sacred and secular texts (literary and documentary). It is difficult to know why so many non-religious documents are present in this genizah: perhaps the vision of sacredness at the time was vast and any texts written by or about Jews were considered intrinsically sacred,[47] or perhaps Jews in Fusṭāṭ simply did not take the trouble to systematically sort their writings into those to be put in a genizah and those that could just be disposed of.[48]

The Cairo Genizah contains manuscripts with a broad chronological range from the late 9th through to the 19th century, and these originate from different places, mainly Egypt, north Africa, Sicily and Palestine. A particularly large number of documents date to the period from the end of the 10th century to 1265, called the "classical" Genizah period by Goitein. This period of the Cairo Genizah corresponds to the time between just before the destruction and reconstruction of the synagogue to a period when great fires devasted the city. These fires led to the *dhimmi*s being fined heavily, and thus probably caused a drop in the number of documentary records in the Genizah.[49]

The content of the Genizah is mostly written in Hebrew, though other languages such as Arabic, Judeo-Arabic and Aramaic are also well attested. The

45 Cohen, 'Geniza for Islamicists, Islamic Geniza, and the "New Cairo Geniza"', 130; Reif, *A Jewish Archive from Old Cairo*; Stefan C. Reif, 'The Cairo Genizah: A Medieval Mediterranean Deposit and a Modern Cambridge Archive', *Libraries & Culture* 37, no. 2 (2002): 125; Goitein, *A Mediterranean Society: Economic Foundations*, 5.

46 https://fjms.genizah.org.

47 Reif, 'The Cairo Genizah'.

48 Reif et al., 'Cairo Geniza'.

49 Goitein, *A Mediterranean Society: Economic Foundations*, 19.

manuscripts and documents are written on a variety of writing substrates such as paper, leather, parchment, papyrus and even textile.

The great diversity of geographical and historical data makes the Cairo Genizah an attractive subject of study. The vast majority of Genizah fragments are literary texts, with only 5%[50] to 10%[51] of the whole collection being represented by documentary texts. The former can be found in the form of single leaves from codices, such as medieval Hebrew poetry, halakhic literature, midrashic texts, philosophical works, magical texts, and, finally, liturgical compositions usually attested by single pages from prayer books. In addition, the Genizah also contains material concerning everyday life, which will be referred to as "private" material: letters, accounts, pen trials, lists, calendars and notes. These documents give a broad overview of day-to-day life in Muslim countries during the classical Genizah period.[52] Moreover, they provide us with an enormous amount of information on the Jewish legal system and the practices and names of people. Many legal documents – such as marriage contracts (*ketubot*), deeds of divorce (*get*), deed of sales, powers of attorney, acknowledgements of debt, court records or leases – preserved in the Genizah present a unique opportunity to obtain insights into the legal system of that time.[53] For example, court records of the Palestinian community from the 11th century that belonged to the archive of the court or the community have been recently reconstructed.[54]

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50 Cohen, 'Geniza for Islamicists, Islamic Geniza, and the "New Cairo Geniza"', 131.

51 Phillip Isaac Ackerman-Lieberman, 'Commercial Forms and Legal Norms in the Jewish Community of Medieval Egypt', *Law and History Review* 30, no. 4 (2012): 1014, https://doi.org/10.1017/S0738248012000685.

52 Cohen, 'Geniza for Islamicists, Islamic Geniza, and the "New Cairo Geniza"', 131.

53 Mordechai Akiva Friedman, *Jewish Polygyny in the Middle Ages* (Tel Aviv: Tel Aviv University & Bialik Institute, 1986); Oded Zinger, 'A Karaite-Rabbanite Court Session in Mid-Eleventh Century Egypt', *Ginzei Qedem*, Genizah Research Annual, 13 (2017): 95–117; Oded Zinger, 'Women, Gender and Law: Marital Disputes According to Documents of the Cairo Geniza' (PhD Thesis, Princeton University, 2014); Judith Olszowy-Schlanger, *Karaite Marriage Documents from the Cairo Geniza. Legal Tradition and Community Life in Mediaeval Egypt and Palestine*, Études Sur Le Judaïsme Médiéval 20 (Leiden & New York & Köln: Brill, 1998); Gershon Weiss, 'Legal Documents Written by the Court Clerk Halfon Ben Manasse (Dated 1100-1138): A Study in the Diplomatics of the Cairo Geniza' (PhD Thesis, Pennsylvania, University of Pennsylvania, 1970), http://repository.upenn.edu/dissertations/AAI7107871/; Gershon Weiss, 'Documents Written by Hillel Ben Eli: A Study in the Diplomatics of the Cairo Geniza Documents."' (MA Dissertation, University of Pennsylvania, 1967).

54 Bareket, *The Jewish Leadership of Fustat in the First Half of the Eleventh Century* **היהודית בפוסטאט ההנהגה במחצית הראשונה של המאה האחת–עשרה**.

As mentioned above, the presence of all these documents in the Genizah is unexpected in a genizah, which is supposedly for religious purposes; these legal documents should be in an archive. Thus, one question often raised in studying the Genizah is: What are legal documents doing in a genizah? Goitein considered the Cairo Genizah as "the very opposite of an archive".[55] He suggests that the documents that were stored, or rather carelessly disposed of, were never meant to be read again or even found: they had basically become "trash"[56] after having been used, and sometimes reused, extensively. In addition, the Genizah has been in use for almost a thousand years: its contents were turned over continuously – ruling out any possibility of using stratigraphy[57] – and therefore not ordered. It was not possible to track back a specific document and access it. Therefore, the Genizah is not a proper archive as such, although it contains many documents of the type that might be expected in an archive.[58]

1.3 *Conservation and Current Storage of the Fragments at the CUL*

The work presented here is based on an instrumental analysis of manuscripts and this project thus required direct access to the relevant manuscripts. For technical reasons, then, the corpus of interest had to be limited to the collection preserved in the CUL.

A complete inventory of the Cambridge Genizah manuscript collections – as a part of a larger project of registering and drawing up an inventory of all the Genizah fragments, undertaken by the Friedberg Genizah Project[59] – was compiled between the years 2004 and 2006.[60] That project aimed to prepare for the digitisation of all the manuscripts (not only of Cambridge's collection but of all the fragments found in the Cairo Genizah), a task that has been underway since the beginning of 2009. At the end of the inventory, a total of 193,654 manuscripts (and 225,141 folios) were recorded in the CUL.[61] The Genizah manuscripts in Cambridge are divided into a number of different

55 Goitein, *A Mediterranean Society: Economic Foundations*, 7.
56 Hoffman and Cole, *Sacred Trash*.
57 Judith Olszowy-Schlanger, 'Les archives médiévales dans la genizah du Caire : registres des tribunaux rabbiniques et pratiques d'archivage reconstituées', *Afriques. Débats, méthodes et terrains d'histoire*, no. 07 (2016), https://doi.org/10.4000/afriques.1885.
58 Olszowy-Schlanger.
59 https://fjms.genizah.org.
60 Rebecca J. W. Jefferson, 'The Historical Significance of the Cambridge Genizah Inventory Project', in *Language, Culture, Computation. Computing of the Humanities, Law, and Narratives*, ed. Nachum Dershowitz and Ephraim Nissan, vol. 8002 (Berlin & Heidelberg: Springer, 2014), 9–37, https://doi.org/10.1007/978-3-642-45324-3_2; Mark R. Cohen, 'Digitizing the Geniza', *Jewish History* 32 (2019): 547–50, https://doi.org/10.1007/s10835-019-09324-4.
61 Jefferson, 'The Historical Significance of the Cambridge Genizah Inventory Project', 34.

collections, depending on different criteria, such as the person who purchased the manuscripts or donated them to the library, or how or when the manuscripts were catalogued.[62]

Considering their age and the quality of storage, the manuscripts found in the Cairo Genizah were in a relatively good condition. Nevertheless, they needed a conservation treatment to keep the fragments stable, on one hand, and accessible to scholars, on the other. Many conservation solutions have been explored. After many years of use (from 1895 to 1973),[63] glass has been rejected due to such characteristics as its weight, the risk of it breaking and possibly damaging the fragments, and difficulties connected with re-mounting the pieces. The CUL found that a better solution was to use Melinex – a PET (polyethene terephthalate) material that is light, flexible, unbreakable and free of chemicals that could interfere with the fragments. In addition, it has the non-negligible advantage of saving room compared with glass. Manuscript can be encapsulated – or rather sewn – into transparent Melinex envelopes allowing researchers to study and manipulate them without having to touch the manuscripts directly.

Three different types of Melinex with different thickness have been used:

- Melinex 516[64] (referred to as Melinex A in this study) produced by Dupont Teijin Films.
- Melinex 401[65] (Melinex B), of 75 microns, also produced by Dupont Teijin Films.
- P1A5Y75[66] (Melinex C), also of 75 microns thickness, produced by Secol Archival products (UK).[67]

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62 Stefan C. Reif and Shulamit Reif, *The Cambridge Genizah Collections: Their Contents and Significance*, vol. 1 (Cambridge University Press, 2002); Jefferson, 'The Historical Significance of the Cambridge Genizah Inventory Project'.

63 Shulamit Reif, *The Written Word Remains: The Archive and the Achievement; Articles in Honour of Professor Stefan C. Reif* (Cambridge: Cambridge University Press, 2004); Jefferson, 'The Historical Significance of the Cambridge Genizah Inventory Project'; Rebecca J. W. Jefferson, 'Thirty Years of the Taylor-Schechter Genizah Research Unit', in *The Written Word Remains: The Archive and the Achievement; Articles in Honour of Professor Stefan C. Reif*, ed. Shulamit Reif (Cambridge: Cambridge University Press, 2004), 9–27.

64 'MELINEX® 516', accessed 17 May 2019, https://marianinc.com/wp-content/uploads/2013/10/pdf-data-sheet-MELINEX%C2%AE-516.pdf.

65 http://www.doganak.com/urunlerimiz/elektrik-izolasyon-malz/melinex-401-cw-50-100/ (accessed 17 May 2019).

66 https://www.secol.co.uk/products/pockets__covers__folders__and_sleeves/polyester_pockets/standard_pockets/75_micron_polyester_pockets_/168/p1a5y75/standard_pockets_a5 (accessed 17 May 2019).

67 Jefferson, 'The Historical Significance of the Cambridge Genizah Inventory Project', 34.

Information about the existence of a protection leave was found especially useful for the establishment of the measurement protocol (see section 3.1.3.1).

2 Presentation of the Corpus

To study possible connections between the types of document and writing materials, on the one hand, and possible preferences within different communities, on the other, we sought to obtain a statistically relevant number of documents from a reasonably short and well-defined period of time with clear authorship. A corpus of documents authored by known personalities from different Jewish communities living in Fusṭāṭ in the first half of the 11th century answers these requirements.

By the 11th century, there were two distinct groups of Jews in Cairo: the Rabbanites, who acknowledged the authority of the Talmud, and the Karaites, who rejected the authority of the Talmud and that of the rabbis. As mentioned in section I.1, the Rabbanites were themselves divided into two subgroups: the "Babylonians" (also called "Iraqis"), who were allied with the rabbinic *Ge'onim* of Babylonia; and the "Palestinians" (sometimes called "Jerusalemites") connected with the rabbinic *Ge'onim* of the Land of Israel. Each community had its own synagogue, with its own rites – and probably each had its own genizah, using the one of the Palestinians only in exceptional cases,[68] but only the Ben Ezra Synagogue has survived until today.

Two synagogues, that of the Babylonian community and that of the Palestinian community, were very close to each other, both in the Qasr al-Sham, as can be seen on the map in Figure 1.1. The synagogues are highlighted in blue: the Palestinian synagogue, the Kanîsat al-Shâmiyîn, is to the north of the Babylonian one, the Kanîsat al-'Îrâqiyîn. They are separated only by a small number of houses along a single street, often called the Zuqaq al-Yahud "the street of the Jews" because of the proximity of the two synagogues.

Before the persecutions by Caliph al-Hakim, it seems that the Babylonian community was more important in Cairo than the Palestinian one. During the 10th and 11th centuries, Egypt was an attractive place for immigration, welcoming many Jews from Iraq, which resulted in a powerful Babylonian community. Until 1011, there was only a Babylonian court in Fusṭāṭ.[69] Its importance, how-

68 Shlomo Dov Goitein, 'Changes in the Middle East (950-1150) as Illustrated by the Documents of the Cairo Geniza', *Islamic Civilization* 19 (1973): 17–33.

69 Judith Olszowy-Schlanger, 'Manuscrits hébreux et judéo-arabes : Paléographie des documents juridiques de Fustat du Xe siècle.', *Annuaire de l'École Pratique des Hautes Études* (*EPHE*), Section des sciences historiques et philologiques. Résumés des conférences et travaux, no. 149 (2018): 29–33.

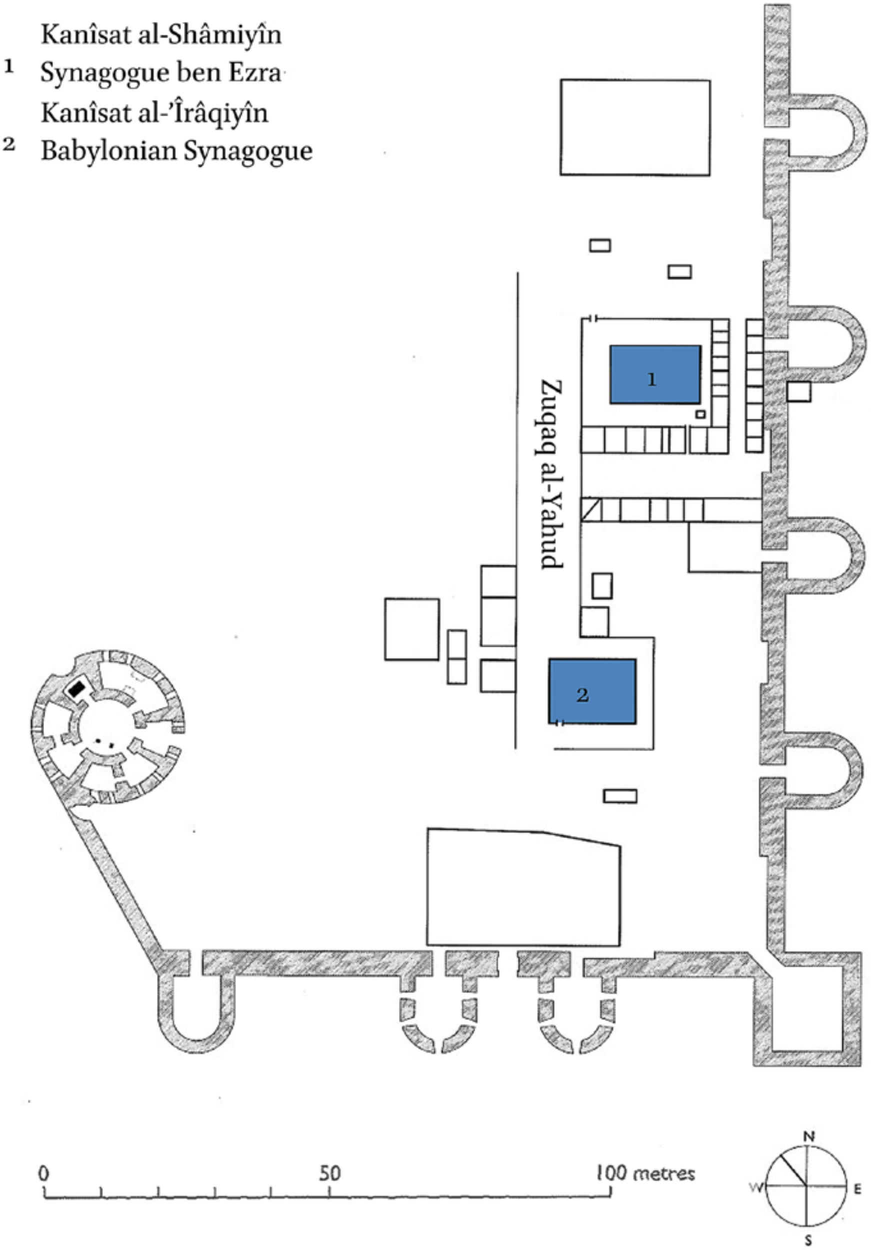

FIGURE 1.1 Map of medieval Fusṭāṭ with the synagogues of the Palestinian and the Babylonian communities, based on the survey plan of the fortifications of Qasr al-Sham after a drawing by Kate Spence, Peter Sheehan and Charles le Quesne, 1993

Note: Menahem Ben-Sasson, 'The Medieval Period: The Tenth to Fourteenth Centuries', in *Fortifications and the Synagogue: The Fortress of Babylon and the Ben Ezra Synagogue, Cairo*, ed. Phyllis Lambert (London: Weidenfeld & Nicolson, 1994), 201–23.

ever, is difficult to estimate, because not many Babylonian legal documents have been found so far in the Genizah. Babylonian community leaders received the title of *aluf* as a symbol of their allegiance to the Babylonian *Ga'on* and the Babylonian *yeshiva*.

The Palestinian community was initially subordinate to the *yeshiva* in Jerusalem. The leaders of the community in Fusṭāṭ, like other Palestinian leaders in the rest of Egypt, were granted the title of *ḥaver* and were in contact with their *Ga'on* in Palestine for guidance and advice. The letter exchange between these two parties has been preserved in the Genizah and shows the trajectory of this relationship. By the 12th century, the situation changed direction, and Fusṭāṭ became the centre of religious power for the whole region of Egypt, Syria and Palestine.

We find many indications of the ambivalent nature and the quality of the relationship between the two Rabbanite communities. On one hand, there is evidence of mutual assistance: in the letter T-S 24.43, the *Ga'on* Solomon b. Joseph, of the Palestinian *yeshiva* in Jerusalem, writes to the leaders of both communities asking for their help. The Genizah contains several letters that mention fundraising, either to help the poor or to release captives. In T-S 13J34.3, both Rabbanite communities in Alexandria ask for help in raising money to pay a ransom for Jewish boys who were taken prisoners by pirates. On the other hand, the relationship between the different leaders of the Rabbanite communities in Fusṭāṭ was strained. It is sufficient to mention here that the Palestinian *Ga'on* Solomon b. Judah was writing to the leaders of both communities in Fusṭāṭ in attempt to improve their relationship. An example can be seen in the letter T-S 13J23.11, where he is asking Ephraim b. Shemarya, the leader of the Palestinian community, to calm down with respect to Sahlān b. Abraham, the leader of the Babylonian community.

Another example of the complex relationship can be seen in T-S 10J29.13, where Solomon b. Shemah, the Palestinian community leader in Ramla, writes an angry letter to Ephraim b. Shemarya, complaining about his bad manners which had for effect to convince people to "switch over to the other synagogue and to the Karaite congregations".[70] This is not the only example in the Genizah which shows the fluidity of the affiliation of individuals to a particular congregation. Another example is offered by the change of allegiance from the Babylonian to the Palestinian one made by no lesser personality than Shemarya b. Elḥanan, the leader of the Babylonian community, who ended his connections with the

70 Marina Rustow, 'The Genizah and Jewish Communal History', in *From a Sacred Source*, ed. Ben Outhwaite and Siam Bhayro, Études Sur Le Judaïsme Médiéval 42 (Leiden: Brill, 2011), 306, http://booksandjournals.brillonline.com/content/books/10.1163/ej.9789004190580.i-420.76.

Pumbedita *yeshiva* and proclaimed his loyalty to the Palestinian *yeshiva* as a result of a conflict he had with the *Ga'on* of the Pumbedita *yeshiva* in 1006.[71] Yefet b. Tobiah al-Baghdadi, who was connected to the Palestinian *yeshiva* and community despite a Babylonian origin, offers yet another example.[72] Though the move from one Rabbanite congregation to another is perhaps understandable, the fluidity of affiliation with respect to the Karaite congregation seems rather more surprising.

The Karaites formed the third major Jewish community in Fusṭāṭ. Karaites[73] constitute a sect founded by Rabbi Anan b. David around the middle of the 8th century. Their doctrine is based on a strict reading of the Torah and a more rigorous application of Jewish law.[74] They deny any interpretation of the biblical text, do not respect talmudic rabbinic law and do not recognise the authority of the *Ge'onim*. The relationship of this sect with Judaism is complicated since, on one hand, they were considered heretics by the Jews and, on the other, they did not consider themselves to be Jews. However, based on the social interactions between the Karaite and Rabbanite Jewish communities reported by the Genizah documents, this was not precisely the case in medieval Fusṭāṭ. In addition to the example of the letter mentioned above (T-S 10J29.13) showing a possible fluidity between Rabbanite and Karaite communities, *ketubot* of intermarriages attest to close contacts between the two parties. In the Genizah, only a small number of Karaites documents exist; among them, there is a large predominance of *ketubot*.[75] Over 58 Karaite *ketubot* have been found so far, and four of them attest to mixed weddings, between Rabbanites and Karaites,[76] however these intermarriages seem to have stopped around the 12th century – Maimonides was against these intermarriages, not in principle, but due to the problems of the *get* (divorce act) in cases where the couple wanted to separate, as he considered that the Karaite *get* would not be sufficient for Rabbanite standards. The somewhat puzzling presence of 54 *ketubot* relating only to marriage between Karaite parties in a Rabbanite Palestinian genizah could be explained by the reuse of the support for other purposes, or as a sign of a later marriage, in the generations to follow.[77]

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71 Elinoar Bareket, *Fustat on the Nile: The Jewish Elite in Medieval Egypt*, The Medieval Mediterranean 24 (Leiden & Boston & Köln: Brill, 1999), 116.

72 Bareket, 180–84.

73 *Baalei ha mikra* (בַּעֲלֵי מִקְרָא, בְּנֵי מִקְרָא, קָרָאִים), meaning "the people of the scriptures".

74 Shlomo Dov Goitein, *Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of the Cairo Geniza. Vol. II: The Community* (Berkley: University of California Press, 1971), 7.

75 Zinger, 'A Karaite-Rabbanite Court Session in Mid-Eleventh Century Egypt'.

76 Rustow, *Heresy and the Politics of Community*.

77 Olszowy-Schlanger, *Karaite Marriage Documents from the Cairo Geniza*.

The question of Rabbanite–Karaite contact is also related to the question of the existence (or non-existence) of Karaites courts: a matter highly debated by scholars but not yet unequivocally solved. It is worth noting that most of the Karaite legal documents found in the Genizah happen to be *ketubot*, which do not require a court. It is true that most of the documents – if not all – came from the Ben Ezra Synagogue, thus from a Palestine genizah, and Karaites documents were, of course, less likely to be thrown in a Rabbanite genizah than in their own; however, this does not explain the imbalance in the proportion of legal documents. There is evidence that Karaites appeared in Rabbanite courts, as witnesses (see e.g. T-S 13J30.3) or as a main party (as shown in T-S 16.171 and T-S 12.150, written for Karaites by a scribe working for the Babylonian court of Shemarya b. Elḥanan[78]). Other documents show that the custom of Karaites using Rabbanite courts was not limited to Fusṭāṭ but is also attested in other cities. Two documents, Document A[79] and Document B,[80] associated with an inheritance,[81] and T-S 20.187, which is a power of attorney,[82] present further evidence of the existence of joint Rabbanite–Karaite courts. In contrast, the question of a dedicated Karaite court is discussed explicitly in several documents (e.g. Mosseri Ia1 and Mosseri Ia2[83]), indicating that if Karaites were not maintaining functioning courts everywhere in Egypt, they seem to have been able to gather for a court when needed, especially in large cities like Fusṭāṭ.

This study focuses on the first half of the 11th century, and more precisely, the period between 996 and 1057 – a crucial period in the history of the Jewish communities in Egypt. During this period, the leaders of the communities had hostile relationships because they were fighting for a dominant role for their respective communities – by the 12th century, the Babylonian rite had been accepted almost everywhere, leading to the merging of the Palestinian and Babylonian communities. However, at this earlier time, the differences between the Rabbanite communities are particularly noticeable, raising our expectation that the marked differences between the scribal practices might be reflected in the scribal materials. We have also made use of the fact that the period under investigation is well studied.

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78 Judith Olszowy-Schlanger, 'Manuscrits hébreux et judéo-arabes', *Annuaire de l'École Pratique des Hautes Études* (*EPHE*), Section des sciences historiques et philologiques. Résumés des conférences et travaux, no. 150 (2019): 24–32.

79 Mosseri VII.43 + T-S Ar.53.53.

80 T-S AS 145.299 + T-S AS 135.261 + T-S AS 104.178 + T-S NS 145.160 + T-S NS 324.75 + T-S 6J2.26.

81 Zinger, 'A Karaite-Rabbanite Court Session in Mid-Eleventh Century Egypt'.

82 Hary et Rustow, « Karaites at the rabbinical court: a legal deed from Mahdiyya dated 1073 (T-S 20.187) ».

83 Olszowy-Schlanger, 'Manuscrits hébreux et judéo-arabes'.

TABLE 1.1 Presentation of the scribes investigated in the project, with the dates of their leadership

Palestinians	Babylonians	Karaites	Additional
Ephraim b. Shemarya (1007–1055) Yefet b. David (1014–1057)	Elḥanan b. Shemarya (994–1026) Abraham b. Sahlān (1017–1030) Sahlān b. Abraham (1024–1050)	No particular scribe, several documents	Solomon b. Judah (1025–1051)

Three of the scribes chosen for this study (see Table 1.1) – Elḥanan b. Shemarya, Abraham b. Sahlān and Sahlān b. Abraham – were leaders of the Babylonian community in Fusṭāṭ, while two others – Ephraim b. Shemarya and Yefet b. David – were respectively the leader and the secretary of the Palestinian community. We have also included Solomon b. Judah, the *Ga'on* of the Palestinian *yeshiva*, due to his extensive communications with the leaders of both Rabbanite communities. In addition, several Karaites documents written in the same period are used in this corpus as a point of comparison. Following Goitein's common-sense argument that "the common people adopt the ways of their rulers",[84] we can assume that these very well-known people were likely setting the trends followed by the members of their respective communities. Therefore, concentrating on their texts should allow us to make detailed comparisons between Palestinians, Babylonians and Karaites.

In addition to the relationship between different Jewish communities in Fusṭāṭ, there is also the question of the relationship between Jewish and non-Jewish communities. When looking at a map of the religious buildings in Fusṭāṭ during the Middle Ages, as can be seen in Figure 1.2, one sees that communities were not confined to definite quarters. As Goitein stresses, "since [...] the Genizah people were not hemmed in by occupational, geographic, or cultural ghettos, they had many things in common with other, contemporary societies, Muslim and Christian".[85] On this map, Jewish religious buildings are

84 Goitein, 'Changes in the Middle East (950-1150) as Illustrated by the Documents of the Cairo Geniza', 18.

85 Shlomo Dov Goitein, *Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of the Cairo Geniza. Vol. V: The Individual* (Berkley: University of California Press, 1988), 1.

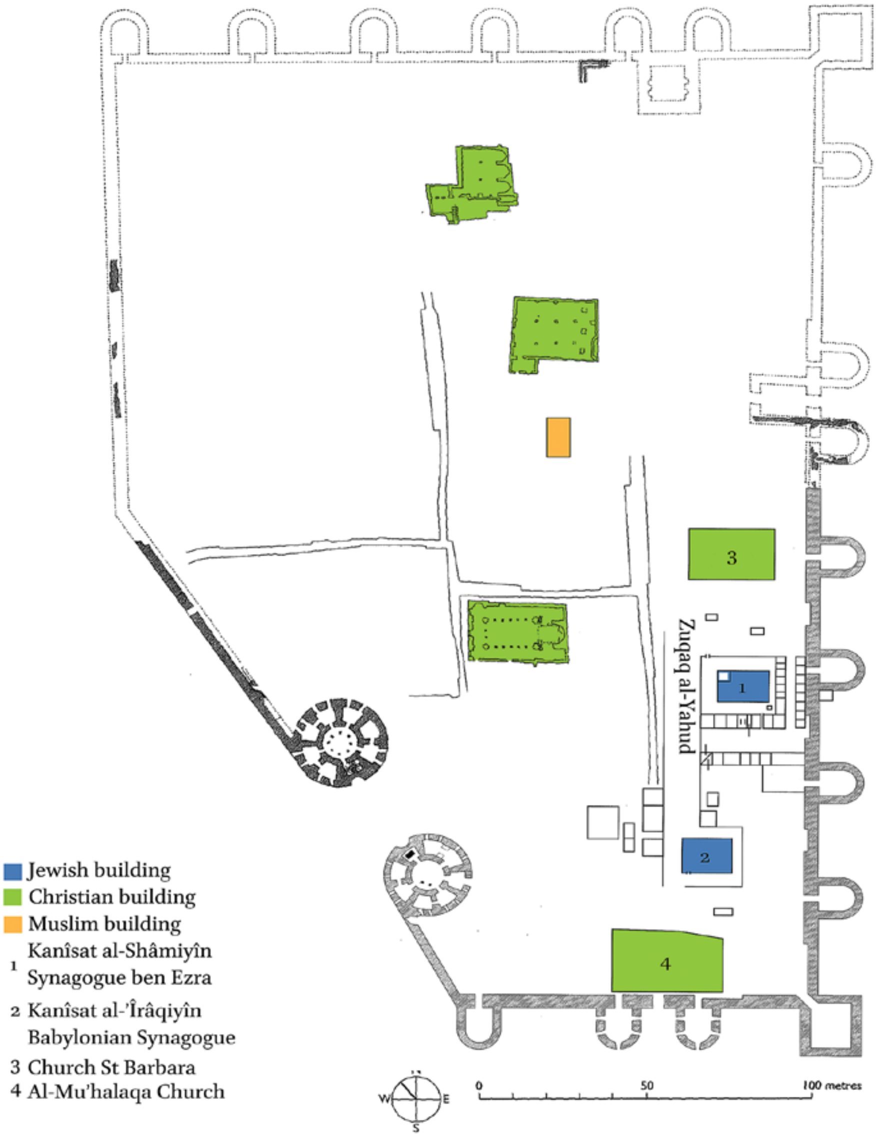

FIGURE 1.2 Map of the southern end of Qasr al-Sham in Fusṭāṭ, around the Ben Ezra Synagogue and major religious buildings, based on the survey plans of the fortifications of Qasr al-Sham, after a drawing by Kate Spence, Peter Sheehan and Charles le Quesne, 1993
Note: Ben-Sasson, 'The Medieval Period'.

represented in blue, the Muslim one in orange and Christian ones in green. As can be seen, the two Rabbanites synagogues are located amid several Christian religious buildings and at least one Muslim building.

It would of course be interesting to know whether the things in common shared by Jews and non-Jews included writing materials. When it comes to these, a connection has been already shown between Hebrew documents and documents written at the same place and time by non-Jews, with the link having been shown, in scholarly work (see the discussion in section 2.2.4) and also analytically.[86] We have added a number of documents written by non-Jews to explore this point. We also analysed a further 56 documents written outside of Cairo, with the intention of checking whether a specific scribal practice could be associated with a type of a religious community.

Since one of the objectives of the study is to produce a database of writing materials, the question of the definition of an individual document took a central position. Current cataloguing system made this task especially challenging. On one hand, many documents could be entered under the same classmark, while on the other, a single document could be spread over different classmarks. Ink designation presented an even more difficult question: several inks could be used to write the same document, and the same ink could be used for several different documents. Some of the manuscripts were written on different folios but need to be considered as a whole, while others were written on the same folio but at different times and could be considered as different documents. Examples of different cases of later additions within the same folios can be found in T-S 16.124 (addition), T-S 8J29.12 (corrections), T-S NS J51 (several cases written one after the other), T-S 10J27.7 (reuse of the back side) and T-S 12.182 (palimpsests). We consider additions and corrections as belonging to the original document; but we consider the rest of the cases as new documents, since the primary text has no connection with the secondary text.

This raises the question of reuse: when several documents are written on the same writing surface, how should we count them? In this corpus, we had to face three main types of reuse of the support. In the first scenario, additions

86 Rabin, Hahn, and Binetti, 'Inks used in medieval Hebrew manuscripts: a typological study'; Ira Rabin, 'Building a Bridge from the Dead Sea Scrolls to Mediaeval Hebrew Manuscripts', in *Jewish Manuscript Cultures: New Perspectives*, ed. Irina Wandrey, Studies in Manuscript Cultures 13 (Berlin & Boston: Walter de Gruyter, 2017), 310–22, https://doi.org/10.1515/9783110546422-012; Silvia A. Centeno and Nellie Stavisky, 'The Prato Haggadah: An Investigation into the Materials and Techniques of a Hebrew Manuscript from Spain in Relation to Medieval Treatises', in *Craft Treatises and Handbooks: The Dissemination of Technical Knowledge in the Middle Ages*, ed. Ricardo Córdoba, De Diversis Artibus (DDA) 91 (Turnhout: Brepols Publishers, 2013), 161–84, https://doi.org/10.1484/M.DDA-EB.5.102153.

are made on an original document, related to the primary one. This may be a short addition in the margin, as in manuscript T-S 16.124, where there is an update on the status of the document, or a longer case, like with manuscript T-S 13J37.12. The second case involves additional text on a different subject but from the same original type of document: this is the situation with a legal notebook, for example, such as T-S 8J4.1 where different legal cases are presented. Finally, the third scenario is where unrelated texts, such as pen trials, are found, like in T-S 18J1.3 or T-S 16.49, or where there is a completely new document, as with T-S 18J2.16. The question of palimpsests was not considered since previous studies have shown that the characterisation of removed ink is unreliable.[87]

Taking these remarks into account, a document has been defined as a coherent entity, such as a legal case, or a letter. The analysis of the text written on a certain surface can establish if this was conceived as part of one or more documents. If the lines of a text show any discrepancy in their content then they are labelled as different documents. Therefore, an address on the verso of a letter would be considered still in relation to the main text, while a second legal case, separated or not from the first one by a physical mark, would be considered as a new document. I define a single manuscript here as being something that corresponds to a single classmark, making navigation into the CUL catalogue easier.

Consequently, the corpus was constituted by 391 manuscripts, comprising 498 documents. Due to reuse and the complicated story of several of the manuscripts from the Cairo Genizah, the corpus, although focusing on the first half of the 11th century, stretches from the 6th century to the first half of the 13th century.

The chronological distribution of the type of support used to pen the documents is presented in Figure 1.3. Leather is represented by blue dots, parchment by green dots and paper by pink dots. The original intent was to present this same distribution for the entire corpus of documents from the Genizah, unfortunately, the difficulty of assessing what is a document and how to count them made this impossible, at least for this study. All the documents written on leather are part of the subcorpus of scrolls.

2.1 *Types of Document*

As mentioned in section 1.1.2, both religious and non-religious documents have been found in the Genizah. Similarly, the corpus for this study contains documents of a religious and a non-religious nature, both private and legal, so

87 Zina Cohen et al., 'Composition of the Primary Inks in Medieval Palimpsests: Effects of Ink Removal', *Opuscula Musealia*, no. 23 (2015): 75–82, https://doi.org/10.4467/20843852.OM.15.007.5385.

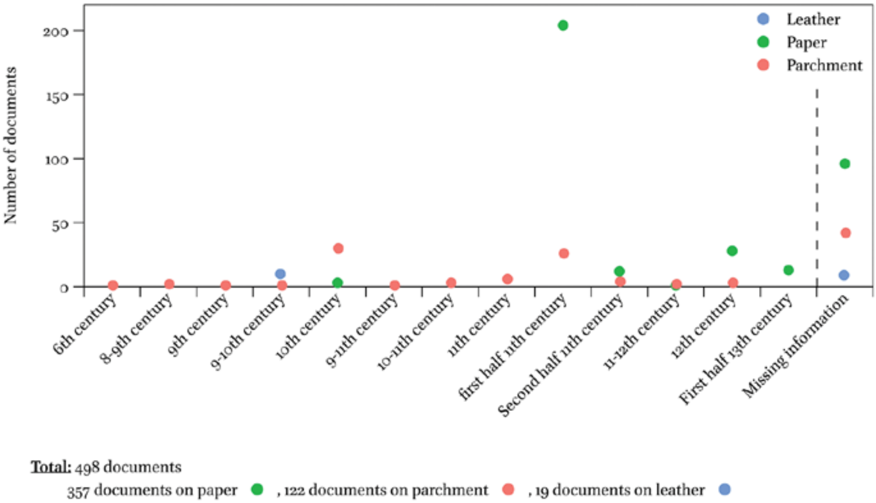

FIGURE 1.3 Chronological distribution of the corpus, showing the number of documents with each type of writing surface

TABLE 1.2 Presentation of the number of documents in the corpus, according to their type

Type of documents	Number of manuscripts	Number of documents
Private documents	122	130
Legal documents	175	200
Official documents	12	11
Religious documents	105	90
Unclassified	62	67
Sum	476[a]	498

a This number does not match the number of 391 manuscripts given so far (and afterwards) as the same manuscript could be reused for a different purpose than the original one (with a legal document on the recto and on the verso some notes, for example).

that the study connects to different aspects of life in the first half of the 11th century. The documents studied have been divided into four main categories:
– Private documents
– Legal documents
– Official documents
– Religious documents

The distribution of manuscripts and documents, as a function of their type, is presented in Table 1.2. Admittedly, this typology is arbitrary, as the borders between them are rather fluid. It is, for example, important to remember the fact that the synagogue was central not only for the community's religious life but also for its legal, social, economic and political life as well, as the synagogue was a meeting point, a place of study and a courthouse (*bet din*).

2.1.1 Private Documents

We selected a large group of documents, that we have called "private", comprising letters, accounts, calendars and jottings.

Letters are written on a single sheet of paper, often very long, sometimes glued with another one if the letter was longer than expected (e.g. T-S 16.283, T-S 16.284). The text of letters is written only on one side and justified. The verso usually contains only the address, which is written sometimes with both Arabic and Hebrew letters. In some documents, however, the verso was reused for either drafts (e.g. T-S 18J4.5) or personal documents (e.g. T-S 13J11.7 and T-S 13J16.11).

2.1.2 Legal Documents

The legal documents of the Genizah – and this corpus – are divided into three subcategories:

- Courts records (archives of the *bet din*)[88]
- Deeds
- Marriage documents: betrothal, *ketubah*, *get*[89]

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88 Elinoar Bareket, *The Jews of Egypt 1007-1055: based on documents from the 'archive' of Efraim Ben Shemarya* [*Hebrew*] (Jerusalem: The Ben-Zvi Institute of Yad Izhak Ben-Zvi, 1995); Olszowy-Schlanger, 'Les archives médiévales dans la genizah du Caire'; Judith Olszowy-Schlanger, 'Formules juridiques des documents médiévaux en caractères hébraïques et les livres de formulaires-modèle', *Annuaire de l'École Pratique des Hautes Études* (*EPHE*), Section des sciences historiques et philologiques. Résumés des conférences et travaux, no. 143 (2012): 23–27; Zinger, 'A Karaite-Rabbanite Court Session in Mid-Eleventh Century Egypt'; Phillip Isaac Ackerman-Lieberman, 'Legal Pluralism among the Court Records of Medieval Egypt', *Bulletin d'Études Orientales*, no. 63 (2015): 79–112, https://doi.org/10.4000/beo.2904; Weiss, 'Legal Documents Written by the Court Clerk Halfon Ben Manasse (Dated 1100-1138): A Study in the Diplomatics of the Cairo Geniza'; Norman Golb, 'Legal Documents from the Cairo Genizah', *Jewish Social Studies* 20, no. 1 (1958): 17–46; Geoffrey Khan, *Arabic Legal and Administrative Documents in the Cambridge Genizah Collections*, ed. Stefan C. Reif, vol. 10, Genizah Series (Oxford: Cambridge University Press, 1993).

89 Don S. Browning, M. Christian Green, and John Jr. Witte, eds., *Sex, Marriage, and Family in World Religions* (New York: Columbia University Press, 2006); Shlomo Dov Goitein, *Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of the Cairo Geniza. Vol. III: The Family* (Berkley: University of California Press, 1967); Olszowy-Schlanger, *Karaite Marriage Documents from the Cairo Geniza*; Rebecca J. W. Jefferson, 'Genizah Marriage Contracts: Contrasting Biblical Law and Halakhah with Mediaeval Practice', in *A Question of Sex? Gender and Difference in the*

The Genizah is an extraordinary source of medieval legal[90] and archive[91] documents. These form the largest group among the Genizah documents,[92] and comprise the most exciting part of this corpus for several reasons. They are usually dated, and even sometimes located. These documents often allow us to distinguish the use of different inks from one point to another (betraying, perhaps, the use of different inks within the same document). It should also be noted that sometimes these documents have been intentionally written at different points in time (e.g. T-S 16.124, where an update on the reimbursement of the debt is added in the margin) or marked with different signatures.

All these documents offer a unique opportunity to witness how the court (*bet din*) was producing, filing and conserving legal documents and enlighten the relationship of the Jewish court with other legal systems (mainly Muslims, but also Christians). As a general rule, the court records here bear at least two signatures since, according to Jewish law, two persons were sufficient as witnesses according to the treaty Baba Metzia 75b (e.g. T-S 8J6.18 f.1, T-S 16.45). In practice, though, more witnesses would frequently be present. Five of them, for example, would often sign a *ketubah* (e.g. T-S 24.12) – no fixed procedures seem to have prevailed in this matter. In most cases, there is no indication of who acted as the president of the court. Blanks are avoided as much as possible in legal documents (to prevent fraudulent additions from being made *a posteriori*). The page is usually regular, justified, mostly written on one side, and updates are then added either in the margin[93] (e.g. T-S 16.124) or on the verso (e.g. T-S 18J1.17).

Concerning non-Jewish bureaucracy, Ackerman-Lieberman stresses that documents produced by non-Jewish courts were accepted in Jewish courts,

Hebrew Bible and Beyond, ed. Deborah W. Rooke, Hebrew Bible Monographs 14 (Sheffield: Sheffield Phoenix Press, 2007), 162–74; Friedman, *Jewish Polygyny in the Middle Ages*; Zinger, 'Women, Gender and Law'.

90 Golb, 'Legal Documents from the Cairo Genizah'; Weiss, 'Legal Documents Written by the Court Clerk Halfon Ben Manasse (Dated 1100-1138): A Study in the Diplomatics of the Cairo Geniza'; Khan, *Arabic Legal and Administrative Documents in the Cambridge Genizah Collections*; Olszowy-Schlanger, *Karaite Marriage Documents from the Cairo Geniza*; Ackerman-Lieberman, 'Commercial Forms and Legal Norms in the Jewish Community of Medieval Egypt'.

91 Olszowy-Schlanger, 'Les archives médiévales dans la genizah du Caire'; Ackerman-Lieberman, 'Legal Pluralism among the Court Records of Medieval Egypt'; Bareket, *The Jews of Egypt 1007-1055*.

92 Reif et al., 'Cairo Geniza'.

93 Judith Olszowy-Schlanger, 'Un petit guide de description des écritures hébraïques', *Instrumenta BwB 1*, 2013, 6.

whether signed by Jews or non-Jews.[94] Furthermore, he points out that the Jewish court seems to have produced documents which might have been used in Islamic courts. The use of ink or of writing surfaces offers an interesting way to assess how cultural exchanges, and in particular technical exchanges, worked. The idea was to draw a comparison between Jewish and non-Jewish documents to see if material differences could be found. For this purpose, we selected several Arabic legal documents, written in Arabic, that did not seem to have been written by, or to concern Jews, as well as documents attesting relationships between Jews and non-Jews. All of them were found in the Genizah, are stored in the Cambridge collection and were censed by Khan.[95] In addition to those, two legal documents found outside of the Genizah were also analysed. These two documents are currently stored in the Michaelides collection (charta) and are written on paper.

2.1.3 Official Documents

The category "official documents" comprises documents produced by or for the central power and its representatives, meaning:

- Petitions
- Tax

However, our interest mainly lies in their later reuse by the scribes of the corpus, who wrote letters (e.g. T-S 13J26.24) or biblical verses (T-S Ar.7.38) on the other side.

2.1.4 Religious Documents

Finally, this corpus contains some religious – usually undated – documents: some palimpsests, and some scrolls, mainly Talmud and biblical ones, both Palestinian and Babylonian. These documents are part of a parallel project[96] and were used here to see if a difference was visible between the inks used in religious and non-religious manuscripts.

In addition, some religious poems (*piyyutim*) and religious responsa (*teshuvot*), written by the scribes studied here, have been added, permitting the study of both sacred and non-sacred religious documents.

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94 Ackerman-Lieberman, 'Legal Pluralism among the Court Records of Medieval Egypt', 81

95 Khan, *Arabic Legal and Administrative Documents in the Cambridge Genizah Collections*.

96 Judith Olszowy-Schlanger, 'The Anatomy of Non-Biblical Scrolls from the Cairo Geniza', in *Jewish Manuscript Cultures: New Perspectives*, ed. Irina Wandrey, Studies in Manuscript Cultures 13 (Berlin & Boston: Walter de Gruyter, 2017), 49–88, https://doi.org/10.1515/9783110546422-004.

2.2 *Presentation of the Scribes*

2.2.1 Salomon b. Judah, *Ga'on* of the Palestinian *yeshiva*

The Genizah contains information about the Jewish community in Fusṭāṭ, but also information about those from outside the city, or indeed outside the country, because they were communicating with the inhabitants of Fusṭāṭ or visiting the city. Due to the high number of documents in this corpus that contain his name, and his importance within the world of the Genizah, we begin by presenting Salomon b. Judah, a major figure in the Jewish world during the 11th century.[97] He was the head of the Jerusalem *yeshiva* and the official head of the Jews of the Fatimid empire. He died in 1051 CE.

Salomon b. Judah was in extensive correspondence with the heads of both communities in Fusṭāṭ, although he was indisputably on the side of Ephraim b. Shemarya, the leader of the Palestinian community at the time. The Genizah preserved many of his letters, and in the present corpus, 22 letters are written by him; he also signed one deed of quittance (T-S 16.191).

Some other documents in the corpus are written by the hand of his son, Abraham b. Salomon b. Judah. It was common among *Ge'onim* (from both the Palestinian and the Babylonian *yeshivot*) to entrust their sons with writing their correspondence, thus training them to the responsibilities inherent in their position.[98]

2.2.2 The Representatives of the Palestinian Community

2.2.2.1 *Ephraim b. Shemarya*

Ephraim b. Shemarya, like the other scribes of this corpus, was well known in the world of the Cairo Genizah, and much research has been conducted on him.[99] He was born around 975 and died in 1055. His full name was Abū Kathīr

97 Marina Rustow, 'Solomon Ben Judah', in *Encyclopedia of Jews in the Islamic World* (Leiden & Boston: Brill, 2010), https://referenceworks.brillonline.com/entries/encyclopedia-of-jews-in-the-islamic-world/solomon-ben-judah-SIM_0020450?s.num=0&s.f.s2_parent=s.f.book.encyclopedia-of-jews-in-the-islamic-world&s.q=Salomon+ben+Judah+gaon; Ben Outhwaite, '"In the Language of the Hagri": The Judaeo-Arabic Letters of Solomon Ben Judah', in *The Written Word Remains: The Archive and the Achievement; Articles in Honour of Professor Stefan C. Reif*, ed. Shulamit Reif (Cambridge: Cambridge University Press, 2004), 52–69; Jacob Mann, 'The Jews in Egypt and in Palestine Under the Fatimid Caliphs: A Contribution to Their Political and Communal History Based Chiefly on Genizah Material' (PhD Thesis, Oxford, Oxford University, 1920), 75–152.

98 Gil, *Jews in Islamic Countries in the Middle Ages*, 133.

99 Elinoar Bareket, 'The Relationship Between the Babylonians in Fustat and the Yeshiva in Palestine during the First Half of the Eleventh Century [Hebrew]', *Cathedra* 21 (1981): 41–48; Elinoar Bareket, 'Origins and Society in the Jewish Community of Fustat in the Eleventh Century [Hebrew]', *Pe'amim* 34 (1988): 3–28; Elinoar Bareket, 'Struggles over

Ephraim ben Shemarya [Maḥfūẓ] ha-Melammed ha-ʿAzzati (or al-Muʿallim al-Gazī) – the final part indicating "of Gaza". Ephraim crafted perfumes and scents and traded medicines (his epithet, al-ʿAṭṭār in Arabic and ha-Bosman in Hebrew, means "the perfumer"). He lived in the Qasr al-Sham, the central quarter of Fusṭāṭ and the district of the synagogues where the majority of the Jewish inhabitants dwelt.

Ephraim b. Shemarya was the spiritual leader of the Palestinian congregation in Fusṭāṭ and of the entire Jewish community of Fusṭāṭ for nearly 50 years, from around 1007 until his death in 1055. His status of rabbinical chief judge (*av bet din*) and leader of the Jewish community of Fusṭāṭ was approved by five successive Palestinian *Ge'onim*. The title of judge (*dayan*) was given to him in 1007 by Shemaiah *Ga'on*.[100] By 1025, Josiah ben Aaron *Ga'on*, Shemaiah's successor, had given him the title of fellow (*ḥaver*),[101] the highest title regularly granted by the Palestinian academy, making Ephraim b. Shemarya the highest leader in Fusṭāṭ and in the whole of Egypt.

His extensive correspondence found in the Genizah includes not only exchanges of letters with successive Palestinian *Ge'onim* but also with the leaders of other communities in Fusṭāṭ and abroad. The Genizah kept many traces of his correspondence with the leaders of the Babylonian community in Fusṭāṭ, and of his communication with members and leaders of the Palestinian communities in various other places, but especially in Palestine; he corresponded with *ḥaver* in Jerusalem, Ramla, Acre and Gaza. The diverse topics of the letters

Jewish Leadership in Fustat in the Mid-Eleventh Century', in *Zion*, vol. 54 (Historical Society of Israel, 1989), 161–78; Elinoar Bareket, 'More About Ephraim Ben Shemariah [Hebrew]', *Hebrew Union College Annual* 61 (1990): 15–46; Bareket, *The Jews of Egypt 1007-1055*; Bareket, *Shafrir Mitzrayim*; Bareket, *Fustat on the Nile*, 129–60; Elinoar Bareket, 'Exegetic Writing of Ephraim Ben Shemaria, Head of Community in Fustat, Egypt, during the First Half of the Eleventh Century [Hebrew]', *Hebrew Union College Annual* 75 (2004): 25–50; Elinoar Bareket, 'Ephraim Ben Shemariah', in *Encyclopedia of Jews in the Islamic World* (Leiden & Boston: Brill, 2014), http://dx.doi.org/10.1163/1878-9781_ejiw_SIM_000732; Gil, *A History of Palestine, 634-1099*, 582–90; Efraim Lev and Zohar Amar, 'Reconstruction of the Inventory of Materia Medica Used by Members of the Jewish Community of Medieval Cairo According to Prescriptions Found in the Taylor-Schechter Genizah Collection, Cambridge', *Journal of Ethnopharmacology* 108, no. 3 (2006): 428–44; Efraim Lev, 'Drugs Held and Sold by Pharmacists of the Jewish Community of Medieval (11–14th Centuries) Cairo According to Lists of Materia Medica Found at the Taylor-Schechter Genizah Collection, Cambridge', *Journal of Ethnopharmacology* 110, no. 2 (2007): 275–93, https://doi.org/10.1016/j.jep.2006.09.044; Efraim Lev, 'Legacies and Prospects in Geniza Studies and the History of Medicine: Reconstruction of the Medical Bookshelf of Medieval (Jewish) Practitioners', *Jewish History* 32 (2019): 559–62, https://doi.org/10.1007/s10835-019-09325-3.

100 Gil, *A History of Palestine, 634-1099*, 583.

101 Gil, 584.

touched on community life and more personal things, such as his relationship with his Babylonian opponents, Sahlān b. Abraham and his partisans. He authored 33 documents from this corpus over a total of 30 classmarks, including 17 legal documents and eight letters. Nine documents are signed by him: two documents that he authored, two documents authored by Yefet b. David, one document written by Elḥanan b. Shemarya, one written by Abraham b. Solomon (the son of Solomon b. Judah) and three documents where authorship has not yet been attributed.

2.2.2.2 *Yefet b. David*

Ephraim b. Shemarya's right-hand man was Yefet b. David. More formally known as Abū'l Ali Yefet (Husayn) b. David b. Šeḵanya, he held the positions of cantor (*ḥazan*) and of ritual slaughterer (*shohet*), and was concurrently appointed scribe at the Palestinian court from 1014 to 1057, continuing this role for two years after the death of Ephraim b. Shemarya. Yefet b. David's career in the service of the Palestinian community was very long, like that of Ephraim b. Shemarya, lasting for nearly 40 years. During the rebuilding of the Palestinian synagogue in the 1030s, he was in charge of supervising the construction by recording expenditure, purchasing materials and paying the workers.[102] He penned approximately 40 documents in this corpus and his signature is found 22 times (on 20 different manuscripts).

Yefet b. David's family seem to have hailed from Tyre. He stayed in that city for some time after his father moved to Fusṭāṭ with a large part of their family. He finally joined them in 1013 and quickly obtained the posts of cantor and of scribe of the court, and in 1025 he succeeded his father as *shohet*.[103] This latter office was his main source of income but also made his position precarious with the *Ge'onim*, who was responsible for the payment of his wages; Yefet b. David considered that the part that the *Ga'on* was keeping for the *yeshiva* was excessive. The conflict with the *Ga'on* grew in 1051 when a new *Ga'on*, Daniel b. Azariah, followed Salomon b. Judah in his position as the head of the *yeshiva*. This feud reached culmination point when, in 1055, the *Ga'on* Daniel b. Azariah requested a *herem* (ban) on Yefet b. David and all of his "helpers and supporters, the partakers of his slaughtering, whomever he employs to write a deed or a marriage contract and whoever befriended him" (see e.g. T-S 12.484r, T-S Misc. 25.132).[104] The new head of the Palestinian community, Eli b. Amram, who took over the position after Ephraim b. Shemarya's death, sided with

102 Gil, 589.

103 Gil, 572.

104 Bareket, *Fustat on the Nile*, 175; Gil, *A History of Palestine, 634-1099*, 589.

the *Ga'on*. The conflict affected Yefet's health to such an extent that he had to leave Fusṭāṭ.

2.2.3 The Representatives of the Babylonian Community

2.2.3.1 *Elḥanan b. Shemarya*

From an early age Abū Zakariyya/Yahya Elḥanan b. Shemarya b. Elḥanan had been prepared by his father to become a leader of the community, and he was sent to study in the Pumbedita *yeshiva*. His father, Shemarya b. Elḥanan, was the leader of the Babylonian community in Fusṭāṭ from 966 until his death in Fusṭāṭ in 1011, and as mentioned above, had created close relationships with the Palestinian *yeshiva*, eventually leading him to change his allegiance to them in 1006. When his father died, Elḥanan b. Shemarya was in Damascus, and he tried to return to Fusṭāṭ to take over his responsibilities as leader of the community. However, his journey took almost two years, and he arrived only in 1013–1014, during the time of the decrees of al-Hakim that lead to the destruction of the synagogue. Elḥanan b. Shemarya was the leader of the Babylonian community and of the entire Rabbanite community in Fusṭāṭ as well, maintaining a relationship with both the Palestinian and the Babylonian *yeshivot*. He died in 1026 and was succeeded as head of the Fusṭāṭ community by Ephraim b. Shemarya.

Elḥanan b. Shemarya wrote ten documents in this corpus and signed one of them.

2.2.3.2 *Abraham b. Sahlān*

Abraham b. Sahlān (Abū Ishaq Abraham/Barhun), sometimes called b. Sunbāt, was a leader of the Babylonian community from 1017 to 1030 – although it is hard to determine precisely the date of his death, which seems to be between 1028[105] and 1030. He was a merchant and was therefore in contact with many notable and influential families. He married the daughter of an influential family who died young and left him two sons: Sahlān and Nehemiah. This wedding allowed him to gain respectability and power within the community.

By 1021, he was the right-hand man of Elḥanan b. Shemarya. His many titles underlined his high power and his place in both communities. In the Babylonian community, he was *aluf, behir ha-yeshiva* (the *yeshiva*'s chosen one) and *rosh ha-seder*, while from the Palestinian *yeshiva* he received the titles *mumhe* (the skilled one) and *ḥaver*. However, this does not seem to have been sufficient to gain him the support of Salomon b. Judah: after the death of Elḥanan b. Shemarya, Abraham b. Sahlān wanted to succeed him both as

105 Gil, *A History of Palestine, 634-1099*, 592.

leader of the Babylonian community and leader of the Fusṭāṭ community, but Solomon b. Judah's support for the latter post was entirely in favour of Ephraim b. Shemarya.

Some time after his first wife died, he married again, but seems to have divorced in 1028 – traces of a divorce concerning an Abraham b. Sahlān living at this time in Fusṭāṭ can be found in the Genizah (see T-S 8J4.3, written by Ephraim b. Shemarya, and T-S 13J5.1, written by Yefet b. David),[106] but there is no certainty that these refer to the same person (and in particular, Bodl. MS Heb. c28/29 does not quote any titles for him, suggesting that they could be two different people).[107]

2.2.3.3 *Sahlān b. Abraham*

Abū ʿAmr Sahlān b. Abraham led the Babylonian community in Fusṭāṭ from the death of his father Abraham b. Sahlān until 1049–1050, a period of approximately 20 years. He should not be confused with his grandfather, who has the same name and who witnessed document T-S 16.49. Before his appointment, Sahlān b. Abraham was already active in the leadership of the community and also in the family business, trading scents and perfumes. He was a liturgical poet (*payṭan*), and a cantor (*ḥazan*).

He wrote 18 of the documents in this corpus.

2.2.4 Comparative Documents

We have expanded the corpus to include other documents for comparison. This additional set contains documents written by people from other places (e.g. Solomon b. Shemah from the Palestinian community of Ramla with T-S 18J3.9, T-S 13J13.28, T-S 10J29.13 and T-S 13J34.11), written for the Karaite community and written by non-Jews. The last ones include legal documents from the court of the Qadi (e.g. T-S 18J1.10), litigations involving Christians and Jews (e.g. T-S Ar.38.99, T-S Ar.42.174, T-S Misc.29.21, T-S 8J5.8, T-S Ar.38.114) or Muslims and Jews (e.g. Or.1080 J117). Lastly, we also studied a series of official Fatimid documents (presented above in section 1.2.1.3), and included them simplistically in the group of Muslim documents.

Albeit very limited in number, these manuscripts allowed us to glimpse at the use of writing materials outside of the main Jewish communities. Moreover, it offers some evidence of the interactions between different communities.

106 Bareket, *Fustat on the Nile*, 227; Bareket, *The Jewish Leadership of Fustat in the First Half of the Eleventh Century* **ההנהגה היהודית בפוסטאט במחצית הראשונה של המאה האחת–עשרה**, 14:n12.

107 Goitein, *A Mediterranean Society: Economic Foundations*, 463.

CHAPTER 2

Writing Materials

1 Writing Surfaces

The material support on which writing is done plays an important role in the writing process and therefore constitutes an essential part of the history of documents. From the conservation point of view, the interaction between the support and the ink is of paramount importance. In this work, I will investigate possible correlations between the use of specific supports or writing surfaces and specific inks and try to assess whether it is possible to see a combination of ink and writing support that would serve as a marker of a specific social or religious group or would be characteristic of a single scribe or date.

The writing materials found in the Genizah include papyrus and paper, leather and parchment, and even textiles. However, the documents considered in this study were written only on paper, parchment and leather, and we will therefore limit our description to these materials. The lion's share of the 391 manuscripts presented in this work was written on paper (257) followed by parchment (113). Only a small number of manuscripts – all of them non-biblical scrolls of religious content from the Babylonian community[1] – were written on leather, clearly indicating its specific use.

1.1 *Skin-based Materials: Leather and Parchment*

In general, parchment is a writing material made from animal hides, as is leather. Historically, parchment for writing was predominantly produced from sheep, goat and cattle, with the choice of animal depended on geographical region and date.

Since the Middle Ages, production of parchment has consisted of three main steps: de-hairing with the help of lime solution, drying under tension and finishing.[2] De-hairing is the only production step common to both leather and parchment. Starting from the second step, the treatment becomes

1 None of the analysed scrolls were Torah scrolls.

2 Michael Gullick, 'From Parchmenter to Scribe: Some Observations on the Manufacture and Preparation of Medieval Parchment Based upon a Review of the Literary Evidence', in *Pergament: Geschichte, Struktur, Restaurierung, Herstellung*, ed. Peter Rück, Historische Hilfswissenschaften (Sigmaringen: Jan Thorbecke, 1991), 145–57; Michael L. Ryder, 'The Biology and History of Parchment', in *Pergament: Geschichte, Struktur, Restaurierung, Herstellung*, ed. Peter Rück, Historische Hilfswissenschaften (Sigmaringen: Jan Thorbecke,

 | DOI:10.1163/9789004469358_004

dramatically different. To make leather, a de-haired and washed hide is placed in a tannin[3] solution (or tanned in some other way) whereas for parchment production the hide is dried under tension, being stretched on a frame, thinned and cleaned until it is transformed into a rigid white sheet. In the final step, parchment is smoothed and polished. Though this basic recipe has not changed over centuries, individual and local refinements resulted in writing materials of different qualities and colours. The best writing parchment is made of dermis, whose hair and flesh sides show no difference to the naked eye. Usually, however, these two sides are easily recognisable both in leather and in parchment of lesser quality. Accordingly, the colour of parchment can range from snow-white to ivory.[4]

As noted, generally speaking, one of the major differences between leather and parchment is tanning, at least outside the Jewish world.[5] In contrast to leather, parchment is not normally tanned in order to become a suitable writing surface.[6] The main exceptions known are the parchments of the Dead Sea Scrolls produced in Antiquity and Jewish medieval parchments that were allegedly tanned before sacred texts were inscribed on them.[7]

Studies of the skin-based material of the Dead Sea Scrolls have also revealed that there were different de-hairing techniques in Antiquity in contrast with the single technique of the Middle Ages.[8] In one of the techniques, depilation

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1991), 25–33; Ronald Reed, *The Nature and Making of Parchment*, ed. A. S. Maney, First Edition (Leeds: Elmete Press, 1975).

3 Tannins are a group of polyphenolic compounds of vegetable origin capable of precipitating proteins. Tannins have been traditionally used to convert hides to leather, which process is called tanning (Ann E. Hagerman, *The Tannin Handbook* (Miami: University Oxford, 2011), http://www.users.miamioh.edu/hagermae/.). For the use of tannins in leather production see Ronald Reed, *Ancient Skins, Parchments and Leathers* (London: Seminar Press, 1972), 72–84.

4 Reed, *Ancient Skins, Parchments and Leathers*, 63.

5 As explained, the difference of preparation between leather and parchment is in stretching and not in tanning. However, here we are very interested in the tanned property because tanned parchment is a specificity found mostly in the Jewish world. Furthermore, our equipment is able to detect the use or absence of tannins.

6 We will see in 3.1.2 that the colour of the document is not a criterion for discrimination between leather and parchment, and that the study of the writing surface through UV light is needed to assess whether tannin has been used or not.

7 John B Poole and Ronald Reed, 'The Preparation of Leather and Parchment by the Dead Sea Scrolls Community', *Technology and Culture* 3 (1962): 17–18, https://doi.org/10.2307/3100798., quoting Maimonides, *Mishneh Torah*, chap. 1, 6-9 Laws concerning Phylacteries, the Mezuzah and the Scroll of the Law.

8 Poole and Reed, 'The Preparation of Leather and Parchment by the Dead Sea Scrolls Community', 17–18. quoting Maimonides, *Mishneh Torah*, chap. 1, 6-9 Laws concerning Phylacteries, the Mezuzah and the Scroll of the Law.

of the hides was conducted using sulfur salts that resulted in milky white parchments. These types of parchment were either not tanned or tanned very lightly on the surface. The second technique involved de-hairing with the help of vegetable matter. In these cases, the resulting parchment was usually tanned, meaning that it is not possible to clarify whether tannins were already present in the de-hairing mixture. This type of parchment is, in fact, a hybrid between parchment (since it was dried under tension) and leather (the tanning was quite considerable). It has been proposed that the two different techniques originated from different geographical regions: the pale parchments were associated with the West (i.e. Hellenistic Greece) and were the predecessors of the medieval European parchment, while the brown parchment was related to the working of hides in the East (i.e. the area corresponding to the Seleucid empire).[9]

It is very interesting that only Babylonian scrolls in this study have been found to be written on leather, whereas the scrolls of the Palestinian community are always on untanned parchments.[10] This corresponds well to the fact that only the Babylonian Talmud requires tanning before sacred texts are inscribed.[11]

1.2 *Paper*

In the most general way, paper can be described as a thin flat material produced from various plant fibres through a process of depleting water from an aqueous fibre pulp suspension by placing this in a sieve-like mould. The initial stage of paper production – the beating of the raw material into fibres to produce a pulp – has not changed significantly from the time of its invention in the 2nd century BCE in China during the Han dynasty. It has been claimed that paper technology entered the Islamic world after the defeat of the Tang forces in the Battle of Talas against the Abbasid caliphate in 751 CE,

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9 Ira Rabin and Oliver Hahn, 'Characterization of the Dead Sea Scrolls by Advanced Analytical Techniques', *Analytical Methods* 5, no. 18 (2013): 4648–54, https://doi.org/10.1039/c3ay41076e.

10 The scrolls studied here have been already described and studied in Olszowy-Schlanger, 'The Anatomy of Non-Biblical Scrolls from the Cairo Geniza'. However, at the time of this publication, no thourough study of the inks was made, which is one of the aspects we are offering ourselves to do here.

11 Menahem Haran, 'Technological Heritage in the Preparation of Skins for Biblical Texts in Medieval Oriental Jewry', in *Pergament: Geschichte, Struktur, Restaurierung, Herstellung*, ed. Peter Rück, Historische Hilfswissenschaften (Sigmaringen: Jan Thorbecke, 1991), 35; Rabin, 'Building a Bridge', 311–13.

when several Chinese papermakers fell in captivity.[12] It seems, however, that paper was known before this battle as an rare and exceptional imported good.[13] According to Karabacek, the start of paper production in Baghdad can be dated to 795.[14] From the Islamic world, papermaking moved further west and reached Europe, where it has been produced since the 12th century.

The geographical spread of papermaking and technological progress affected the choice of raw materials and the way in which it was treated following the drying of the primary paper sheets, and indeed even the way the drying process itself was carried out. Today, we distinguish between historical Oriental, Islamic, European and industrial paper: it is Islamic paper of the 11th century that interests us in this work. In the first centuries of papermaking, textile rags were used as the raw material. They were pounded into a pulp, which was then placed on a sieve screen, drained of water and dried. In addition to rags, plants like flax could also be used directly. According to Ibn Bādis, whose early medieval treatise was translated and published in the Western world by Levey,[15] in order to produce paper, flax was soaked in quicklime, rubbed and spread in the sun to dry. The resulting fibres were then washed several times to remove the quicklime, pounded into pulp, washed again, shaped into moulds and dried.[16]

To prepare paper for writing, one had to size and polish it in order to suppress the uncontrolled penetration and spread of the ink. Sizing refers to dipping the primary paper into a glue suspension or applying such a suspension to the paper with the help of brushes.[17] According to Bloom,[18] rice starch

12 Peter F. Tschudin, 'Conférence Inaugurale. Le Développement Technique de La Papeterie, de Ses Débuts En Asie à l'Europe de La Renaissance', in *Le Papier Au Moyen-Âge: Histoire et Techniques*, ed. Monique Zerdoun Bat-Yehuda, vol. 19 (Turnhout: Brepols Publishers, 1999), 9, https://doi.org/10.1484/M.BIB-EB.3.4839; Jonathan M. Bloom, *Paper before Print: The History and Impact of Paper in the Islamic World* (New Haven: Yale University Press, 2001), 42–43.

13 Geneviève Humbert, 'Le Manuscrit Arabe et Ses Papiers', *Revue Des Mondes Musulmans et de La Méditerranée*, no. 99–100 (2002): 58.

14 Joseph von Karabacek, Don Baker, and Suzy Dittmar, *Arab Paper* (London: Archetype Publications Ltd, 2001), 33.

15 Levey, 'Mediaeval Arabic Bookmaking and Its Relation to Early Chemistry and Pharmacology', 39–41.

16 Levey, 10.

17 Colini, 'From Recipes to Material Analysis the Arabic Tradition of Black Inks and Paper Coatings (9th-20th Century)', 15.

18 Jonathan M. Bloom, 'Papermaking: The Historical Diffusion of an Ancient Technique', in *Mobilities of Knowledge*, ed. Heike Jöns, Peter Meusburger, and Michael Heffernan, vol. 10, Knowledge and Space (Cham: Springer International Publishing, 2017), 62, https://doi.org/10.1007/978-3-319-44654-7_3.

was most commonly used for this because wheat starch, besides being difficult to produce, had a bad smell. Burnishers of stone, wood or bone could be used in the polishing process.

In the Cairo Genizah, the earliest example of a document written on paper is T-S 16.181,[19] dated to 933.[20] However, paper seems to have been used commonly in Fusṭāṭ only from the early 11th century.[21] In 1064, Nasir-i Khosrau, wrote that, in Cairo, grocers were giving paper to their clients in which to wrap their groceries,[22] indicating that cheap paper was available at that time.

A study of 21 paper manuscripts from the Cairo Genizah has shown that, based on the state of preservation of the fibres, the paper was produced from secondary raw materials such as rags. Those manuscripts, preserved today in the collection of the library of the Jewish Theological Seminary, were written in the Land of Israel during the 11th and 12th centuries. With the help of microscopy, the researchers found cotton, flax fibres and some wool from the rags.[23] The predominance of cotton fibres is of particular interest since cotton was less common than linen or hemp and grew only in the eastern part of the Islamic empire;[24] one might tentatively suggest that the paper was produced there. Interestingly, no starch was detected on the surface of any of these documents. Another study on paper from the Genizah, conducted by Baker, has confirmed that some paper produced during the second half of the 11th century was not sized with starch; but that other paper was.[25] Baker was unable

19 Olszowy-Schlanger, 'Manuscrits hébreux et judéo-arabes : Paléographie des documents juridiques de Fustat du Xe siècle.', 29.

20 It is quite likely that there are earlier undated documents written on paper.

21 Olszowy-Schlanger, 'Manuscrits hébreux et judéo-arabes : Paléographie des documents juridiques de Fustat du Xe siècle.', 29.

22 Humbert, 'Le Manuscrit Arabe et Ses Papiers', 63; 1003-1088 Nasir-i Khusraw, *Sefer nameh; relation du voyage de Nassiri Khosrau en Syrie, en Palestine, en Égypte, en Arabie et en Perse, pendant les années de l'Hégire 437-444 (1035-1042)*, ed. and trans. Charles Schefer (Paris: Ernest Leroux, 1881), 153, http://archive.org/details/sefernamehrelatio1nasiuoft.

23 Zohar Amar, Azriel Gorski, and Izhar Neumann, 'Raw Materials in the Paper and Textile Industry in Al-Sham during the Middle Ages in Light of an Analysis of Documents from the Cairo Genizah', in *IPH Congress Book*, vol. 15, 2004, 39–44; Zohar Amar, Azriel Gorski, and Izhar Neumann, 'The Paper And Textile Industry In The Land Of Israel And Its Raw Materials In Light Of An Analysis Of The Cairo Genizah Documents', in *From a Sacred Source*, Études Sur Le Judaïsme Médiéval 42 (Leiden: Brill, 2011), 25–42, https://doi.org/10.1163/ej.9789004190580.i-420.11.

24 Amar, Gorski, and Neumann, 'Raw Materials in the Paper and Textile Industry in Al-Sham during the Middle Ages in Light of an Analysis of Documents from the Cairo Genizah'; Bloom, 'Papermaking', 58.

25 Don Baker, 'Arab Paper Making', *The Paper Conservator* 15, no. 1 (1991): 31, https://doi.org/10.1080/03094227.1991.9638394.

to determine the reason for this difference: either the starch on the surface has degraded to the point that it has disappeared, or no starch at all was used to size the paper.

2 Writing Inks

The most common ink used in the Cairo Genizah is black ink – although the category of black ink includes what are now "brown inks", since the current appearance of an ink can result from ageing, degradation and restoration. Black inks in the medieval Islamic world can be divided in four distinguishable categories: inks based on soot or charcoal (carbon), those based on plant material, those based on iron-gall, and mixed inks. The first of these is a fine dispersion of carbon pigments in a water-soluble binding agent; plant inks, said to have been commonly used in the Middle Ages, are made on the basis of tannins contained in tree bark or gallnuts; iron-gall ink is based on the black pigment produced from the reaction between iron(II) and gallic acid, which is found in gallnuts, for example; while mixed inks are writing fluids resulting from the intentional mixing of carbon ink with plant or iron-gall ink.

2.1 *Carbon Ink*

Carbon ink is believed to be the oldest type of black ink.[26] The basic recipe involves soot or pulverised charcoal being mixed with a water-soluble binding medium such as gum arabic (which was used in Egypt) or protein glue (used in China). The resulting paste was pressed into small bars similar to the ones commercially available today as Indian ink. To write with it, the dry ink was mixed with water to produce a suitable fluid, whose viscosity depended on the writing tool to be used. Carbon ink does not penetrate the writing support and resides on its surface so that it can be easily scraped off.[27]

Among the oldest extant recipes of carbon ink, the one recorded by Pliny the Elder in his *Natural History* is the best known;[28] the recipe of Dioscorides from the 1st century BCE, which suggests adding a copper compound to the

26 Alfred Lucas, 'The Inks of Ancient and Modern Egypt', *Analyst* 47, no. 550 (1922): 10; Pierre Tallet, 'Ayn Sukhna and Wadi El-Jarf: Two Newly Discovered Pharaonic Harbours on the Suez Gulf', *British Museum Studies in Ancient Egypt and Sudan* 18 (2012): 147–68; Paul T. Nicholson and Ian Shaw, 'Ancient Egyptian Materials and Technology', 2000, 238.

27 However, we would like to soften this statement by pointing out that in the case of unsized paper the ink will soak through the writing surface.

28 Pliny the Elder, *Naturalis Historia*, vol. XXXV, n.d., sec. 25; Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge (jusqu'à 1600)*, 81–83.

soot, seems to be the earliest indication of inks prepared by mixing carbon pigments and metals.[29] Arabic sources preserved many recipes for carbon inks transmitted in a multitude of treatises from the 10th century on, showing that carbon inks did not lose their importance during the period studied in the present work. The Talmud dedicates many passages to the question of which inks are suitable for writing different types of documents. It is believed that the main ink mentioned in the Talmud refers to a simple carbon type.

Pure carbon inks are easily detected due to their ability to absorb light at long wavelengths. Therefore, they have traditionally been detected using simple near-infrared (NIR) photography, which entered the world of papyrology in the 1930s. Today, Raman spectroscopy is the simplest way to identify this type of ink, since it is sensitive to carbon pigments.

2.2 *Plant Ink and Iron-gall Ink*

Plant ink is a solution of tannins extracted from tree bark or gallnuts.

When iron(II) is added to an extract from tree bark or gallnuts containing gallic acid, a black precipitate is formed upon oxidation in the air. This precipitate, ferrous gallate, forms the black colouring substance of the ink that is traditionally called iron-gall ink. In its generic recipe, then, iron-gall inks are produced via a reaction of the gallic acid in plant ink and soluble iron (i.e., any soluble salt of iron). If so, even an unintentional addition of iron to plant ink would result in a primitive form of iron-gall ink,[30] making the unambiguous distinction between plant and iron-gall inks extremely difficult.

The majority of medieval recipes for iron-gall ink contain gallnuts as the source of gallic acid and vitriol as the source of soluble iron, the main inorganic ingredient of the ink. In medieval Latin manuscripts, vitriol[31] is a mixture of hydrated metallic sulfates, containing manganese, iron, copper, zinc and other metallic sulfates in different proportions depending on the geological source of the vitriol. Though metals other than iron do not participate in

29 Dioscorides Pedanius, *De Materia Medica. Being an Herbal with Many Other Medicinal Materials, Written in Greek in the First Century of the Common Era: A New Indexed Version in Modern English*, trans. Tess Anne Osbaldeston and Robert P. Wood, vol. V (Johannesburg: IBIDIS, 2000), 182–83; Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge* (*jusqu'à 1600*), 80.

30 Robert Fuchs, 'The History of Chemical Reinforcement of Texts in Manuscript: What Should We Do Now?', in *Care and Conservation of Manuscripts 7: Proceedings of the Seventh International Seminar Held at the Royal Library*, ed. Gillian Fellows-Jensen and Peter Springborg, vol. 7 (Care and Conservation of Manuscripts, Copenhagen: Museum Tusculanum Press, 2003), 159–70.

31 Karpenko and Norris, 'Vitriol in the History of Chemistry'.

forming the ferrous gallate, the presence of these satellite impurities allows us to differentiate between different iron-gall inks.

Iron-gall inks naturally contain two phases: the reactants form a soluble phase, which easily penetrates the support; while the product corresponds to the insoluble phase, which resides on the surface. Iron-gall ink is best detected by a combination of NIR reflectography and X-ray fluorescence.

The origin and spread of iron-gall ink has not yet been properly studied. On one hand, a review of extant literary sources places the earliest Arabic recipe in the 10th century[32] and the earliest European recipe in the 12th century.[33] Of note is the manuscript BL Add. 14.644, a Syriac recipe for iron-gall ink, written in both Garshuni (i.e. Arabic written with the Syriac alphabet) and Arabic.[34] That manuscript, stored today in the British Library in London, has been palaeographically dated to the 9th–10th century,[35] and the recipe would appear to be the oldest extant proper recipe for iron-gall, since it mentions all the ingredients needed for its production. On the other hand, analytic results reveal that well-defined iron-gall inks were already in use in the 3rd or 4th century CE.[36]

A predecessor of iron-gall ink, an ink containing tannins and a copper substance whose identity has not yet been completely established, can be found in a recipe for a secret ink, written by Philo of Byzantium in the 3rd century BCE.[37] He says that a text written with tannin on leather is invisible, but becomes visible upon the addition of *chalcanthum*, the copper-based substance. This substance also appears in a number of earlier recipes as well as in the Talmud, albeit in a slightly different spelling. Several mentions of קנקנתום *kankantum* – the Hebrew transcription of *chalcanthum* – are glossed as וידריאול – the Hebrew

32 Raggetti, 'Cum Grano Salis. Some Arabic Ink Recipes in Their Historical and Literary Context'.

33 Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge* (*jusqu'à 1600*).

34 Alain Desreumaux et al., 'Les textes des recettes d'encres en syriaque et en garshuni', in *Manuscripta syriaca : Des sources de première main*, Cahiers d'études syriaques 4 (Paris: Librairie orientaliste Paul Geuthner, 2015), 195–246.

35 Alain Desreumaux, Françoise Briquel-Chatonnet, and André Binggeli, 'Un Cas Très Ancien de Garshouni ? Quelques Réflexions Sur Le Manuscrit BL Add. 14644', in *Loquentes Linguis. Studi Linguistici e Orientali in Onore Di Fabrizio A. Pennacchietti*, ed. Pier Giorgio Borbone, Alessandro Mengozzi, and Mauro Tosco (Wiesbaden: Harrassowitz, 2006), 146–47.

36 Tea Ghigo et al., 'An Attempt at a Systematic Study of Inks from Coptic Manuscripts', *Manuscript Cultures* 11 (2018): 157–64; Aceto et al., 'The Vercelli Gospels Laid Open'.

37 Philo of Byzantium, *Mechanike Syntaxis* (*Μηχανική Σύνταξις*), vol. V, n.d., sec. 77; Yvon Garlan, 'Recherches de Poliorcétique Grecque, Bibliothèque Des Écoles Françaises d'Athènes et de Rome', *Paris: Bibliothèque Des Écoles Françaises d'Athènes et de Rome*, 1974.

transcription of "vitriol" – in the late Middle Ages. Various references are to be found to the substance, among which are the *Kiryat sefer* (City of the book) written by Rabbi Menahem b. Solomon ha-Meiri (Perpignan, around 1306)[38] and the commentary on the Mishnah[39] by Rabbi Ovadiah b. Abraham of Bertinoro[40] (Italy *c*.1445–*c*.1515).

2.3 *Mixed Ink*

This class of ink generally contains a mixture of the previously described pure ink types – carbon ink with the addition of either iron-gall ink or plant ink. Another type of mixed ink contains carbon pigments and compounds of copper or lead of an as yet unknown chemical composition.

A mixed ink of the second type is represented by the recipe of Dioscorides from the 1st century CE. He adds *chalcanthum*, a copper-based substance, to carbon ink to improve its preservation properties.[41]

Mixed inks of the first type are well attested in collections of Arabic recipes. We find several recipes in the medieval treatises written by Ibn Bādis,[42] al-Marrākushī[43] and al-Qalalūsī.[44] In the corpus of Arabic ink recipes written between the 9th and the 19th centuries studied by Colini in her PhD thesis, she estimated the number of mixed ink recipes at about 20% of the total corpus: 6% are carbon inks mixed with plant inks and 14% are carbon inks mixed with iron-gall inks.[45]

Maimonides, who lived during the 12th century, shows his extensive knowledge of the different types of ink in existence at the time, discussing their use as a function of the type of document which needs to be copied.[46] Depending

38 Menahem ben Solomon Meiri, *Kiryat Sefer: on the interpretation of the law, Phylacteries, and the Mezuza* [*Hebrew*], ed. Moshe Hershler (Jerusalem: Vagshel, 1956), 32. Although I was unable to access this work, Judith Olszowy-Schlanger, 'The Making of the Bologna Scroll: Palaeography and Scribal Traditions', in *The Ancient Sefer Torah of Bologna*, ed. Mauro Perani, Studies in Jewish History and Culture 59 (Leiden & Boston: Brill, 2019), 112., refers to the point of interest in this book.

39 Commentary on Mishnah Gittin 2:3 ד.

40 Commonly known as "the Bartenura", in Hebrew עובדיה בן אברהם מברטנורא.

41 Dioscorides Pedanius, *De Materia Medica*, vol. V, secs 182–183; Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge (jusqu'à 1600)*, 80.

42 Levey, 'Mediaeval Arabic Bookmaking and Its Relation to Early Chemistry and Pharmacology'.

43 Chabbouh, 'Two New Sources on the Art of the Mixing Ink'.

44 Chabbouh.

45 Claudia Colini et al., 'The Quest for the Mixed Inks', *Manuscript Cultures* 11 (2018): 41.

46 Between his *Responsa* and his *Mishneh Torah*, he mentions various types of inks, including carbon ink, iron-gall ink, and different types of mixed ink: carbon ink plus tannins, and carbon ink plus vitriol.

on the type of document, the use of one ink or another is defended or forbidden. For example, he advises the use of a carbon ink with the addition of tannins (see more detail in section 2.4) in the case of copying a *Sefer Torah*, *tefillin* or *mezuzot*, in order to obtain a durable ink. On the other hand, he argues against the alleged adhesion properties of a carbon ink to which metallic salts have been added. By mentioning this, he shows that this practice existed at that time.[47]

Analytically, copper added to carbon-based ink was detected in five documents of the Dead Sea Scrolls,[48] which seems to indicate that the ink in those documents is associated with the recipe of Dioscorides. Similar results have been obtained on four documents from the Tebtynis collection, written on papyrus during the 1st–3rd centuries CE.[49] In the Herculaneum papyri, in addition to carbon ink, lead has been detected.[50] Similarly, lead in carbon ink was found in some manuscripts of the Pathyris collection, written in approximately the 2nd–1st century BCE.[51] The enigma of lead in carbon inks is yet to be solved.

2.4 *Inks in the Jewish World*

In this section, we will try to collect the known ink recipes used by Jews and compare them with the analytical results that have been reported in the research literature.

It has become customary to compare the inks used by Jews to the ones prescribed in the Talmud. Though we will also use some of the definitions from the Talmud, we would like to stress the fact that the talmudic discussion is about sacred writings and should not be automatically transferred to everyday life. With that said, we can look more closely at inks used or mentioned by Jews.

Codicological and material studies over the last decade point out the great similarity between the writing materials of Jews and their non-Jewish neighbours.[52] It is interesting to compare, for example, the ink recipes offered

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47 Maimonides, *Mishneh Torah*, 66.

48 Yoram Nir-El and Magen Broshi, 'The Black Ink of the Qumran Scrolls', *Dead Sea Discoveries* 3, no. 2 (1996): 157–67.

49 Christiansen et al., 'Chemical Characterization of Black and Red Inks Inscribed on Ancient Egyptian Papyri'.

50 Brun et al., 'Revealing Metallic Ink in Herculaneum Papyri'.

51 Christiansen et al., 'Chemical Characterization of Black and Red Inks Inscribed on Ancient Egyptian Papyri'.

52 Rabin, Hahn, and Binetti, 'Inks used in medieval Hebrew manuscripts: a typological study'; Malachi Beit-Arié, *Hebrew Codicology. Historical and Comparative Typology of Hebrew Medieval Codices Based on the Documentation of the Extant Dated Manuscripts Using a Quantitative Approach*, ed. Nurit Pasternak and Ilana Goldberg, Preprint Internet

by Maimonides – who lived in 12th-century Egypt – to the ink allegedly used by Rashi[53] – who lived in northern France in the 11th century; we could take these two as representative of ink users in the Sephardic and Ashkenazic worlds, respectively. Maimonides – who could choose from a variety of inks since in 12th-century Egypt carbon, iron-gall, plant and different types of mixed inks are well known – decides on using a specific type of mixed ink, carbon ink with the addition of tannins.[54] His seemingly clear statement is based on the discussion in the Talmud, Mishnah Sotah 2:4,[55] concerning the obligation to erase text that has been written. Since iron-gall ink is difficult to erase, he is against its use. In contrast, the case of Rashi is more difficult to determine because he did not leave an ink recipe. Monique Zerdoun has tried to trace the ink that Rashi was using, based on an analysis of his commentaries on the Talmud.[56] Reading Rashi's commentaries on the tractate Shabbat 23a:5,[57] she concluded that he did not know carbon ink except for what he read in Babylonian geonic responsa,[58] and this would also exclude a large number of the mixed inks presented above. Therefore, she concluded he was using either iron-gall inks or plant inks. From there, using the *Tosafot* on the tractate Gittin 19a:6[59] – which says that adding crushed *kankantum* to the ink turns it black – she suggested that he was probably familiar only with plant inks. Indeed, if adding *kankantum* to what is already an ink changes its colour, then the ink itself must be a plant ink. At present, for as long as there is no autographic evidence from Rashi, we can neither confirm Zerdoun's deductions nor compare them with analytical observations.

It is difficult to assess the differences between the day-to-day life of Jews who belonged to different rabbinic and non-rabbinic communities. As mentioned above, the Talmud, the source for laws regulating the life of a "rabbinic" Jew, comments on inks. Where it does this, it does not give recipes *per se*, but rather conversations between rabbis and suggestions, which are then later

English version 0.2 (Israel Academy of Sciences and Humanities, 2018), https://web.nli.org.il/sites/NLI/English/collections/manuscripts/hebrewcodicology/Documents/Hebrew-Codicology-continuously-updated-online-version-ENG.pdf.

53 Hebrew: רש״י, an acronym for RAbbi SHlomo Itzhaki.

54 Maimonides, *Mishneh Torah*.

55 https://www.sefaria.org/Mishnah_Sotah.2.4?ven=Sefaria_Community_Translation&lang=bi.

56 Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge* (*jusqu'à 1600*), 103, 117–19.

57 https://www.sefaria.org/Rashi_on_Shabbat.23a.5.1?lang=en&with=all&lang2=en.

58 Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge* (*jusqu'à 1600*), 117. quoting Rashi's commentaries on Talmud Bavli Shabbat 23a:6.

59 https://www.sefaria.org/Tosafot_on_Gittin.19a.6.2?lang=bi&with=all&lang2=en.

commented on by Jewish scholars. In the previous example, we saw that while Rashi did not use carbon ink in his everyday life, he knew about it through the study of a Jewish text. On the other hand, in Talmud Bavli Eruvin 13a:8–12, we find a story about Rabbi Meïr, a student of Rabbi Akiva, who speaks of how additives to inks affect their properties: we learn that Rabbi Meïr knew that by adding a particular substance, *kankantum*, he could improve the adherence of the ink. From this story, we deduce that Rabbi Meïr was preparing his ink himself, and that it was a mixed ink that contained carbon and a metallic salt.[60]

When it comes to analytical observations made on Hebrew documents, very little has been done thus far. Analyses made on the Dead Sea Scrolls,[61] mentioned in section II.2.3 about mixed inks, have shown the use of both carbon ink and a single type of mixed ink.[62] In contrast, most analyses conducted on Hebrew codices have shown that iron-gall inks were used in many codices, both European and Oriental: for example, in the Oppenheimer Siddur, an illuminated 15th-century Askenazic book;[63] in Codex Hebraicus 205, written on parchment in 14th–15th century Spain; in Codex Levy 148, a 17th century book from Kurdistan; in Codex Levy 102, written on paper during the 17th century in Yemen;[64] in the giant Erfurt Bible;[65] and in Codex Hebraicus 18 and Codex Hebraicus 53,[66] both written on parchment by the same scribe during the 15th century. A summary of these documents is given in Table 2.1.

60 It is necessary to remind the reader that the word *kankantum* changed its meaning from copper sulfate to iron sulfate at some point in the early Middle Ages.

61 This information is based on only a small number of the Dead Sea Scrolls that have been studied using the XRF method to detect metals.

62 Nir-El and Broshi, 'The Black Ink of the Qumran Scrolls'.

63 Suzanne Wijsman et al., 'Uncovering the Oppenheimer Siddur: Using Scientific Analysis to Reveal the Production Process of a Medieval Illuminated Hebrew Manuscript', *Heritage Science* 6, no. 1 (2018): 1–15, https://doi.org/10.1186/s40494-018-0179-0.

64 Rabin, Hahn, and Binetti, 'Inks used in medieval Hebrew manuscripts: a typological study'.

65 Oliver Hahn et al., 'The Erfurt Hebrew Giant Bible and the Experimental XRF Analysis of Ink and Plummet Composition', *Gazette Du Livre Médiéval* 51, no. 1 (2007): 16–29, https://doi.org/10.3406/galim.2007.1754.

66 Gottfried Reeg, 'Codex Hebraicus 18 and Codex Hebraicus 53 in the Hamburg State and University Library – "Corrected by Yiṣḥaq of Arles"', in *Jewish Manuscript Cultures: New Perspectives*, ed. Irina Wandrey, Studies in Manuscript Cultures 13 (Berlin & Boston: Walter de Gruyter, 2017), 363–420, https://doi.org/10.1515/9783110546422-015.

TABLE 2.1 Summary of the analytical observations conducted on Hebrew documents

Document	**Date**	**Support**	**Place**	**Type of ink**
Dead Sea Scrolls	3rd century BCE–1st century CE	Light parchment, brown parchment and leather	Found in the Judean desert	Carbon ink; carbon ink + Cu
Prato Haggadah (MS 9478)	1300	Parchment	Spain	Iron-gall ink for the text; carbon ink for illumination
Erfurt Bible	14th century	Parchment	German Ashkenazic	Iron-gall ink
Codex Hebraicus 205	14th–15th century	Parchment	Spain	Iron-gall ink
Codex Hebraicus 53	1410	Parchment	Italy, Perugia	Iron-gall ink
Codex Hebraicus 18	1416	Parchment	Italy	Iron-gall ink
Oppenheimer Siddur	1471	Parchment	Askenazic, Rhine region	Iron-gall ink
Codex Levy 148	17th century	Paper	Kurdistan	Iron-gall ink
Codex Levy 102	17th century	Paper	Yemen	Iron-gall ink

Finally, it is important to reiterate that, strictly speaking, the religious limitations in the use of inks relates only to sacred manuscripts. Therefore, no correlations should be made between the talmudic prescription and the use of inks in the medieval codices. We plan a detailed study of religious Hebrew documents that will hopefully reveal whether such a correspondence exists within those specific documents.

2.5 *Inks in the Cairo Genizah*

While black writing ink is undoubtedly the most common type of ink used in the Cairo Genizah (though it may now be brown following deterioration), it is worth mentioning that coloured inks were also in use. Red inks seem to have been the most common non-black ink in the Genizah, and were used for a number of different purposes: to write a document (e.g. T-S K5.85, Or.1080 1.63, T-S NS 159.183 and T-S 16.73); to decorate a document (e.g. T-S K6.163); or as vocalisation enhancement (e.g. T-S Ar.42.1, T-S AS 107.66 and T-S AS 155.65). Other colours have also been used in different documents for writing, illuminations, vocalisations and contouring: for example, green (e.g. T-S K5.2 and T-S 16.113), gold (e.g. T-S K5.13 and T-S 16.107), blue (e.g. T-S 16.106) and purple (e.g. T-S AS 162.57). In this study, however, only documents written in black ink were investigated.

Using examples found in the Cairo Genizah, Goitein claims that ink was usually not prepared by the scribe but by a specialist.[67] To substantiate his claim, he used manuscript T-S 13J10.5, where a scribe from Sahrajt, in Egypt, asks someone in Cairo to fill an empty inkwell with a good quality ink because the one he bought before, also in Cairo, was of no use. Goitein notes as well that in manuscript T-S 8.86, a scribe writes to his father that, since the ink he was using was not good, it was necessary to prepare a new batch or to buy fresh ink.[68] Based on this document, it would seem that there were two options: preparing the ink oneself or buying it from an ink manufacturer.

Five recipes for black inks have been found in the Genizah so far;[69] these are given in Table 2.2. Two of the manuscripts containing these recipes are stored in the CUL, while the remaining recipes have been graciously shared with me by Ashur.[70] None of these manuscripts is dated, and only two of them – ENA 3370.4 and ENA 3381.4 – are written in Judeo-Arabic, while the remaining manuscripts are written in Arabic.

TABLE 2.2 Manuscripts containing ink recipes that have been found in the Genizah, together with their description

Classmark	**Support**	**Language**	**Ingredients**[a]	**Ink type**
ENA 3381.4	Paper	Judeo-Arabic		
ENA 3370.4	Paper	Judeo-Arabic	Gum arabic, vitriol	Iron-gall ink
ENA 3960.5	Paper	Arabic	Vinegar, vitriol, honey	Iron-gall ink
T-S Ar.40.64	Paper	Arabic	Gallnuts, gum arabic, wine of Tabas	Plant ink
T-S Ar.39.199	Paper	Arabic	Gum arabic, mulberry tree, vitriol	Iron-gall ink

a Identification of the elements for all these recipes has been made by Wissem Gueddich.

67 Goitein, *A Mediterranean Society: The Community*, 233–34.

68 Goitein, 574.

69 Ink recipes for colours other than black have also been found in the Genizah. For example, Mosseri I.122.1 (formely called Med 15) gives a recipe for red ink or golden ink, and there is a similar recipe in T-S Ar.39.199. In ENA 3960.5, the preparation of other coloured inks is described: blue, red, green, argent and golden inks.

70 I am grateful to Amir Ashur for bringing these manuscripts to my attention and to Wissem Gueddich for translating them to me.

2.6 *Limits of Material Analysis*

As was explained very clearly by Colini in her PhD thesis, the role of ink recipes has not yet been sufficiently studied,[71] although recently a number of different studies have been conducted to examine how accurate medieval recipes are.[72]

The role of the recipe needs to be clarified in every case since it is most probably not constant but rather dependent on the document to be written with the ink. However, it is important to stress that ink formulations are usually not very different from one another; or at least, they are sufficiently similar to mask any chance of correlating between a formulation and a recipe. For us, then, the main possible way of differentiating between specific iron-gall inks is to record and compare their fingerprints – not looking for markers of a specific recipe but rather for markers of a specific vitriol, that is, markers of a specific source of metallic sulfates. The specific vitriol is, incidentally, only rarely mentioned in the ink recipes. Using only non-invasive protocols, it is practically impossible to attribute the ink under investigation to a specific formulation of a recipe, and any declaration to the contrary is, in our opinion, false. Thus in Table 2.3 below, which gives examples of the extant recipes and the corresponding analytical results, we refer only to the ink types.

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71 Colini, 'From Recipes to Material Analysis the Arabic Tradition of Black Inks and Paper Coatings (9th-20th Century)', 132–37.

72 Rafael Javier Díaz Hidalgo et al., 'New Insights into Iron-Gall Inks through the Use of Historically Accurate Reconstructions', *Heritage Science* 6, no. 63 (2018): 1–15, https://doi.org/10.1186/s40494-018-0228-8; Colini, 'From Recipes to Material Analysis the Arabic Tradition of Black Inks and Paper Coatings (9th-20th Century)'; Fani, 'Le arti del libro secondo le fonti arabe originali. I ricettari arabi per la fabbricazione degli inchiostri (sec. IX-XIII)'; Martin Levey, 'Some Black Inks in Early Mediaeval Jewish Literature', *Chymia* 9 (1964): 27–31; Abarrou, *L'art du livre et sa fabrication au XI^{e} siècle*; Alkin Lewis, 'The Lachish Letters and the Use of Iron Inks in Antiquity', *Nature* 139 (1937): 470–470; Lucas, 'The Inks of Ancient and Modern Egypt'; Schopen, *Tinten und Tuschen des arabisch-islamischen Mittelalters*; Zekrgoo, 'Methods of Creating, Testing and Identifying Traditional Black Persian Inks'; Raggetti, 'Cum Grano Salis. Some Arabic Ink Recipes in Their Historical and Literary Context'; Michaelle Biddle, 'Inks in the Islamic Manuscripts of Northern Nigeria: Old Recipes, Modern Analysis and Medicine', *Journal of Islamic Manuscripts* 2, no. 1 (2011): 1–35, https://doi.org/10.1163/187846411X566869.

TABLE 2.3 Examples of extant recipes and the corresponding analytical results

	Literary sources – Recipes			**Analytically confirmed**		
Carbon ink	Pliny	1st century	Roman empire[a]		Antiquity	
	Vitruvius	1st century BCE	Roman empire[b]			
	Ibn Bādis	1025	Morocco[c]		7th–12th century	Middle East
	Maimonides	12th century	Egypt[d]			
Iron-gall ink	Papyrus V of Leyden	3rd century	Greek[e]	MS Berol. Orient. Oct. 987	3rd–4th century	Egypt (Coptic)[f]
	BL Add. 14.644	9th century	Syriac[g]	Vercelli Gospels	4th century	Northern Italy[h]
	Al-Razi	925–935	Iran	Island codices	9th century	Ireland–UK[i]
	Ibn Bādis	1025	Morocco			
	Theophilus[j]	12th century CE	Germany[k]			

a Pliny the Elder, *Naturalis Historia*, vol. XXXV, sec. 25; Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge (jusqu'à 1600)*, 81–83.

b Vitruvius, *De Architectura*, vol. VII, n.d., sec. 10.

c Levey, 'Mediaeval Arabic Bookmaking and Its Relation to Early Chemistry and Pharmacology'.

d Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge (jusqu'à 1600)*, 124–126; Schopen, *Tinten und Tuschen des arabisch-islamischen Mittelalters*, 141–144.

e An edition of this text is apparently available in Karl Preisendanz, *Papyri Graecae Magicae. Die Griechischen Zauberpapyri, Herausgegeben Und Übersetzt von Karl Preisendanz. V. 2* (Berlin: Teubner, 1931), 83. Unfortunately, however, I was unable to access this work, and rely on Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge (jusqu'à 1600)*, 94.

f Ghigo et al., 'An Attempt at a Systematic Study of Inks from Coptic Manuscripts'.

g Desreumaux et al., 'Les textes des recettes d'encres en syriaque et en garshuni'.

h Aceto et al., 'The Vercelli Gospels Laid Open'.

i Susan Bioletti et al., 'The Examination of the Book of Kells Using Micro-Raman Spectroscopy', *Journal of Raman Spectroscopy* 40, no. 8 (2009): 1043–49, https://doi.org/10.1002/jrs.2231; Lucia Burgio, Susan Bioletti, and Bernard Mehan, 'Non-Destructive, in Situ Analysis of Three Early Medieval Manuscripts from Trinity College Library Dublin (Codex Usserianus Primus, Book of Durrow, Book of Armagh)', in *Making Histories: Proceedings of the Sixth International Conference on Insular Art, York 2011*, ed. Jane Hawkes (Making Histories: Sixth International Conference on Insular Art, York, 2013), 42–49; Katherine L. Brown and Robin J. H. Clark, 'The Lindisfarne Gospels and Two Other 8th Century Anglo-Saxon/Insular Manuscripts: Pigment Identification by Raman Microscopy', *Journal of Raman Spectroscopy* 35, no. 1 (2004): 4–12, https://doi.org/10.1002/jrs.1110.

j Although according to Zerdoun, Theophilus' recipe is an iron-gall ink, in our interpretation this is a plant ink as the primary product is only a plant ink: the addition of atramentum or of iron is secondary. Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge (jusqu'à 1600)*, 153–65.

k Presbiter Theophilus, *De Diversis Artibus.*, vol. I, n.d., sec. 40.

TABLE 2.3 Examples of extant recipes and the corresponding analytical results (*cont.*)

	Literary sources – Recipes				Analytically confirmed			
Plant ink	Martinus Capella	5th century	Cartages[l]		Stuttgarter Psalter	9th century	Unknown[m]	
	Rashi?	11th century	Northern France, Troyes					
Mixed ink	Dioscorides	1st century	Roman empire[n]	CI + Cu	Dead Sea Scrolls	1st century	Found in the Judean desert[o]	CI + Cu
	Rabbi Meïr	1st–2nd century	Land of Israel[p]	CI + copper-based substance	Tebtynis collection	1st–3rd century	Found in Egypt, Fayyum[q]	CI + Cu
	Maimonides	12th century	Egypt[r]	CI + tannins	Herculaneum papyri	3rd century BCE–1st century CE	Found in Italy, Herculaneum[s]	CI + Pb
	Ibn Bādis	1025	Morocco	CI + iron-gall ink				
Other	Philo of Byzantium	3rd century BCE	Greece[t]	invisible ink, probably a predecessor of iron-gall ink	Bilingual papyri stored in the Louvre collection	3rd–2nd century BCE	[u]	

Note: CI refers to a carbon ink.

l Martianus Capellae, *De Nuptiis Philologiae et Mercurii*, vol. III, n.d., sec. 225, https://ia802708.us.archive.org/1/items/denuptiisphilolo00martuoft/denuptiisphilolo00martuoft.pdf.

m Oliver Hahn, 'Die Farben und Tinten im Stuttgarter Psalter-Naturwissenschaftliche Untersuchungen', in *Kupfergrün, Zinnober & Co. – Der Stuttgarter Psalter*, ed. Vera Trost, Andrea Pataki-Hundt, and Enke Huhsmann (Stuttgart: Württembergische Landesbibliothek, 2011), 111–21.

n Dioscorides Pedanius, *De Materia Medica*, vol. V, secs 182–183; Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge (jusqu'à 1600)*, 80.

o Nir-El and Broshi, 'The Black Ink of the Qumran Scrolls'; Solomon H. Steckoll, 'Investigations of the Inks Used in Writing the Dead Sea Scrolls', *Nature* 220, no. 5162 (October 1968): 91–92, https://doi.org/10.1038/220091b0.

p Talmud Bavli, Eruv in 13a:8-12; Zerdoun Bat-Yehuda, *Les Encres Noires au Moyen-Âge (jusqu'à 1600)*, 105–7.

q Christiansen et al., 'Chemical Characterization of Black and Red Inks Inscribed on Ancient Egyptian Papyri'.

r Maimonides, *Mishneh Torah*.

s Brun et al., 'Revealing Metallic Ink in Herculaneum Papyri'.

t Philo of Byzantium, *Mechanike Syntaxis* (*Μηχανική Σύνταξις*), vol. V, sec. 77; Garlan, 'Recherches de Poliorcétique Grecque, Bibliothèque Des Écoles Françaises d'Athènes et de Rome', 324.

u Elisabeth Delange et al., 'Apparition de l'encre métallogallique en Égypte à partir de la collection de papyrus du Louvre', *Revue d'Égyptologie* 41 (1990): 213–17.

CHAPTER 3

Experimental Methods

There are a number of methods available today that can be used for analysing inks; all have previously been used in studies of black writing inks.[1]

1 Experimental Protocol

The BAM (Bundesanstalt für Materialforschung und -prüfung) and the CSMC (Centre for the Study of Manuscript Cultures) in Hamburg are working towards setting up a standard procedure for the study of writing materials and, more specifically, of inks. The procedure features portable or transportable instruments that use non-contact techniques, so that analysis can be carried out *in situ*, that is, directly in archives and libraries. I used the following protocol for characterisation of the writing materials in this work:

- General observations of the writing support and its state of preservation;
- Ink typology using near-infrared (NIR) reflectography;
- Elemental ink composition by micro X-ray fluorescence (micro-XRF).

Reflectography and XRF spectrometry have the advantage of providing a non-destructive analysis, at least on the macro level, thus preserving the manuscript.

As described in the Introduction, section 1.3, the manuscripts of the CUL are kept in Melinex protective mounts. To test whether Melinex would influence the results of the analytic study, I conducted tests using mock-up samples

1 Easton and Noel, 'Infinite Possibilities'; Aceto et al., 'The Vercelli Gospels Laid Open'; Gambaro et al., 'Study of 19th Century Inks from Archives in the Palazzo Ducale (Venice, Italy) Using Various Analytical Techniques'; Hahn, 'Charakterisierung historischer Eisengallustinten mittels mikro-RFA und mikro-XANES'; Brun et al., 'Revealing Metallic Ink in Herculaneum Papyri'; Nastova et al., 'Spectroscopic Analysis of Pigments and Inks in Manuscripts'; Nosnitsin et al., 'A" Study Manuscript" from Qäqäma (Tagray, Ethiopia)'; Tanevska et al., 'Spectroscopic Analysis of Pigments and Inks in Manuscripts'; Christiansen et al., 'Chemical Characterization of Black and Red Inks Inscribed on Ancient Egyptian Papyri'; Hamdan, Alawadhi, and Jisrawi, 'Integration of μ-XRF, and u-Raman Techniques to Study Ancient Islamic Manuscripts'; Bicchieri et al., 'Non-Destructive Spectroscopic Investigation on Historic Yemenite Scriptorial Fragments'; Zekrgoo, 'Methods of Creating, Testing and Identifying Traditional Black Persian Inks'; Adami et al., 'Micro-XRF and FT-IR/ATR Analyses of an Optically Degraded Ancient Document of the Trieste (Italy) Cadastral System (1893)'; Goler et al., 'Characterizing the Age of Ancient Egyptian Manuscripts through Micro-Raman Spectroscopy'; Mocella et al., 'Revealing Letters in Rolled Herculaneum Papyri by X-Ray Phase-Contrast Imaging'.

of iron-gall ink,[2] with and without a Melinex cover – the Melinex cover samples used in my tests were kindly provided by the conservation department of the CUL.[3]

1.1 *Preparation of the Manuscripts*

During the 20th century, most of the manuscripts from the Genizah collection of the CUL were mounted in books and bound volumes with other manuscripts of a similar size. To protect the manuscripts, the folios were encapsulated in Melinex covers.[4] Several religious documents, mostly scrolls, have been treated somewhat differently, placed in a ring binder together with other manuscripts on similar subjects or from the same time; however these documents were also mostly covered with a Melinex protection.

The manuscripts that form the corpus are mostly single leaves or bifolios. During NIR reflectography analysis, the manuscripts were protected by their Melinex covers (however the Melinex was removed during XRF analysis, see section 1.3.1). The Melinex prevented direct contact between the instrument and the folio under investigation and, thus, limited the exposure of the manuscript to physical stress. Where possible, the same spot was chosen for both reflectography and XRF analyses. The planning of the individual ink tests – i.e. for XRF analysis but as well for NIR as we tried to measure the same spot in both cases – required multiple factors to be taken into consideration:

- There should be no ink on the back side of the page where the ink was tested, to avoid detecting that ink by the XRF.
- The location where the ink was tested should not be in the margins, since margins are usually rather dirty.
- To obtain characteristic results, at least three measurements on each ink and the support were requested.

When the manuscript was kept in a ring binder, the fragment could be removed from the layer of protection, meaning the Melinex, and placed on a cardboard frame with a small hole, allowing investigation without contamination. When the fragment was not flat, small ceramics weights without sharp edges, designed for this purpose, were placed on the fragment to render the surface more suitable for analysis. For those fragments bound into a single volume, we used our handling protocol for the analysis of codices; that is, we positioned the volume on foam pillows and isolated the page for the study using specially developed spacers.

2 The samples of ink used are similar to the ones used in Cohen et al., 'Composition of the Primary Inks in Medieval Palimpsests: Effects of Ink Removal'.

3 I would like to take this opportunity to thank Rebecca Goldie for her work and for providing me with the samples of Melinex for these experiments.

4 Jefferson, 'The Historical Significance of the Cambridge Genizah Inventory Project'.

It must be stressed that some of the manuscripts of the corpus contained different marginalia and other additions, so that the timeline of the writing of the document was sometimes difficult to determine. Furthermore, during even in the first analyses undertaken of legal documents using reflectography, I encountered both carbon and iron-gall inks in a single document, used to write and sign the documents. Consequently, to check for the heterogeneous use of inks of different types and compositions within one and the same manuscript, I divided each manuscript into different regions of interest: main text, address, marginalia, signatures and addition.

1.2 *Near-infrared Reflectography*

Reflectography[5] is a technique largely used when studying underdrawing of paintings, but has been adapted for the determination of ink types.[6] This method is based on the optical properties of different materials with respect to light absorption. Carbon ink absorbs light through the whole light spectrum, from visible to near-infrared, whereas iron-gall ink loses its opacity under NIR light between 750 to 1000 nm, and becomes transparent around 1400 nm.[7] Plant ink, on the other hand, becomes transparent by around 750 nm.[8]

In this work, I used a portable microscope (Dino-Lite AD4113T-I2V USB) with illumination in the ultraviolet (UV, 390 nm), visible (VIS), and near-infrared (NIR, 940 nm) regions of the electromagnetic spectrum and magnifications of 50x to 200x.

Figure 3.2 summarises the reflectography tests conducted on ink with and without Melinex. We see that the protective cover affects the reflectographic tests for neither carbon nor iron-gall ink. The former remains black under both illuminations, whereas iron-gall ink loses its opacity under NIR light. Therefore, I performed the tests for the ink typology directly through the Melinex cover.

While working on the analysis of the writing material of the Dead Sea Scrolls, Reed developed a simple method of testing whether skin-based

5 Although the word reflectography originally referred specifically to a vidicon technology with a central wavelength of 2microns, the term is now used in a broader way. to speak of “Any of various techniques for producing an image or graphical representation based on properties of reflection; specifically a technique for revealing hidden drawing lines beneath paintings using infrared scanning”. ‘Definition of Reflectography’, in *Oxford University Press*, 2020, https://www.lexico.com/definition/reflectography.

6 Mrusek, Fuchs, and Oltrogge, ‘Spektrale Fenster zur Vergangenheit: Ein neues Reflektographieverfahren zur Untersuchung von Buchmalerei und historischem Schriftgut’.

7 In Mrusek, Fuchs, and Oltrogge. article, it is claimed that iron-gall ink becomes transparent at 1200 nm. However, some recent tests made using a IR camera have shown that iron-gall ink disappears at 1400 nm.

8 Rabin, Hahn, and Binetti, ‘Inks used in medieval Hebrew manuscripts: a typological study’; Rabin and Binetti, ‘NIR Reflectography Reveals Ink Type’.

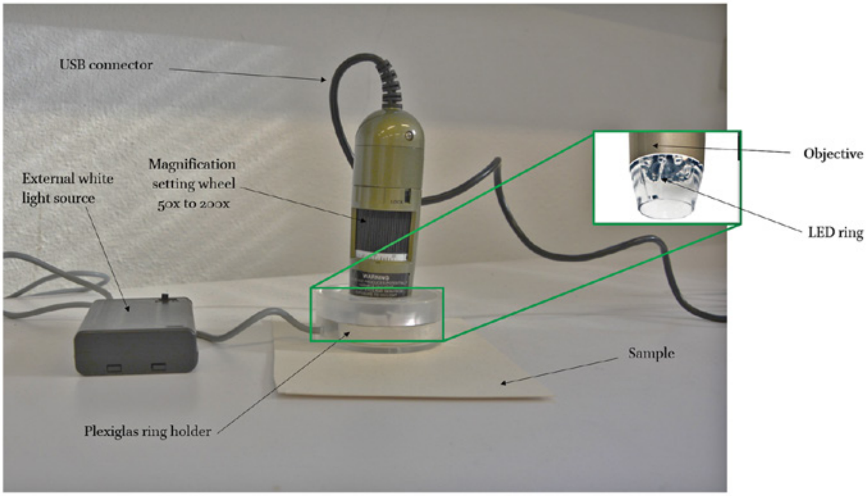


FIGURE 3.1 Dino-Lite setup

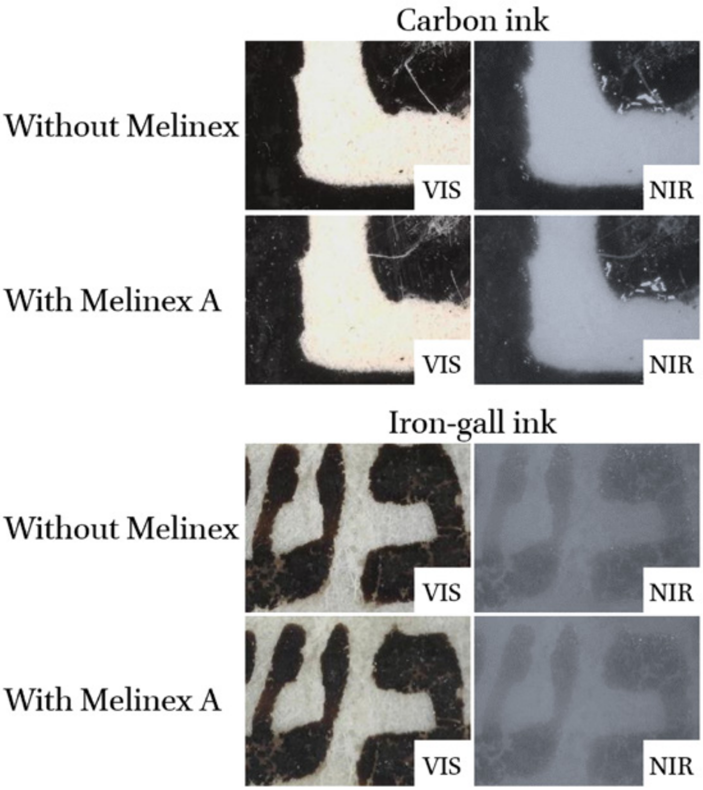
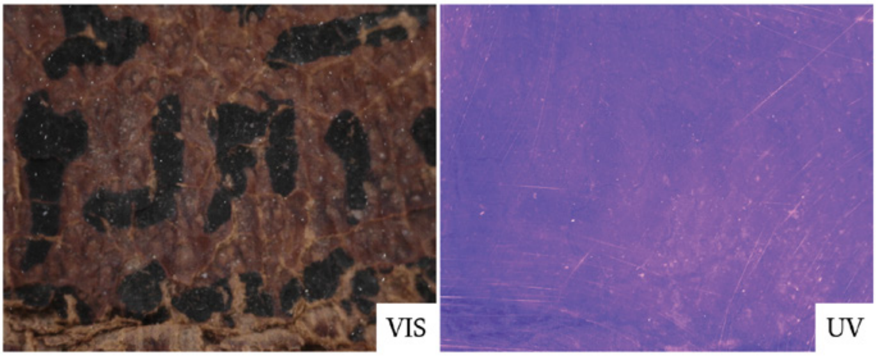


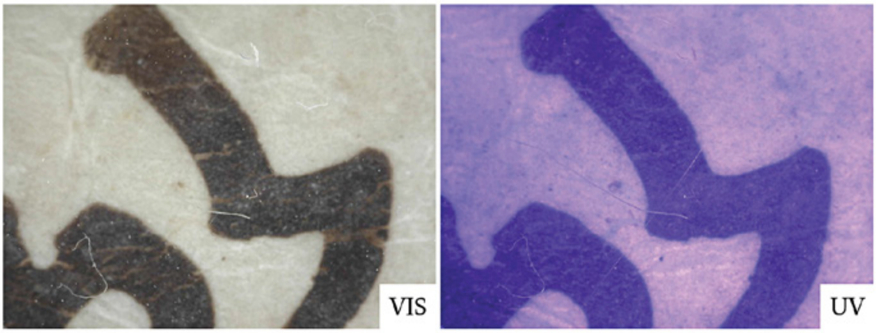
FIGURE 3.2 Pictures of carbon and iron-gall ink samples with and without Melinex, in visible and near-infrared light

material used in the scrolls (in particular, parchment) was tanned.[9] This method is based on the property of tannins to quench the UV-induced fluorescence of parchment. If no fluorescence is detected upon illuminating a parchment with UV light, the skin must have been tanned. In fact, this property of the tannins is best observed when iron-gall or plant inks on parchment are illuminated with UV light. If the contrast is enhanced and the degradation pattern of the iron-gall ink almost disappears, one can be sure that the writing support was not tanned. In contrast, iron-gall inks are difficult to see under UV light if they are inscribed on leather or tanned parchment.

We adopted Reed's method and double-checked it by routinely examining the parchment surfaces and the inks under UV light. Figure 3.3 illustrates these



3.3a Leather



3.3b Parchment

FIGURE 3.3 Pictures of a) leather (manuscript T-S Misc. 26.53.17) and b) parchment (manuscript T-S 10J2.2); each is presented in visible and in UV light, both inscribed with iron-gall ink

9 Reed, *Ancient Skins, Parchments and Leathers*, 252–64; Ronald Reed, 'The Examination of Ancient Skin Writing Materials in Ultra-Violet Light', in *Proceedings of the Leeds Philosophical and Literary Society: Scientific Section*, vol. 9, 10 (Leeds Philosophical and Literary Society, Leeds, 1965), 257–76.

effects with a leather and a parchment manuscripts, both inscribed with iron-gall ink. On the manuscript T-S Misc. 26.53.17 written on leather (Figure 3.3a) ink and leather contain tannin and, therefore, the text is invisible; while in the second manuscript T-S 10J2.2 (Figure 3.3b), the enhanced contrast between the text and the parchment results from the fact that the tannins are localized only in the ink. Since we found that in the corpus under study only the leather was tanned, we did not include these findings in the results.

1.3 *Elemental Analysis*

X-Ray fluorescence (XRF) spectroscopy is a non-invasive, non-contact and non-destructive method for the characterisation of inorganic materials. XRF spectroscopy is a technique often used in cultural heritage to analyse the elemental composition of metals, ceramics,[10] paintings,[11] drawings and manuscripts.[12]

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10 D. N. Papadopoulou et al., 'Development and Optimisation of a Portable Micro-XRF Method for In Situ Multi-Element Analysis of Ancient Ceramics', *Talanta* 68, no. 5 (2006): 1692–99, https://doi.org/10.1016/j.talanta.2005.08.051; Harry Bennett and Graham J. Oliver, *XRF Analysis of Ceramics, Minerals, and Allied Materials* (Chichester & New York: Wiley, 1992); Alice M. W. Hunt and Robert J. Speakman, 'Portable XRF Analysis of Archaeological Sediments and Ceramics', *Journal of Archaeological Science* 53 (2015): 626–38, https://doi.org/10.1016/j.jas.2014.11.031.

11 Anabelle Križnar et al., 'Portable XRF Study of Pigments Applied in Juan Hispalense's 15th Century Panel Painting', *X-Ray Spectrometry* 40, no. 2 (2011): 96–100, https://doi.org/10.1002/xrs.1314; Z. Szökefalvi-Nagy et al., 'Non-Destructive XRF Analysis of Paintings', *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, Radiation and Archaeometry, 226, no. 1 (2004): 53–59, https://doi.org/10.1016/j.nimb.2004.03.074; Francesca Rosi et al., 'A Non-Invasive XRF Study Supported by Multivariate Statistical Analysis and Reflectance FTIR to Assess the Composition of Modern Painting Materials', *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 71, no. 5 (2009): 1655–62, https://doi.org/10.1016/j.saa.2008.06.011.

12 Hamdan, Alawadhi, and Jisrawi, 'Integration of µ-XRF, and u-Raman Techniques to Study Ancient Islamic Manuscripts'; Oliver Hahn, 'Analyses of Iron Gall and Carbon Inks by Means of X-Ray Fluorescence Analysis: A Non-Destructive Approach in the Field of Archaeometry and Conservation Science', *Restaurator*, International Journal for the Preservation of Library and Archival Material, 31, no. 1 (2010): 41–64, https://doi.org/10.1515/rest.2010.003; Hahn et al., 'The Erfurt Hebrew Giant Bible'; R. Cambria et al., 'A Methodological Test of External Beam PIXE Analysis on Inks of Ancient Manuscripts', *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* 75, no. 1–4 (1993): 488–92, https://doi.org/10.1016/0168-583X(93)95702-7; Miloš Budnar et al., 'Analysis of Iron Gall Inks by PIXE', *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* 243, no. 2 (2006): 407–16, https://doi.org/10.1016/j.nimb.2005.10.013; Lorzenzo Giuntini et al., 'Galileo's Writings: Chronology by PIXE', *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* 95, no. 3 (1995): 389–92, https://

Through a primary X-ray beam, core electrons of an atom are expelled. The atom is, therefore, excited and unstable. In order to return to a stable state, this vacancy must be filled by another electron from an outer shell. A secondary X-ray is emitted to fill it, and the difference in energy used to fill the vacancy is characteristic of the element analysed. The intensity of the signal is related to the amount of the element contained in the analysed object.

In a conventional hand-held XRF spectrometer no detection of elements with an atomic number (Z) of less than 13 is possible because their weak X-rays are absorbed by air, although the use of a vacuum chamber or helium gas increases the detection range, down to sodium (Na, Z = 11). This explains why only inorganic material can be detected with XRF. No detection of organic elements can be done with this technique; this includes carbon (C, Z = 6), which is too light to be detected by these methods.[13]

As well as XRF, there are a number of other techniques based on characteristic X-ray emissions, such as particle-induced X-ray emission (PIXE) and energy-dispersive X-ray spectroscopy (EDX). In the former, excitation is achieved by energetic particles (e.g. protons) whereas the latter uses electrons as the primary beam. The different X-ray emission techniques present different advantages and limitations when it comes to their mobility, the need for specific facilities, the detection of lighter elements, information depth, and so on. PIXE would have been able to better characterise lighter elements than XRF in the present study, but it is not a transportable technique and therefore would require transporting the manuscripts out of the library, and EDX, part of an electron microscope, has the same issues. In addition, EDX requires samples to placed into a vacuum chamber, contradicting the principle of non-invasive studies for we are aiming.

Thus, after considering the advantages and disadvantages of the various techniques, we decided to use XRF.

During this work, I had four XRF spectrometers at my disposal: Elio XGLab, Tracer SD-III, ArtTAX and JetStream M6 (Bruker Nano GmbH). All four spectrometers have previously been used several times for the characterisation of

doi.org/10.1016/0168-583X(94)00538-9; A.-M.B. Olsson et al., 'Micro-PIXE Analysis of an Ancient Egyptian Papyrus Identification of Pigments Used for the "Book of the Dead"', *Nuclear Instruments and Methods in Physics Research B* 181 (2001): 707–14.

13 However, it is worth mentioning that new μ-XRF spectrometers, such as M4 Tornado developed by Brucker, have increased sensitivity, allowing detection of elements down to carbon (C, Z = 6). In order to obtain this quality of detection, two large silicon detectors are used, together with a vacuum chamber.

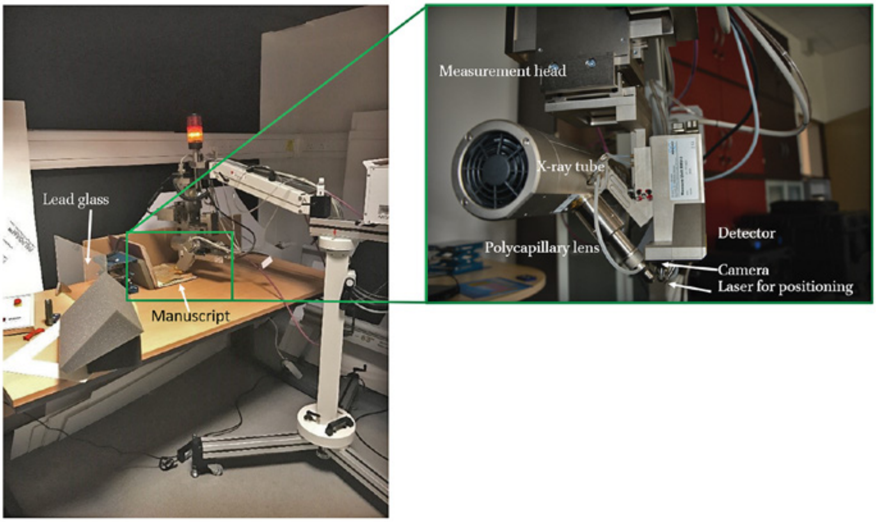

FIGURE 3.4 ArtTAX (Bruker Nano GmbH), during the analysis of manuscript T-S 18J1.9 in the Digital Content Unit of the Cambridge University Library

cultural heritage objects.[14] The choice of the specific device for the analyses depends on a number of factors such as the precision of the result needed, the size of the feature and therefore of the measuring spot of the machine, the time available for a good acquisition and the possibility of being able to transport the machine to the material to be studied.[15]

ArtTAX (Bruker Nano GmbH) was chosen to be used in this study (Figure 3.4). Its microbeam and signal enhancement due to the capillary optics, together with its mobility and the fact that it could be easily hosted by the CUL, made it

14 Ira Rabin, 'Ink Identification to Accompany Digitization of Manuscripts', in *Analysis of Ancient and Medieval Texts and Manuscripts: Digital Approaches*, ed. Tara L Andrews and Caroline Macé (Turnhout: Brepols Publishers, 2014), 301, https://doi.org/10.1484/M.LECTIO-EB.5.102576.

15 A detailed comparison of the results obtained by different XRF spectometers to different samples for which the composition was known can be found in: Grzegorz Nehring, 'Praca teoretyczno-badawcza: Zastosowanie spektroskopii fluorescencji rentgenowskiej w badaniu atramentów żelazowo-galusowych (The use of the X-ray fluorescence spectroscopy in the analysis of iron-gall inks)' (Master Thesis, Torun, Uniwersytet Mikołaja Kopernika/University Nicolaus Copernicus, 2019). The description of the results, although in Polish, is summarised in Figure 46. The results obtained are very similar for Artax and JetStream and very close to the results of the sample composition, especially in the case of copper. The comparative results obtained with Elio shown similar results. They are not published yet but will be the object of a publication in the future. However, the choice of this spectrometer was discarded as the analyses was time consuming and as did not override the inhomogeneity of the ink. Indeed, Elio needs single points analyses, while Artax allows linescans analyses.

the preferable device for the study. ArtTAX consists of an air-cooled low-power X-ray tube, polycapillary X-ray optics, a measuring spot size of 100 μm in diameter, an electro-thermally cooled Xflash detector and a CCD (charge-coupled device) camera for sample positioning.

The analysis was carried out in six sessions, spread between September 2015 and October 2018. During all these sessions, the Digital Content Unit of the Cambridge University Library kindly hosted us.[16] All measurements were made using a 30 W low-power Mo tube, operating at 50 kV and 600 μA, and with acquisition times of 20–40 s (live time). ArtTAX does not have a vacuum chamber but helium atmosphere is routinely used to increase the detection limit.

ArtTAX has an X-Y-Z movable probe that is usually positioned some 5 mm above the object of study. Due to the high inhomogeneity of the ink, it is standard procedure to operate ArtTAX for a line measurement of several points, called a line scan, to obtain a statistically significant distribution of the elements on the spot analysed. Except when specified, all the line scans contained ten-point measurements along a single line of a different length that was decided for each measurement. On a typical manuscript, I used three line scans for an ink and three line scans for the support to obtain a reliable average. An example of the results accumulated from different line scans is presented in Figure 3.5, where six accumulated spectra from six different line scans are shown. One line scan corresponds to the analysis of the support whereas the other five analyses correspond to different ink spots on the same manuscript: the main text and the signatures of Yefet b. David, Ephraim b. Shemarya, Yaacov b. Mevasser and Shmuel ha-Cohen b. Avtalyon. Note the single intensity scale for all the spectra, done to facilitate easy comparison between them. The peaks corresponding to chlorine (Cl) at 2.6 keV are the only ones that display similar intensity on all spectra. Other elements appear in different quantities, as reflected by the different strengths of the corresponding peaks: potassium (K) at 3.3 keV, calcium (Ca) at 3.7 and 4 keV; iron (Fe) at 6.4 keV for $K\alpha$ and 7 keV for $K\beta$.

In order to compare the different inks, one needs to use a model. To eliminate the influence of the thickness of the ink, Oliver Hahn et al. developed a fingerprint model that permits comparison and differentiation of vitriolic iron-gall inks.[17]

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16 I would like to take this opportunity to thank Grant Young and Maciej Pawlikowski, Marc Box, Scott Maloney, Blazej Mikula and Amelie Deblauwe for their kind welcome and their help at each of these sessions.

17 Hahn et al., 'Characterization of Iron-Gall Inks in Historical Manuscripts and Music Compositions Using X-Ray Fluorescence Spectrometry'; Wolfgang Malzer, Oliver Hahn, and Birgit Kanngießer, 'A Fingerprint Model for Inhomogeneous Ink–Paper Layer Systems

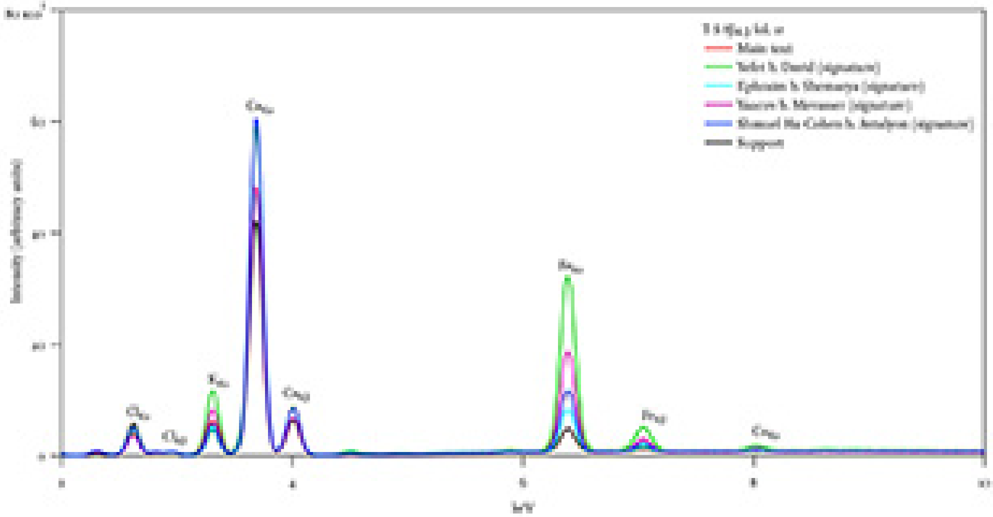

FIGURE 3.5 Accumulated XRF spectra of various points on a single manuscript, T-S 8J4.3 fol. 1r

As discussed in section 2.2.2, iron-gall ink may contain different metallic components other than iron (Fe), such as copper (Cu), zinc (Zn), manganese (Mn) and lead (Pb) in various quantities. Copper, manganese and zinc are present as satellite impurities of iron in the vitriol, the metallic salt used to prepare the ink, while lead often comes as a contaminant in the water. The fingerprint model relies on the identification and on the semi-quantitative comparison of these inorganic components contained in iron-gall inks, when analysed by the XRF analysis. The signal of these metallic components – Cu, Zn, Mn and Pb – contained in the ink is normalised to that of iron, as it is the main component of iron-gall ink. In other words, the model establishes the ratios of those elements compared to iron. Note that although calcium and potassium may be also contained in the ink, we did not consider these in the establishment of the fingerprint as they can come from various sources, and thus the fingerprint has been based only on the comparison of the ratios of the aforementioned elements normalised to iron: copper, manganese, zinc and occasionally lead.

Measured with Micro-x-Ray Fluorescence Analysis', *X-Ray Spectrometry* 33, no. 4 (2004): 229–33, https://doi.org/10.1002/xrs.676.

In order to use the fingerprint model, it is essential to have enough data to subtract the signal components due to the support, given that the during the scan of the inked area, the X-ray detects not only the ink but also the support under it, and the values are therefore contaminated by the ratios of the elements contained in the support. Hence, it is necessary to measure the contribution of the support without ink as well, to subtract it from the data obtained when measuring the ink.

The model accepts a 10% margin of error, experimentally established. However, this model has been developed for documents written on European paper with a homogeneous composition. Unfortunately, heterogeneous distribution of elements such as Ca and Fe is more characteristic for medieval Arabic paper, and this reduces the evaluation of our analyses to a semi-quantitative one.

We would like to stress here that this model cannot be used to attribute a specific ink to a specific recipe, but is rather a tool for comparing between different ink compositions. Indeed, in order to understand this technique and the results it provides, it is crucial to understand the differences between recipes. A change from wine to vinegar or to beer, or soaking the galls in water or vinegar solution for a longer or shorter time, will not be visible in the spectra. Nothing of this will affect the proportion of metallic components in the ink, which is the only output of the XRF analysis and the fingerprint model.

Note that the fingerprint calculation is not possible in the case of carbon ink. As already mentioned, the main component of those inks, carbon (Ca, Z = 6), is too light to be detected by a customary XRF spectrometer. However, some of those inks have nevertheless been analysed, for qualitative purposes, or to compare the intensity profile of the writing surface and the ink in order to detect the addition of metallic elements such as copper, zinc or manganese.

This fingerprint model, used frequently since it was developed, usefully enables us to follow the evolution of ink-making across different times and places.[18]

1.3.1 Testing the Effect of Melinex

To check whether the protective Melinex cover would influence the XRF analysis we analysed the same mock-up samples measured by reflectography with ArtTAX. The outcome is presented in Figure 3.6a and b.

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18 Hahn et al., 'The Erfurt Hebrew Giant Bible and the Experimental XRF Analysis of Ink and Plummet Composition'; Hahn, 'VI Results of Non-Destructive Instrumental Analysis. XRF-, FTIR-Spectroscopy and Microscopy'; Čechák et al., 'Application of X-Ray Fluorescence in Investigations of Bohemian Historical Manuscripts'.

In Figure 3.6a, the accumulated line scans of the ArtTAX measurements without (in black) and with two different types of Melinex (in red for Melinex A and in green for Melinex C) are visible; unfortunately, no measurements were able to be done with Melinex B, as I did not have a sample of this type of Melinex. The difference between these three line scans shows how the Melinex is blocking part of the response. This is especially true for lighter elements, such as sulfur (S), potassium (K) and calcium (Ca), but the concentration of iron (Fe), and to a lesser extent the concentration of copper (Cu) and of zinc (Zn) are also affected by the Melinex. Figure 3.6b presents the calculation of the fingerprints of the three line scans of the mock-up: one for just the ink, one for the ink covered by the Melinex of type A and one for the ink covered by the Melinex of type C. The fingerprint is substantially affected by the presence of Melinex, going from 27% of copper (Cu) and 16% of zinc (Zn) after normalisation to iron, to 40% of copper and 22% of zinc when covered by a Melinex of type A and 36% of copper and 22% of zinc when covered by a Melinex of type C.

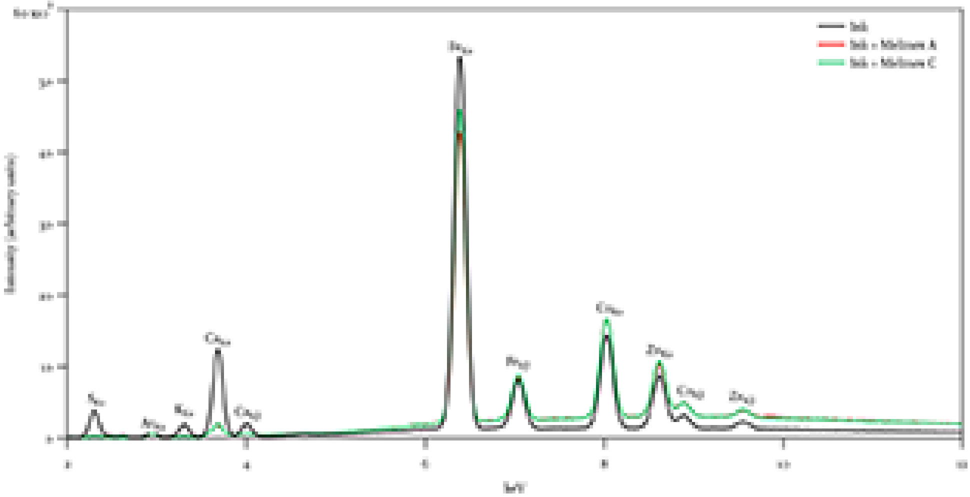
Due to this difference in the results, for each session of the analysis, the conservation department in CUL was kind enough to remove all the manuscripts that we analysed from their Melinex covers.[19]

1.4 *Statistical Analysis: Multinomial Regression Analysis*

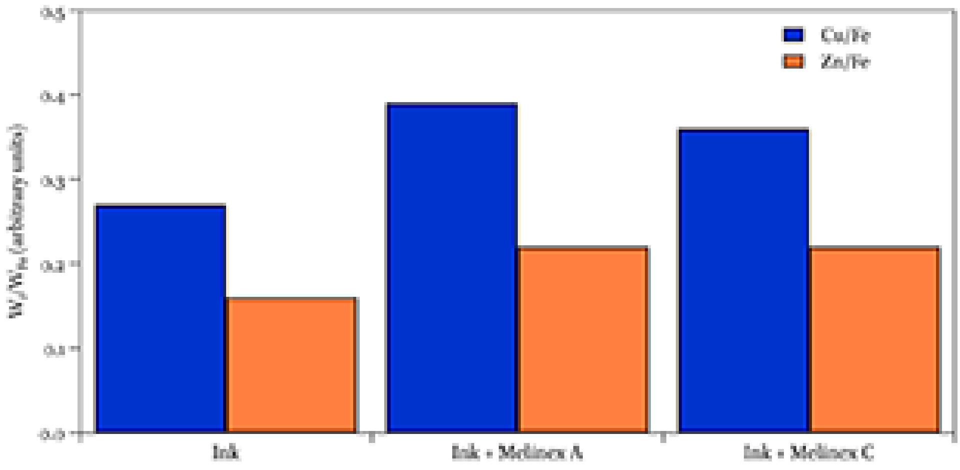
The amount of data gathered for this study was substantial, for both qualitative and semi-quantitative observations. Typically, the protocol applied here is used to compare ink type and composition within the same manuscript, or within the production of one scribe in particular. To enable this, reflectography was performed on the total corpus (i.e. 391 manuscripts) and XRF analysis on 202 manuscripts. To process the experimental data, different types of statistical analysis have been performed on the dataset.

One of the goals was to understand if there were a pattern of use of a writing material. In order to study this, it was necessary to compare the results of the comparison of the observation (i.e. type of writing surface and the results of reflectography analyses) to the descriptive data of the manuscripts, in order to identify the factors likely to affect a modification. Throughout this project, we observed the use of both carbon and iron-gall inks over the course of the limited period of time in which these manuscripts were written. Further, XRF investigations showed that mixed ink was used as well. We have tried to classify

19 I would like to thank Ben Outhwaite and James Bloxam for agreeing that the manuscripts could be removed from their protective coverings for my analysis; and I would like to thank Rebecca Goldie, Anna Johnson, Emma Nichols and Ngaio Vince-Dewerse for kindly removing them for each of my visits.



3.6a



3.6b

FIGURE 3.6 Comparison of inks with and without Melinex on a mock-up sample, analysed with ArtTAX; a) line scan and b) fingerprint representing the elements copper (Cu, blue) and zinc (Zn, orange) after normalisation to iron (Fe) the qualitative observations gathered to deduce possible criteria that could help us to predict the outcome (i.e. the use of the writing materials) and to build a model applicable to a different corpus of documents. In other words, the model aims to identify the reasons for which a scribe might choose one type of support or one type of ink over others.

To this aim, we started by building a database that includes both the reflectography data and the descriptive data for each document (writing support, name of the scribe, type of document, use of ink, date of copying). Then we explored how each of these variables affects the probability of using one type of ink over another for a specific type of document. The simplest model to use to do this would be logistic regression: that is used to predict a binary outcome (yes/no, win/loss) in combination with one (or several) explanatory variables. However, as the results have multiple rather than binary outcome variables (in particular, iron-gall ink, carbon ink or mixed ink), we used a more complex model allowing further variances: multinomial regression analysis. This uses a tree, called a conditional inference tree, to order the responsible multivariate variables in a framework.[20] The algorithm tests the relationship between the input variables and the response, which can be multivariate.

In a hypothesis test, two propositions are studied: the null hypothesis, and an alternative one. The latter is the one we are aiming to support. If the data does not provide sufficient evidence to prove it wrong, the null hypothesis is presumed to be true. If the hypotheses about the responses are validated, the model selects the variable with the strongest association to the response as the first priority, and then recursively repeats the same step until the end of the model. The association between the descriptive variables and the response is measured by the p-value, a statistical test measuring the association between predictor variables and a result. The p-value is defined as the smallest level of significance that would lead to the rejection of the null hypothesis, and takes on values between 0 and 1. The smaller the p-value, the more evidence there is that the variable is significant. However, the p-value also needs to be compared to the significance level that has been set for the test.

All of the statistical analyses were performed using R software (ver. 3.2.4)[21] from the CRAN (Comprehensive R Archive Network), using the environment RStudio.

20 Hothorn, Hornik, and Zeileis, 'Unbiased Recursive Partitioning'; Hothorn et al., 'A Lego System for Conditional Inference'.

21 R Core Team, 'R: The R Project for Statistical Computing'.

CHAPTER 4

Results and Discussion

In this work, we have attempted to examine several hypotheses, one of these researching a possible link between an ink composition (or several) and a scribe. Although this question was central to the constitution of our corpus, it was accompanied by a long list of other hypotheses that we wanted to test: that of the link between the writing surface used and the choice of ink type, between ink type and communities or between ink types and document type.

The complete dataset investigated in this work consists of 391 classmarks. Reflectography has been performed on the complete dataset, while 202 manuscripts have been analysed with XRF spectrometry. A total of 1,823 measurements were conducted on 782 spots.

1 Use of Writing Surfaces

In this subchapter, we will see whether the type of support used when documents were penned correlates with other features, such as the type of document, the community or the scribe. In this respect, the early 11th century presents a crucial period because it is at this point that paper started to be used for legal documents and became a standard writing surface.[1] It is, therefore, not surprising that most manuscripts studied here were written on paper. All in all, the dataset comprises 391 manuscripts: 257 manuscripts on paper, 113 on parchment and 21 on leather (see section 2.1). The relative frequency of the different writing surfaces is presented in Figure 4.1.

Paper and parchment documents (except the scrolls documents written on parchment) are firmly dated to the 11th century whereas leather ones belong to the corpus of (non-biblical) scrolls that can be neither accurately dated nor localised, since no such information is contained in their text. However, every scroll was dated palaeographically and they all fall in a time span between the 7th century for the earliest to the 12th century[2] for the latest, with some being dated as written during the 11th century (T-S 16.282, T-S H 8.84, T-S B 13.16, T-S 18

1 Olszowy-Schlanger, 'Manuscrits hébreux et judéo-arabes : Paléographie des documents juridiques de Fustat du Xe siècle'.

2 Olszowy-Schlanger, 'The Anatomy of Non-Biblical Scrolls from the Cairo Geniza'.

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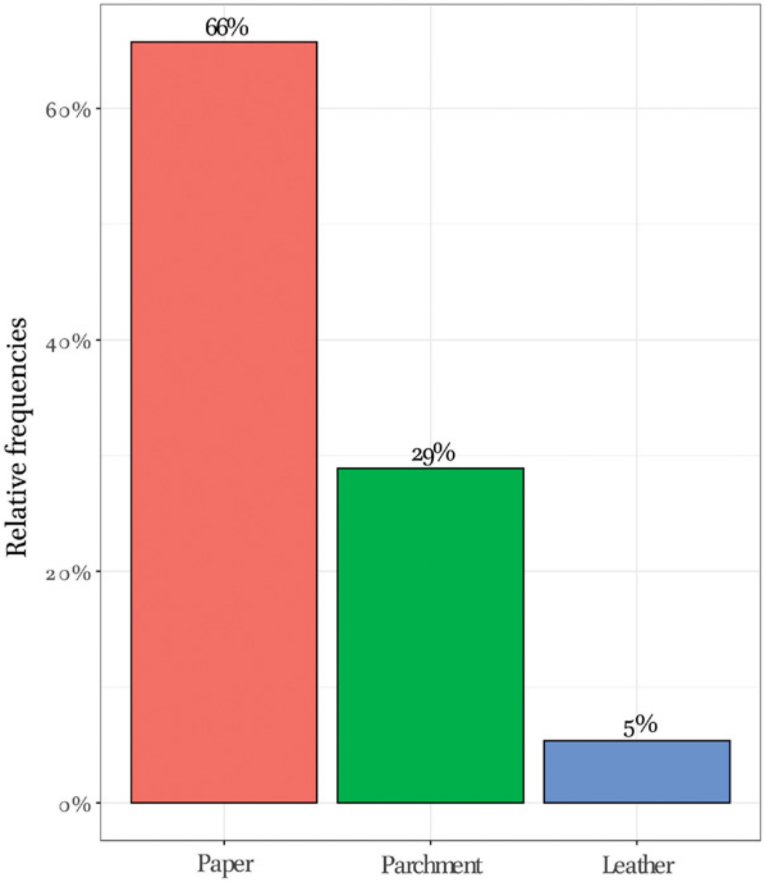

FIGURE 4.1 Distribution of the types of writing surface in the corpus, normalised by the total number of classmarks

H2, T-S Misc.29.11, T-S 28.13, T-S NS 122.124 + T-S NS 122.132, T-S H7.47). Thus, at least three types of writing support were used concurrently in the 11th century.

In Figure 4.1, the frequency of the types of support is based strictly on the number of manuscripts, that is, on classmarks. However, as discussed in the section dedicated to the presentation of the corpus in the section 1.2, such a formal distribution might be misleading since a single classmark does not necessarily represent a single document. Due to the complicated history of cataloguing and conservation, there is no simple correspondence between the number of classmarks and the number of documents. On one hand, fragments of a single document could be registered under different classmarks, which would result in a larger number of documents of that particular type showing in Figure 4.1. On the other hand, reuse of the writing support could cause two different classmarks to correspond to the same writing support, which would act in the opposite direction, decreasing the number of individual results.[3]

Rather than discussing the corpus in terms of consisting of 391 classmarks, then, it is better to treat it as a corpus of 498 documents : 357 documents on paper, 122 on parchment and 19 on leather. Hence, from now on, results will be reported and graphed in terms of documents, not manuscripts (classmarks), except when specifically indicated otherwise.

No specific research was dedicated to the elucidation of the pattern of follicles that might have indicated the type of animal used for the parchments. However, we can affirm that no tanned parchment has been found within the corpus of documents presented here: manuscripts written on a skin-based material were written either on non-tanned parchment or on leather.

Inspection of the paper has shown that it was characteristic of early paper produced in the Middle East: neither watermarks nor laid or chain lines could be observed. Also, the paper was cut into different lengths and sizes: when a particular piece of paper was too small for the text, the writing support was extended by adding another piece of paper, glued to the first, to produce a larger page (as was the case with e.g. T-S B12.39, T-S 20.93 and T-S Ar.7.38), a praxis also well attested in papyrus documents.

1.1 *Correlation with Type of Document*

Since several types of writing surfaces were used within the same period, it is important to determine whether patterns of use can be detected. Has a conscious consideration been made to write a document on one writing surface rather than on another that was available? In order to answer this question, I explored different explanatory variables to see if one – or several – could explain a preferential use of the writing surface and perhaps mark a conscious consideration by the scribe.

Table 4.1 presents the distribution of the type of writing support as a function of the type of document. The three types of support – paper, parchment and leather – and the three categories of documents – legal, private and religious[4] – are presented.

3 The complexity of dealing with documents in the Genizah, due to the practice of reuse has been noted previously, including in Shlomo Dov Goitein, *Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of the Cairo Geniza Vol II: The Community*, II (U of California Press, 1971), 233.

4 Official documents were dismissed as they were a very homogeneous category, all written by non-Jews, on paper with carbon ink.

TABLE 4.1 Documents sorted according to the type of composition and writing surface

	Paper	Parchment	Leather	Sum[a]
Legal	148	52	–	200
Private	122	8	–	130
Religious	26	51	13	90

a Not all the documents had enough information to be displayed in this table, or in the following one, which explains the variation in the numbers of documents mentioned through this chapter.

Remember that we are comparing the type of composition based on documents, not on manuscripts or classmarks. However, it is clear that the corrected distribution confirms the rough one shown in Figure 4.1: paper is the most common type of writing surface in this corpus, followed by parchment and then by leather. However, paper and parchment are used in different proportions for the three types of composition, and in particular the small number of documents written on leather belong to compositions of a religious character only.

Figure 4.2 presents the distribution of the writing supports by type of composition, normalised by the number of documents in each respective category. It clearly shows the dominating preference for paper in private documents, with 94% against 6% for parchment. Taking no account of the exact type of legal composition, we find that some 74% of all legal documents are written on paper. These numbers contrast strongly with the 24% of religious documents found on paper, all of them being religious poems (*piyyutim*) or religious responsa (*teshuvot*).

Turning to parchment as a writing surface, we see that while it was extensively used for religious purposes (around 64%), it was only used for around 26% of the legal documents, and it was hardly found in private documents (6%). In addition, it should be noted that the use of parchment for private purposes was in fact limited to its reuse (e.g. for pen trials).

As for leather, it is hardly present at all in the corpus under study. All documents of this category come from the corpus of (non-biblical) scrolls and were used only for religious purposes, as mentioned above.

In conclusion, there seems to be no correlation between the type of the document and the writing support in the case of legal or private documents, although the cheapest writing support, paper, dominates in both cases. In contrast, paper does not seem to have won the premises in the case of religious

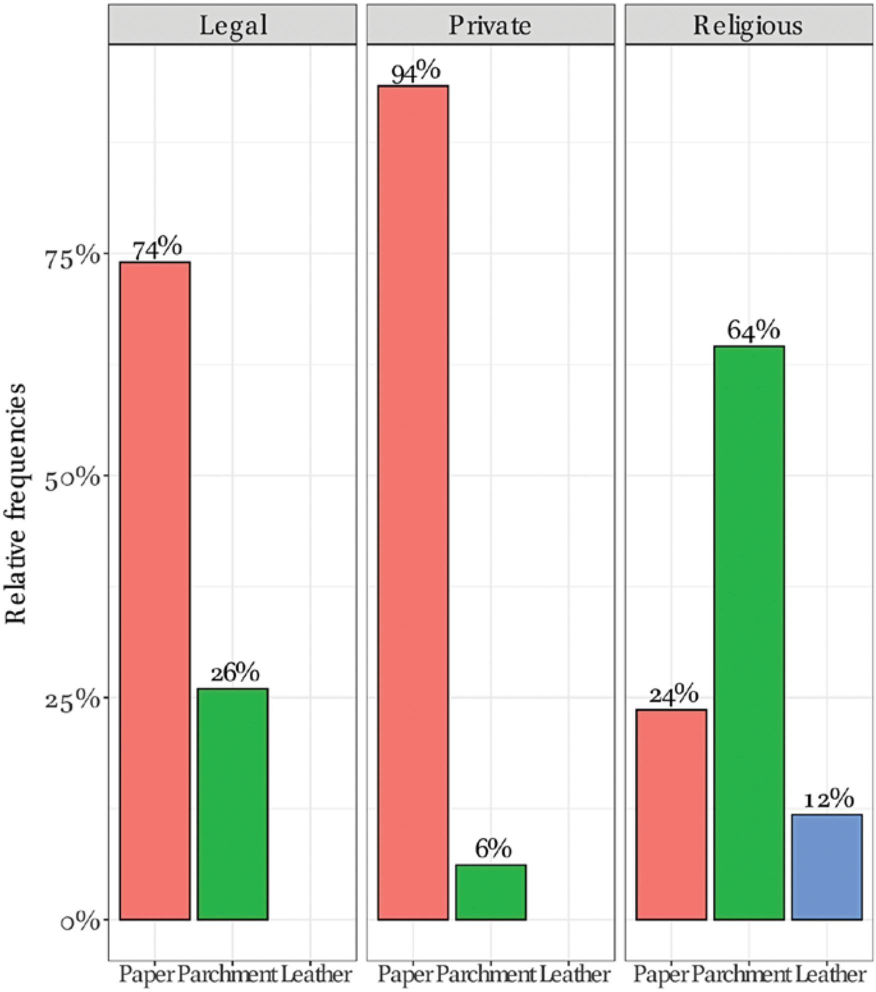

FIGURE 4.2 Distribution of the support type as a function of the type of the composition, normalised by the total number of documents in the respective category

documents. More details concerning the use of particular writing surfaces for religious documents will be discussed in section 5.3.

1.2 *Correlation with a Community*

We would like now to check whether there was a preferential use of a particular writing support within one or the other of the Jewish communities discussed in the study. This is a difficult question to answer because the borders between the different communities were not always clear enough to

TABLE 4.2 Comparison of the distribution of the writing surface type depending on the community

	Paper	Parchment	Leather*	Sum
Palestinian	75	21	–	96
Babylonian	39	3	12	54
Karaite	8	11	–	19
Palestinian *yeshiva*	31	–	–	31

*Note: All the documents written on leather are scrolls.

attribute any individual uniquely to one community. As shown in section 1.2, it was not uncommon for people to change communities during their life, apparently even between Rabbanites and Karaites. Moreover, only certain names are known well enough to be attributed to one community or another. For that reason, the analysis focuses largely on the leaders of the Rabbanite communities since there is enough information about them and they usually belonged to a single community throughout their life. In Figure 4.3 and Table 4.2, the question of preferential use of the writing support has been reduced to the choices made by the known members of the different Jewish communities.

Figure 4.3 represents the same data as Table 4.2, but with normalised observations. The communities are represented on the abscissa, while the ordinate maps the relative frequency.

Both Figure 4.3 and Table 4.2 show that paper seems to be used by all the communities represented in the study. Paper was used by both the Palestinian and the Babylonian communities in more or less the same proportions, with about 75% of use. All the documents of the Palestinian *yeshiva* are written on paper. But since all these documents are letters, and letters are normally written on paper, the type of document certainly plays a role in this distribution. Parchment was mostly used by members of the Palestinian community and the Karaites, while only 6% of the documents authored by Babylonian scribes were written on parchment. As for leather, it was only used by Babylonians and only for scrolls.

The use of different writing surfaces seems to be impacted by the community only when it comes to the use of leather, a writing surface used purely by Babylonians, to write scrolls. Let us, therefore, explore if another variable, the known scribes of this corpus, could explain this distribution of writing surfaces.

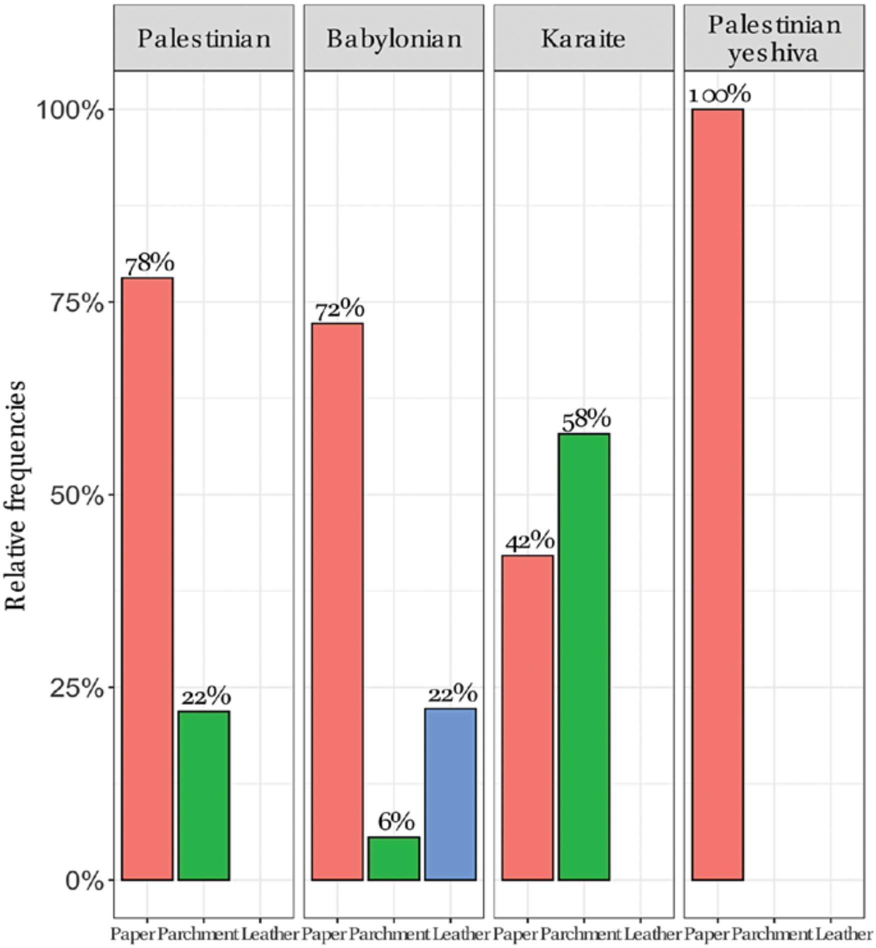

FIGURE 4.3 Distribution of the type of support used in the corpus, normalised by the total number of documents produced in the respective community

1.3 *Individual Use of the Writing Surface*

Investigation on a possible preference of a type of writing surface by the scribes in this study is summarised in Table 4.3. As in the previous cases, three different types of writing surface are presented: paper, parchment and leather. The scribes, together with their affiliation, appear in the second and first columns, respectively.

Figure 4.4 plots these observations, normalised by the total number of documents. Nearly all the scribes presented here, regardless of their community, are almost exclusively using paper as a writing surface (Elḥanan b. Shemarya has one document written on parchment in the corpus under study). Except

TABLE 4.3 Comparison of the distribution of the type of writing support depending on the scribe

Community	Scribe	Paper	Parchment	Leather	Sum
Palestinian	Ephraim b. Shemarya	31	–	–	31
	Yefet b. David	24	10	–	34
Babylonian	Abraham b. Sahlān[a]	–	–	–	–
	Sahlān b. Abraham	13	–	–	13
	Elḥanan b. Shemarya	10	1	–	11
Palestinian *yeshiva*	Solomon b. Judah	22	–	–	22

a Although Abraham b. Sahlān did not author any documents of this corpus, only signing some, it seemed relevant to include him in this census.

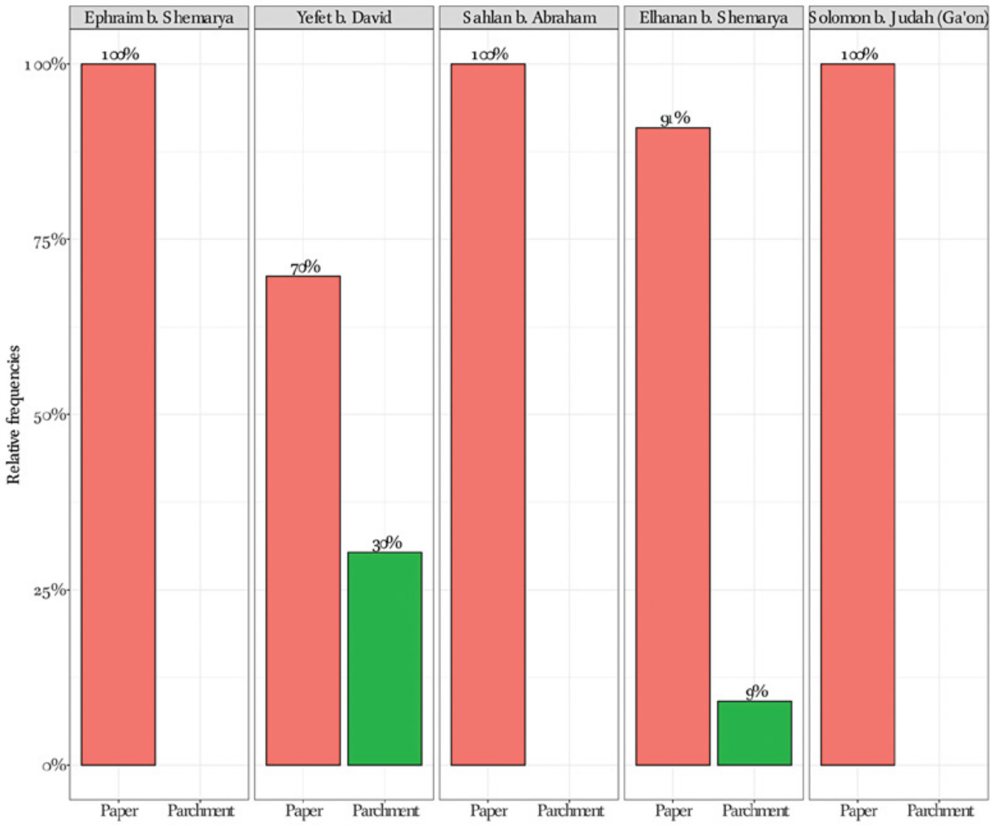

FIGURE 4.4 Distribution of the type of support used in the corpus, depending on the scribe, normalised by the total number of documents in the respective category

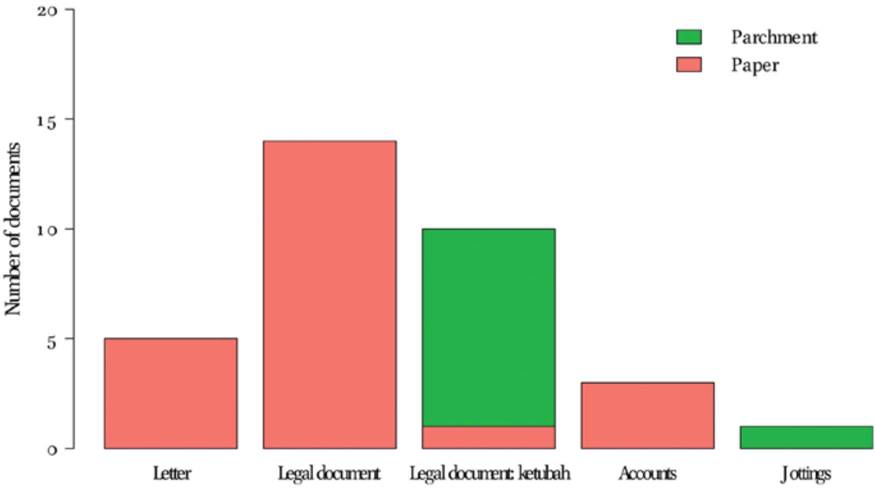

FIGURE 4.5 Distribution of the type of document according to the writing surface's type, on the documents written by Yefet b. David

for one scribe – the only scribe who seems to be using parchment extensively is Yefet b. David.

Given the anomalous nature of Yefet b. David's documents, let us look now at the distribution of documents written by him, presented in Figure 4.5. On the abscissa, the different types of documents are represented – with all legal documents other than *ketubot* represented together – while on the ordinate, one can find the number of each type of document.

In Figure 4.5, we see that ten documents out of total 34 are written on parchment. Nine of those are *ketubot*. Though I consider *ketubot* to be a type of legal document, they seem to display a property of religious documents with respect to the writing surface used for them, namely they are predominantly written on parchment (see section 4.1.1). It is particularly worth noting that the single non-*ketubah* parchment document, consisting of jottings, is written on the verso of one of the *ketubot*. The remainder of the documents scribed by Yefet b. David are exclusively written on paper, like those of the other scribes. The high number of documents written on parchment by Yefet b. David can therefore be explained by the high number of *ketubot* he wrote. Since the scribe belongs to the Palestinian community, this also explains the high number of documents written on parchment by members of the Palestinian community compared to the Babylonian community seen in section 4.1.3.[5]

5 This coincides with the observations collected by Goitein in Shlomo Dov Goitein, *Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of*

Just as for the previous qualitative variables, then, the scribe who wrote each document does not seem to explain the type of writing surface used. However Yefet b. David, the most prolific scribe of this study, was choosing parchment for *ketubot* and paper for other document types, suggesting that there is in fact an influence of the type of document on the use of the type of writing surface at least in his case, despite what was seen in section 4.1.3.

1.4 *Conditional Inference Trees on the Choice of Support*

Considering the interdependence of the criteria in the choice of writing surface, I treated the data with regression analysis using a conditional inference model fitting the different qualitative observations.

The correlation between the support used and the type of the document and the community that used it is investigated in Figure 4.6. As above, the choice of support is given in three classes: paper, parchment and leather. The root of the tree now contains the 210 documents for which information on the community exists, and has nine terminal nodes. In addition to the dataset presented so far, we added documents written by other communities, as a comparison point (the official documents written by the Fatimid chancery, legal documents written for mixed or non-Jewish community and a document written by the Pumbedita *yeshiva* which has been discarded so far from the previous presentations of the various Jewish communities too small to say anything). The p-value indicates the significance of the association between the type of support and the predictor variables, namely community and type of documents. In other words, the p-value gives for each node the probability that the predictor variable given has no influence on the outcome distribution. In this graph, all the p-value are under 1% (i.e. >0.001, and =0.004), which is highly significant.[6] It means that the probability to have a different distribution is in general below 1%.

The first decision node, node 1, shows that the type of document is the variable which is most strongly associated with the type of support. The node splits the documents into two groups: legal, private and official documents on one side, and religious documents on the other.

The second node relates to the first category (legal, private and official). The node divides in two according to community: Karaite, Christian, Jewish-Christian, Muslim-Jewish documents on one side, and documents from the

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the Cairo Geniza Vol I Economic Foundations, I (Univ of California Press, 1978), 112; Goitein, *A Mediterranean Society: The Community*, 232.

6 As an indication, in most fields, an p-value is considered as significant when it is under 0.05 Kim H. Esbensen et al., *Multivariate Data Analysis: An Introduction to Multivariate Analysis, Process Analytical Technology and Quality by Design*, 6th edition (Oslo Magnolia, TX: CAMO, 2018), 27–28, 316.

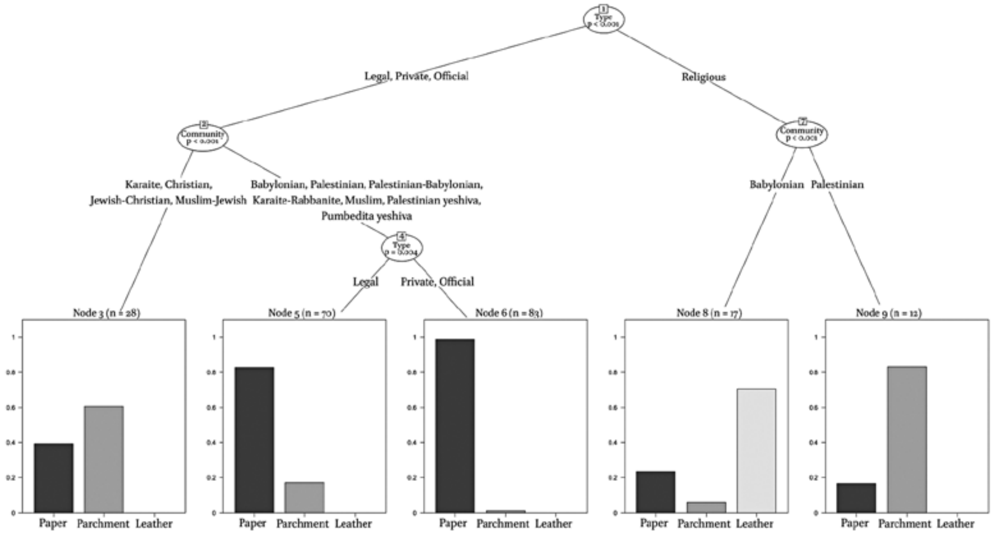


FIGURE 4.6 Conditional inference tree for the use of support in the corpus of interest. For each inner node, the adjusted p-values are given, and the fraction of use of parchment, paper and leather are displayed in each terminal node

Babylonian, Palestinian, Palestinian *yeshiva*, Palestinian-Babylonian, Muslim (i.e. mostly documents from the Fatimid chancery), Pumbedita *yeshiva*, Karaite-Rabbanite on the other. For the first one, the type of support is almost equally distributed between parchment and paper (60% vs 40%), for a total number of 28 documents. Leather is not used in this node.

On the other side, the type of document is again separated in two by a node: on one side, legal documents, and on the other, official and private documents. For the 70 legal documents, the use of paper amounts to around 80%, those on parchment only to 20%, while leather documents are again completely missing. Of the 83 official and private documents, almost all are written on paper, very few on parchment (and these are mostly pen trials on the verso of a legal document), and none on leather. No community-based distinction seems to be found within this group.

Node 7 pertains to the other part of the tree: the religious documents, which are then divided by community. In the case of scribes coming from the Babylonian community, around 70% of the religious documents were written on leather, more than 20% on paper and less than 10% on parchment, from a total of 17 documents. The results for the Palestinian community show that 80% of the 12 available religious documents were written on parchment, against 20% on paper. Religious documents were not written on leather within the Palestinian community.

Such a small corpus of observations does not allow a firm conclusion. Further research is necessary, extending it as well to biblical scrolls and other manuscripts.

What one can learn from this tree, is that for the case of religious documents, one can see a real separation between Rabbanite communities. In this corpus, the Palestinians mostly use parchment, and no leather at all; the Babylonians mostly use leather but can use other types of support. Although those results are identical to the ones presented above, the use of this model allows a better overview of the different criteria necessary to take into account when choosing a writing surface.

The corpus of scrolls studied has been too small to conclude anything that would go beyond what has already been stated, and it should be extended to include biblical scrolls in order to make more reliable statements. It is, nevertheless, worth mentioning that these results are confirming the hypothesis formulated independently by Haran and by Rabin for the use of tanned and non-tanned parchments in Jewish Antiquity (cf. section 2.1.1). One can see a clear difference between communities: parchment is used by the western community – here referred to as the Palestinians – while writing on leather corresponds exclusively to the eastern community, here referred to as Babylonians, as Schlanger has demonstrated.[7]

2 Ink Typology

Similar to the analysis of the use of the writing supports in section 4.1, the statistical treatment in this section aims to identify a pattern in the use of inks. Of course, in doing this we assume that the scribes knew what type of ink they were using. First, we will explore the distribution using criteria such as the type of writing support, the type of composition, community affiliation, the scribe, and so on. To be certain that no existing pattern was missed, we then additionally perform a regression analysis.

2.1 *Distribution of the Ink Types*

Reflectography was performed on the entire dataset (391 classmarks – 498 documents). The interpretation of the pictures showed the concomitant use of both iron-gall ink and carbon ink in this corpus. After processing the results of the XRF measurements made on the subset of 202 documents, a third group

7 Olszowy-Schlanger, 'The Anatomy of Non-Biblical Scrolls from the Cairo Geniza'.

TABLE 4.4 Distribution of the types of ink according to their purpose in the documents

Ink type	Main text[a]	Signatures	Corrections, additions	Other*	Sum
Iron-gall	345	248	16	92	753
Carbon	131	91	10	51	312
Mixed	15	33	1	-	49

*Note: "Other" corresponds to the sum of marginalia, address, vowelling and decoration

a The number of main texts here are not adding to 498: one document (T-S 8J7.18 v.) does not have a main text but only signatures while others were palimpsest or fading away and could therefore not be securely identified.

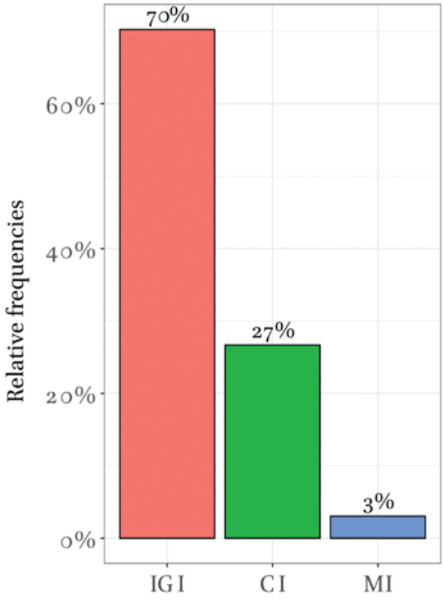
of ink revealed itself: mixed ink. It is therefore apparent that, even on the relatively small scale of the city of Fusṭāṭ, the three groups of iron-gall ink, carbon ink and mixed ink coexisted during the period of time under study.

Since it was not possible to use imaging XRF, which would have allowed an analysis of all the inks of each manuscript, the results were automatically biased by the choice of the spots analysed. To overcome this bias, I divided the inks in the documents into different regions of interest according to their purpose: main text, signatures, corrections and additions, marginalia, address, vowelling and decoration.

Table 4.4 shows that the main text of 347 of the documents studied here were written in iron-gall ink, 131 were written in carbon ink, whereas mixed inks could be unequivocally determined for the main text of only 15 documents. In total, the number of uses of ink analysed in this corpus amount to 755 instances of iron-gall ink, 312 of carbon ink and 49 of mixed ink.

Figure 4.7a shows the weighted results for the ink used to write the main text, Figure 4.7b gives the equivalent for the signatures, Figure 4.7c for the corrections and additions and Figure 4.7d for all other spots analysed in the documents of the corpus.

Every case presented above shows preferential use of iron-gall ink over carbon ink, with this trend most pronounced in the case of the main texts. In contrast, mixed inks seem to be by far more frequent in signatures than in the main texts or corrections and additions (9% vs 3% and 4%). Unfortunately, the current analytical protocol is not well suited to identify mixed inks, and therefore the use of it might be underestimated in this study. However, the larger number of cases of mixed inks in signing documents shows they are preferentially used by witnesses in legal documents.



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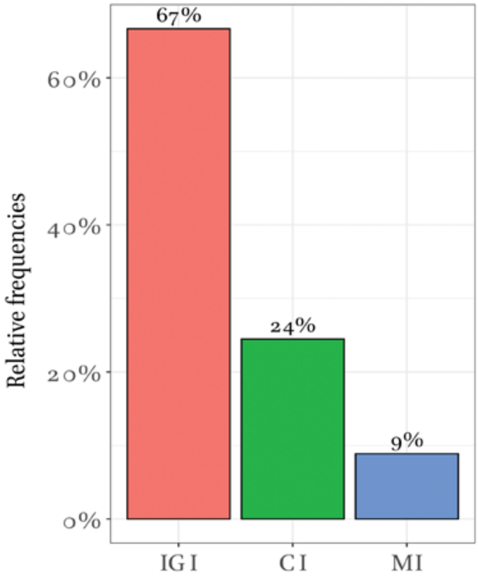

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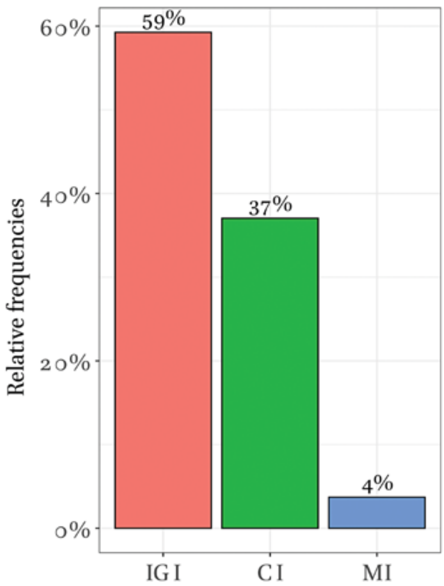

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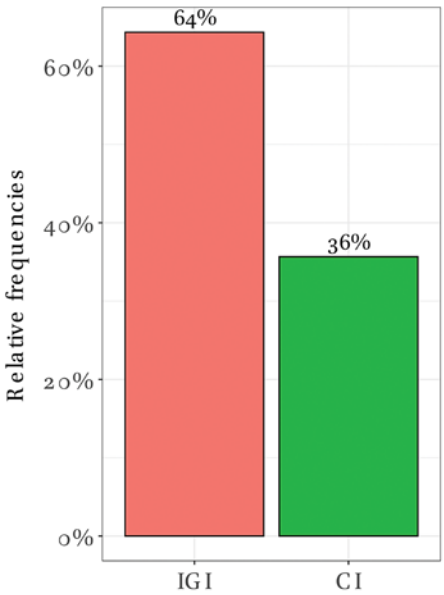


4.7d

FIGURE 4.7 Distribution of the inks according to the type of ink used for a) the main texts, b) the signatures, c) additions and corrections, and d) all the rest, normalised by the total number of documents in the respective category. Abbreviations: Iron-gall ink (IGI), carbon ink (CI), mixed ink (MI)

2.1.1 Correlation with the Type of Support

Similar to the way in which we studied the different factors that may cause variation in the uses of different types of surfaces in section 4.1, the factors that may cause variation in the uses of different types of inks were also studied. The first factor studied was the relationship between the type of ink and the type of writing surface used to write the document. Table 4.5 presents the distribution of the types of ink as a function of the types of support.

The use of iron-gall ink on paper and parchment matches the overall ink distribution, which would seem to be a trivial result since most of the documents in this study are on paper and written with iron-gall ink. The use of iron-gall ink also dominates in the case of leather, although every type of ink is found on this support. For carbon inks, the same dependence exists only for the documents on paper: with only three main texts executed in carbon ink on parchment and a similar number on leather, we would say carbon ink was predominantly used on paper.

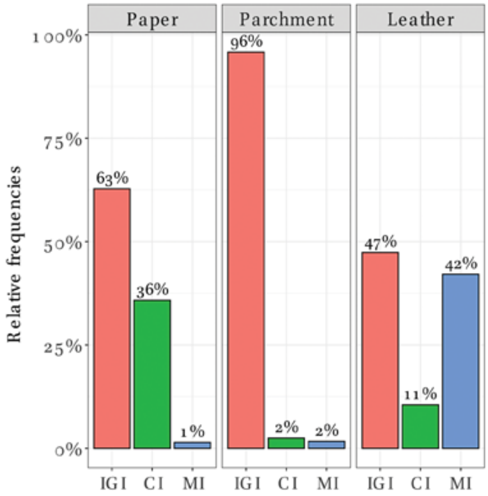
After weighing, the results of Table 4.5 are plotted in Figure 4.8, which shows the distribution of the ink type depending on the type of support, normalised

TABLE 4.5 Distribution of the type of ink depending on the type of support

	Support	Iron-gall ink	Carbon ink	Mixed ink	Sum[a]
Main texts	Paper	221	126	5	352
	Parchment	115	3	2	120
	Leather	9	2	8	19
Signatures	Paper	128	81	30	239
	Parchment	120	10	3	133
	Leather	–	–	–	–
Corrections and additions	Paper	15	9	1	25
	Parchment	1	1	–	2
	Leather	–	–	–	–
Other*	Paper	74	46	–	120
	Parchment	17	5	–	22
	Leather	1	–	–	1

*Note: "Other" corresponds to the sum of marginalia, address, vowelling and decoration.

a The sum of main texts here (493) – i.e. corresponding to the number of documents analysed – matched the number given in the previous Table 4.5 – and not the total number of documents given since the beginning of the thesis (498).



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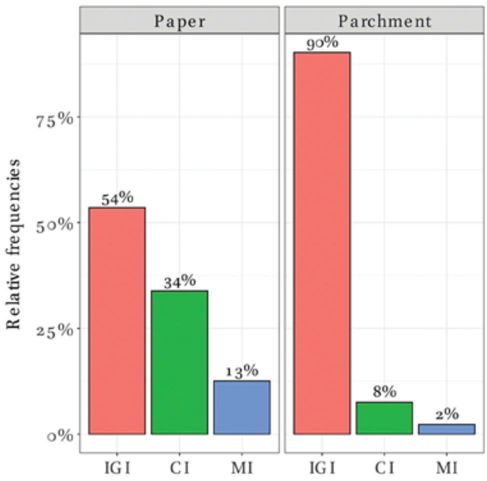

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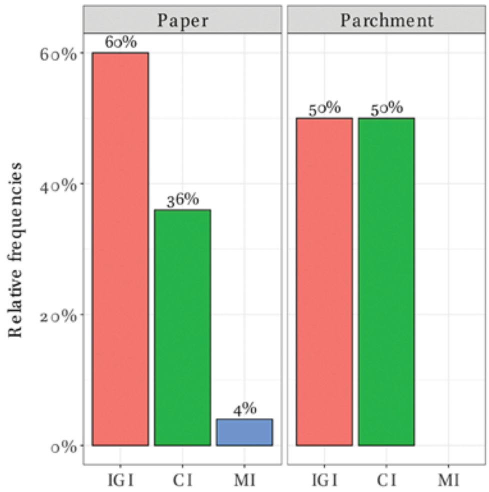

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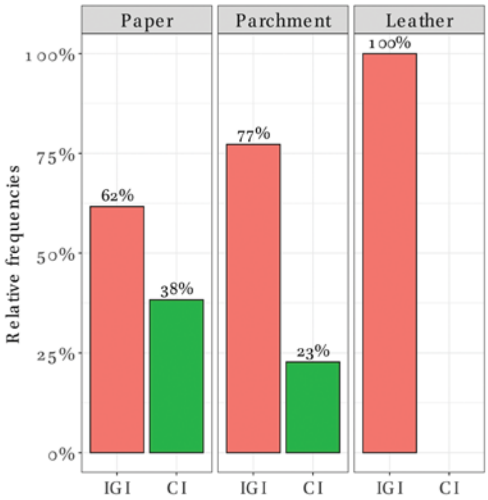


4.8d

FIGURE 4.8 Distribution of the type of ink depending on the type of support normalised to the number of occurrences for a) the main texts, b) the signatures, c) additions and corrections, and d) all the rest, normalised by the total number of documents in the respective category. Abbreviations: Iron-gall ink (IGI), carbon ink (CI), mixed ink (MI)

to the number of inks in each category. Figure 4.8a displays the results for the main text, Figure 4.8b for the signatures, Figure 4.8c for additions and corrections, and Figure 4.8d for all the other parts of the documents. The reason for creating those different plots was to evaluate whether there is an effect in the cases of signatures or later additions. Since XRF analyses have not been conducted on all the inks perceived as “carbon ink” by reflectography, there is a certain bias that influences our interpretation of what is a carbon ink and what is a mixed ink in the corpus. It is important to keep this limitation in mind when examining Figure 4.8. More insight into this class of mixed inks will be presented in section 4.3.3.2. In the four graphs, the abscissa represents the type of support, and the ordinate the frequency. The three types of inks are presented in different colours: iron-gall ink (IGI) in pink, carbon ink (CI) in green and mixed ink (MI) in blue.

Those analyses show that a type of support does not necessarily go together with an ink type. The identification of the ink type in this corpus of the study shows that if carbon ink is less used than iron-gall ink. In case of parchment, one can observe the almost exclusive use of iron-gall ink.

2.1.2 Correlation with the Type of Composition

As the writing surface was only partially related to the type of ink used to write the document, we move to the next potential factor, the type of document. We have seen previously that in some cases, the recipe suggests a specific use of the ink depending on the type of the document are listed. This is especially important for religious documents. In the previous section, Table 4.1 and Figure 4.2 have already shown that type of writing surface and type of document were partly correlated. Leather was used only for religious documents, while the study of the documents penned by Yefet b. David has shown that in case of *ketubot*, the type of writing surface chosen was parchment. It thus raises the question of whether there is a similar dependence regarding ink. In other words, what is the gap between theory and practice? Did scribes change inks when they switched from religious to legal documents? Or did they change inks when they changed the writing support? The relevant results are summarised in Table 4.6.

Figure 4.9 presents the distribution of the ink type as a function of the document type, normalised to the total number of documents in each category; that is, it displays the weighted results of Table 4.6. It shows four different plots: Figure 4.9a, which contains the ink typology only of the main text, Figure 4.9b which contains the inks used to sign the document, Figure 4.9c the inks used to correct the document and add information, and Figure 4.9d for all the inks used in other sections of the document. The three types of ink are presented in different colours: iron-gall ink (IGI) in pink, carbon ink (CI) in green and mixed ink (MI) in blue. In these four graphs, the abscissa represents the type of document and the ordinate represents the relative frequency.

Let us keep in mind the unreliable number of mixed inks, probably largely underestimated in those results due to the limitation of identification.

TABLE 4.6 Comparison of the distribution of ink types depending on the type of document

	Type of document	Iron-gall ink	Carbon ink	Mixed ink	Sum[a]
Main texts	Legal	146	48	2	196
	Private	96	33	1	130
	Religious	74	9	5	88
Signatures	Legal	231	83	33	347
	Private	17	5	–	22
	Religious	–	–	–	–
Corrections and additions	Legal	11	3	1	15
	Private	3	1	–	4
	Religious	–	–	–	–
Other*	Legal	21	11	–	32
	Private	59	29	–	88
	Religious	6	4	–	10

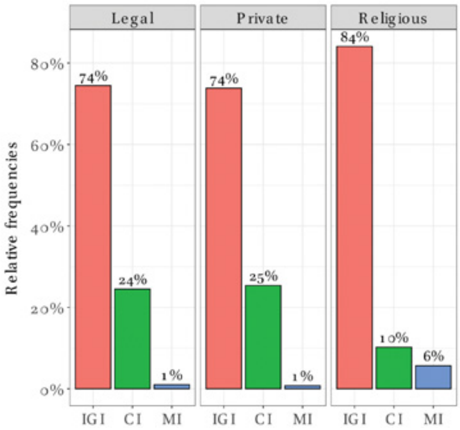
*Note: “Other” corresponds to the sum of marginalia, address, vowelling and decoration.

a As there are a lot of unknown documents, the numbers presented here are much less than the ones presented in Table 4.5 and Table 4.6. In addition, official documents were once again discarded as here only as homogeneous comparison category.

Once again, iron-gall ink is the main type of ink for all categories. When considering the total number of inks analysed in the corpus in both legal and private documents, the distribution shows about 25% of carbon ink in contrast with about 70% of iron-gall ink. For religious purposes, the use of carbon ink is even more scarce, with 15%. Iron-gall ink use is around 80% for religious documents. Mixed inks were found mostly in the signatures of legal documents (10%, for correction and addition, due to the small number of observations, the percentage is of 7% but for only one observation) and the main text of religious documents (6%).

2.1.3 Correlation with the Community

The third dimension of the analysis of ink examines the impact of membership of a community on the choice of the type of ink. Figure 4.6 has shown that a correlation existed between the choice of support for religious documents and the community writing those documents. Could there be a pattern behind ink choice depending on which community a scribe belonged to?



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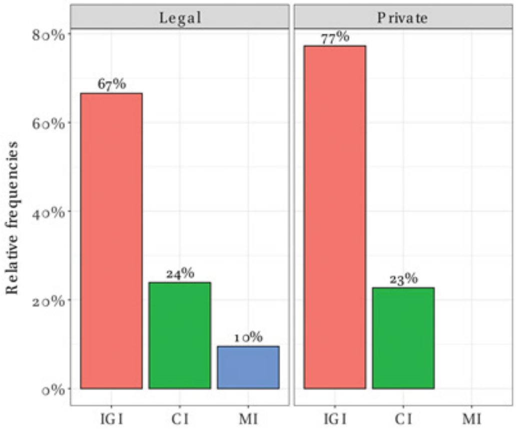

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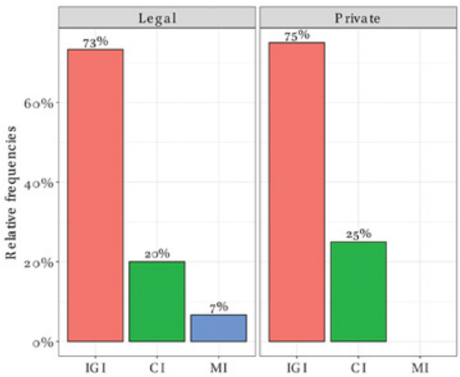

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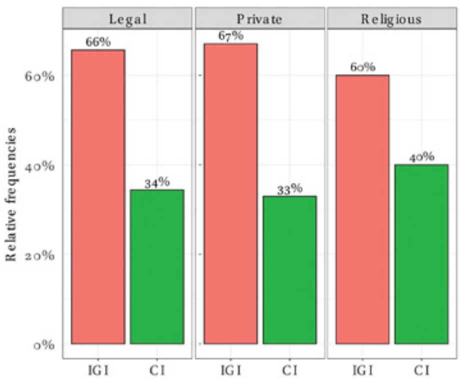


4.9d

FIGURE 4.9 Distribution of the ink type depending on the type of document for a) the main texts, b) the signatures, c) additions and corrections, and d) all the rest, normalised by the total number of documents in the respective category. Abbreviations: Iron-gall ink (IGI), carbon ink (CI), mixed ink (MI)

The results are summarised in Table 4.7, showing the number of documents as a function of the leader of the community producing it. The documents considered here belong to the Palestinian, Babylonian and Karaite communities, together with the ones produced by members of the Palestinian *yeshiva*.

Some tendencies can be seen in Table 4.7. Of the 201 documents presented, about 23% of the main text is written with carbon ink, 74% with iron-gall ink, and 3% with mixed inks. On the 19 documents written by the Karaite community, none of the main texts was penned in an ink type other than iron-gall. The only occurrence of carbon ink in a Karaite document is a correction

TABLE 4.7 Comparison of the distribution of the ink types depending on the community

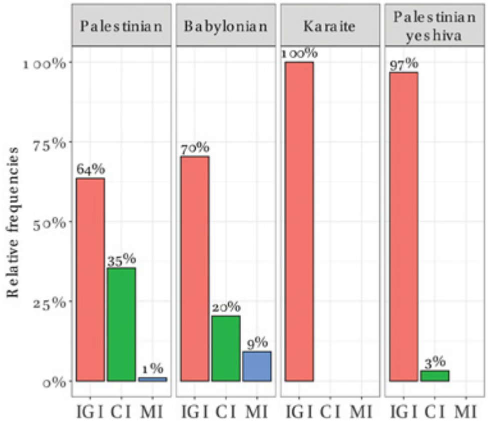
	Community	Iron-gall ink	Carbon ink	Mixed ink	Sum
Main texts	Palestinian	61	34	1	96
	Babylonian	38	11	5	54
	Karaite	19	–	–	19
	Palestinian *yeshiva*	30	1	–	31
Signatures	Palestinian	41	10	6	57
	Babylonian	12	7	1	20
	Karaite	11	1	2	14
	Palestinian *yeshiva*	10	–	–	10
Corrections and additions	Palestinian	4	3	1	8
	Babylonian	2	–	–	2
	Karaite	2	–	–	2
	Palestinian *yeshiva*	–	–	–	–
Other*	Palestinian	13	15	–	28
	Babylonian	8	1	–	9
	Karaite	2	–	–	2
	Palestinian *yeshiva*	20	3	–	23

*Note: "Other" corresponds to the sum of marginalia, address, vowelling and decoration.

made on a draft of a Karaite *ketubah*, written by a scribe who was working for the Babylonian court of Shemarya b. Elḥanan, as Schlanger has recognised.[8] Similarly, the majority of documents written by the Palestinian *yeshiva* were written with iron-gall ink.

Again, since the distribution of the documents produced by each community is uneven, even a tentative comparison requires normalisation. Figure 4.10 presents the relation between a weighted number of occurrences of a certain ink type and the Jewish communities: Figure 4.10a for the ink of the main text, Figure 4.10b for the signatures, Figure 4.10c for corrections and additions and Figure 4.10d for the inks in the remainder of the documents. As before, the

8 Olszowy-Schlanger, 'Manuscrits hébreux et judéo-arabes'.



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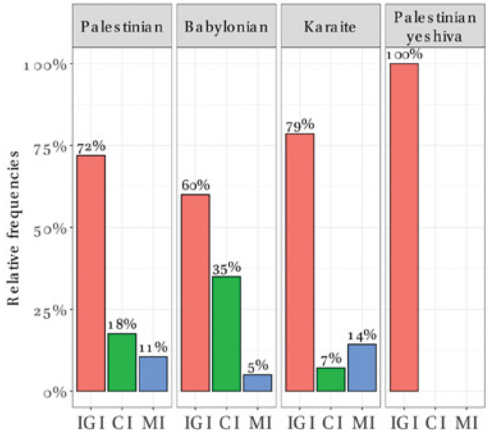

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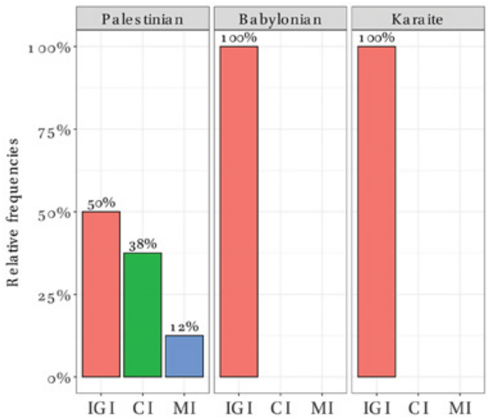

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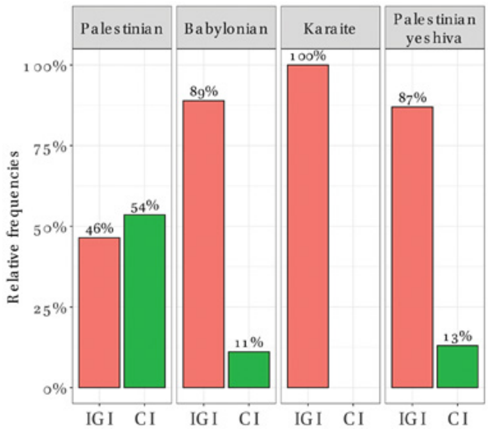


4.10d

FIGURE 4.10 Distribution of the ink type depending on the community for a) the main texts, b) the signatures, c) additions and corrections, and d) all the rest, normalised by the total number of documents produced by each group. Abbreviations: Iron-gall ink (IGI), carbon ink (CI), mixed ink (MI)

three classes of ink types are presented for each community: iron-gall ink (IGI) in pink, carbon ink (CI) in green and mixed ink (MI) in blue.

Similarly to the previous cases, all the figures show once more the primacy of iron-gall ink over carbon ink, except for Figure 4.10d. We see that members of both Rabbanite communities used iron-gall ink, carbon ink and mixed ink to write their documents: seemingly different proportions between the two Rabbanite communities estimated from the investigation of this corpus might be an artefact of the study, since the number of documents produced by each

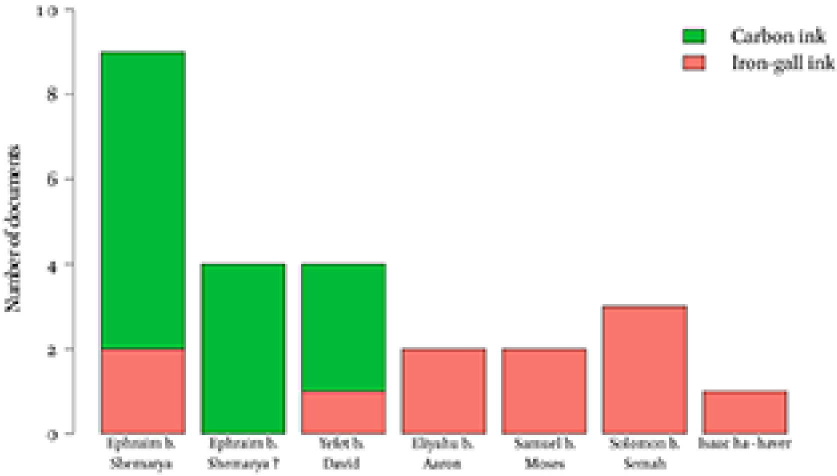


FIGURE 4.11 Distribution of the type of inks used within the Palestinian community, for the category “other”, depending on the scribe. Abbreviations: Iron-gall ink (IGI), carbon ink (CI)

community studied here is too small and uneven to establish an unambiguous preference. This is not the case for Karaites documents: with exception of a single occurrence of a carbon ink and two occurrences of the mixed ink in the signatures, all the inks encountered here in Karaite documents were of the iron-gall type. Similarly, practically all documents produced by the Palestinian *yeshiva* are written with iron-gall ink, with a single occurrence of carbon ink identified in one of the main texts and three in the category of other.

Despite being based on a very small number of instances, it is worth noting that Figure 4.10c, corrections and additions, shows a similar pattern to the rest. In Figure 4.10d, instances which were not the main text, signatures or additions and corrections, on the other hand, for Palestinian documents we see a larger proportion of carbon ink in use (46% of iron-gall ink vs 54% of carbon ink, in a total of 28 instances). Let us, therefore, have a closer look at the data represented in Figure 4.10d, for the Palestinian community, to understand the difference of the results.

Figure 4.11 presents the distribution of the type of ink used in the Palestinian community, organised by scribes, for the category “other”, in order to understand the difference between Figure 4.10 d and the other figures. The results given in Figure 4.10 d are more understandable when we look at Figure 4.11. The distribution largely depends on the scribe who used the ink: the spots written by Ephraim b. Shemarya, Yefet b. David and by scribes who could be Ephraim

b. Shemarya or who have a similar hand to his, are written with carbon ink, while the rest are written with iron-gall ink.

It seems therefore that within the community, different ink types are used by different scribes. Let us try to see whether this distribution holds for other spots and members of the other communities.

2.1.4 Individual Use of the Inks

One question raised from the beginning of this project was to see if it would be possible to match specific inks to individual scribes. If so, one might try to find a chronological correlation between the production of a scribe and his inks. Even more, if such a correlation exists it might serve to establish the dates of the undated documents. Table 4.8 presents the ink types used by the scribes studied in this project.

TABLE 4.8 Comparison of the distribution of the ink types depending on the scribes

	Community	Scribes	Iron-gall	Carbon	Mixed	Sum
Main texts	Palestinian	Ephraim b. Shemarya	5	26	–	31
		Yefet b. David	29	4	–	33
	Babylonian	Abraham b. Sahlān	–	–	–	–
		Sahlān b. Abraham	12	1	–	13
		Elḥanan b. Shemarya	7	4	–	11
	Palestinian *yeshiva*	Solomon b. Judah	22	–	–	22
Signatures	Palestinian	Ephraim b. Shemarya	4	2	2	8
		Yefet b. David	20	2	–	22
	Babylonian	Abraham b. Sahlān	1	2	1	4
		Sahlān b. Abraham	3	–	–	3
		Elḥanan b. Shemarya	2	1	–	3
	Palestinian *yeshiva*	Solomon b. Judah	8	–	–	8

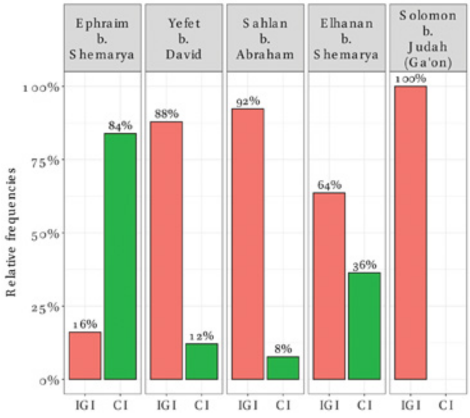
TABLE 4.8 Comparison of the distribution of the ink types depending on the scribes (*cont.*)

	Community	Scribes	Iron-gall	Carbon	Mixed	Sum
Corrections and additions	Palestinian	Ephraim b. Shemarya	2	2	1	5
		Yefet b. David	–	–	–	–
	Babylonian	Abraham b. Sahlān	–	–	–	–
		Sahlān b. Abraham	–	–	–	–
		Elḥanan b. Shemarya	–	–	–	–
	Palestinian *yeshiva*	Solomon b. Judah	–	–	–	–
Other*	Palestinian	Ephraim b. Shemarya	2	10	–	12
		Yefet b. David	1	3	–	4
	Babylonian	Abraham b. Sahlān	–	–	–	–
		Sahlān b. Abraham	2	1	–	3
		Elḥanan b. Shemarya	3	–	–	3
	Palestinian *yeshiva*	Solomon b. Judah	14	1	–	15

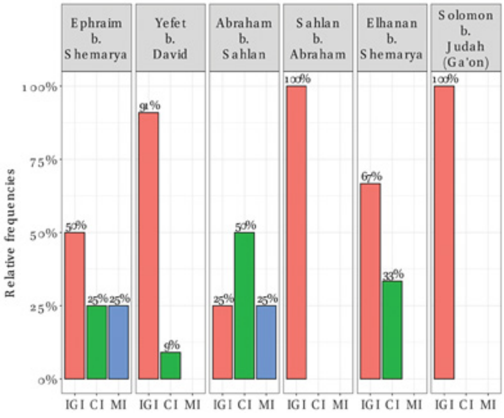
*Note: "Other" corresponds to the sum of marginalia, address, vowelling and decoration.

In order to obtain comparable observations, the results are weighted by the number of instances of ink use for each scribe. In Figure 4.12, the distribution of the type of inks used by the following scribes is given: Ephraim b. Shemarya and Yefet b. David representing the Palestinian community; Sahlān b. Abraham, Abraham b. Sahlān and Elḥanan b. Shemarya, representing the Babylonian community; and Solomon b. Judah (*Ga'on*) for the Palestinian *yeshiva*.[9] The three types of inks presented are iron-gall ink (IGI, in pink), carbon ink (CI,

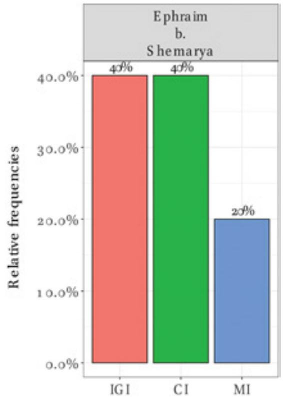
9 Not all the scribes are present in the graphs, although their names are represented in the table. When no data is presented in the table, a scribe's production is not represented in the graphs.



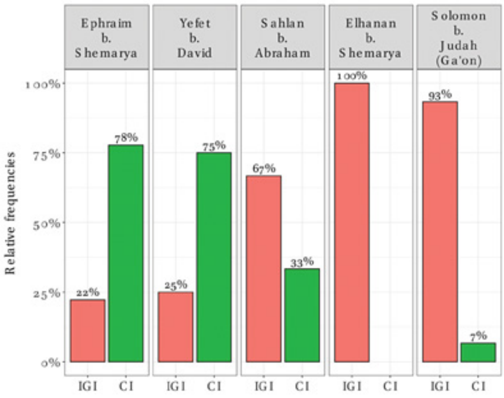
4.12a



4.12b



4.12c



4.12d

FIGURE 4.12 Distribution of the types of the ink used by the scribe in a) the main texts, b) the signatures, c) additions and corrections, and d) all the rest, normalised by the total number of documents in the respective category produced by each scribe. Abbreviations: Iron-gall ink (IGI), carbon ink (CI), mixed ink (MI)

in green) and mixed ink (MI, in blue). The subfigures a-d of Figure 4.12 correspond to the main texts, signatures, corrections and additions and other parts of the documents (i.e. marginalia, address, vowelling and decoration), respectively. Note, that Abraham b. Sahlān's production is only represented in the signatures, while Ephraim b. Shemarya is the only scribe to whom corrections and additions could be securely ascribed.

Here, clear preferences can be seen. Figure 4.12a and b shows that Yefet b. David, Solomon b. Judah and Sahlān b. Abraham consistently preferred iron-gall ink. These scribes represent both Rabbanite communities; we can therefore establish firmly that there was no ink preference within one or the other Rabbanite community. Furthermore, the fact that the Palestinian scribe Ephraim b. Shemarya used mostly carbon ink in the documents whose main text he authored indicates an individual preference. Interestingly, when it comes to the signatures and the additions and corrections, all three types of the inks are well represented, with the iron-gall ink as the most abundant one in the category of signatures, although the corpus was, once again, very restricted.

While the scribes of this study show a clear preference for one ink type or another, the same observation cannot be said about the whole community. In addition, we see that none of the scribes in this study restricted himself to the use of a single ink type.

However, it is necessary to underline again that these results are based solely on the measurements conducted with the help of reflectography or reflectography combined with XRF analysis. Therefore, the number of mixed inks in this study might be underestimated.

2.2 *Conditional Inference Trees on the Choice of the Types of Ink*

As it has become clear that no single variable is able to explain the choice of ink types, and in order to see the large dataset with more clarity, I have displayed the regression results again in trees, similar to the ones used in Figure 4.6, in order to ensure a better understanding of the choice of ink type. The dataset is still the same, however, I have the same comparative documents than in the previous tree, Figure 4.6. However, this time, I am using the results gathered not only on the main text but for all the inks analysed by reflectography, enriched with the XRF results that identify some carbon inks as mixed ones.

In this graph, all the p-value are under 2% (i.e. <0.001 and $p=0.02$), which is once again highly significant. It means that the probability to have a different distribution is in general below 1%.

Figure 4.13 presents a decision tree that shows the ink typology as a dependent variable. Three classes are presented: iron-gall ink, carbon ink and mixed ink. The root of the tree contains 1,012 observations, as missing data is automatically discarded. The tree has seven terminal nodes. The tree investigates here if a pattern can be found behind the choice of ink, using the following predictor variables: the type of support, the type of document, and the community of the scribe using the ink in question.

The first node, at the top of the tree, shows that support is the variable which is most strongly associated with the type of ink used. That node splits the documents in two based on their support: leather and paper on one side, parchment, on the other.

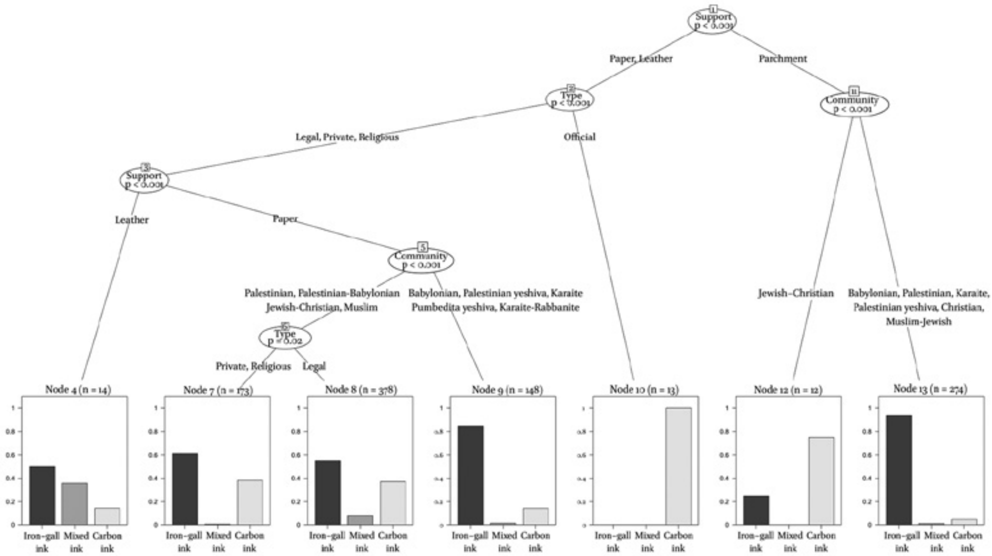


FIGURE 4.13 Conditional inference tree for the use of different types of ink in the corpus of interest. For each inner node, the adjusted p-values are given, and the fraction of use of iron-gall ink, carbon ink and mixed ink is displayed in each term

The second node pertains to the first category, which is documents written on leather and paper. These once again divide into two parts, according to the type: one one side legal, private and religious documents, on the other official ones. On the side of legal, private and religious documents, the next node splits the documents in two based on their support: leather or paper.

Node 4 contains therefore legal, private and religious documents written on leather. It contains 14 observations and shows a distribution of 50% of documents written with iron-gall ink, 10% with carbon ink and 40% with mixed inks.

For the paper documents, a new division is made according to the respective community. Node 6 contains documents written by Palestinian, Muslim (containing therefore the legal documents copied in the court of the Qadi) and documents which are the product of joint Palestinian–Babylonian sessions; there were also documents written for cases bringing together a Christian and a Jewish party.

Node 6 again divides these documents based on the type of composition: religious and private, vs legal. For religious and private documents written on paper, in node 7, the distribution is about 60% of iron-gall ink, about 40% of carbon ink and one occurrence of mixed ink, from 173 instances of ink. In case of legal documents, in the eight node, the ink type is relatively equally distributed between iron-gall ink and carbon ink (55% vs 40%) and less than 5% of mixed inks, over the 378 instances of use of ink.

Of the documents produced by Babylonian, Karaites, the Palestinian *yeshiva*, the Pumbedita *yeshiva*, and by a joint Karaite–Rabbanite court, more than 80% were written with iron-gall ink, while 15% were written with carbon ink, and two instances with mixed ink for 148 observations.

Official documents are exclusively written with carbon ink, although there are only 13 instances.

The next node pertains to the other part of the tree: parchment. This time, the community seems to be the relevant criterion which divides the data into two parts. On one side are those documents that concern several communities at the same time – Christian–Jewish documents – and on the other, documents concerning the Babylonian, Palestinian, Karaite, Christian, Muslim–Jewish and the Palestinian *yeshiva*. In the case of those documents relating to both the Christian and Jewish communities – and where we can, therefore, imagine an official court, with a Muslim scribe – node 12 shows that about 75% of the documents are written with carbon ink and 25% with iron-gall ink; nothing is written with mixed ink. The node, unfortunately, contains only 12 documents, which, once again, constitutes an inadequate statistical basis and therefore does not allow conclusions to be drawn.

The last node, node 13, contains 274 documents and concerns documents written on parchment by scribes from the Babylonian, Karaite and Palestinian communities, the Palestinian *yeshiva*, and again probably a Muslim scribe for the legal documents concerning Muslim–Jewish parties and the Christian official documents. In this node, 95% of the documents were written with iron-gall ink and about 5% with carbon ink. Once again, no use was made of mixed ink.

From this tree, one can see that the primary use of mixed ink was for documents on leather (i.e. scrolls) and for legal documents written on paper. Every node proves a preponderant use of iron-gall ink, except for interreligious legal documents and official documents written on paper, where carbon ink is more frequent. More insight concerning the use of writing materials by type of document will be found in the next chapter.

3 Elemental Composition of the Inks and Writing Surfaces within the General Dataset

3.1 *Inorganic Contamination of the Writing Support*

To determine the fingerprint of an ink, one has to be able to distinguish between the contribution of an element to the ink from its contribution to the support. To achieve this, the inked and uninked support areas can be independently analysed and then compared. Since the signal from the ink always contains also the signal from the support, the signal due to the support (on its own) can be subtracted from the signal measured from the ink (plus support) to obtain the signal that corresponds to the ink only (using the techniques of Chapter 3.1.3).[10] Strictly speaking, this procedure does not provide absolutely correct values because the measured signal depends on a number of factors including the matrix, that is, the elements contained in the ink and the support. As a first-order approximation, though, it delivers excellent results leading to a reliable comparison of the iron-gall inks derived from vitriol.[11]

However, this type of evaluation of the measurements relies strongly on the assumption that all the element distributions of the support are homogeneous and thus that any measurement of the bare support supplies us with its representative elemental composition. This is especially crucial when the element in question is iron, since the calculation of the fingerprint of an iron-gall ink is based on the amount of iron in the ink. In fact, in the corpus under study, the paper support used for the majority of the documents contained large amounts of iron and sometimes other metallic elements such as copper, albeit in much smaller amounts. Such contamination has been reported elsewhere in the literature[12] and several possible explanations have been advanced to account for it, such as the use of contaminated water, the use of rusty moulds, the contamination of sizing solutions, and other ideas. The situation of the uneven distribution of metallic components in the support and the effect of this on the determination of the ink fingerprint is discussed in more detail in section 4.3.3.4.

The parchment analysed in this work was found to contain less iron than the paper. Moreover, the distribution of iron in the parchment contrasted strongly with that in the paper, being relatively homogeneous. A typical difference in the quantity of iron in paper and parchment is shown in Figure 4.14. It shows two XRF spectra, with the red curve corresponding to an XRF spectrum of the paper of manuscript T-S 8.220 and the green curve showing an XRF spectrum from the parchment of manuscript T-S 10J2.2. The identical scale of the ordinate makes it easy to compare the individual peak intensities of the element

10 Hahn et al., 'Characterization of Iron-Gall Inks in Historical Manuscripts and Music Compositions Using x-Ray Fluorescence Spectrometry'.

11 Mirjam Geissbühler et al., 'Advanced Codicological Studies of Cod. Germ. 6 (Hamburg, Staats- Und Universitätsbibliothek): Part 2', *Manuscript Cultures* 11 (2018): 133–39.

12 Marina Bicchieri et al., 'Microscopic Observations of Paper and Parchment: The Archaeology of Small Objects', *Heritage Science* 7, no. 1 (2019): 1–12, https://doi.org/10.1186/s40494-019-0291-9.

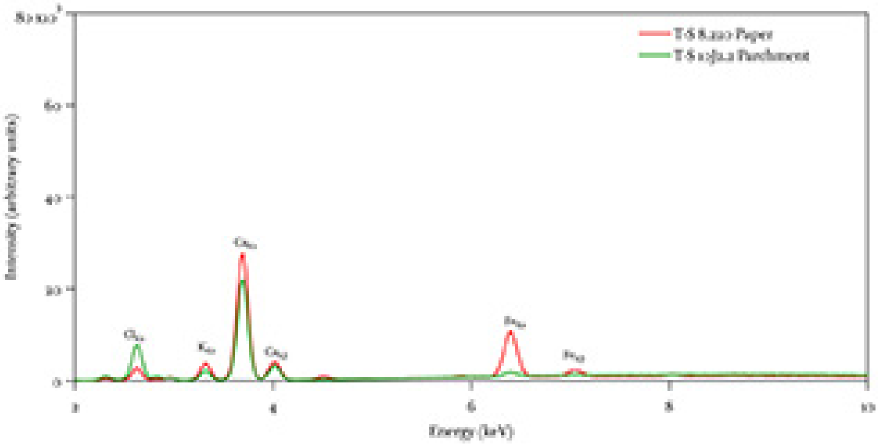


FIGURE 4.14 Typical XRF spectra of the writing surfaces of two manuscripts, T-S 8.220, written on paper (in red), and T-S 10J2.2, written on parchment (in green)

iron in both spectra. In the XRF spectrum of the paper, we observe two strong principal emission K-lines of iron at 6.4 keV and 7 keV for Kα and Kβ, respectively, while the XRF spectrum of the parchment is weak in this energy region. In contrast, the intensities of the peaks of calcium (Ca) – at 3.7 keV for the Kα and 4 keV for Kβ – and that of potassium (K) at 3.3 keV are similar in both spectra. Finally, the intensity of the chlorine (Cl) signal at 2.6 keV is higher in the parchment than in the paper, due to the traditional salting of the skins in the primary step of parchment production.

To illustrate the heterogeneity of some elements, let us have look at the dispersion of their intensity measured under constant experimental parameters. Figure 4.15a and Figure 4.15b contain box-and-whisker charts of the distribution of the relevant elements detected in paper and parchment respectively: calcium (Ca), chlorine (Cl), copper (Cu), iron (Fe), potassium (K), manganese (Mn), lead (Pb) and zinc (Zn). These box-and-whisker charts are a graphical representation of the statistical distribution of these elements in the writing surface. The lower and upper part of the box indicate the lower and upper quartiles of the distribution and are separated in two by the median. The length of the whiskers shows the 10th to 90th percentile range.

Note that the measured values for manganese (Mn), lead (Pb) and zinc (Zn) are scarcely dispersed for either of the writing surfaces, whereas the dispersion of the points for copper (Cu) in paper exceeds that for parchment. However, when it comes to iron (Fe), its sizeable dispersion of points is still much smaller and less spread for parchment (from 1.6×10^4 to 2.3×10^5) than for paper (from

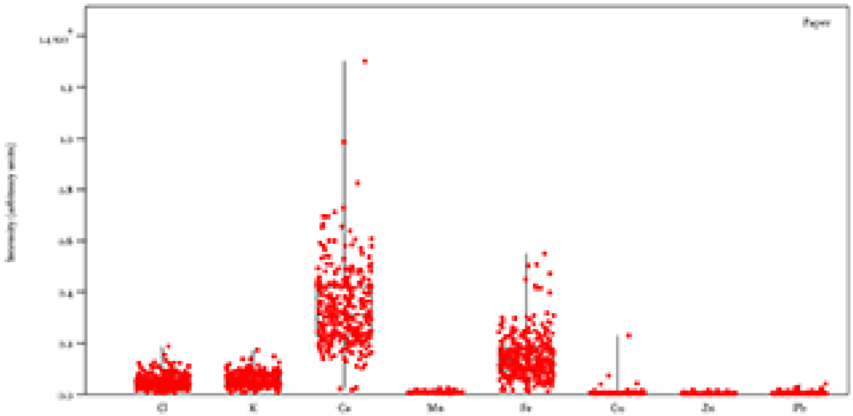
1.3×10^4 to 5.5×10^5). The dispersion of the intensities for calcium (Ca) is large in both cases, and varies substantially; however this variation does not play a big role in the analysis because it was excluded from the fingerprint calculation, since the calcium and the potassium may originate from more than one source. Experimentally, this is reflected by the higher heterogeneity of its signal as compared to that of the main ink element, iron.

Unfortunately, it is rather rare for the literature to provide the measured composition of writing surfaces. It is, therefore, difficult to determine whether the relatively high amount of diverse metallic components in the paper in this study is a local problem of contaminated Genizah documents or if it is a more general one related to the Islamic paper of this period. The heterogeneous dispersion of iron in some of the paper writing supports has made the evaluation of inks belonging to those documents challenging. It also explains why the fingerprint model could not be applied successfully in certain documents, all written on paper[13] (see section 4.3.3.4).

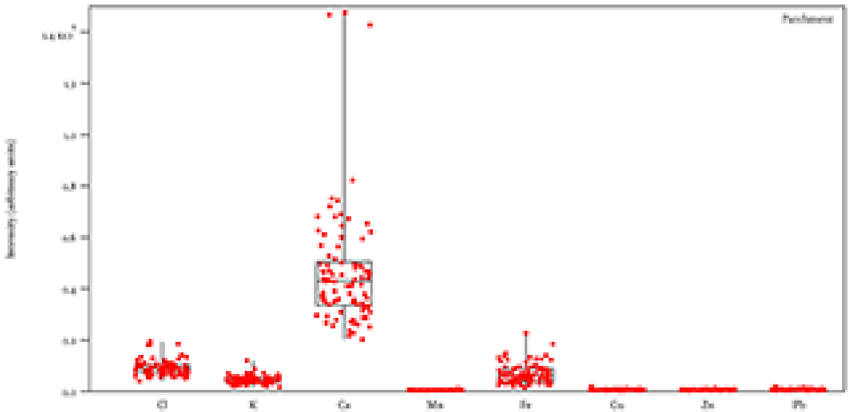
3.2 *Elemental Analysis of the Inks*

After considering the different ink types observed using reflectography in the previous section, let us focus on the composition of the inks, measured using XRF analysis. The final dataset for the XRF analysis consists of 151 classmarks, with 202 documents analysed for a total of 571 regions of interest. The inks studied in this work show high diversity. Let us consider Table 4.9, a version of Table 4.4 modified by adding the results of the XRF measurements. As explained when presenting the first version of this table (Table 4.4), the results of the XRF analysis were at that point used only to differentiate, when it was possible, mixed inks from carbon inks. Now that we need to rely more preceisely on the composition, fewer results are available, but these results allow a discrimination between vitriolic and non-vitriolic iron-gall ink and help in identifying another category of ink, which might be a plant ink. The latter, whose specificity will be presented in detail in section 4.3.3.3 below, was identified as iron-gall ink reflectographically, but presumably did not contain iron contributions except those also contained in the non-inked areas of the support.

13 In order to obtain better results, a possibility would have been to scan those documents using JetStream M6 (Bruker Nano GmbH). This XRF device, mentioned above in section 3.1.3, through element mapping, would have allowed to observe how heterogenous those elements were dispersed on the writing surface. Unfortunately, it was not possible due to the lack of space to host us in the DCU and the complexity of transportation of the device.



4.15a



4.15b

FIGURE 4.15 Composition box-and-whisker plot showing the dispersion of calcium (Ca), chlorine (Cl), copper (Cu), iron (Fe), potassium (K), manganese (Mn), lead (Pb) and zinc (Zn) contained in the support in a) paper and b) parchment

TABLE 4.9 Distribution of the ink type

<table>
<tr><th></th><th></th><th colspan="2">Iron-gall</th><th>Carbon</th><th>Mixed</th><th>Plant?</th><th>Sum</th></tr>
<tr><th></th><th></th><th>Vitriolic</th><th>Non-vitriolic</th><th></th><th></th><th></th><th></th></tr>
<tr><td rowspan="4">Results based on reflectography</td><td>Main text</td><td colspan="2">347</td><td>146</td><td>–</td><td>Not detected</td><td>493</td></tr>
<tr><td>Signatures</td><td colspan="2">248</td><td>124</td><td>–</td><td>Not detected</td><td>372</td></tr>
<tr><td>Additions, corrections</td><td colspan="2">17</td><td>11</td><td>–</td><td>Not detected</td><td>28</td></tr>
<tr><td>Other*</td><td colspan="2">94</td><td>55</td><td>–</td><td>Not detected</td><td>149</td></tr>
<tr><td rowspan="8">Results based on reflectography + XRF</td><td>Main text</td><td>92</td><td>53</td><td>46</td><td>15</td><td>1</td><td>207</td></tr>
<tr><td></td><td colspan="2">145</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Signatures</td><td>113</td><td>88</td><td>56</td><td>33</td><td>5</td><td>295</td></tr>
<tr><td></td><td colspan="2">201</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Additions, corrections</td><td>7</td><td>1</td><td>3</td><td>1</td><td>–</td><td>12</td></tr>
<tr><td></td><td colspan="2">8</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Other*</td><td>26</td><td>17</td><td>13</td><td>–</td><td>1</td><td>57</td></tr>
<tr><td></td><td colspan="2">43</td><td></td><td></td><td></td><td></td></tr>
</table>

*Note: "Other" corresponds to the sum of marginalia, address, vowelling and decoration.

Only 238 of a total of 571 observations display the use of a vitriolic iron-gall ink. The rest of the inks are split between non-vitriolic iron-gall ink (see section 4.3.3.1), carbon ink, mixed ink (see section 4.3.3.2) and probable plant ink (see section 4.3.3.3). Moreover, there were 16 cases in which the heterogeneity of iron in the writing support prevented me from using the fingerprint model to characterise the ink (see section 4.3.3.4). Since the fingerprint model relies on comparing the characteristic concentration of the vitriolic metallic components, it is not usually used to compare the composition of the other categories of inks. Although the category of mixed inks should also be excluded from the study of the composition because we are not able to identify the presence of organic compounds other than carbon, they are included here for the composition of their inorganic part and the nature of these mixed inks which are, in my opinion, mostly a mixture of carbon and iron-gall inks. Similarly, the cases of non-vitriolic iron-gall ink have been included as well, in order to observe if they are used in a specific part of the corpus.

In addition to the metallic elements copper (Cu), manganese (Mn) and zinc (Zn) attributable to the vitriol, I found the occasional presence of lead (Pb) although no lead is present in vitriol and its presence is probably due to contamination in the water used to prepare the ink.[14] The characteristic ratios of these four elements (Cu, Mn, Zn and Pb) to iron were used in the fingerprint model. Generally, elements showing a ratio to iron of below 3% are considered as traces, while elements displaying a ratio below 2% are not considered at all. I conducted an analysis of the element profiles within each line scan as a routine check of the correct attribution of a metallic element to the ink. Overall, I treated 1,802 spectra in this way.

Copper is the most common element in the iron-gall inks found in this corpus, with relative amounts compared with iron varying from 0% to 36%. The relative amount of manganese varies between 0% and 15% and the relative portion of zinc goes from 0% to 7%. Lead varies up to 15%.

Let us have a closer look at the fingerprints collected during this project and compare them to each other. Because manganese and copper show the greatest variation, I have used them to cluster the fingerprints.

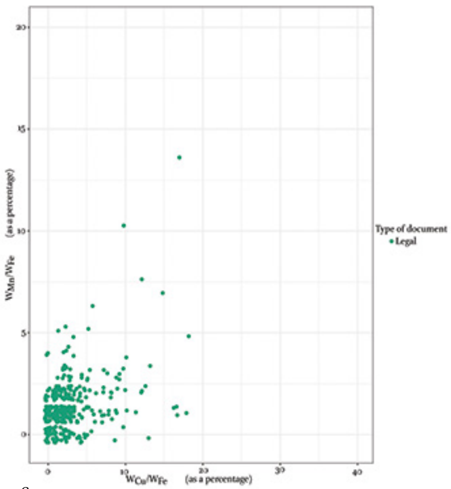
3.2.1 Presentation of the Fingerprint

Figure 4.16 presents all the comparable fingerprints analysed; that is, the fingerprints of iron-gall inks and of inks that were detected as mixed inks. Iron-gall inks that lack the characteristic vitriolic components, so called "non-vitriolic", are shown around the 0,0 position in the graph (see section 4.3.3.1 for further explanations).

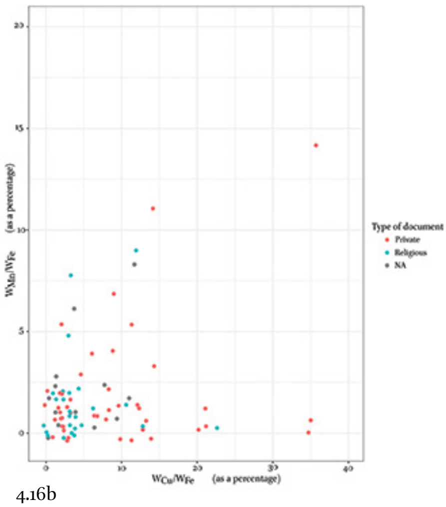
On the abscissa, the relative amount of copper (Cu) is indicated, normalised to iron, showing a variation from 0% to 36%. On the ordinate, the amount of manganese (Mn), normalised to iron, is indicated, varying from 0% to 15%. Dots of different colours indicate the type of document analysed: legal, private, religious or non-identifiable. No documents from the 'official' category are presented here since they were all written with carbon ink.

Since the number of observations for the legal documents is very high and obscured the reading of the plot, we decided, for clarity, to separate the data into two different plots: one for the legal documents in Figure 4.16a and another plot for the rest of the data in Figure 4.16b.

14 It should be noted, however, that this hypothesis has no resonance in the scientific literature. We have found so far nothing to corroborate or invalidate this hypothesis, especially since all the literature we have found refers to the archaeological documents from a rather different epoch. However, there are few sources of contamination that can be connected to the composition of the ink to this extent (following exactly the same pattern as the iron) and be present in the ink in such large proportions (up to 15% as it will be mentioned afterwards) and water seems to us to be the most plausible.



4.16a



4.16b

FIGURE 4.16 Fingerprint values w(i)/w(Fe) (i = Cu or Mn) obtained by XRF analyses for a) legal documents b) religious, private and for "NA" which indicates that data on the type of document is not available. Green dots correspond to the ink used in legal documents, orange dots to the inks used in private documents, purple dots to those in religious texts and grey dots to those on documents where data was not available.
Notes: As several points had an identical position, we added a small random variation to the location of each point, to avoid overplotting. This gives the impression that certain points have a negative position and therefore that the fingerprints could have negative amounts of these metallic components, which is not the case

The inks on legal documents, symbolised by green dots, appear most frequently with 271 fingerprints. This is unsurprising, since in order to see if an ink could be linked to a specific scribe, and due to the high numbers of hands involved in the writing of legal documents, most of the analyses carried out in this study concerned legal documents. The majority of the inks used in legal documents vary between 0% and 15% in their copper ratio and between 0% and 7% in their manganese ratio. Results specifically on legal documents will be presented in the next chapter, in section 5.1.

With 45 observations, private documents constitute the second-largest group, represented by orange dots. Based on Figure 4.16b, it seems that the inks used to write private documents are primarily clustered into two groups: one with about 10% of copper and no manganese, and one with the same amount of copper and about 5% of manganese. The remaining fingerprints do not seem to be clustered into a group, however further investigation is needed, focusing more closely on the main scribe or the place of writing.

Finally, the category of the religious documents is constituted of 28 fingerprints, represented by purple dots. Most of them show a concentration of copper (Cu) between 0 and 5% and a low amount of manganese (Mn). But, as emphasised above, further research is necessary before clustering them.

3.2.2 Fingerprints Clustered by the Main Scribe

Figure 4.17 studies the relationship between copper (Cu) and manganese (Mn) in the fingerprints of documents assigned to the main scribes. On the abscissa, the amount of copper is indicated, normalised to iron. On the ordinate, the amount of manganese is given, normalised to iron. The graph includes a total of 69 fingerprints. Different colours were used to represent the scribe using the ink in question. The amount of copper varies between 0% and 35%, while the amount of manganese varies from 0% to 5%. The non-vitriolic inks are surrounded by a red circle.

Figure 4.17 shows that there is no simple correlation between a scribe and an ink of a single fingerprint. For instance, Solomon b. Judah, from the Palestinian *yeshiva* of Jerusalem, used ten of the inks presented here. Six of these are quite similar, with no manganese but an amount of copper varying between 10% and 13%; a further two inks also have no manganese, but contain some 20% of copper; and the two final inks are non-vitriolic.

Yefet b. David with his large scribal production, seems to have been using three different kinds of ink: one containing a low amount of copper and of manganese, the second ink containing less than 5% of copper and an amount of manganese between 2% and 4%, and the third one containing no manganese but about 15% of copper. We will have a closer look specifically at the scribal production of Yefet b. David in the next section.

The data gathered about the iron-gall inks used by other scribes was not sufficient to even attempt a reliable clustering of the inks: we observe a great spread over all possible compositions.

3.2.3 The Case of Yefet b. David

Of all the scribes that we were able to analyse in this study, Yefet b. David is the one with the largest writing production. Due to his largely identified participation in legal documents, he is also the scribe with the largest number of dated documents. One of the questions raised during this study was whether an individual scribe might be identifiable on the basis of the composition of the inks he used, or if the composition of the ink could allow us to discriminate between types of document. A similar study has been conducted using PIXE analysis on Galileo's letters,[15] and through the comparison of the ink finger-

15 Giuntini et al., 'Galileo's Writings'; Piero Del Carmine et al., 'Further Results from PIXE Analysis of Inks in Galileo's Notes on Motion', *Nuclear Instruments and Methods in Physics*

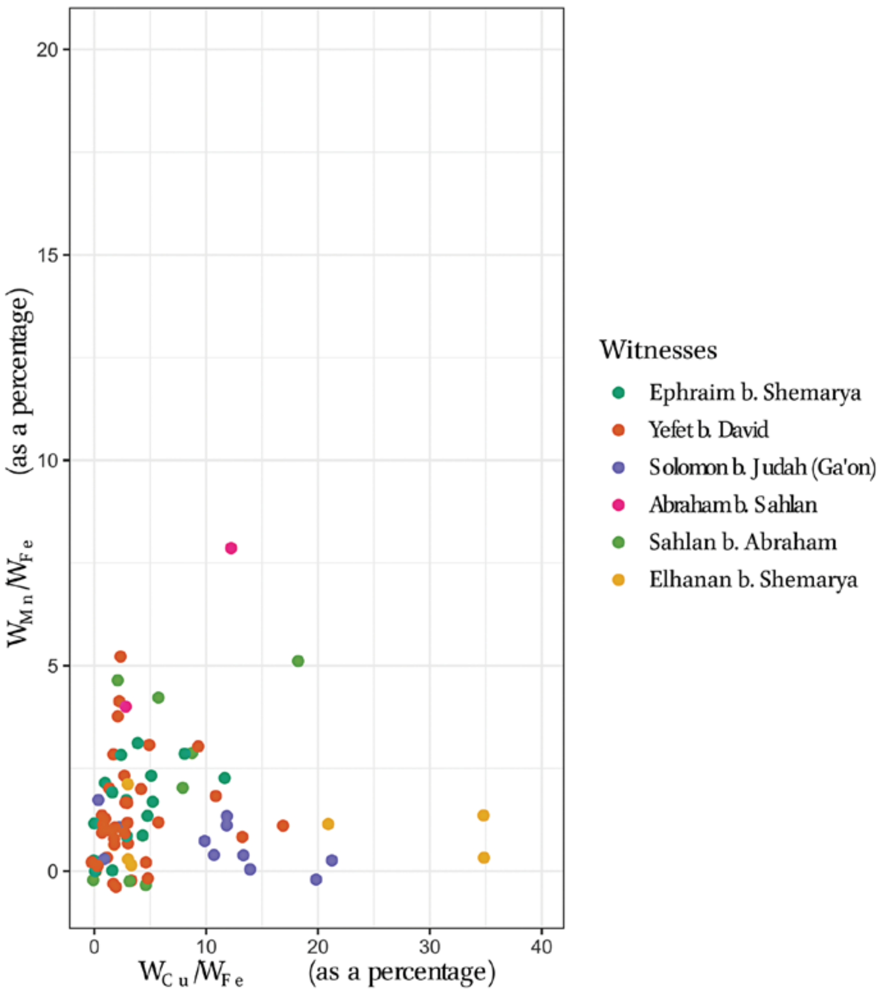


FIGURE 4.17 Fingerprint values w(i)/w(Fe) (i = Cu or Mn) obtained by XRF analyses. Green dots correspond to the inks used by Ephraim b. Shemarya, orange dots correspond to those used by Yefet b. David, purple dots to those used by Solomon b. Judah, pink dots to those used by Abraham b. Sahlān, khaki dots to those used by Sahlān b. Abraham and yellow dots to those used by Elḥanan b. Shemarya.
Notes: As several points had an identical position, we added a small random variation to the location of each point, to avoid overplotting. This gives the impression that certain points have a negative position and therefore that the fingerprints could have negative amounts of these metallic components, which is not the case

prints of undated documents with dated ones, studies of Galileo's manuscripts have narrowed down the chronology of his writing. I was, therefore, interested to see if we could obtain similar results on at least one of the scribes in this study. I have chosen Yefet b. David due to his extensive writing and his no less extensive use of iron-gall inks.

Figure 4.18 presents the fingerprint of the inks used by Yefet b. David. Legal documents, represented by green dots, constitute the majority of the fingerprints on the graph. The single private document, a letter, is represented by an orange dot and contains around 13% of copper. Different symbols indicate the status of the text written with each ink: marginalia, signature and main text. Most of the legal documents in the figure display three main ink compositions. A large group of documents was written with non-vitriolic iron-gall ink with a 0,0 nominal fingerprint indicated by the red circle, while the second-largest group, within the blue circle, is formed by 4–5% of copper and no manganese. The third one shows a fingerprint containing about 3–4% of copper and traces of manganese, within the green circle. The rest of the inks appear to be outliers.

We can see that only some of the inks used by Yefet b. David can be clustered on the basis of their fingerprints. Let me remind the reader that the same recipe does not necessarily lead to the same ink (as explained in II.2.6). We generally assume that a single composition corresponds to a single writing phase while similar fingerprints correspond to the same ink prepared in different batches. Since most of the fingerprints within any individual document written by Yefet b. David were rather homogeneous, it seems that despite the fact that ink analyses cannot be used for absolute dating, it is sometimes possible to determine the chronology of certain documents using ink composition, as was done in the case of Galileo's documents. The hypothesis would, therefore, be that documents written with the same ink would have been penned with the ink from a single ink batch. To check whether this type of dating might also be possible in the case of Yefet b. David, whose scribal production contains dated and undated documents, I have checked whether the dated documents can be correlated.

Figure 4.19 shows the fingerprint of the inks used by Yefet b. David, both to sign and to write documents, in chronological order. The documents are arranged in ascending order from 1007 to 1053; the remaining documents,

Research Section B: Beam Interactions with Materials and Atoms 113, no. 1–4 (1996): 354–58, https://doi.org/10.1016/0168-583X(95)01335-0; Franco Lucarelli and Pier Andrea Mandò, 'Studying the Chronology of Galileo's Writings with PIXE', *Nuclear Physics News* 6, no. 2 (1996): 24–31, https://doi.org/10.1080/10506899609411075.

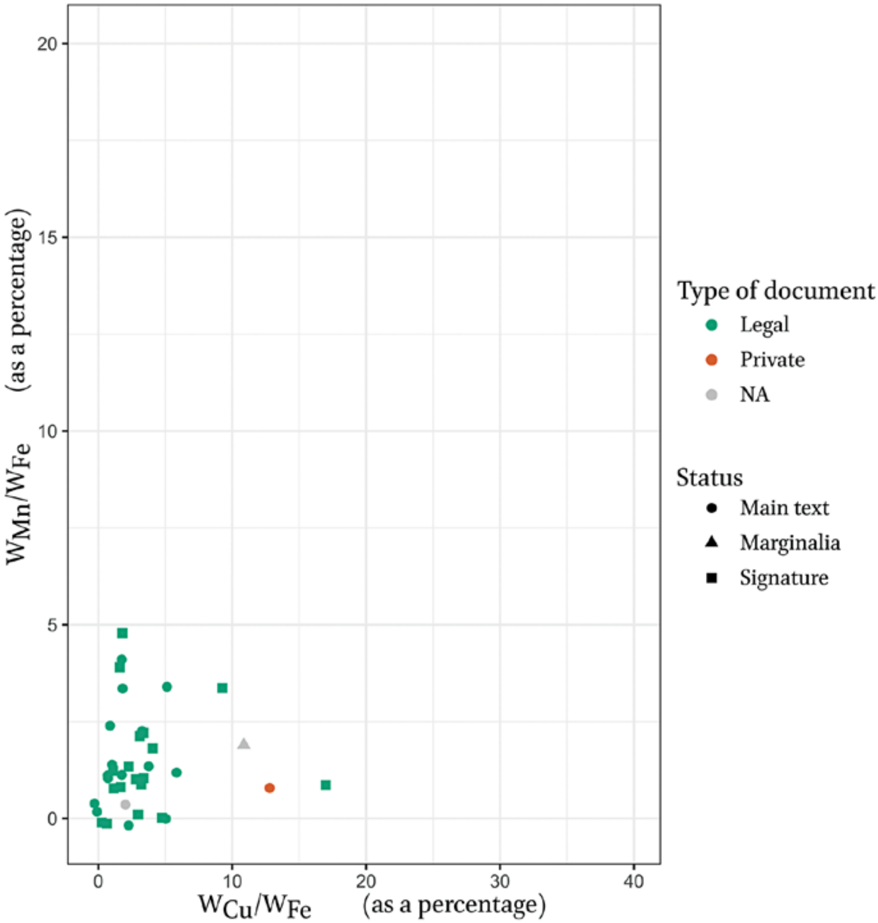


FIGURE 4.18 Fingerprint values w(i)/w(Fe) (i = Cu or Mn) obtained by XRF analyses, showing the characteristic fingerprints of different iron-gall inks used by Yefet b. David. Use of different colours sorts the documents according to their type: green for legal, orange for private and grey for those for which data is not available (NA). The use of different symbols distinguishes inks according to their purpose: circular dots for the main text, triangles for marginalia and squares for signatures.
Note: As several points had an identical position, we added a small random variation to the location of each point, to avoid overplotting. This gives the impression that certain points have a negative position and therefore that the fingerprints could have negative amounts of these metallic components, which is not the case

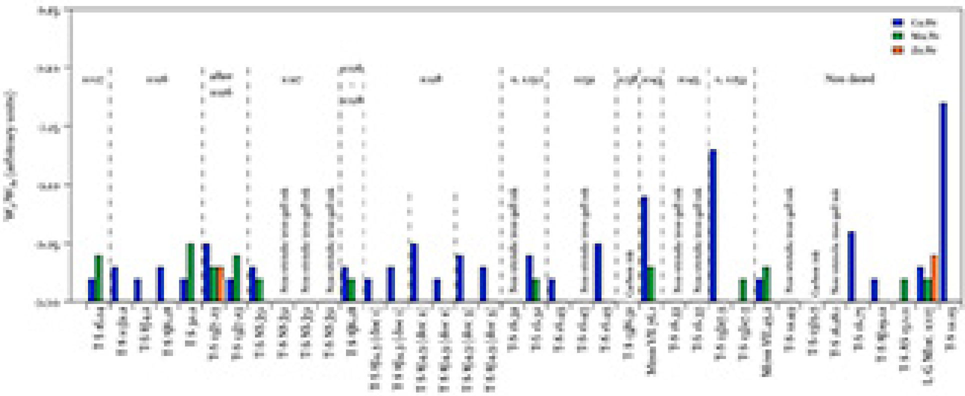


FIGURE 4.19 Fingerprint values w(i)/w(Fe) (i = Mn, Cu, or Zn) obtained by XRF analyses on the different inks used by Yefet b. David, plotted in chronological order

presented on the right, are undated. The fingerprint displays the elements manganese (Mn), copper (Cu) and zinc (Zn), all normalised to iron. On the abscissa, the classmarks of the documents are indicated. There are 38 inks presented here, the total of Yefet b. David's scribal production that was analysed using both XRF and reflectography. The two carbon inks analysed here do not display any of the vitriolic satellites of iron; and mixed inks have been detected among the inks used by Yefet b. David. Nine of the inks used by Yefet b. David are non-vitriolic iron-gall inks, and unfortunately our current protocol does not include comparison of inks that have no metallic components other than iron. Summarising, we see that Yefet b. David used quite different inks over the long period of time displayed here. Within each shorter period of time, he used inks of the same type (iron-gall ink), but not necessarily of the same composition. But often, a document written with a vitriolic iron-gall ink in a single time period displayed the same ink composition for different use, suggesting that they were written in a single go or at least while using the same batch of ink (e.g. T-S 8J4.3 document 1 to document 3, quite likely the document T-S 13J7.23 which presents variation taking into account the 10% margin of error allowed by the model). This might be an indication that if we had a larger number of documents from each point in time we would have been able to build a chronology based on the use of different batches, as has been done for the documents of Galileo.

The question of material studies is often tied to questions of date, attribution and origin. One of the questions raised during this project was whether one could relate the production of a document to a specific author or date or community or place by drawing on the results obtained here, either the fingerprints or the use of specific and characteristic materials. Such a question was based on the assumption that scribes would make their own inks that would be easily identifiable. Alternatively, another assumption, namely that the Jewish communities in Fusṭāṭ were quite separated, required testing whether their documental production could be easily identified by the means of material analysis. However, the results of this work clearly show that the Palestinian and Babylonian communities used the same inks (see e.g. Figure 4.10 and Figure 4.12). It seems appropriate at this point to outline a new and important hypothesis: scribes did not prepare their own inks but purchased them. Moreover, it seems that in most cases they were not aware of the specific composition of the ink. This conjecture is supported by the extremely complex dependencies presented in the conditional inference tree for the use of different types of ink that was presented in Figure 4.13.

3.3 *Other Inks*

3.3.1 Non-vitriolic Iron-gall Ink

Of the compositions that were obtained during the analyses of the 202 documents, a total of 77 documents have shown an ink with a fingerprint containing iron as the only metallic component (either in the main text or in an other region of interest). This absence of other metallic components – present as companions in the vitriol – seems to prove that ways of obtaining the iron necessary to produce iron-gall ink other than by using vitriolic salts existed in the Middle Ages. Similar has already been found in the study of a corpus of early Coptic manuscripts.[16] In fact, some medieval recipes, given for example by al-Marrākushī[17] and al-Qalalūsī,[18] list the use of iron filings, with and without vitriol. Iron filings are still used in ink production today,[19] with the recipes sometimes transmitted only orally;[20] this is probably done to circumvent the difficulty of obtaining vitriol.

The use of iron filings in a Jewish context and their mention in Arabic recipes shows a connection between Jews and the societies that are hosting them. This link has been shown theoretically by Zerdoun based on the ink recipes given by Maimonides and by Rashi (see discussion in section 2.2.4), similar

16 Ghigo et al., 'An Attempt at a Systematic Study of Inks from Coptic Manuscripts'.
17 Colini, 'From Recipes to Material Analysis the Arabic Tradition of Black Inks and Paper Coatings (9th-20th Century)', 81–82.
18 Colini, 88–89.
19 Biddle, 'Inks in the Islamic Manuscripts of Northern Nigeria: Old Recipes, Modern Analysis and Medicine', 14–16.
20 Colini, 'From Recipes to Material Analysis the Arabic Tradition of Black Inks and Paper Coatings (9th-20th Century)', 94.

to the ones known and used at the same time in their regions by non-Jewish scribes. Analytical results have come to confirm this.[21]

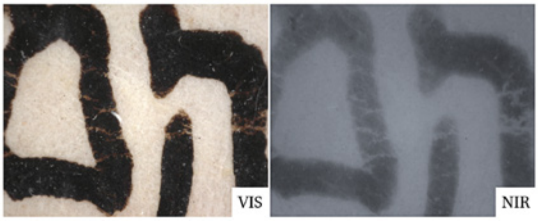
The examples of iron-gall inks in the present corpus that contain iron as the only metallic component show the features seen in Figure 4.20a, which presents manuscript T-S 12.49. This manuscript is a *ketubah* written during the middle of the 11th century by Yefet b. David, and was signed by at least five other people (the document is fragmentary). Figure 4.21 displays primarily the results based on the signature of Sahlān b. Abraham, but all the spots measured on this document possess the same properties. The reflectography, Figure 4.20b, shows that the ink loses opacity under NIR light, which is characteristic of iron-gall inks. Figure 4.20c represents the XRF spectra of the support, represented in red, and different spots of inks in the manuscript, represented in black, with different types of dashing depending on the precise spot. Comparing the different spectra, it is possible to see that, besides iron which increases significantly when ink is present, none of the spectra of the inks differ greatly from that of the support when it comes to metallic vitriolic components. Indeed, all the spectra display two peaks at 6.4 keV for Kα and 7 keV for Kβ, the principal emission K-lines of iron, where they increase significantly from the support to ink. But no difference can be seen when it comes to manganese (Mn) or copper (Cu): the peaks, at 5.9 keV and at 8 keV respectively, display the same intensity on all spectra, showing the absence of these elements in both support and inks. The intensity of the calcium (Ca) peaks – at 3.7 keV for Kα and 4 keV for Kβ – and that of potassium (K) at 3.3 keV also increase in the inks compared to the support.

Figure 4.21 displays the intensity profile of the ink used specifically for the signature of Sahlān b. Abraham in this manuscript, showing the profile for the elements iron (Fe) and potassium (K). These values are extracted from a 40-point line scan, with the first 20 points on the parchment and the later 20 points on the ink. This ink, as was seen in Figure 4.20c, contains only iron. Moving from the parchment to the ink, the amount of iron increases significantly (seen in red). The values for the potassium (in purple) display the same pattern as the iron only in the portion of the graphic corresponding to the ink; this shows that the ink contains potassium in addition to iron. No other elements that were detected displayed the same behaviour.

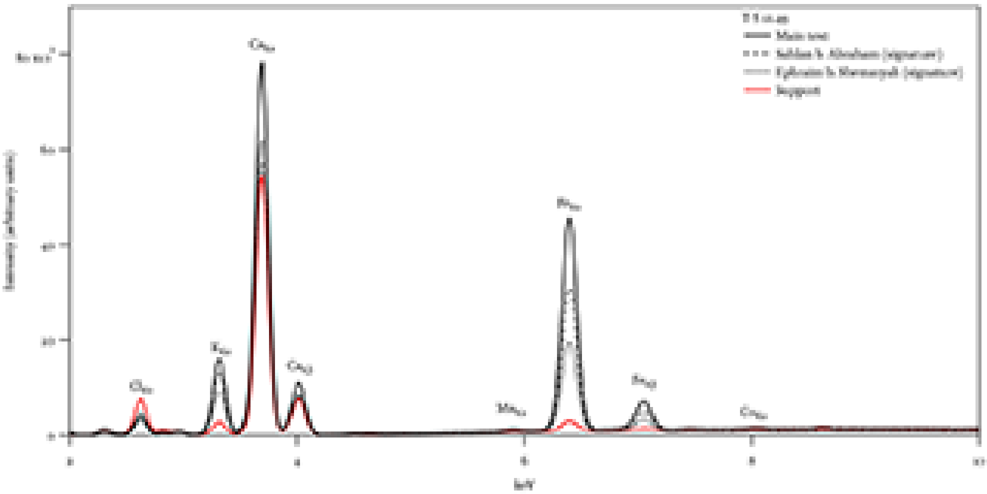
In addition to the inks that present a total lack of vitriolic satellites of iron, I also considered as being among the non-vitriolic iron-gall inks those few inks that present manganese in small quantities. Indeed, it has been reported that

21 Rabin, Hahn, and Binetti, 'Inks used in medieval Hebrew manuscripts: a typological study'; Rabin, 'Building a Bridge'.

4.20a



4.20b



4.20c

FIGURE 4.20 Presentation of the manuscript T-S 12.49; a) photograph of the manuscript reproduced by kind permission of the Syndics of Cambridge University Library, b) VIS/NIR imaging of the inks, and c) a portion of the XRF spectra corresponding to the ink (in black) and the support (in red)

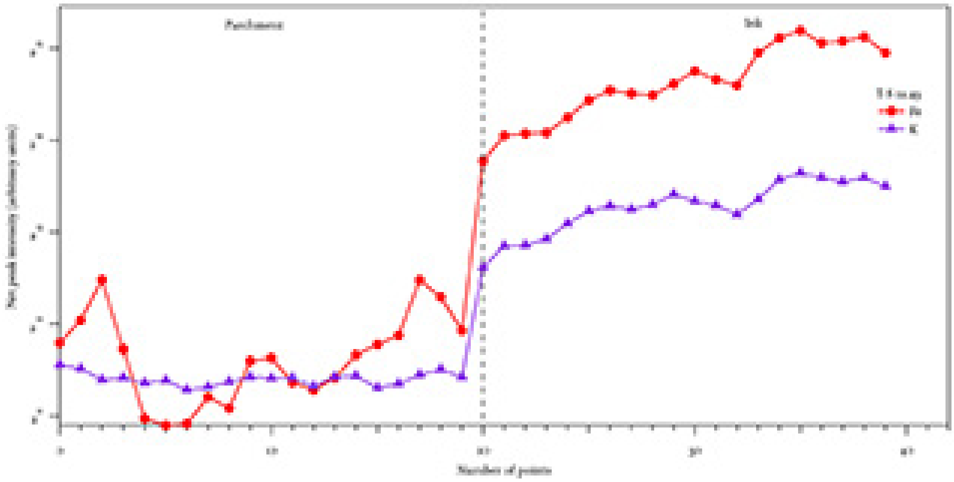


FIGURE 4.21 Intensity profile of the ink used in the signature of Sahlān b. Abraham and the support from manuscript T-S 12.49, showing the profile of the elements potassium (K, purple) and iron (Fe, red)

the use of iron filings is marked by the presence of manganese in small quantities, for both a corpus of early Coptic manuscripts and for a corpus made of mock-ups of Arabic treatises.[22]

Adding together the iron-gall inks with no vitriolic satellites of iron and the iron-gall inks with a very low concentration of manganese, there are 169 instances of use of inks with this composition. From a closer consideration of non-vitriolic inks, we can conclude that they were fairly common during the period under investigation, and indeed that their use was not limited to Fusṭāṭ, since they are well attested in documents that originated from other cities in Egypt (Alexandria, Malij) and also from cities in Tunisia (Kairouan, Zawilat al-Mahdiyya) and Lebanon (Tyre). In addition to these observations about location, there are a high number of legal documents written with non-vitriolic iron-gall ink.

22 Colini, 'From Recipes to Material Analysis the Arabic Tradition of Black Inks and Paper Coatings (9th-20th Century)', 112; Ghigo et al., 'An Attempt at a Systematic Study of Inks from Coptic Manuscripts'.

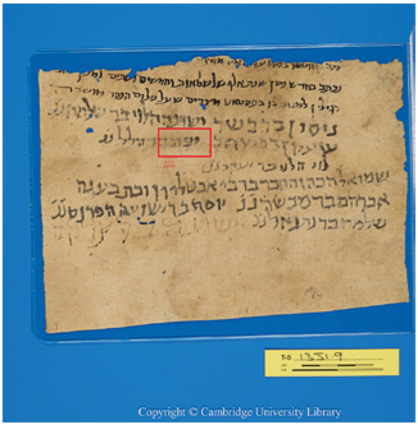
3.3.2 Mixed Inks

Even if ink recipes written during this time period frequently mention mixed inks, not much research has been done thus far to investigate this subject. However, during the exploration of the present corpus, one could not help but recognise that some of the inks used in the corpus were mixed inks. These inks possess characteristic features of both carbon inks and iron-gall inks. Like carbon inks, they do not disappear under NIR light, during reflectography analysis; like iron-gall inks, they possess at least twice as much iron as the substrate.

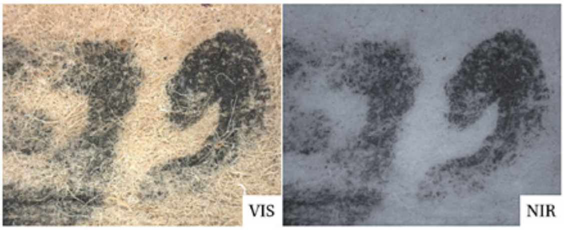
The ink of T-S 13J1.9, presented in Figure 4.22a, shows an example of this. The main text of this manuscript is written with a normal iron-gall ink, whereas all the signatures would initially seem to be executed in carbon ink: compare the images under visible and near-infrared illumination in Figure 4.22b for the signature of Yefet b. Hillel. In contrast, the XRF spectrum of these signatures show a large amount of iron in the ink, as can be seen for Yefet b. Hillel's signature in Figure 4.22c.

In Figure 4.22c, the ink in the signature of Yefet b. Hillel shows a high concentration of iron, greatly exceeding the iron detected in the support and similar in intensity to the iron in the ink of the main text, which is an iron-gall ink. This mixed ink, however, does not show any metallic components in its composition other than iron, if we ignore the slight increase in manganese (Mn) at 5.9 keV. The presence of copper (Cu) at 8 keV and of zinc (Zn) at 8.6 keV are visible only in the spectrum of the main text and not in the signature of Yefet b. Hillel. This absence of zinc and copper and the insignificant presence of manganese (probably coming from nails or iron filings) are consistent with the description of non-vitriolic iron-gall inks in the previous section. The ink used by Yefet b. Hillel to sign T-S 13J1.9 is therefore a mixed ink, consisting of a mixture between a carbon ink and a non-vitriolic iron-gall ink, as can be seen in Figure 4.23.

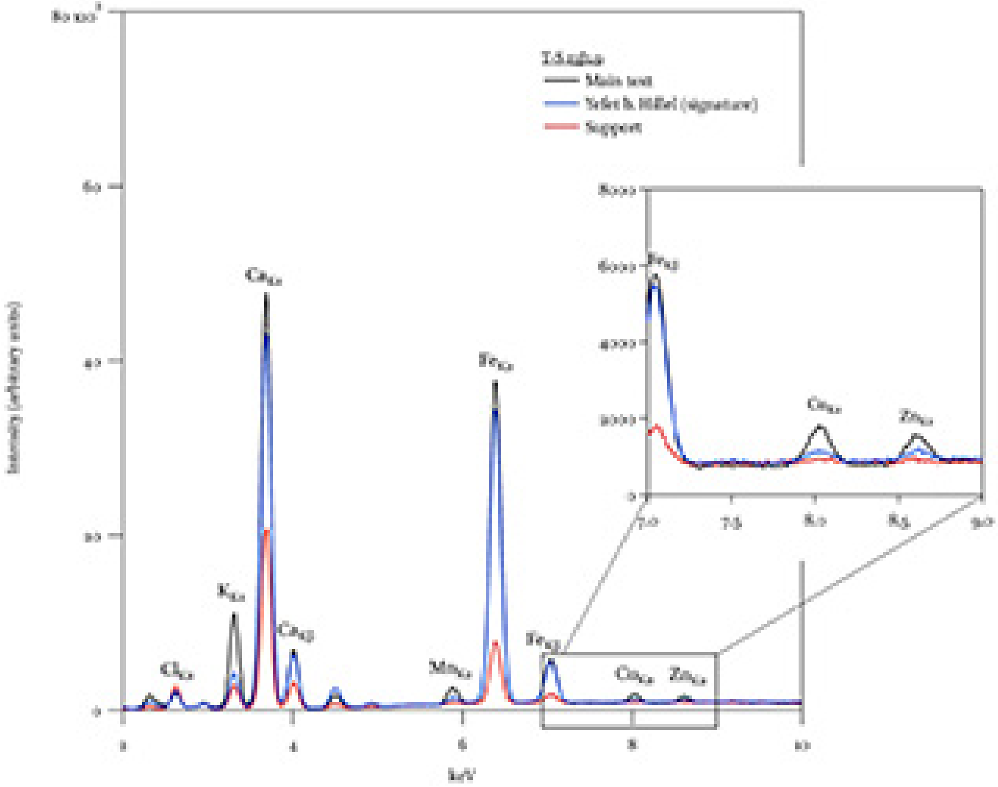
Figure 4.23 displays the intensity profile of the ink used by Yefet b. Hillel to sign the legal documents. The values are extracted from a 30 points line scan, with 10 points measured on the support, 10 additional points in the ink and the 10 last ones again in the support. This ink contains mostly iron (Fe, seen in red), although the values for the manganese (Mn, in green) seem to slightly increase as well when passing in the ink (see the comments on the increase of manganese in case of non-vitriolic iron-gall ink in the previous section). No other vitriolic elements have been detected in this ink.



4.22a



4.22b



4.22c

FIGURE 4.22 Presentation of the manuscript T-S 13J1.9; a) photograph of the manuscript reproduced by kind permission of the Syndics of Cambridge University Library, b) VIS/NIR imaging of the signature of Yefet b. Hillel, and c) a portion of the XRF spectra corresponding to the ink of the main text (in black), the signature of Yefet b. Hillel (in blue) and the support (paper, in red)

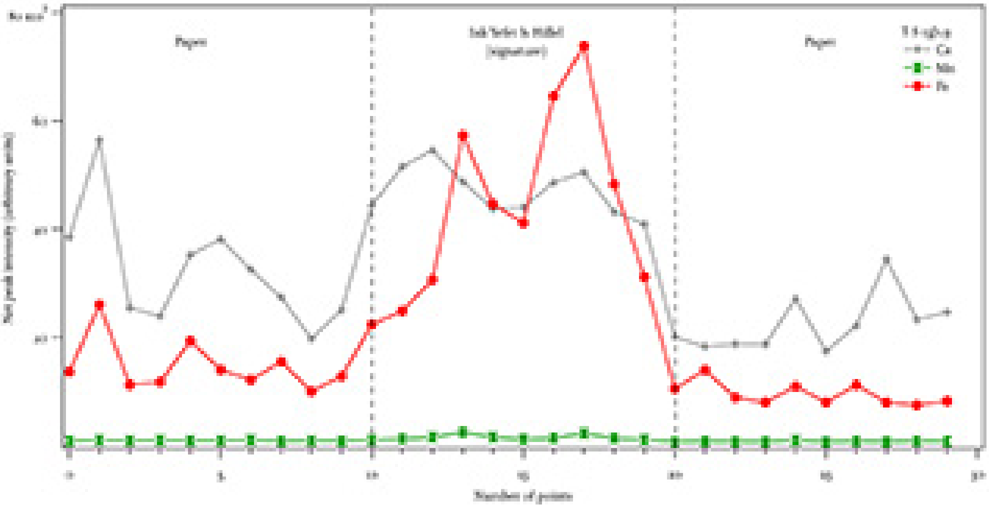
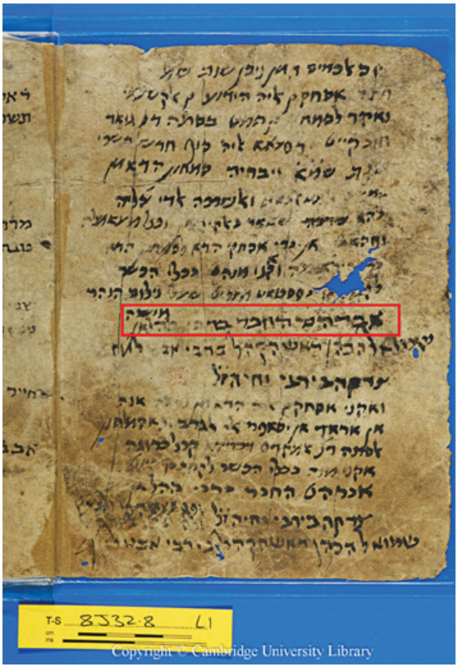


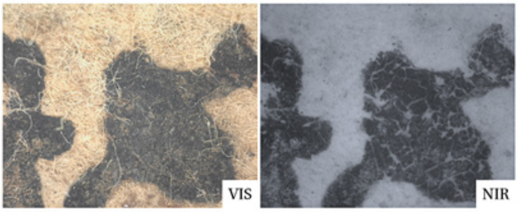
FIGURE 4.23 Intensity profile of the signature ink of Yefet b. Hillel from manuscript T-S 13J1.9, showing the profile of the elements calcium (Ca, grey), manganese (Mn, green) and iron (Fe, red)

Other mixed inks detected in the corpus also contain copper and a higher amount of manganese – for example, the signature of Abraham b. Sahlān in manuscript T-S 8J32.8 (Figure 4.24a). The micrograph (see Figure 4.24b) of this signature shows in NIR an ink that does not lose opacity, a characteristic feature of a carbon-based ink. However, the XRF spectrum of the signature, shown in Figure 4.24c, displays a high peak of iron, and also higher concentrations of manganese and copper compared to the intensities from these elements in the support.

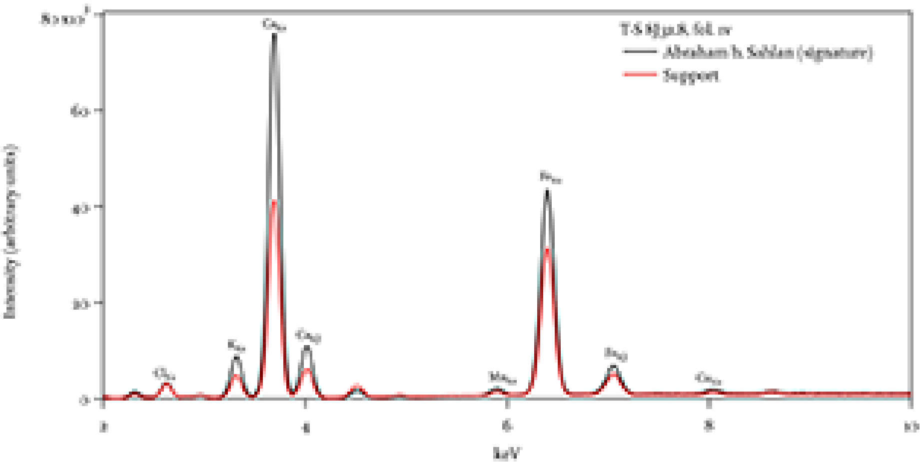
The study of a line scan of this same document, moving from the support to the ink of the signature, is also very characteristic of iron-gall inks. Figure 4.25 displays the intensity profile of the elements potassium (K), manganese (Mn), iron (Fe) and copper (Cu). The measurements have been taken along a 20-point line scan connecting the support to the signature ink of Abraham b. Sahlān (shown above in Figure 4.24c). The ten first points in Figure 4.25 show the profile measured on the paper, and the following ten on the ink. When passing to the ink, the amount of iron (Fe) displays a net increase, connected with an increase of manganese (Mn), copper (Cu) and potassium (K). From the similarity of the profiles, it can be seen that all these elements are connected to the ink.



4.24a



4.24b



4.24c

FIGURE 4.24 Presentation of the manuscript T-S 8J32.8, fol. 1v; a) photograph of the manuscript reproduced by kind permission of the Syndics of Cambridge University Library, b) VIS/NIR imaging of the signature of Abraham b. Sahlān, and c) a portion of the XRF spectra corresponding to the ink of the signature of Abraham b. Sahlān (in black) and the support (in red)

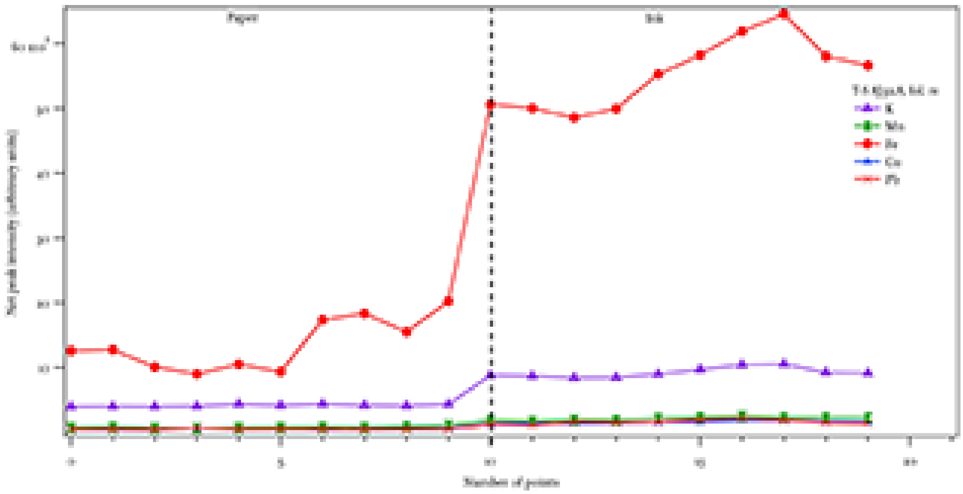


FIGURE 4.25 Intensity profile of the signature ink of Abraham b. Sahlān from manuscript T-S 8J32.8, showing the profile of the elements potassium (K, purple), manganese (Mn, green), iron (Fe, red) and copper (Cu, blue)

TABLE 4.10 Distribution of detected mixed inks in the corpus

Ink type	Main text	Signatures	Corrections, additions	Other*	Sum
Mixed	15	33	1	–	49

*Note: "Other" corresponds to the sum of marginalia, address, vowelling and decoration.

In the corpus there are 49 occurrences of mixed inks, ranging from mixed inks containing iron as the only metallic component to mixed inks with 10% of copper (Cu) and 10% of manganese (Mn) (remembering that amounts less than 2% of an element are not considered relevant). Looking more closely at when mixed inks were used, summarised in Table 4.10, the number of signatures is easily noticeable.

Table 4.10 shows that the majority of the mixed inks that were detected are used in signing the documents. The question of the large difference between the number of observations of mixed inks for signing and for writing documents was raised above, in section 4.2.1, when discussing Figure 4.7. Once again, let us remember that at least part of this difference can be explained by the bias in the data gathered: more legal documents were studied, which means that more mixed inks can be detected in the signatures of those legal documents. However, looking at the composition of these mixed inks in more detail, one can observe that many of these mixed inks were used to sign legal documents which additionally often contained both iron-gall ink and carbon ink. Moreover, each of these mixed inks presents a fingerprint with the same concentrations as the iron-gall ink used within the same document, regardless of whether the ink used in the document was vitriolic or not.

An example can be given from manuscript T-S 13J1.9, presented above in Figure 4.22. In addition to the main text, the document holds ten signatures of ten different witnesses. Two of the inks used in the document are iron-gall inks, one is a carbon ink, and eight of them are mixed inks, recognisable by the high amount of iron in the ink.

TABLE 4.11 Description of the results obtained through reflectography and XRF analyses on manuscript T-S 13J1.9. The concentration of the elements is obtained by normalising each element to iron, after subtraction of the support. Results are given in percentages

Status	**Name**	**Type of ink**	**Fingerprint**		
			Cu	**Mn**	**Zn**
Main text	?	Iron-gall ink	Trace	5%	Trace
Signature	Yeshu'a b. Tsedaqa	Iron-gall ink	–	–	–
Signature	Nissim b. Bishr	Mixed ink	–	–	–
Signature	Yeshu'a ha-Levi b. Solomon	Mixed ink	Trace	Trace	–
Signature	Sha'yun b. Isaac	Mixed ink	–	–	–
Signature	Yefet b. Hillel	Mixed ink	–	Trace	–
Signature	Levi ha-Levi b. Jacob	Mixed ink	–	–	–
Signature	Samuel ha-Cohen b. Avtalyon	Mixed ink	–	Trace	Trace
Signature	Abraham b. Mevasser	Carbon ink	Carbon ink	Carbon ink	Carbon ink
Signature	Joseph b. Yeshu'a ha-Parnas	Mixed ink	–	Trace	–
Signature	Solomon b. Nathaniel	Mixed ink	–	–	–

Note: "Trace" indicates more than 2% but less than 3%.

Table 4.11 presents the results gathered used both reflectography and XRF analyses on manuscript T-S 13J1.9. The main text of the manuscript is written with a non-vitriolic iron-gall ink. Of the ten signatures validating the document, one is written with a carbon ink, one with an iron-gall ink and the rest with a mixed ink containing no vitriolic metallic components other than iron (Fe), or only as traces. Traces of zinc (Zn) have been found in only one of the signatures.

While it is impossible to measure the intention behind the choice or the making of such mixed inks, it is remarkable that several of these inks are used on similar occasions. Given the impossibility, with the methods used in this study, to detect tannins, it was not possible to differentiate carbon inks with an addition of metal from a mixture of these two types of inks (carbon ink and iron-gall ink). Further investigation should be therefore done before confirming these results. However, as the mixed inks present in each case a similar pattern to the iron-gall ink of the same document, it seems to me most probable that they are a mixture between two different inks: iron-gall ink and carbon ink. In my opinion, the mixed ink has been created by dipping accidentally a contaminated quill in an inkwell containing another ink type. More details on this can be found in the next chapter when focusing on legal documents.

These observations, however, cover only the mixed inks that have been detected. In addition to ink which has been identified as carbon ink but was not analysed by using XRF but only through reflectography, and which may therefore actually be mixed ink, it is also possible that other types of mixed ink exist in this corpus and that, due to the techniques used to characterise the inks during this study, it was not possible to detect all of them. The only type that could be detected with the available techniques was the type described above, and depending on the type, different methods would have been necessary to detect all of them properly. For example, as tannins could not be detected with the techniques at our disposal, it was not possible to detect carbon inks to which tannins had been added. Mass spectrometry would seem to be a promising technique to remedy this issue.[23]

23 Tea Ghigo, Ira Rabin, and Paola Buzi, 'Black Egyptian Inks in Late Antiquity: New Insights on Their Manufacture and Use', *Journal of Archaeological and Anthropological Sciences* 12 (2020), https://doi.org/10.1007/s12520-019-00977-3.

3.3.3 Plant Inks?

Even if it is not easily distinguishable, one can see a shadow under NIR light in Figure 4.26b, following the same pattern as the ink, a characteristic sign of iron-gall ink. However, characteristic of a carbon ink or a plant ink, no addition of iron can be detected when passing from the support to the ink, as can be seen on the XRF spectra presented in Figure 4.26c. There is no noticeable difference between the two spectra lines, when it comes to metallic components, neither for the two principal emission K-lines of iron (Fe) at 6.4 keV for Kα and 7 keV for Kβ, nor for the peak of manganese (Mn) at 5.9 keV or the peak of copper (Cu) at 8 keV. The intensity of the peak of potassium (K) at 3.3 keV does not change either, and remains the same for the support as for the ink.

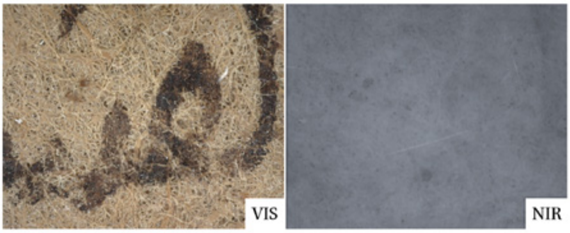
Figure 4.27 displays the intensity profile of the spectrum shown in Figure 4.26c for potassium (K), calcium (Ca), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn) and lead (Pb). The line scan is 20 points long, with ten points measuring the paper before passing to the ink. No change in the profile of most of the elements can be detected when passing from the paper to the ink, except that the signal becomes more homogenous; a decrease in the concentration of calcium and potassium can be observed when passing from the paper to the ink. This profile shows the heterogeneity of the support, visible in the first portion of the line scan, and that there is a lack of all metallic components in the ink.

However, it is worth noting that the peaks of iron are already very high in the support, visible both in the spectrum in Figure 4.26c and in the intensity profile in Figure 4.27. It is, therefore possible that the gallic acid contained in the ink reacted with the iron in the support, creating an iron-gall ink. For that, it depends on the state of the iron contained in the support.

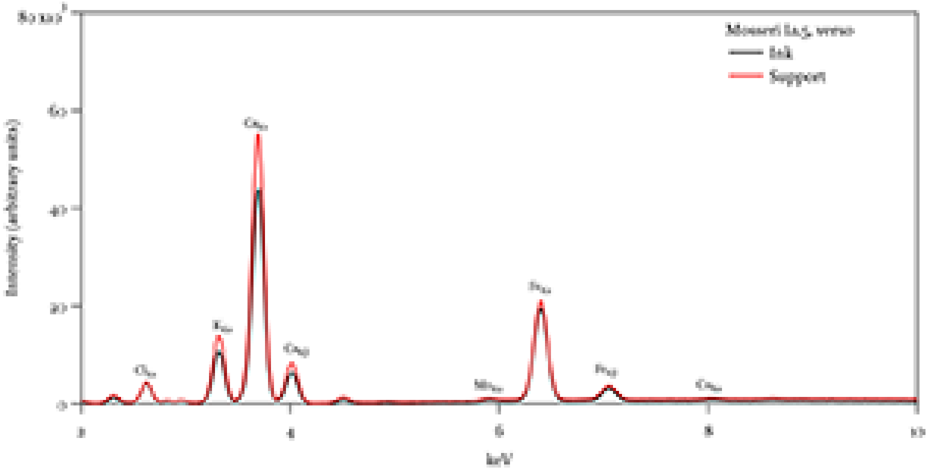
Figure 4.28 displays a comparison between the intensity profile of iron in the support and in the ink of two manuscripts: Figure 4.28a presents the intensity profile of iron (Fe) measured in a standard iron-gall ink, and Figure 4.28b that of iron in manuscript Mosseri Ia.5. In a standard iron-gall ink as found in T-S 6J2.19, the difference between the intensity profile in the ink and in the support is very large: it is possible to see that in addition to the iron contained in the support, a large amount of iron is contained in the ink, and that in this case there is about seven times more iron in the ink compared to the amount contained in the support. On the other hand, in manuscript Mosseri Ia.5, it is not possible to distinguish the two lines. The line representing the intensity profile of iron in the support and that of the iron in the ink are entangled. This is due to the inhomogeneity of iron in the support but also the lack of iron in the ink.

The same characteristics – iron-gall ink under NIR light, but no iron in the ink – may be found in four other manuscripts as well; the manuscripts are listed in Table 4.12. It is worth noticing that these manuscripts were all written on paper.

4.26a



4.26b



4.26c

FIGURE 4.26 Presentation of the verso of Mosseri Ia.5; a) photograph of the manuscript reproduced by kind permission of the Syndics of Cambridge University Library, b) VIS/NIR imaging of the inks, and c) a portion of the XRF spectra corresponding to the ink (in black) and the support (in red)

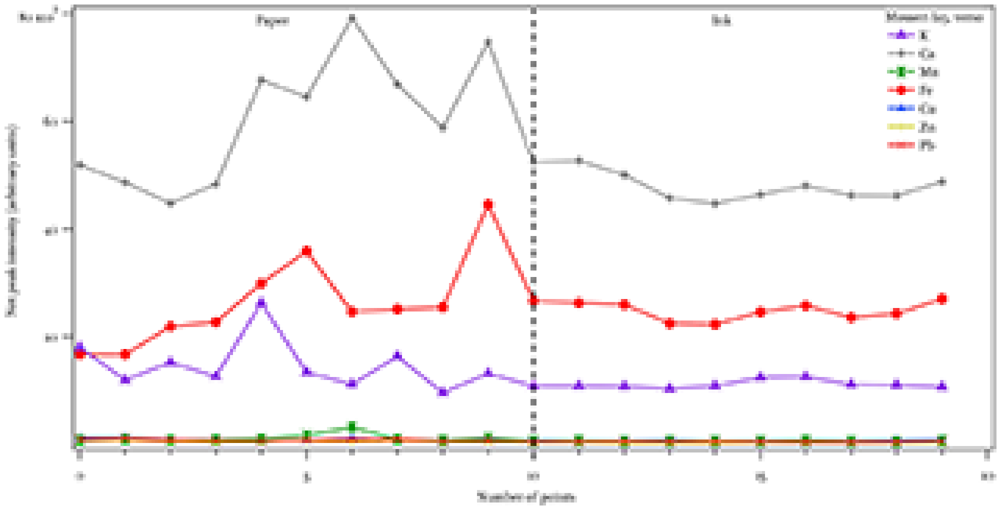
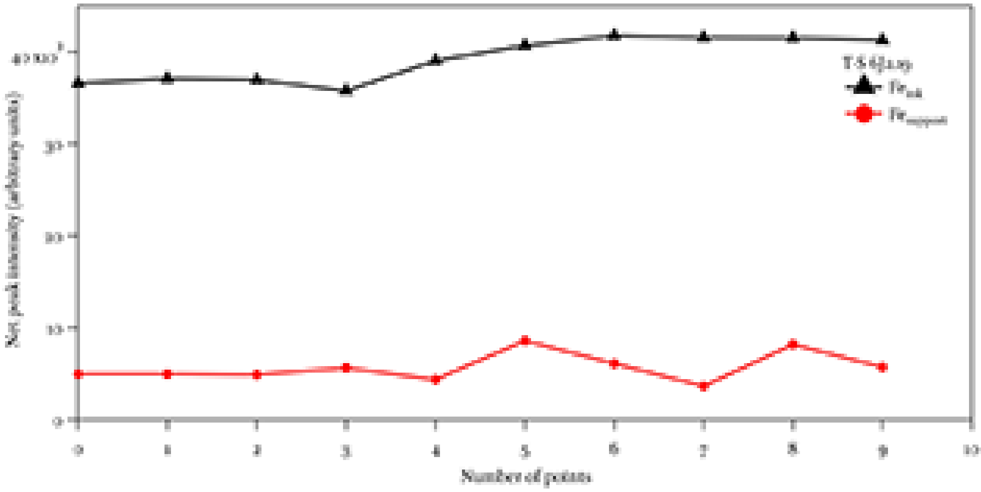


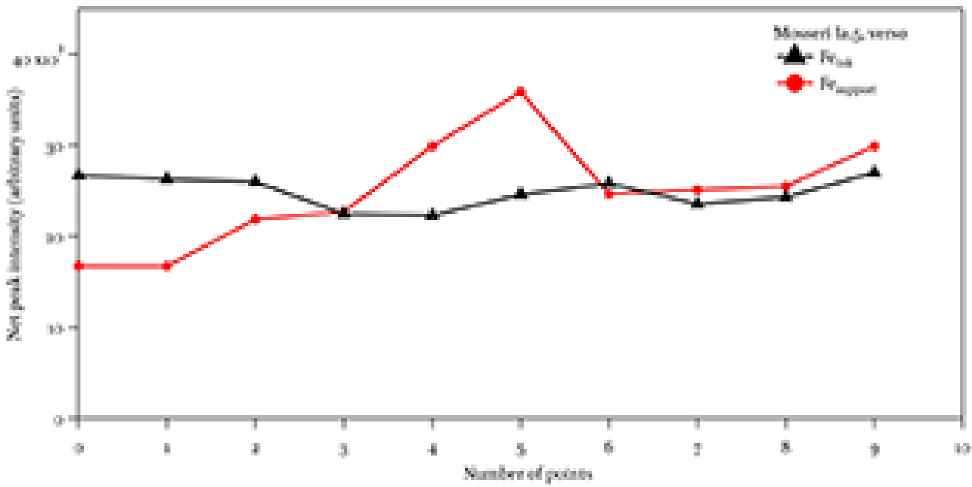
FIGURE 4.27 Intensity profile of the ink presented in Figure 4.26 in manuscript Mosseri Ia.5, showing the elements potassium (K, purple), calcium (Ca, grey), manganese (Mn, green), iron (Fe, red), copper (Cu, blue), zinc (Zn, yellow) and lead (Pb, thin red)

TABLE 4.12 List of the manuscripts and the occurrences where probable plant ink has been detected

Classmark	Support	Date	Type	Status	Witnesses
T-S 10J10.22	Paper	*c.*1033	Letter	Main text + signature	Solomon b. Judah (*Ga'on*)
T-S 13J1.3	Paper	1016	Legal document	Signature	Solomon b. Fashat
T-S 16.162	Paper	1049	Deed of release	Signature	Moshé b. Ephraim
T-S 13J7.23	Paper		*Get*	Signature	Yefet b. Shlomo
				Signature	Ibrahim b. […]
Mosseri Ia.5	Paper	1037	Letter	Address	?



4.28a



4.28b

FIGURE 4.28 Comparison of the intensity profile of iron in both support (in red) and ink (in black) in a) manuscript T-S 6J2.19 and b) manuscript Mosseri Ia.5

3.3.4 No Fingerprint Possible

As mentioned in section 4.3.1, certain manuscripts, all written on paper, present a high inhomogeneity of metallic components in their support. Sometimes, the inhomogeneity was so substantial that the fingerprint could not be obtained. The protocol used in this study seems to be unfortunately unable to handle the spectra obtained during the XRF analyses. An example will be given with manuscript T-S 10J15.16 (Figure 4.29a). While the NIR picture of the main text shows that the ink fades away (Figure 4.29b), the inhomogeneity of the elements from the support make the establishment of a fingerprint impossible (Figure 4.29c).

Figure 4.29c plots the distribution of the elements chlorine (Cl), potassium (K), calcium (Ca), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn) and lead (Pb) in the support of manuscript T-S 10J15.16. The points represent the total of raw counts measured during the two line scans of the XRF analyses.

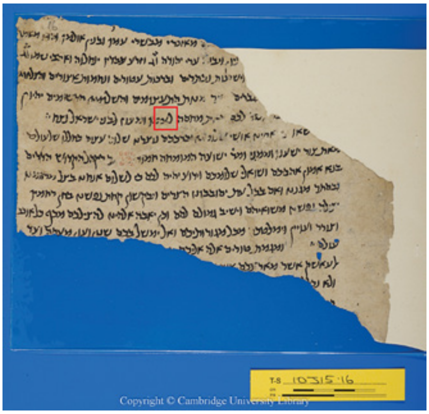
For most of the elements (Cl, K, Mn, Cu, Zn and Pb), the spread of the different measurements and therefore of the box-and-whisker plot is very localised. However, for calcium (Ca) and for iron (Fe), most of the data is widely spread – from $15x10^6$ to $40x10^6$, three times the amount. Therefore, the average concentration for these two elements would be meaningless, and the fingerprint model cannot be applied here.

The difference with the cases presented in section 4.3.3.3 can be seen in Figure 4.30, below. Figure 4.30a is what we interpret to be plant ink, and the intensity profiles of the iron (Fe) in both the support and the ink are very close, and cannot be differentiated. But they are rather homogeneous compared to the intensity profile of iron presented in Figure 4.30b.

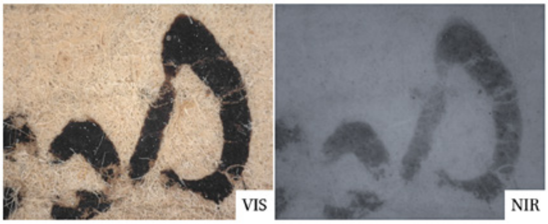
Table 4.13 lists all the occurrences where a fingerprint cannot be obtained in a manuscript because of similar characteristics to those shown in Figure 4.29 and Figure 4.30b.

Through this table, it is possible to add another criterion which helped us to distinguish between what we identified as plant ink and those inks where we realised that no fingerprint could be obtained. In the category of what we identified as plant ink, a fingerprint was usually obtainable for the rest of the inks used in the manuscripts. But where there was a high inhomogeneity of iron in the support, all the inks from the documents were affected by it, and in these cases, no fingerprint could be obtained for any of the spots.

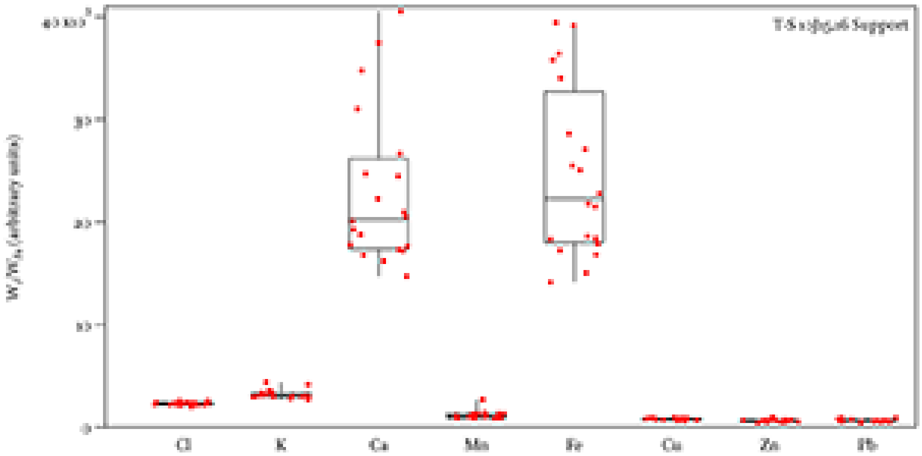
As discussed above, in section 4.3.1, the presence of metallic components, and in particular of iron, is difficult to trace in Arabic paper based on the available literature. Most publications on ink analyses, when presenting their results, do not present the results for the support. It is therefore difficult to



4.29a

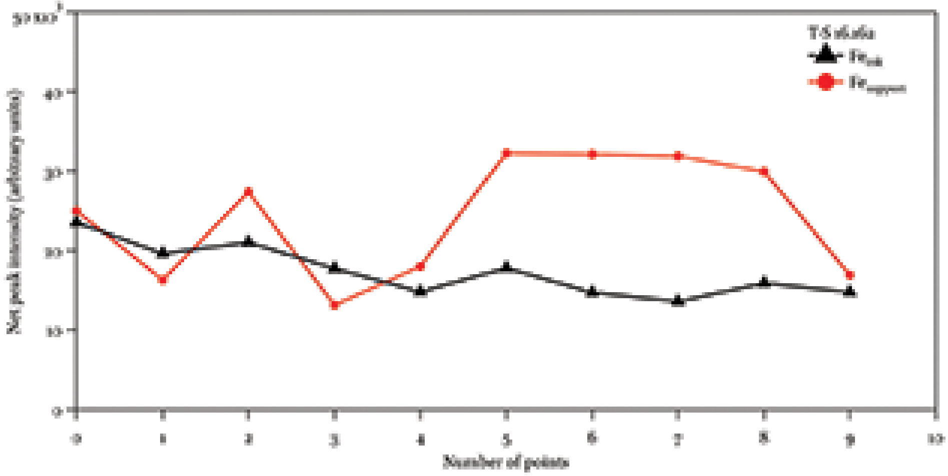


4.29b

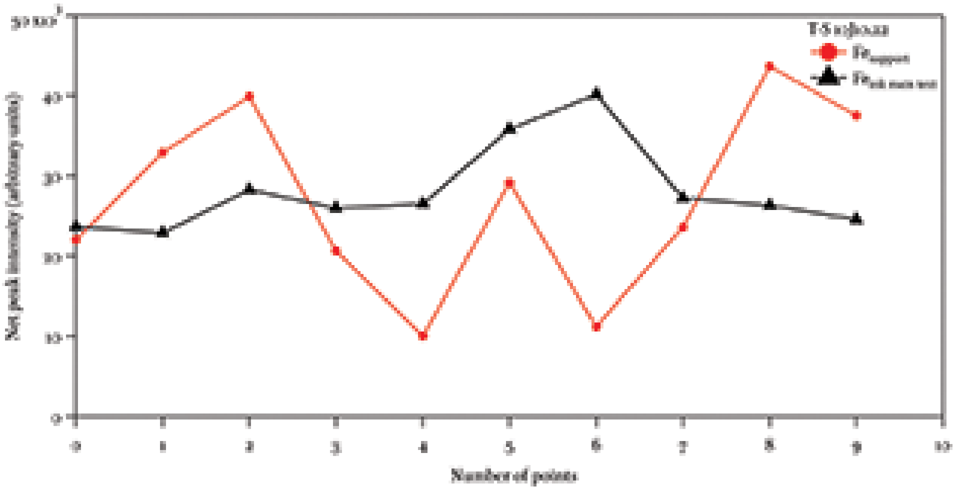


4.29c

FIGURE 4.29 Presentation of the manuscript T-S 10J15.16; a) photograph of the manuscript reproduced by kind permission of the Syndics of Cambridge University Library, b) VIS/NIR imaging of the ink, and c) box-and-whisker plot of some elements measured through the XRF analysis on the paper



4.30a



4.30b

FIGURE 4.30 Comparison of the intensity profile of iron in both support (in red) and ink (in black) in a) manuscript T-S 16.162 and b) manuscript T-S 10J10.22

TABLE 4.13 List of the manuscripts and the occurrences where no fingerprint could be obtained

Classmark	Support	Date	Type	Status	Witnesses
T-S 10J14.3	Paper	before 1030	Letter	Main text	Sahlān b. Abraham
				Signature	Sahlān b. Abraham
T-S 10J15.16	Paper	1025–1031	Letter	Main text	Sahlān b. Abraham
T-S 8J7.13	Paper		Letter	Main text	Elḥanan b. Shemarya
T-S Ar.18(1).133	Paper	1039–1049	Court record	Main text	Ephraim b. Shemarya?
				Addition	Ephraim b. Shemarya?
T-S 13J37.12	Paper		Deed of sale	Main text	Mevorak b. Nathan
				Signature	Mevorak b. Nathan
				Signature	Joshua he-haver
				Main text	–
T-S 16.152	Parchment	1057	*Ketubah*	Main text	Yefet b. David
				Signature	Hassan b. […] ha-Cohen
				Signature	Jacob b. Joseph
				Signature	Solomon b. Yahya
				Signature	Sa'adya b. Jacob
				Marginalia	–

assess whether the issue here a localised problem or if it is more generally present in manuscripts from different places and different times.

4 Conclusion of the Chapter

To conclude this chapter, let us summarise what we have learned. Even a cursory survey of the different inks used to compose the documents of this corpus have shown that the inks used in Fusṭāṭ around the 11th century are diverse: there are iron-gall inks, carbon inks, mixed inks and plant inks. The elemental composition of iron-gall inks also shows high diversity, with both vitriolic and non-vitriolic ones. The different Jewish communities do not show a preference for a certain type of ink formulation. While certain scribes in this corpus do perhaps seem to have preferences for a specific ink type, neither their community nor the time they were writing the document seems to have a link with their choice.

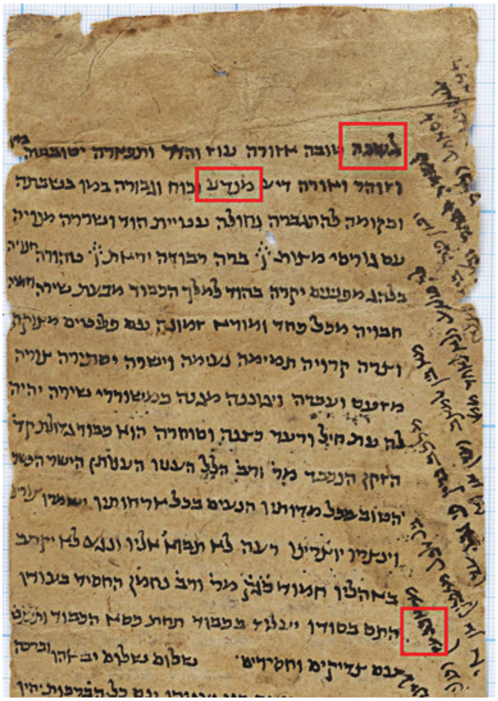
The observations of ink use suggest that the scribes of this study did not prepare inks themselves but rather bought them. Moreover, I believe that, unless they were writing specific types of documents that had to fulfil certain requirements, they did not care about the ink they were using except for its colour.

To substantiate this hypothesis, I will present one document in detail. It is not the only example of this type but it is the most impressive and easy to visualise. During the final stages of this work, I had the opportunity to study another collection of the Cairo Genizah, stored in the Österreichische Nationalbibliothek in Vienna. Analyses performed on a corpus of 11th–12th-century documents showed results consistent with the results gathered in this study and presented in this chapter and the next. As I was already in the final stages of writing this work, I could not include the full results from this corpus. However, one of the documents is worth presenting, even briefly.

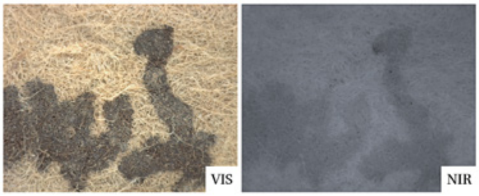
Document H 00161, seen in Figure 4.31a, is a letter from the 1467 of the Era of the Creation, i.e. 1156 CE, preserved today in the Papyrus Collection in Vienna. The document is written in judeo-arabic and under the form of a letter, a legal deposition concerning a shipwreck that occurred in Aden (Yemen) on its way to Quilon (India).[24] The document is extensively discussing the status of the widow of one of the victims, according to the *Halakha* (Jewish Law). The document is signed in the margin of the verso by notable of Aden agreeing on the conclusion of the document.

As we have shown, the signatures can be different from the main text, therefore, we will focus here only on the main text of the recto. The first line and a half and the marginalia are both written with iron-gall ink, while the rest of the text is written with carbon ink; this can be seen in Figure 4.31 b-d, through the change or maintenance of opacity under NIR light. On the verso, the ink varies as well, changing from iron-gall ink to carbon ink and vice versa, several times. Only reflectography has been performed on this document, so no further comparison between the iron-gall ink(s?) and the carbon-based ink can be made. One cannot be sure that the iron-gall ink is the same throughout, or whether the apparent carbon-based ink is actually a carbon ink or a mixed

24 Eliyahu Ashtor, 'A Journey to India: A Letter from Aden to Egypt, A.D. 1153 [in Hebrew]', *Zion* 4 (1939): 217–31; Shaul Shaked, *A Tentative Bibliography of Geniza Documents*, vol. 5, Études Juives (Paris & la Haye: Mouton & École Pratique des Hautes Études, 1964), 235; Shlomo Dov Goitein and Mordechai Akiva Friedman, *India Traders of the Middle Ages: Documents from the Cairo Geniza 'India Book'*, Études Sur Le Judaïsme Médiéval 31 (Leiden & Boston: Brill, 2007), 530–40; Roxani Eleni Margariti, 'Wrecks and Texts: A Judeo-Arabic Case Study', in *Maritime Studies in the Wake of the Byzantine Shipwreck at Yassıada, Turkey*, ed. Deborah N. Carlson, Sarah M. Kampbell, and Justin Leidwanger, Rachal Foundation Nautical Archaeology Series (College Station: Texas A&M University Press, 2015), 189–201.

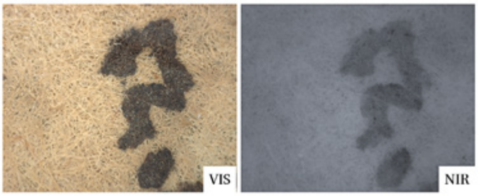


4.31a



4.31b

4.31c



4.31d

FIGURE 4.31 Details of document H 00161; a) photograph of a detail, copyright Papyrussammlung der Österreichischen Nationalbibliothek, b) VIS/NIR imaging of the first line of the document, c) VIS/NIR imaging of the second line of the document, and d) VIS/NIR imaging of the margin

ink. In any case, considering what is known at this stage, it would appear that the scribe of this letter started to copy his document with an iron-gall ink, switched to a carbon ink and finished using an iron-gall ink again, with further variations within the letter. This would seem to be a clear sign that the scribe did not care about the type of ink he used. He wrote with what he had, and the use of the different inks nearly simultaneously cannot be considered as his own production.

CHAPTER 5

Implications of This Research, Conclusions and Outlook

1 Inks Detected on Jewish Legal Documents

In a large number of the manuscripts analysed, the fingerprint model worked very well, rarely deviating from the 10% margin of error considered in the model as acceptable in the establishment of the fingerprint. But, as we saw in the previous chapter, the same ink was not always used to both write and sign legal documents. It is thus worth examining more closely the inks used on the subgroup of legal documents.

XRF analysis was carried out on 107 legal documents, divided into 86 different classmarks. After processing the spectra of these documents, it became apparent that the ink used to write a legal document and the ink used to sign it were not always the same. The use of ink to write and to sign the legal documents could be divided into five cases, each case being represented by one manuscript in Figure 5.1.

1. There is a continuous use of the same ink through the whole legal document (e.g. T-S 12.644).
2. Two different inks are used in the document. One is used for the main text – and in some cases for one of the signatures as well – while a second ink is used for the rest of the signatures (e.g. T-S 20.6).
3. Two different inks are used in the document. However, the distinction is not between the main text and the remaining elements. Rather, the main text and all the signatures except one are written with one ink, while the remaining signature is penned in a different ink (e.g. T-S 24.11).
4. More than two inks are found in the document, though some are similar in composition in terms of their metallic content (e.g. T-S 13J1.9).
5. The main text and each signature is penned in a different ink (e.g. T-S 16.124).

In Figure 5.1, the abscissa presents the different regions of interest analysed for each manuscript (main text and signatures of the witnesses[1]) and the ordinate

1 Except when proven otherwise, the signature of the witness should be considered as autographed.

DOI:10.1163/9789004469358_007

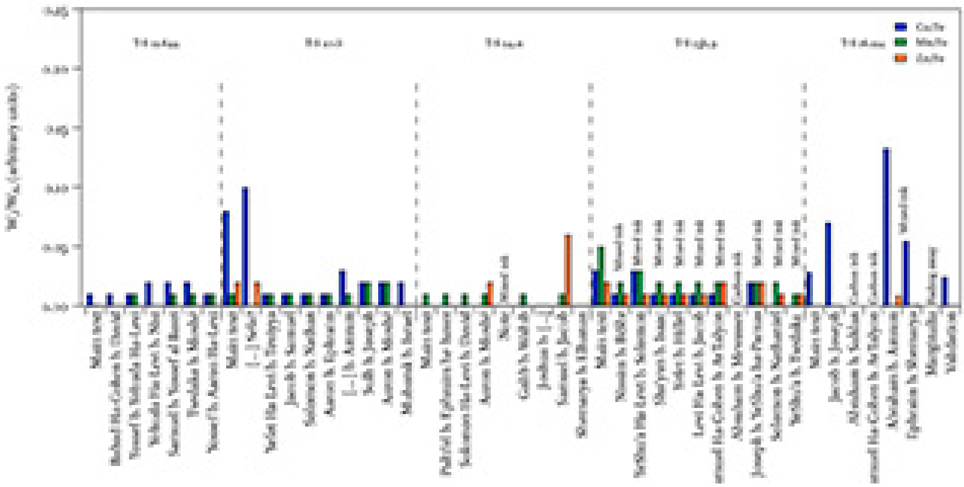


FIGURE 5.1 Fingerprint values w(i)/w(Fe) (i = Cu, Mn and Zn) obtained by XRF analyses for the inks of manuscripts T-S 12.644, T-S 20.6, T-S 24.11, T-S 13J1.9 and T-S 16.124

shows the net peak intensity of the elements, normalised by the intensity of iron.

In the first case, illustrated by manuscript T-S 12.644, the inks used to write the main text and to write the signatures display a similar fingerprint. Strictly speaking, the use of the same ink composition does not mean that the document and the signatures were written at the same time; however, considering the high number of inks of different types and different metallic compositions used in Fusṭāṭ in the same period, it is plausible to assume that the text was written in front of the witnesses and signed by them in the court.

The second case, represented by manuscript T-S 20.6, shows the use of two different inks with distinct fingerprints in the manuscript. The main text is written with one ink, while all the signatures are written with a second ink (or in certain cases, all signatures except one are written with one ink, while the ink of that single signature has the same fingerprint as the ink used to write the main text). In the fourth scenarios where the ink changes between the main text and the signatures, or between one signature and another, several explanations can be put forward, although each would need to be confirmed by further research. In this particular scenario, it seems likely that the text was written in advance and then presented to all the gathered witnesses, who probably signed it at the same time with the same ink. In the specific case of manuscript T-S 20.6, the actual name in the first signature – executed in the ink of the main text – is missing, but honorific formula "זל״ע"[2] does remain;

2 Abbreviation for זכרונו לחיי עולם.

this was attached to the name of the father of the first witness. Eight other signatures follow, all of them written with an ink which presents an identical profile that is different from that of the main text and the first signature. The ink of the main text contains about 10% of copper, a low amount of zinc and only traces of manganese, in contrast to the inks of the remaining signatures with their very low amount of all three main vitriolic satellites, copper, zinc and manganese. The use of the same ink for the main text and the first signature might indicate that the first signature belonged to the scribe himself. In such a case, the scribe/judge would write and sign or authenticate the deed, and only after that present it to the witnesses to be signed – this scenario would explain the use of a second ink for these other signatures. The witnesses would, in this case, not be there to acknowledge the writing of the deed but to acknowledge the reading of the deed and the acceptance of its content by the different parties.

The third scenario also suggests that two different inks were used to write and sign the document, similar to the previous case. Here, however, the difference between the inks is not a distinction between the main text, on one hand, and the signatures, on the other hand, but rather the main text and most of the signatures are written with the same ink, while one signature is singled out with a different ink. Manuscript T-S 24.11 is a deed of indemnity written by Palti'el b. Ephraim, signed by four witnesses (including the scribe himself), and validated by two other people. The whole document, including all the signatures except for one, is written with a similar non-vitriolic ink; but a different ink was detected in the signature of Galib b. Whahib. Why is this signature the only one for which the ink has a different composition and, in this particular case, is even an ink of a completely different type? Two possibilities are worth considering: firstly, this particular signature could have been made at a different time, as we usually assume that one ink corresponds to one writing phase; secondly, this witness might have brought his own tools with him. Let us consider the second possibility first. While certain names recur often in this corpus, and more generally in the documents written at this time, others are relatively unknown. When a witness is unknown, it is difficult to assess how skilled and experienced at writing he was, as we only have a single autograph on a legal document. Several archaeological pieces of evidence, together with several drawings, have shown that a portable inkwell, called a penner,[3] was in

3 The penner is sometimes called a scribe's case, or a pen case. Although very little archaeological evidence has been found, these were already in use in Antiquity. Roi Porat, Hanan Eshel, and Amos Frumkin, 'A Bronze Scribe's Case from En Gedi', *Israel Museum Studies in Archaeology* 6 (2007): 3–12. Some other penners, stored today in the British Museum or in

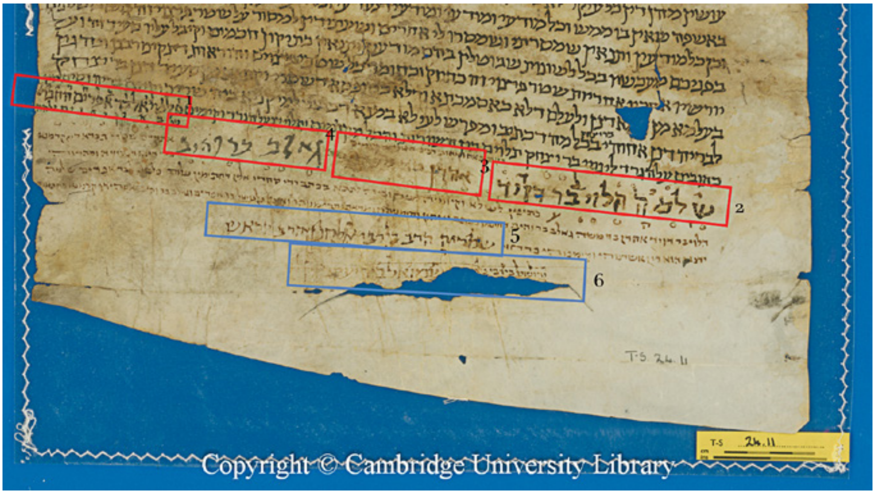


FIGURE 5.2 Detail of manuscript T-S 24.11, highlighting the autographs of the witnesses. Reproduced by kind permission of the Syndics of Cambridge University Library

use during a large part of the Middle Ages. Considering the results found in this study, the use of penners by the scribes seems rather unlikely in most cases, although it cannot be entirely dismissed: while some tendencies have been observed among certain scribes, no pattern has been observed in their use of inks, and if a scribe used a penner, he would be attached to his tool and his ink; but the results of our analyses have shown that, at least for the scribes we studied extensively, they were not reluctant to use inks other than their own.[4] So much for the first possibility, that one particular witness brought his own ink with him. In the particular case of T-S 24.11, though, there is a strong possibility that this specific signature could have been added at a different time to the other signatures. As seen in Figure 5.2, The witnesses signed the document in order: first the author of the document, Palti'el b. Ephraim *he-Ḥaver* (1), then Shlomo ha-Levi b. David (2), then Aaron b. Moshé (3), and finally Galib b. Whahib (4). Below that, the document was validated, (5) and (6), with in

other museums, date to later times, beginning from the 13th or 14th century, e.g. OA+.1692 from Iran stored in the British Museum, and 89.2.194 produced probably in Iraq and stored at the Metropolitan Museum of Art. A pen box, produced in Egypt during the 12th century, was sold by Christies: https://www.christies.com/lotfinder/Lot/a-fatimid-carved-ebony-and-ivory-penbox-5125180-details.aspx.

4 In addition, several examples in this corpus show that some of the witnesses might not have be able to write their name down properly. There are cases where it seems likely that witnesses misspelled their names, showing, if not illiteracy, at least perhaps dyslexia. In that case, why would they walk around with a penner?

between a note. Galib b. Whahib had, therefore, enough space to sign the document after the rest of the witnesses.

The fourth scenario is presented through manuscript T-S 13J1.9. This manuscript is a damaged document written in 1041: it is fragmentary, and only the lower part with the end of the text and the signatures remains. Analysis of the remaining text as well as the signatures of the deed shows that three different inks were used. An iron-gall ink containing traces of the iron satellites from vitriol was used to write the main text, one signature was written with carbon ink and the other eight signatures were penned with a mixed ink containing traces of the iron satellites from vitriol, with a similar fingerprint to the ink used to write the main text. The autographs of the witnesses are, in order: Nissim b. Bishr (1), Yeshu'a ha-Levi b. Solomon (2), Sha'yun b. Isaac (3), Yefet b. Hillel (4), Levi ha-Levi b. Jacob (5), Samuel ha-Cohen b. Avtalyon (6), Abraham b. Mevasser (7), Joseph b. Yeshu'a ha-Parnas (8), Solomon b. Nathaniel (9) and Yeshu'a b. Tsedaqa (10). Although most of the autographs have a similar fingerprint, except for that of Abraham b. Mevasser, they do not belong all to the same type. The first six signatures, the eighth and the ninth ones (in red boxes in Figure 5.3) are written with a mixed ink, while the tenth (in green boxe) is written with an iron-gall ink. The remaining signature, that of Abraham b. Mevasser (in an orange box), is written with a carbon ink. In addition, the main text presents the same fingerprint as the iron-gall and mixed inks.

For this specific document, it seems that two explanations could hold. Either the witnesses came in different sessions to sign the document (which would explain the three different inks used) or there are two batches of ink which have then been mixed, either by contamination or on purpose, to produce the third, mixed, ink.

Finally, the last scenario, where the main text and each signature is different, is presented here with manuscript T-S 16.124. This manuscript is an acknowledgement of a debt of 30 dinars.[5] The deed is written and signed. In the margin, an update indicates that part of the debt has been paid. On the verso, there is a document written in Arabic. The verso is not in a very good condition, making the reading of the document complicated; however, it mentions money. It is, therefore, possible that that document relates to the debt on the recto and announces that another part of the debt or perhaps the entire

5 To give an idea of what this amount was worth, Eliyahu Ashtor, *Histoire Des Prix et Des Salaires Dans l'Orient Médiéval* (SEVPEN, 1969), 226–27. indicates that at this time in Fusṭāṭ, a private teacher earned 1.5 dinar a month. More comparisons about the cost of living in Fusṭāṭ at the time can be found in Ashtor, 'Le coût de la vie dans l'Égypte médiévale'. In a document described below in section 5.2.1 (Or.1080 J117), a house is purchased for 60 dinars.

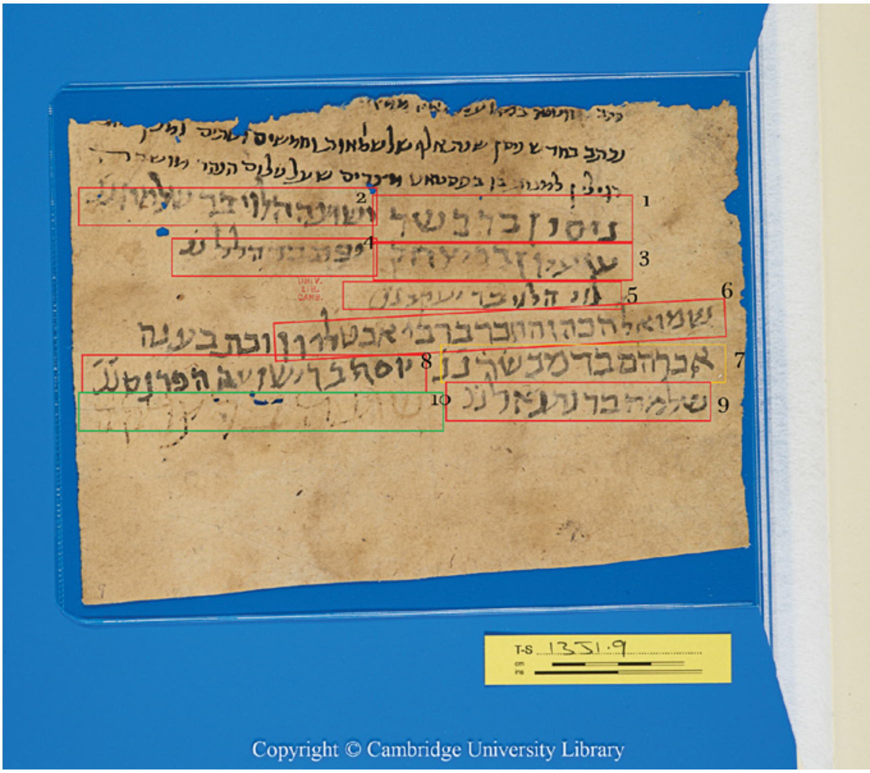


FIGURE 5.3 Detail of manuscript T-S 13J1.9, highlighting the autographs of the witnesses. Reproduced by kind permission of the Syndics of Cambridge University Library

debt has been settled. The document written on the recto comprises iron-gall inks with different fingerprints for all the locations analysed: the main text and every signature is penned in a different ink. That makes manuscript T-S 16.124 a special document: it is the only case detected in this corpus of a document with such heterogeneity in its ink composition, making it the only document representing case 5. However, when considering the signatures of the witnesses, one can gauge the importance of this document, as there are six autographs, and they come from at least two different Rabbanites communities: it is signed by Abraham b. Sahlān and Elḥanan b. Shemarya, who are known to be from the Babylonian community, and also by Ephraim b. Shemarya and Samuel ha-Cohen b. Avtalyon from the Palestinian community. This is a trans-congregational document, containing several high-ranking names of the Jewish community of Fusṭāṭ. Once again, several explanations can be suggested to explain the use of different inks in this document. One possibility is that the document was written and then the witnesses each signed with their own ink that they had brought with them; this hypothesis brings back the consideration of penners. However, bringing their own tools would show that these witnesses had a certain attachment to their own writing material; but most of the personalities in this document are known through the rest of our study, and we could not trace back the fingerprint of the inks they used to sign this document in other documents. This does not entirely exclude this hypothesis, but does make it, in my opinion, rather unlikely. Another possibility would be that the witnesses came one by one to sign the document. However, this possibility also seems rather unlikely, considering that although we cannot predict how long a batch of ink is in use, this would seem to imply very long lapses of time between each of the signatures. Considering the high rank of the witnesses of document T-S 16.124 – Ephraim b. Shemarya, Abraham b. Sahlān and Elḥanan b. Shemarya – and the many different inks used in it, it seems more likely that the document was sent to them, in order for them to signed it. It is true that when the court travels it is usually indicated in the legal document itself (e.g. T-S 18J1.10, a declaration of assets written at the bedside of an ill person, where it is mentioned that due to the health of that person, the court had to move to write the document in his presence: "We, the witnesses, travelled to the sick person[6]). However, until other documents with the same pattern are discovered, it will be hard to assess the reasons which led to the high number of inks used in this particular document. In my opinion, though, it is a sign that in certain prestigious cases, a document would travel to the witnesses and not the witnesses to the document.

The distribution of the documents according to the different cases are presented in Figure 5.4, for the 53 legal documents analysed by XRF and signed by at least two witnesses.[7] Of those, 50% were signed according to case 1 presented above: all the inks in the document – the main text and signatures – are the same. Another 18% of the legal documents correspond to case 2, with two different inks used, one for the main text (and sometimes one of the signatures), and one ink the signatures. Case 3 is used in 6% of documents; here once again there are two inks, one to write and sign the document, with another used just for one of the signatures. Among the remaining legal documents, 24%

6 Note, however, that these two documents are written at more than 50 years' remove, meaning that they belong to different law practices: T-S 16.124 was earlier, written in Hebrew in 1017, while T-S 18J1.10 was written in Judeo-Arabic in 1072, when the judicial system was more rigorous.

7 107 legal documents were analysed using XRF spectrometry, but only 55 of these documents had at least two signatures. Of those, two were unfortunately incompletely analysed, and therefore excluded from the distribution counts.

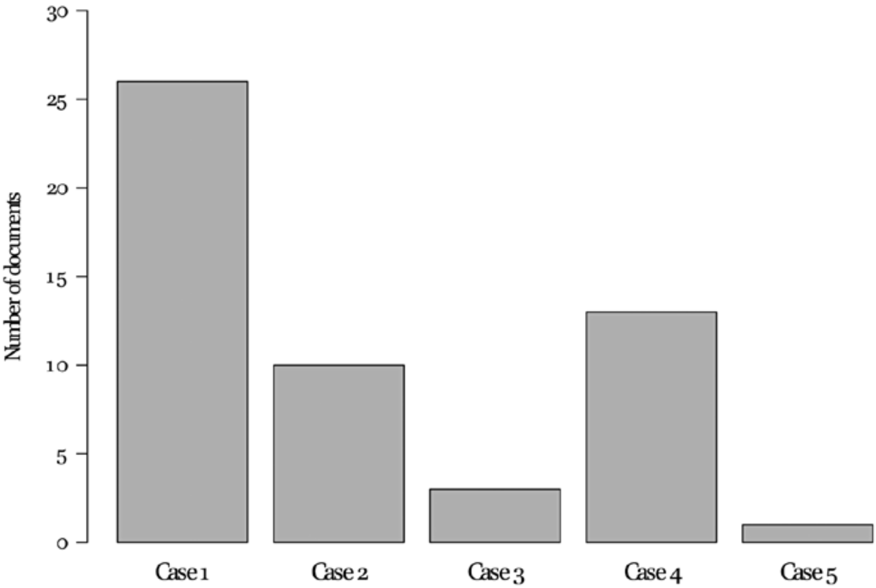


FIGURE 5.4 Distribution of the different scenarios of writing and signing the legal documents of the corpus. Case 1: only one ink has been used to write and sign the document, case 2: two different inks are used in the document (one for the main text, the other one for the signatures), case 3: two different inks are used in the document (one for the main text and most of the signatures except for one), case 4: more than two inks are used in the document, case 5: all regions of interest is penned in a different ink

were written and signed with more than two inks (case 4), while only one (2%) belongs to case 5.

Figure 5.4 shows that case 3 (with three documents) and case 5 (with only one document) are the least frequent scenarios. On the other hand, case 1, where the whole document is written and signed with the same ink – probably meaning that the document was written in front of the witnesses – is the most frequent.

Let us now consider whether there is a correlation between the type of legal document and the different ways of signing the documents. Is there a pattern that would allow us to recognise a certain strategy behind the number of the signatures and the way they were produced? Due to the fragmentary state of preservation of some of the documents in the Genizah, it is not always possible to determine which kind of legal documents a particular manuscript is. For example, some documents were not readable enough to assess exactly the type of deed, while in others, only the signatures remained (e.g. T-S 13J1.9 and T-S 8J7.18). In these cases, the legal document is just called a "deed". Figure 5.5

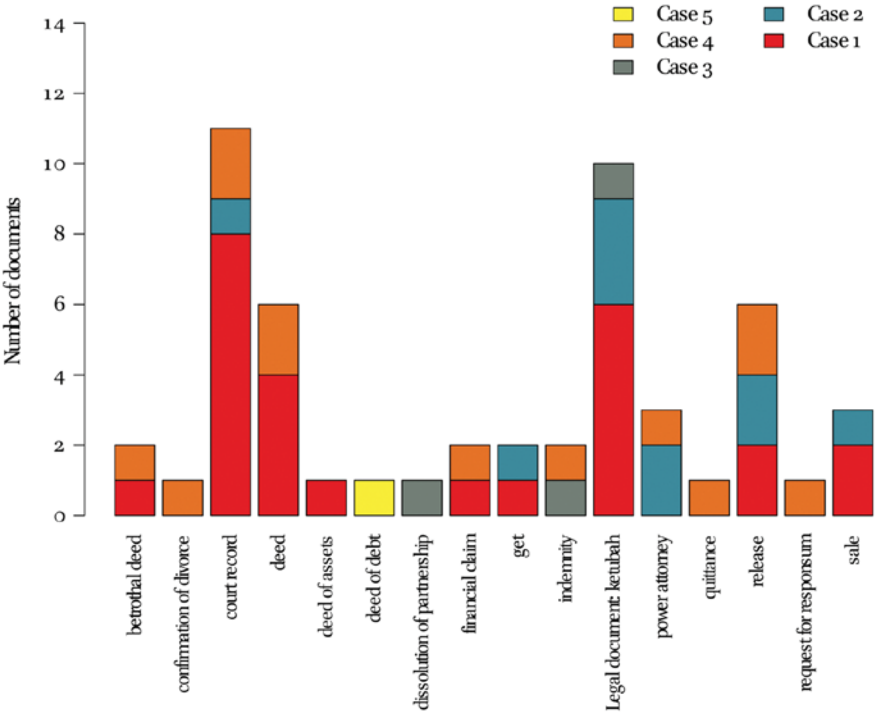


FIGURE 5.5 Distribution of the different scenarios of writing and signing the legal documents of the corpus according to the type of legal documents

presents the five different cases described above for the 53 legal documents. On the abscissa, the type of document is presented, while on the ordinate, we have the number of documents. Different colours correspond to the different cases.

Documents signed according to case 1 and case 4 are to be found in almost every type of legal document. Perhaps of particular interest, we analysed ten documents of the nine fragments coming from the court notebook of the Palestinian congregation reconstituted by Bareket.[8] Of these documents – i.e. documents written on the manuscripts T-S 8J4.1, T-S 8J4.2, T-S 8J4.3, T-S 8J6.18

8 Bareket has identified nine fragments, in order to reconstruct one court notebook: ENA NS 7.24, ENA NS 7.25, T-S 13J5.1, T-S 8J4.1, T-S 8J4.2, T-S 8J4.3, T-S 8J6.18, T-S 8K20.1 and T-S NS J51. Bareket, 'Books of Records of the Jerusalem Court from the First Half of the Eleventh Century in the Cairo Geniza פנקסים של בית דין הירושלמיים מן הגניזה במחצית הראשונה של המאה האחת-עשרה'. Two of those nine fragments are stored today in New York at the Jewish Theological Seminary; I analysed four of the others using both reflectography and XRF. In addition to this notebook, another, dated to 1156, is stored in the Firkovitch collection in St Petersburg at the National Library of Russia. It consists of 60 deeds and is still bound,

and T-S NS J51 – all belong to case 1: only one ink has been used to both write and sign each of the documents. Documents belonging to other court records are not like this: two of them seem to be signed according to case 4 (T-S 16.45 and T-S 8J32.8 f.1r) and one according to case 2 (T-S 8J32.8 f.1v). Similarly, none of the types of document seems to correspond to only one type of "signing strategy" – it does not seem to be the case that any particular type of legal document calls for a specific way of being signed.

We tried to create a decision tree, similar to those plotted in the previous chapter, to see if some qualitative observations (such as number of witnesses, type of deed, writing support, or date) could help understand how a document would be signed according to one case or another, but no conclusive tree could be drawn. A more extensive study would be needed, gathering more information, before any conclusions could be drawn on this subject.

It is rather unfortunate that a clear view of the complex Jewish legal system in Egypt during the Middle Ages is still lacking, although an increasing number of studies have been addressing this subject in recent years.[9] This is because knowledge of how the Jewish courts operated in this society is crucial for understanding the relationship between the different communities.

As *dhimmi*s, Jews had the right to use their own legal institutions. As mentioned in chapter 1, they were allowed to use the Muslim legal system but did not often resort to this possibility.[10] The explanations offered for this attitude include that the parties were afraid of the consequences for them from the Jewish community; that they had a better relationship with their peers than with the Muslim authorities; that an internal settlement would be less costly;[11] and that there was strong loyalty within the community.[12] Most of the legal

as noted by Goitein, *A Mediterranean Society: The Community*, 343; Olszowy-Schlanger, 'Les archives médiévales dans la genizah du Caire', sec. 18.

9 Zinger, 'Introduction to the Legal Arena'. The information contained in Zinger. has been of great help in understanding the legal system and writing this chapter.

10 The cases where this was done were rather specific, mostly cases of real estate matters and taxes; Khan, *Arabic Legal and Administrative Documents in the Cambridge Genizah Collections*, 10:1. Under other circumstances, it was avoided as much as possible. See also, Goitein, *A Mediterranean Society: The Community*, 400–401. It is to be noted though that Zinger, 'Introduction to the Legal Arena'. mentions that a series of studies have shown that the use by Jews of Muslim courts was more extensive than believed in previous research. Unfortunately, the main source he gives for this is in a work about the 12th century and Maimonides. I was unable to access this reference and therefore could not directly access the sources he quotes.

11 Goitein, *A Mediterranean Society: The Community*, 311–12.

12 Eve Krakowski and Marina Rustow, 'Formula as Content: Medieval Jewish Institutions, the Cairo Geniza, and the New Diplomatics', *Jewish Social Studies* 20, no. 2 (2014): 113, https://doi.org/10.2979/jewisocistud.20.2.111.

problems concerning Jews were therefore settled in front of a Jewish court (*bet din*), held in a synagogue.[13] From 966 to 1011, the only Jewish court held in Fusṭāṭ was that of Shemarya b. Elḥanan, the leader of the Babylonian community,[14] and later it seems that the court held in Fusṭāṭ was the central Jewish court in Egypt, even though other courts did exist. The *bet din* was chaired by three judges[15] who kept their position for a number of years, often for decades. Legal documents that were produced by Jewish courts could be used in Muslim courts, and vice versa,[16] and consequently some documents written by the Jewish court were written in Arabic, rather than in Hebrew or in Judeo-Arabic.

When a settlement was required, it was standard practice for a scribe to take notes during hearings, as several months could pass between the first hearing and the next court session (e.g. T-S NS 320.29).[17] A draft often followed (e.g. Or.1080 J7) or sometimes several drafts (e.g. Mosseri VII.43 + T-S Ar.53.53 and T-S AS 145.299 + T-S AS 135.261 + T-S AS 104.178 + T-S NS 145.160 + T-S NS 324.75 + T-S 6J2.26);[18] this draft was an intermediate step between the notes of the court during the official record and the establishment of the final deed. Subsequently, clean versions were written, with at least two copies being produced, one for each party. Moreover, another transcription entered the court record, which was also validated by signatures from the witnesses. At least two witnesses had to testify,[19] although it was common that more witnesses were present. The number of signatures varies considerably from one document to another, as can be seen in Figure 5.6.

Figure 5.6 presents the distribution of the number of signatures depending on the type of legal document, for the 83 legal documents in the corpus having at least two signatures[20] – note that this includes the legal documents which have not been analysed with XRF. The abscissa presents the type of legal document (if this information cannot be precisely clarified, the document is classed

13 Olszowy-Schlanger, 'Les archives médiévales dans la genizah du Caire'.

14 Olszowy-Schlanger, 'Manuscrits hébreux et judéo-arabes : Paléographie des documents juridiques de Fustat du Xe siècle.'

15 Olszowy-Schlanger, 'Les archives médiévales dans la genizah du Caire'; Goitein, *A Mediterranean Society: The Community*, 312.

16 Ackerman-Lieberman, 'Legal Pluralism among the Court Records of Medieval Egypt', 81.

17 Goitein, *A Mediterranean Society: The Community*, 231–32.

18 Zinger, 'A Karaite-Rabbanite Court Session in Mid-Eleventh Century Egypt'.

19 Deuteronomy 19:15 (NJPS): "A single witness may not validate against a person any guilt or blame for any offense that may be committed; a case can be valid only on the testimony of two witnesses or more."

20 Due to the fragmentary state of some legal documents, signatures were sometimes missing. In other cases, they were only preliminary drafts and therefore not signed.

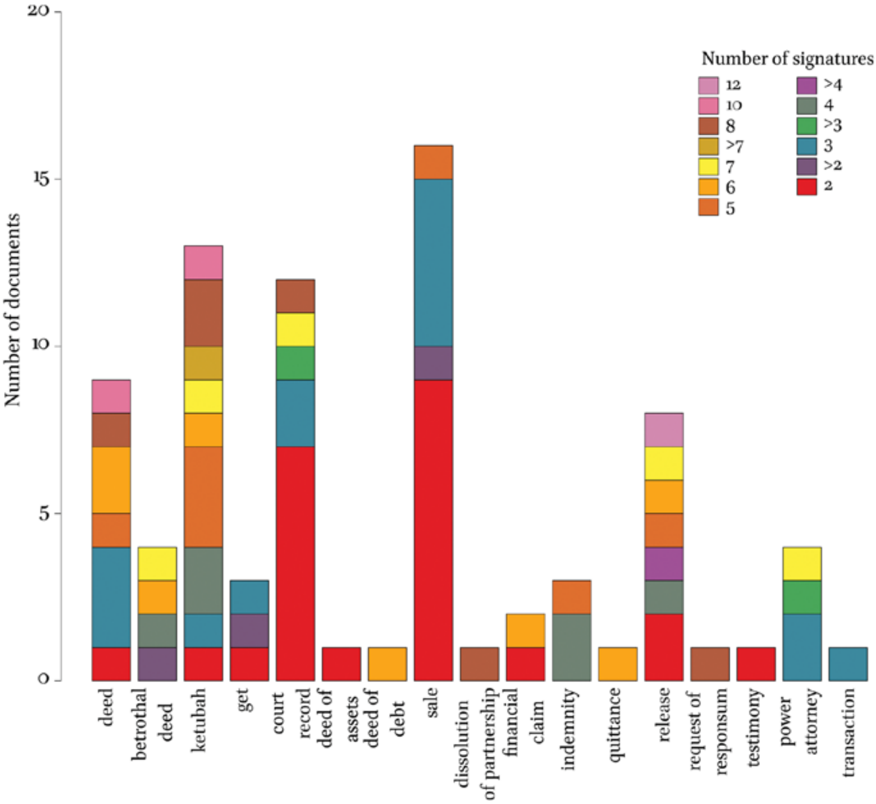


FIGURE 5.6 Number of signatures in the legal documents in the corpus, classified by document type

as a "deed"). On the ordinate, the number of signatures is indicated. When the document is torn or damaged, I counted the number of signatures that can be seen; obviously, the total number of signatures may be higher than this, and such cases are therefore indicated with ">n".

The copies for the different parties involved were usually written on individual pieces of paper or parchment while the court record was copied into a court book, sometimes with numerous cases on the same page (e.g. T-S 8J4.1, T-S 8J4.2 and T-S 8J4.3). In some cases, there is a line separating the different entries (e.g. T-S 8J6.18), making navigating between the different cases easier. When a legal case had further developments, an update could be added on the verso of the original deed (e.g. T-S Misc.29.21 or Or.1080 J117; and perhaps also T-S 16.124 presented above in case 5) or in the margin (e.g. T-S 16.124).

Research on Muslim legal documents in medieval Egypt has found features which are similar to what we have seen with Jewish legal documents in this corpus. Some scholars have noted a space of time between when a deed was written and when it was signed.[21] Like for Jewish deeds, only two witnesses were mandatory to approve a document, although more could be added,[22] depending on the importance of the document.

In addition, it has been previously noted by Rāġib that different inks could be used within the same Muslim legal document, to write it and to sign it. He notes that witnesses were not systematically using the ink of the clerk who wrote the main text but their own ink or the ink of a third party who was willing to share it with them. They were also able to witness in a place other than the one where the deed was copied or written.[23] His considerations seem to be mostly based on the visual aspects of the inks, criteria that we dismiss as not enough to differentiate inks since the colour of the inks greatly depends on the degree of degradation. However, after the evaluation of the preliminary analyses made on the Jewish legal documents of the corpus, the question of whether such a practice also existed in Jewish legal documents naturally came up, as we were facing similar cases. This parallel is based on the similarity of the Jewish documents preserved in the Genizah with the documents produced by the Muslim court at the same period: on the layout, the organisation of the document, its formulation and the content.[24] In other words, how similar were legal and scribal practices between Jewish and Muslim courts? A following question then arises: Would it be possible, through the study of the ink of these legal documents, to gather more information concerning the legal practice of the time and its evolution?

2 Arabic Documents

One of the questions from the beginning of this project was to know if there was any community specificity in the 11th-century Fusṭāṭ in the use of writing materials. This quest for a community specificity pushed us to compare the results across the Rabbanite communities and Karaites, but also with non-Jewish communities. To do this, a corpus of 34 Arabic documents was developed.[25]

21 Yūsuf Rāġib, *Actes de vente d'esclaves et d'animaux d'Égypte médiévale*, vol. 2, Cahier des Annales Islamologiques 28 (Cairo: Institut Français d'Archéologie Orientale (IFAO), 2006), 4; Khan, *Arabic Legal and Administrative Documents in the Cambridge Genizah Collections*, 10:7.

22 Rāġib, *Actes de vente d'esclaves et d'animaux d'Égypte médiévale*, 2:105.

23 Rāġib, 2:4.

24 Krakowski and Rustow, 'Formula as Content', 115.

25 Although the selection of the documents was mainly done thanks to G. Khan, *Arabic Legal and Administrative Documents in the Cambridge Genizah Collections*, their reading

It is important to remind the reader that the language of a document is not an indicator of the religion of the scribe. As we explained in the first chapter, during the whole period under discussion the Middle East was marked by its multilingual society with much travel and interconnection all around the Mediterranean Sea. The religion of a scribe – or of witnesses – cannot be assessed based on the language of a document he wrote or signed; this can only be done based on the content of the document, the use of a particular calendar, or the use of different epithets of the parties.[26] This means that, for some of the documents in this Arabic corpus, we could not unequivocally attribute a community or a religion to a scribe or to a witness.

The Arabic corpus consists of documents dated to a similar time as the main corpus. It includes private documents and court records, and in addition, it includes petitions sent by or to the Fatimid central administration. We added two documents from outside the Genizah that are found in the Michaelides collection (Michaelides Charta A169 and Michaelides Charta B48), but the remainder of this subcorpus is composed of Arabic documents that had been reused by Jews (mostly by Ephraim b. Shemarya) to write letters or documents, all of them found in the Genizah.

The distribution of the type of ink used in Arabic documents is presented in Table 5.1. Unlike other tables of this type presented in this study, only two purposes have been shown: the main text versus everything else. While it is possible to choose the writing support for the main text, this was not possible for other parts of the documents – as they were the continuation of the main text – therefore, the data have been merged.

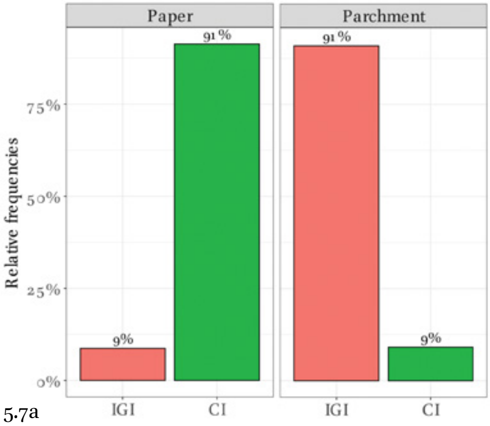
TABLE 5.1 Distribution of the type of ink depending on the type of support, in Arabic documents

		Iron-gall	Carbon	Mixed	Plant	Sum
Main texts	Paper	2	21	–	–	23
	Parchment	10	1	–	–	12
Other*	Sum	14	23	3	1	41

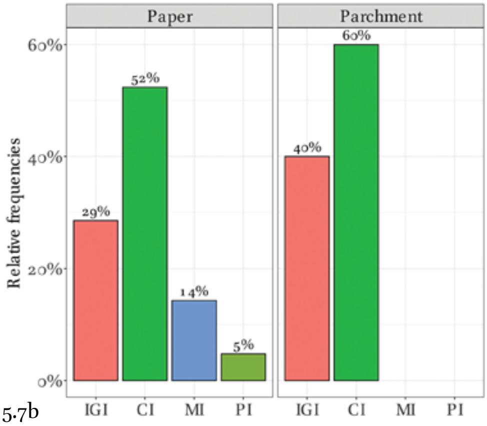
*Note: "Other" corresponds to the sum of additions, addresses, notes, signatures and marginalia.

and comprehension was made possible thanks to the constant help of Wissem Gueddich. I would like to thank her here for our discussions on the Genizah.

26 Khan, *Arabic Legal and Administrative Documents in the Cambridge Genizah Collections*, 10:1.



5.7a



5.7b

FIGURE 5.7 Distribution of the type of ink in Arabic documents depending on the type of support normalised to the number of occurrences for a) the ink used to write the main text of the documents of this corpus and b) for the the ink used to write the remainder of the documents

Figure 5.7 displays the observations of Table 5.1, weighted by the total number of instances in each category. Four types of inks are shown here – iron-gall ink (IGI, in pink), carbon ink (CI, in green), mixed ink (MI, in blue) and plant ink (PI, in khaki) – as well as two classes of writing surface, parchment and paper; no leather was used to write these documents. In both graphs, the abscissa represents the type of support, and the ordinate the relative frequency.

For the main texts, Table 5.1 and Figure 5.7a show a stronger correlation between the type of writing surface and the type of ink in this corpus than in the corresponding legal Jewish documents. However, this relationship basically disappears when we consider the inks used for other purposes, as can be seen in Figure 5.7b: on paper, carbon ink still predominates (with 52%), followed by iron-gall ink (29%) and then mixed ink and plant ink.[27] These two last types of ink were not found on parchment in the corpus. On this writing surface, like with paper, carbon ink was most used (with 60%), followed by carbon ink (40%).

To enable a clearer comparison with Jewish documents, let us have a closer look at the use of different ink types, divided by the main types of Arabic document in the corpus, legal documents and official documents.

2.1 *Arabic Legal Documents*

One of the difficulties when studying legal documents from the Genizah written in Arabic is the assessment of whether the document was produced by

27 Measured on an ink recipe, describing what seems to be a plant ink.

a Muslim or by a Jewish court. On one hand, the Jewish court did produce documents in the Arabic language, and on the other, the Muslim court could deal with matters that only concerned Jews. Sometimes we find documents delivered by both courts written on the same writing support, as can be seen in manuscript T-S 18J1.10: on the recto, there is a Jewish legal document, while the verso is used for a Muslim marriage contract.[28] In other cases, like Or.1080 J117 which will be presented shortly, one legal document is produced by one court, but then on the verso, a follow-up on the same issue is produced by another court. The identification of the two courts, in this case, has been made purely on the basis of the use of different calendars.

The establishment of a Muslim contract follows strict prescriptions: a specific vocabulary, a specific ordering of elements, a date (which could be in certain cases be omitted), and witness clauses.[29] Each witness clause, at the bottom of the document, contains an autograph of the witness – his name followed by the name of his father (and occasionally more details concerning his filiation), like in Jewish documents – and occasionally by other attributes such as his occupation or his religion, followed by an indicator "in his writing" when the witness wrote his name himself.[30] The autograph could be followed by another declaration, testifying that the witness saw both parties acknowledge the terms of the transaction.[31] Like for Jewish legal documents, in order to be valid, the deed had to be validated by at least two witnesses.[32] In Egypt, starting from 790 CE, on the instigation of Ibn Fudala, the court occasionally referred to professional witnesses.

Or.1080 J117 is a legal document written on parchment in 1088–1089 CE (481–482 AH) which records the purchase of a house: the buyer and the seller are Jewish. The entire document is written in Arabic and was written and signed in front of a Muslim court, although it concerned only Jews. This is because the document deals with a real estate matter, which involves the Qadi court.

28 Verso and recto are defined not according to chronological order but conservation choices. Here, in this case, it is the recto, the Jewish document, which is a reuse of the verso. Both documents are written with the same orientation.

29 Rāġib, *Actes de vente d'esclaves et d'animaux d'Égypte médiévale*; Khan, *Arabic Legal and Administrative Documents in the Cambridge Genizah Collections*.

30 One can occasionally find documents where the witness did not sign himself, when he was unable to do so; Khan, *Arabic Legal and Administrative Documents in the Cambridge Genizah Collections*, 10:7.

31 Rāġib, *Actes de vente d'esclaves et d'animaux d'Égypte médiévale*, 2:108; Yūsuf Rāġib, 'La parole, le geste et l'écrit dans l'acte de vente', *Arabica* 44, no. 3 (1997): 418, https://doi.org/10.1163/1570058972582399.

32 Khan, *Arabic Legal and Administrative Documents in the Cambridge Genizah Collections*, 10:7, 29.

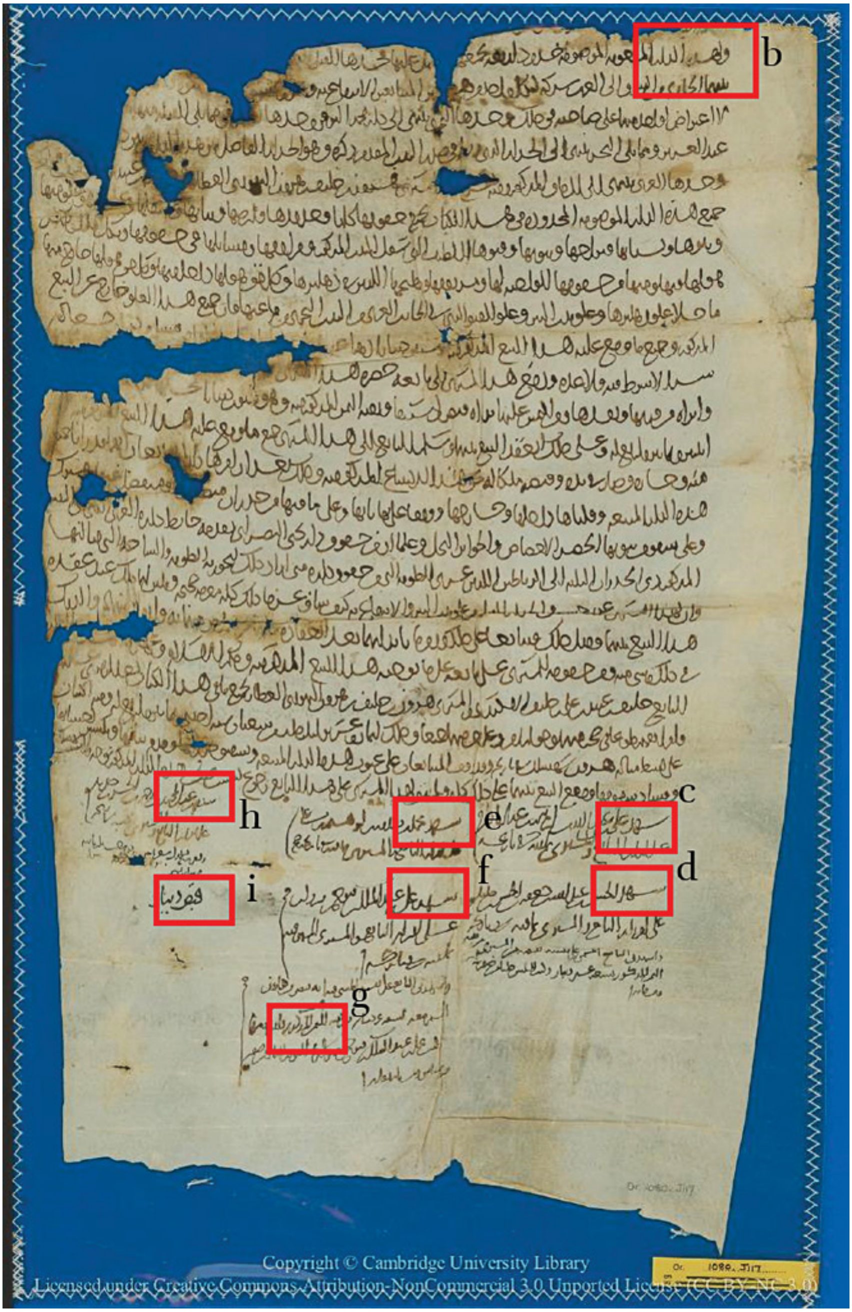
On the recto of this document (Figure 5.8a), there is a description of the house and the conditions of the sale. Only a deposit of 30 dinars was made during the drafting of the contract, and the mention of this is followed by the witness clauses. Two notes mention the sums of 19 and 1 dinar on the bottom right and the bottom left corner, respectively (j and i), as partial payments of the debt. Finally, on the verso, we find an update on the situation added four months after the sale. This later text states that the full payment has been received and that the seller has no further rights with regards to this house. Witness clauses follow, with the signatures of two witnesses, confirming that the payment has been completed according to what is stated in the deed. In addition to this legal document, the verso contains two further documents, also related to the same real estate property,[33] but written after the previous documents.

The reflectographic analysis of the document shows that the main text (see Figure 5.8b) is executed with an iron-gall ink, since the ink loses opacity but does not disappear under NIR light. Figure 5.8c to Figure 5.8f and Figure 5.8h present the signatures of the witnesses. All the witnesses signed this document using iron-gall ink. Without XRF analysis, it is not possible to say whether the same or different inks were used for the signatures. Finally, the ink used by the scribe to attest that he is the author of the document is as well written with an iron-gall ink (see Figure 5.8h). On the two updates on the recto concerning the payment of the debt, only one has been analysed, and it is clear that carbon ink was used (Figure 5.8i). When it comes to the update that was added to the document four months after it was first drawn up, an iron-gall ink has been used (Figure 5.8k) while the witnesses have signed with a carbon ink to confirm that the buyer of the house is released from his debts (Figure 5.8l and Figure 5.8m).

To summarise, on the recto, most of the document is written with an iron-gall ink: the main text (Figure 5.8b), the signatures (Figure 5.8c to Figure 5.8f and Figure 5.8h), and the attestation of the scribe (Figure 5.8g) are written with the same type of ink. Carbon ink is used only in the second and third phases of writing, for the updates on the payment of the debt (Figure 5.8i). In the case of the update on the verso, the inks of the main text and of the signatures are of different types.

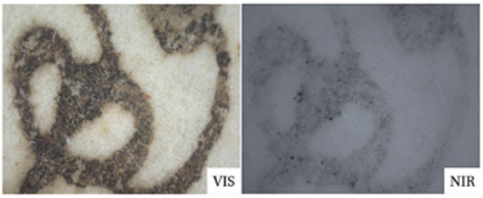
This document is of particular interest for several reasons. First, it offers an example of the reuse of the verso to follow up on the state of a transaction.

33 The first of these later documents is a statement of gift, produced by a Jewish court, as can be seen from the use of the Jewish calendar to date the document, rather than dating it relative to the Hegira, which was done with the two previous documents. The final document is a lease contract for the house, involving two brothers.

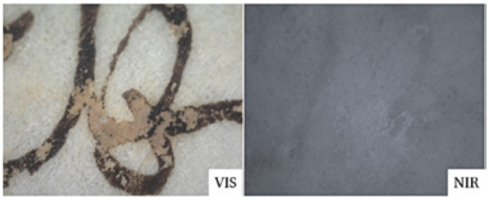


5.8a

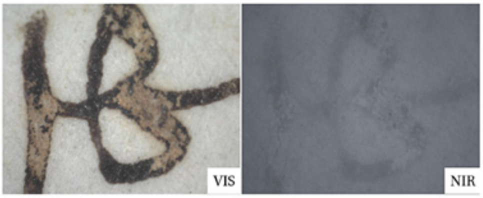
FIGURE 5.8 Presentation of the manuscript Or 1080 J117 reproduced by kind permission of the Syndics of Cambridge University Library; a) photograph of the recto, b)–i) VIS/NIR imagining of parts of the text, j) detail of the verso, and k)–m) VIS/NIR imaging of parts of the text



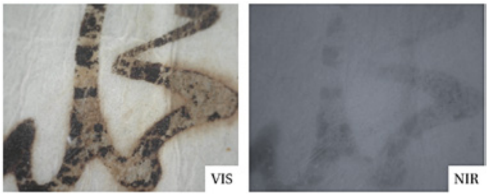
5.8b



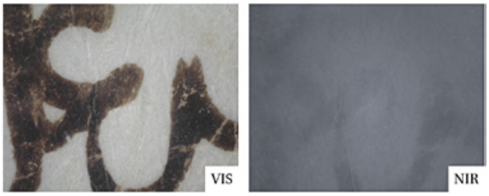
5.8c



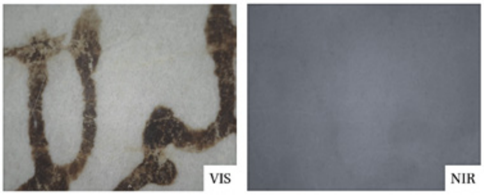
5.8d



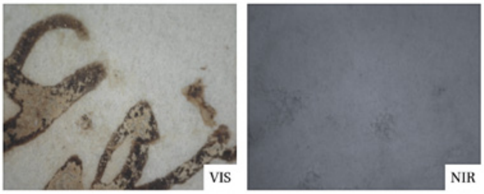
5.8e



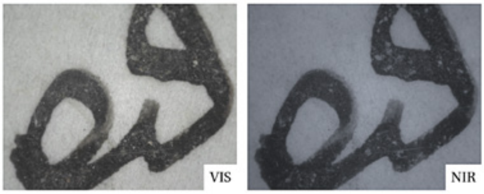
5.8f



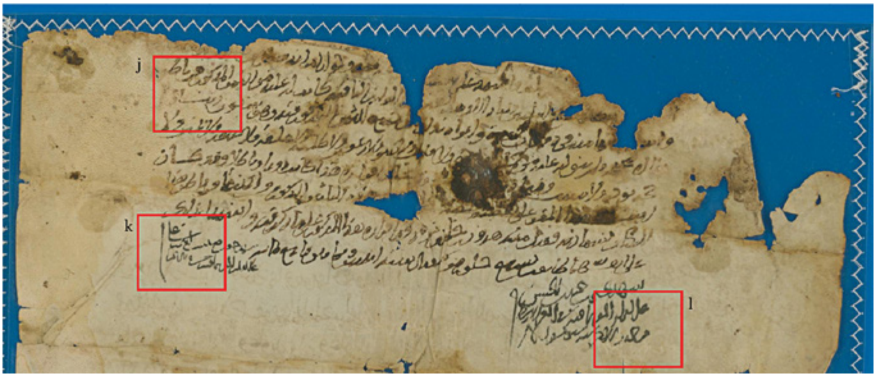
5.8g



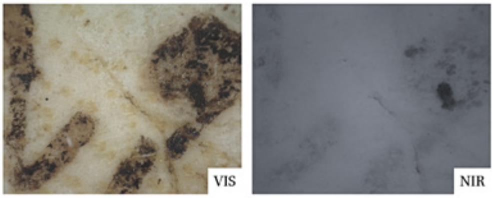
5.8h



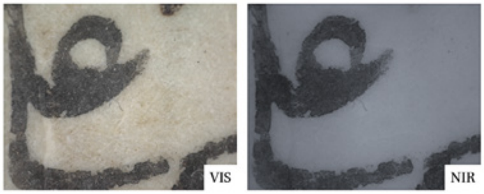
5.8i



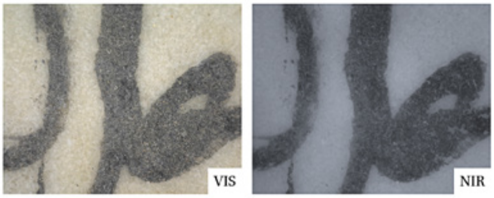
5.8j



5.8k



5.8l

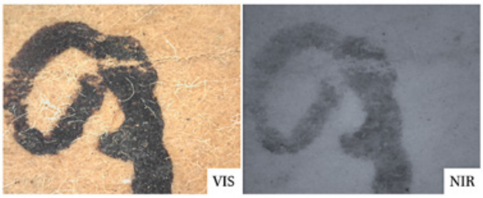


5.8m

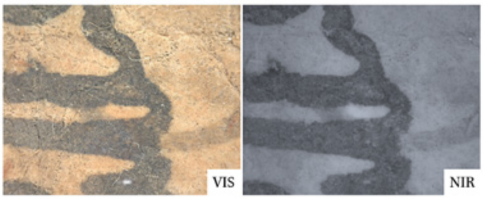
We saw a similar practice in the Jewish court in section 5.2.1, with the use of marginalia on T-S 16.124.[34] Secondly, although we cannot confirm it without XRF analysis, it seems that the signing of the deed on the recto and the signing on the verso corresponded to different signing cases (see section 5.1): the part on the recto seems to be written and signed with the same ink – corresponding to case 1 – while the part on the verso is written with one ink but signed with another – corresponding to case 2. Finally, we see here an alternating use of

34 And probably of the verso as well, although as we mentioned when introducing the document, we cannot confirm that the Arabic document on the verso is truly connected to the text of the recto.

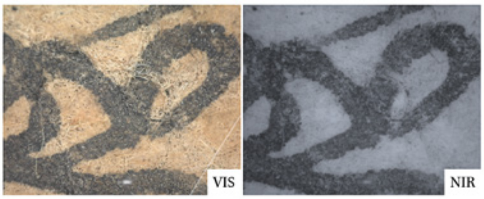
5.9a



5.9b



5.9c



5.9d

FIGURE 5.9 Presentation of the manuscript T-S Ar.5.1 a) detail of the verso reproduced by kind permission of the Syndics of Cambridge University Library, b)–d) VIS/NIR imaging of part of the text the Jewish and the Muslim courts. Although the transaction affected Jews only, the deed of sale had to be established in front of the Qadi court, because it was related to real estate. However, on the verso, the lease concerning the same house was drawn up after the two deeds presented here (the sale of the house and the reimbursement of the debt), and thus the Qadi court no longer needed to be involved. The lease was therefore presented to the Jewish court, as can be seen from the choice of the witnesses and the calendar used for recording the date.

Similar observations can be made for other documents. For instance, T-S Ar.5.1 is a manuscript on paper that contains several different documents, in both Hebrew and Arabic. One of them relates to the lease contract of a house, drawn up in December 1032 CE (424 AH). This document contains the main text with a description of the conditions of the lease and the signatures of witnesses. Figure 5.9b to Figure 5.9d compare results from the reflectographic analysis of the main ink to those of the ink of the signatures in this document.

In Figure 5.9b, it can be seen that the ink of the main text fades away under NIR light indicating that we are dealing here with iron-gall ink. In contrast, the signatures of the witnesses (Figure 5.9c and Figure 5.9d), do not lose opacity under NIR light, showing that the ink used to sign the document is a carbon-based type.

The evaluation of XRF spectra reveals that the iron-gall ink used to write this lease did not contain any of the vitriolic satellite elements. The autographs of the witnesses were in fact written with a mixed ink, as the ink contains large amounts of iron. However, none of the vitriolic satellite element of iron were found in those inks either. Therefore, we conclude that we have here a mixed ink that consists of a carbon-based ink with a considerable addition of iron. Such a mixed ink has been already attested in legal documents produced in the Jewish courts: a mixture between a carbon ink and an iron-gall ink with the same profile as an iron-gall ink used elsewhere in the text. The writing and signing of this document would correspond to case 2 of section 5.1.

The two manuscripts examined in detail here belong to two of the five different scenarios presented in section 5.1 for Jewish legal manuscripts: the sale of the house in Or.1080 J177 seems to belong to case 1, while the reimbursement of the debt on the verso of that manuscript and the legal document in T-S Ar.5.1 seem to both belong in case 2. Two other legal documents, involving members of both Christian and Jewish communities, namely T-S Misc.29.21 and T-S Ar.38.114, have been analysed using only reflectography. While the first one belongs once again to case 1 (with all the ink used being carbon ink), the second document belongs to case 2 (with the main text written with an iron-gall ink and the two signatures written with a carbon ink).

TABLE 5.2 List of official documents in the corpus

Classmark	Support	Date	Type of document	Community sender	Community receiving	Ink typology
T-S Misc.20.92	Paper	996–1021	Decree	Fatimid Chancery	Karaite community	Carbon
T-S 10J4.5	Paper		Petition	Fatimid Chancery		Carbon
T-S 13J26.24	Paper		Petition	Fatimid Chancery		Carbon
T-S AS 152.236 + T-S AS 152.269	Paper		Official document	Fatimid Chancery		Carbon
T-S Ar.39.452 + T-S Ar.39.453	Paper	12th century	Appointment of a Christian leader	Fatimid Chancery	Christian	Carbon
T-S 20.32	Paper	996–1021	Petition (jottings)		Fatimid Chancery	Carbon
T-S B12.39	Paper	1021–1036	Petition (pen exercise)		Fatimid Chancery	Carbon
Or.1080 J7	Paper	*c.*1040	Petition (draft)	Palestinian	Fatimid Chancery	Carbon
Michaelides (Charta) A169	Paper		Petition		Fatimid Chancery	Carbon
T-S Ar.7.38	Paper	1031–1032	Petition	Christian	Fatimid Chancery	Carbon

However, a more in-depth study would be needed in order to assess the relevance of the comparison between the establishment of Muslim and Jewish legal documents.

2.2 *Arabic Official Documents*

The official documents among the Arabic corpus are often not related to Jews and have found their way to the Genizah through reuse and the position of Jews as clerks in government offices.[35] There are two sets of official documents:

35 Khan, *Arabic Legal and Administrative Documents in the Cambridge Genizah Collections*, 10:2.

ones sent to the chancery and ones emitted by the chancery. Both sets are presented in Table 5.2.

While some legal documents are written on parchment (particularly *ketubot*, which are meant to be kept for a long period of time), the writing material used for administrative documents is almost always paper, and all the documents written by and to the Fatimid chancery in the corpus were written on paper, using carbon ink. Although we can only speculate on the reason why all documents sent to the Fatimid chancery following an identical pattern, we can more easily interpret the results from the documents emitted by the chancery. When it comes to both the support and the type of ink used by the chancery, it would seem that the chancery offices had one type of provider, which would explain the uniformity of the observations.

3 Religious Documents

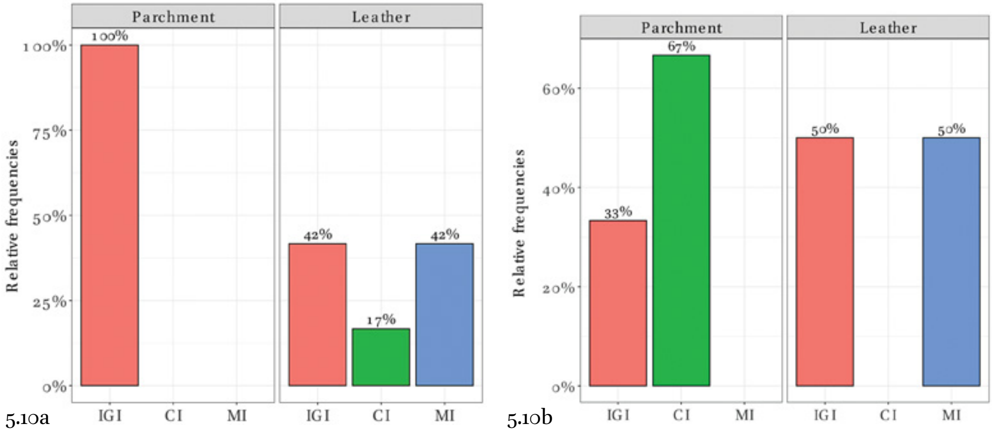
The inks and writing surface used in the Jewish religious documents in the corpus were explored in the previous chapter, in evaluating whether the type of document had an influence on the type of writing material used. However, the evaluation was very general, in particular because the Jewish religious documents in the corpus are diverse and can be divided into two sets. The first set contains religious poems (*piyyutim*) and religious responsa (*teshuvot*) written by the scribes examined in this work, while the second set consists of liturgical and rabbinic texts, some written as scrolls and another small number found as fragments of codices. In the following subsections, we evaluate those documents in more detail.

3.1 *Liturgical and Rabbinic Texts: the Case of Scrolls*

Through an inference tree in chapter 4 (Figure 4.6), we examined the choice of writing surface. That tree showed that a discrimination was taking place depending on the community, but only in the case of scrolls documents (the list of scrolls in the corpus is to be found in Table 5.3): leather was used for scrolls produced by the Babylonian community, and parchment was used by the Palestinian community. Those observations are a continuation of the different eastern and western traditions of preparing the writing surfaces, such as were observed in the Dead Sea Scrolls. For the rest of the religious documents (mostly *piyyutim* and *teshuvot*), no discrimination could be found in the choice of support on a community basis: most of them are written on paper, for economic reasons. The Babylonian and Palestinian communities included in this analysis wrote religious documents almost exclusively using paper during the period we focus on, and these will be discussed in the next section.

TABLE 5.3 List of the scrolls studied during this project[a]

Classmark	Support	Date	Type	Community	Ink typology
T-S 16.282	Parchment	10–11th century	Midrash	Palestinian	Iron-gall
T-S 20.153	Parchment		Liturgy	Palestinian	Iron-gall
T-S 28.12	Parchment		Piyyut	Palestinian	Iron-gall
T-S 28.13	Parchment	11th century	Psalms	Palestinian	Iron-gall
T-S AS 62.511	Leather	9–10th century	Bible	Babylonian	Carbon
T-S AS 62.512	Leather	9–10th century	Bible	Babylonian	Iron-gall
T-S AS 62.513	Leather		Bible		Iron-gall
T-S AS 78.390 + T-S AS 78.391 + T-S AS 95.291	Leather	9–10th century	Mishnah Bava Batra	Babylonian	Iron-gall
T-S AS 78.392	Leather	9–10th century	Babylonian Talmud	Babylonian	Mixed
T-S H 8.84	Parchment	10–11th century	Liturgy	Palestinian	Iron-gall
T-S K 21.95s	Parchment	9th century	Hekhalot Rabati	Palestinian	Iron-gall
T-S K5.108 f.1+2	Parchment		Bible	Babylonian	Iron-gall
T-S K21.84	Parchment	10th century	Pirqa de Rabbenu ha-Qadosh	Palestinian	Iron-gall
T-S 20.155 + T-S AS 63.51 + T-S AS 63.129 + T-S AS 63.153	Parchment	9th century or earlier	Palestinian Targum	Palestinian	Iron-gall
			Haftarot	Palestinian	Carbon
T-S B13.16	Parchment	11th century	Liturgy	Palestinian	Iron-gall
T-S Misc.26.53.17	Leather		Talmud Yerushalmi	Babylonian	Carbon (Main text) Iron-gall (note)
			Talmud	Babylonian	Iron-gall
T-S AS 4.162 + T-S AS 78.389	Leather	9–10th century	Babylonian Talmud	Babylonian	Mixed
			Document	Babylonian	Iron-gall
T-S AS 78.393 +	Leather	9–10th century	Midrash	Babylonian	Mixed
T-S AS 78.395				Babylonian	Mixed
T-S AS 78.394 +	Leather	9–10th century	Midrash	Babylonian	Mixed
T-S AS 78.396				Babylonian	Mixed



5.10a 5.10b

FIGURE 5.10 Distribution of the type of inks used to write scrolls depending on the type of writing surface for a) primary text and b) later additions, reuse and notes

Classmark	Support	Date	Type	Community	Ink typology
T-S AS 74.324	Leather	9–10th century	Avot of Rabbi Nathan	Babylonian	Iron-gall
				Babylonian	Mixed
T-S AS 86.263	Leather	9–10th century	Commentary	Babylonian	Iron-gall
T-S AS 137.389 + T-S AS 137.447 + T-S AS 137.451	Leather	9–10th century	Selihot of Yom Kippur	Babylonian	Mixed
T-S NS 200.12	Parchment		Liturgy	Palestinian	Iron-gall
T-S NS 122.132[12]	Parchment	11–12th century	Liturgy		Iron-gall

a Most of the attributions have been given in Olszowy-Schlanger, 'The Anatomy of Non-Biblical Scrolls from the Cairo Geniza'.

Let us now have a closer look at the inks used to write scrolls, to see if a similar discrimination can be seen there as in the use of writing support. The distribution of the types of ink used to write scrolls can be seen in Figure 5.10. Some of these scrolls were studied using XRF spectrometry, but the parameters of the analysis and the uneven distribution of metallic components together with their high concentration in the support made the analyses more difficult, and the establishment of the fingerprint unreliable. In most cases, then, XRF spectrometry has been used only to clarify the nature of the carbon-based inks, as either carbon ink or mixed ink.

Figure 5.10 presents the distribution of the type of ink used to write scrolls depending on the type of writing surface, for 24 documents. Three types of ink are presented: iron-gall ink (IGI, in pink), carbon ink (CI, in green) and mixed ink (MI, in blue). In Figure 5.10a, the inks used in the main texts are presented, while in Figure 5.10b, the inks used in the remainder of the scrolls are shown. All of the inks used to write the main text on parchment were iron-gall ink (IGI), while for leather, the use of inks is more dispersed: we encounter about 42% of both iron-gall ink (IGI) and mixed ink (MI) and about 16% of carbon ink (CI).[36] This means that for parchment scrolls – mostly Palestinian – the choice of ink type seems deliberate, while for leather scrolls – mostly Babylonian – there was not the same norm, and the use of inks is diverse.

For the secondary inks – that is, inks used in additions and notes and for reuse – one can see that the ink used to write on parchment was no longer restricted to iron-gall ink, and indeed is more frequently carbon ink (67%) than iron-gall ink (33%). The ink used to write on leather in these cases is evenly divided between iron-gall ink and carbon ink.

It seems to me that the results seen in the use of inks on secondary parts of the documents show that the only regulation within the Palestinian community concerning the ink used on a scroll was addressed to the scribe. Most of the secondary text on the scrolls written on parchment are notes of ownership. However, it is worth noting that the document formed by the classmarks T-S 20.155 + T-S AS 63.51 + T-S AS 63.129 + T-S AS 63.153[37] shows a case of reuse: the verso – used as a rotulus – was reused to copy liturgical text. The ink used to copy those secondary texts is a carbon ink and not an iron-gall ink. However, to my knowledge no identification has been made about which community copied the secondary text. When it comes to the leather scrolls, given that the results on the primary text did not yield any preference, it is not surprising that the inks used for secondary text and ownership notes are divided between two classes of ink: iron-gall ink and carbon ink.

3.2 Piyyutim*, Responsa and the Case of Other Religious Texts as Codices or as Private Documents*

Having examined the specific case of scrolls, we now want to extend this study to other types of religious document, such as copies of the Talmud in the form

36 Although an initial study showed that carbon ink was more frequently used on leather, as mentioned in Olszowy-Schlanger, 68. more thorough analysis has shown that these carbon inks were most often actually mixed inks, as they contain a large amount of iron and other metallic components.

37 And also T-S AS 63.24 + T-S AS 63.72 + T-S AS 63.85 + T-S AS 63.95 + T-S AS 63.96 + T-S AS 63.117, but these have not been analysed during this study.

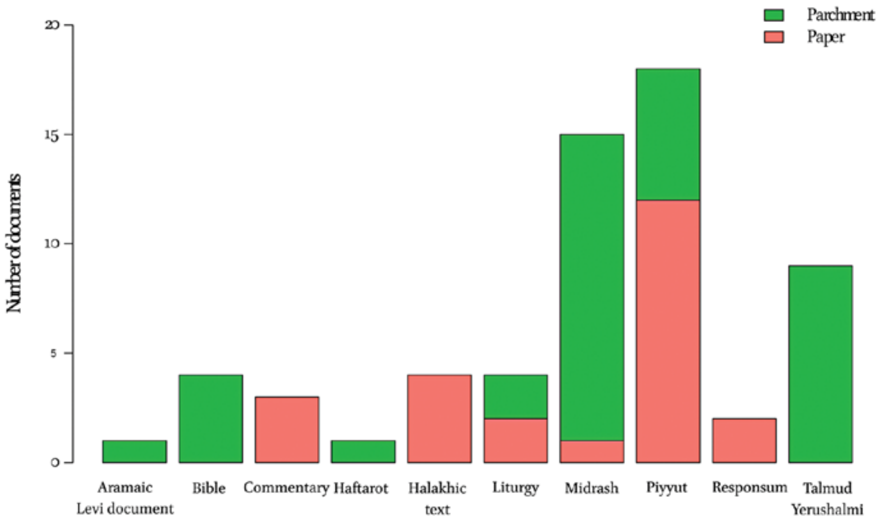


FIGURE 5.11 Type of support used in religious documents depending on the type of document

of a codex (T-S 12.755 + T-S 12.756 + T-S F17.4), commentaries, liturgical verses, responsa and *piyyutim*. Some of these were written as notes (e.g. T-S 10J22.3), while more attention was lavished on others. The relevant documents from the corpus stretch between the 10th century to the end of the 11th century, with a large part of the corpus undated.

The distribution of the type of writing surface as a function of the type of document in this subcorpus is given in Figure 5.11. On the abscissa, the type of document is presented, and the number of each type of document in the ordinate. Two classes of writing surface are presented: parchment (in green) and paper (in pink).

Most of the documents seem to be distributed homogeneously: commentaries, responsa, halakhic texts and *piyyutim* are mostly written on paper, while Bibles, *Midrashim* and copies of the Talmud are mostly written on parchment. Can any correspondence can be found when it comes to the type of ink used to copy the document? Did the scribe change the type of ink according to the type of writing surface?

Figure 5.12 presents the use of different types of ink as a function of the type of support in a total of 61 documents. Two classes of inks are presented: iron-gall ink (IGI, pink) and carbon ink (CI, green). A first look at the figure seems to indicate a relationship, as parchment only receives iron-gall ink and carbon ink is used only on paper. However, the overwhelming use of iron-gall ink versus carbon ink plays a large role here. Therefore, let us investigate if other criteria could play a role in the ink typology.

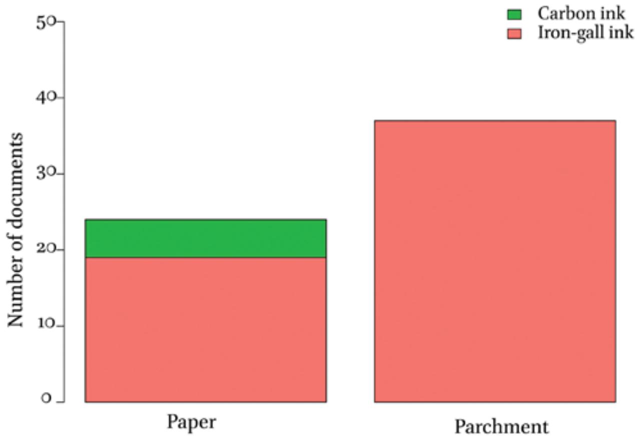


FIGURE 5.12 Type of ink used in religious documents depending on the type of support

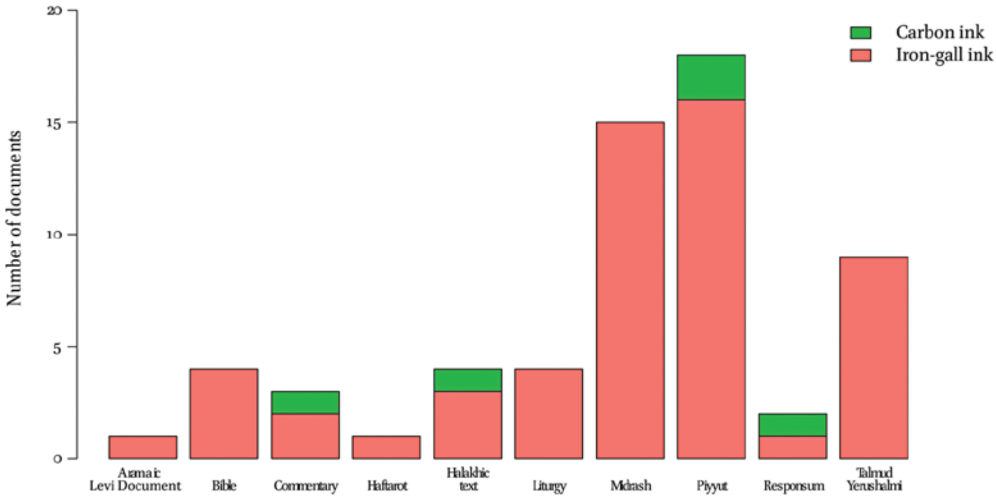


FIGURE 5.13 Type of ink used in religious documents depending on the type of document

Figure 5.13 shows, for the same 61 documents, the relationship between type of ink and type of document, with the type of document on the abscissa and the number of documents of each type on the ordinate. Two classes of ink are presented: iron-gall ink (IGI, pink) and carbon ink (CI, green). Once again, we see that the main type of ink used is iron-gall ink (92% vs 8% for carbon ink), and no pattern can be observed in the use of this type of ink.

Due to the primacy of iron-gall ink over carbon ink in this corpus, it is difficult to assess any reasons for the choice of ink, or even if there is a reason for this. It seems that both Figure 5.12 and Figure 5.13 explain the choice partially, but neither explains it completely. In any case, as the primacy of iron-gall ink has been seen in almost all corpora, and carbon ink was mostly used by certain specific scribes (such as Ephraim b. Shemarya) or by the Fatimid chancery (see 5.2.2), and we are not dealing here with holy documents, it has to be kept in mind that copyists may well have simply used the most readily available ink.

3.3 *Joining Fragments*

The highly fragmented state of the manuscripts in the Cairo Genizah have made the attribution of fragments to a single manuscript an important part of the research into Genizah documents. In the frame of this project, studies of writing material have proven to be a useful way to confirm the attribution of different fragments to a single document, the so-called "identification of the joins". Indeed, through ink characterisation, I have been able to check for consistency in the use of inks and writing supports.

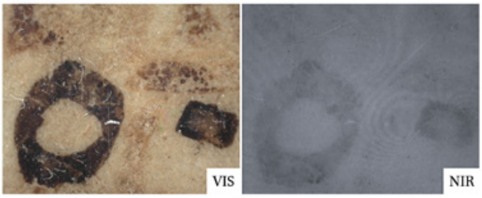
For example, in the BnF (Bibliothèque Nationale de France, Paris), several fragments of a Talmud Yerushalmi have been identified as part of the same original manuscript. These fragments, copied around the 10th century, possibly belong to one of the oldest examples of the Talmud Yerushalmi found so far.[38] The study of other Talmud fragments that are stored today in other libraries – including the Bodleian Library and the CUL – has enabled other fragments from the same initial manuscript to be identified by means of codicological and palaeographical studies. The CUL stores at least three fragments of this Talmud Yerushalmi: T-S F17.4, T-S 12.755 and T-S 12.756. Reflectography has been conducted to identify the inks of the three fragments.

Figure 5.14 presents visible and near-infrared images of the ink of the main text and of the vocalisations in the three fragments, T-S 12.755, T-S 12.756 and T-S F17.4. In all three cases, both inks fade away under NIR illumination, which is a characteristic feature of iron-gall ink. In order to obtain statistically relevant observations, multiple XRF line scans were conducted on each of the fragments, to obtain the elemental composition of each ink.

Figure 5.15 displays the average fingerprint of the ink that was used to write T-S F17.4, T-S 12.755 and T-S 12.756. The fingerprint is exactly the same for the ink used to write the three documents. This indicates that the same ink has been used to write the main text in the three documents. Therefore, the results of the XRF spectrometry can confirm the palaeographical and codicological attribution of these documents as joints.

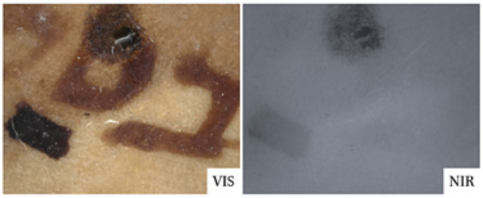
38 Judith Olszowy-Schlanger and Roni Shweka, 'Newly Discovered Early Palimpsest Fragments of the Talmud Yerushalmi from the Cairo Genizah', *Revue Des Études Juives* 172, no. 1–2 (2013): 49–81.

5.14a



5.14b

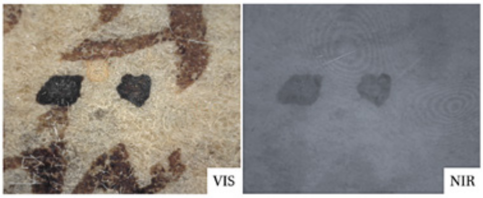
5.14c



5.14d

FIGURE 5.14 Presentation of the document formed by T-S 12.755, T-S 12.756 and T-S F17.4 reproduced by kind permission of the Syndics of Cambridge University Library; a) photograph of the recto of T-S 12.755, highlighting the zone analysed by reflectography; b) VIS/NIR images of the main text and a vowel; c) photograph of the recto of T-S 12.756, highlighting the zone analysed by reflectography; d) VIS/NIR images of the main text and a vowel; e) detail of the recto of T-S F17.4, highlighting the zone analysed by reflectography; and f) VIS/NIR images of the main text and a vowel

5.14e



5.14f

The fingerprint of the ink used to vocalise fragment T-S 12.755[39] shows interesting results. We have seen from the average fingerprint of the inks that the main text of fragments T-S 12.755, T-S 12.756 and T-S F17.4 were indeed written with the same ink. The addition of vowels, however, was conducted in a different ink, which contained almost three times more copper than the ink of the main text. Let us remind the reader that the difference in the colour of the two inks in the visual aspect is a result of degradation, and was not meant originally either as decoration or as a way to highlight information. Although it is speculative, these results make it rather likely that the vocalisation of the text was added after the main text was written and not simultaneously, or possibly that it was done by another person. These results are very similar to the ones obtained when studying the Erfurt Bible:[40] cantillation and vocalisation were often added afterwards.

39 Due to technical constraints, we were unable to carry out measurements on the vowelling of the other fragments.

40 Hahn et al., 'The Erfurt Hebrew Giant Bible'.

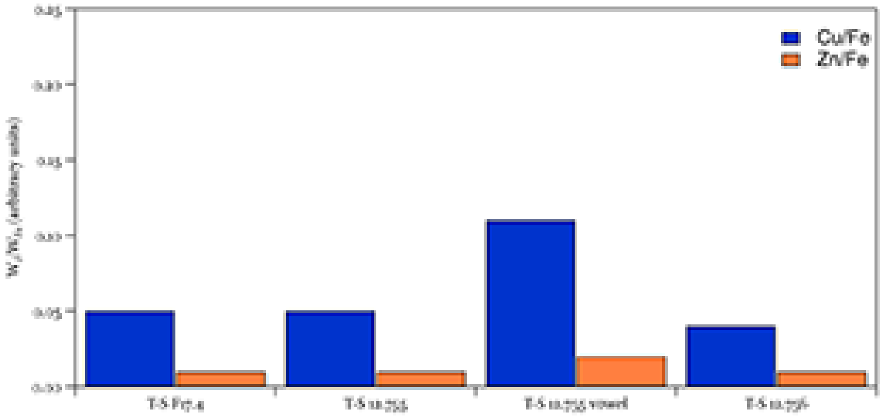


FIGURE 5.15 Fingerprint values w(i)/w(Fe) (i = Cu and Zn) obtained by XRF analyses on the manuscripts T-S F17.4, T-S 12.755 and T-S 12.756

4 Autographs of Maimonides

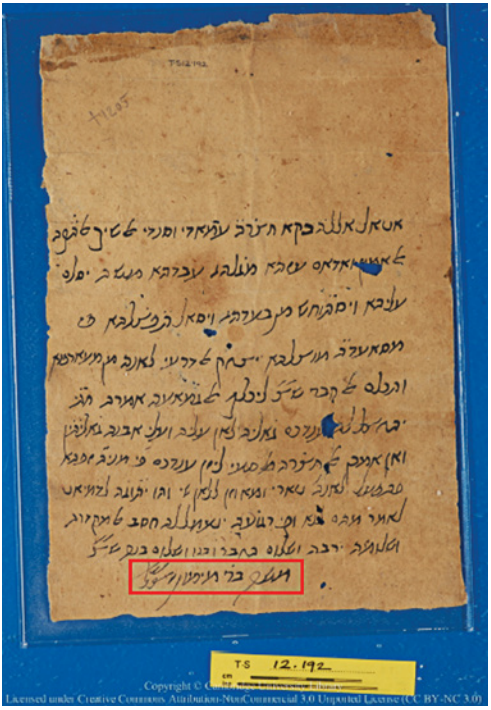
In section 4.2.3.4, we saw that the scribes under investigation could not be assigned to a specific fingerprint: even if some scribes seemed to prefer one type of ink, this did not mean that they did not use another. Moreover, none of the scribes was recommending the use of a specific ink. No recipe written by them could be found, which might explain why the preference for one type of ink over another was not marked. Of course, this does not mean that these scribes never wrote ink recipes, just that none has yet been found.

Moses b. Maimon, commonly known as Maimonides, was a 12th-century philosopher who lived – among other places – in Fusṭāṭ. With an interest in the study of the Torah and the Talmud, he commented on the different meanings of what an ink (דיו) is, and left precise recommendations regarding the way one should prepare an acceptable ink in the case of sacred documents: one should use a carbon ink with the addition of tannins. Since he lived more or less in the time and the location where all the types of inks studied in this work were known, we wanted to see whether he was consequently using one single ink in his work – the one he was describing – or if the use of this ink was restricted only to the copying of sacred documents. As mixed ink that consists of carbon with the addition of tannins cannot be detected in a simple way through the current non-destructive protocol, NIR reflectography and – when possible – XRF spectrometry has been conducted on a number of his autographs preserved at the CUL, the National Library of Israel and the Bodleian Library in Oxford.

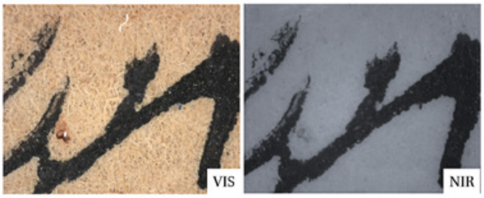
Manuscript T-S 12.192 (see Figure 5.16a) is an undated letter of recommendation for Isaac al-Darʿī, written on paper. Reflectography (see Figure 5.16b) shows that the ink does not change its opacity under NIR light, which leads to the conclusion that the document was written with a carbon ink. Furthermore, XRF spectra show no difference in the intensity of iron between the paper and the ink. In Figure 5.16c, an XRF line scan of 30 points shows the intensity profiles of a number of elements, among them iron and its possible vitriol satellites. The first five and the last five points correspond to measurements conducted on paper only, while the middle portion of the scan consisting of 20 points related to the measurements of the inks. This line scan illustrates the spatial heterogeneity of the elements iron (Fe, in red) and calcium (Ca, in grey) in the paper and clearly shows that no additional abundance of the former can be detected in the inked area. Therefore, we conclude that the ink used to write this document was based on a carbon ink.

Let us turn now to T-S 10Ka4.1, another document written by Maimonides and stored also in the CUL. This manuscript is a draft of *The Guide for the Perplexed*, which has been thoroughly corrected. Reflectographic analyses on folio 2r (see Figure 5.17a) has shown that this folio has been written with two different inks: an iron-gall ink (text, see Figure 5.17b) and a carbon ink (a doodle, see Figure 5.17c).

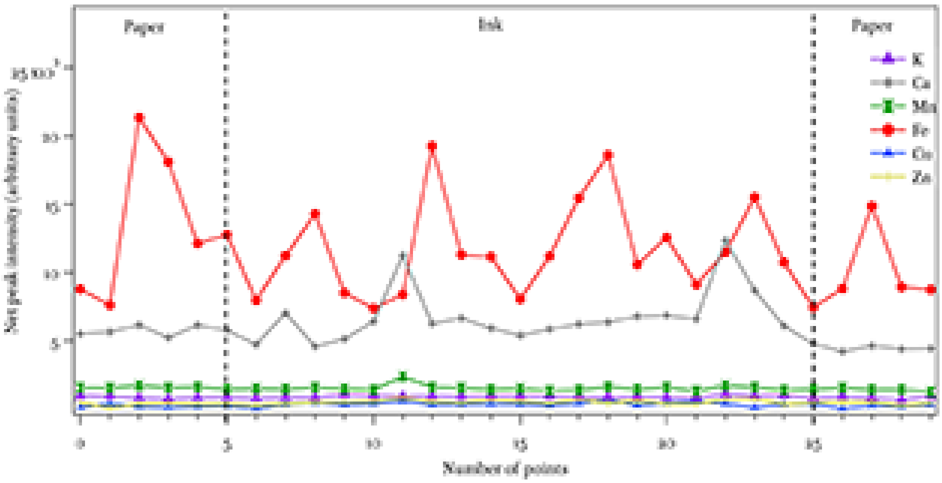
In addition to the loss of the opacity of the ink under NIR light, the evaluation of the XRF spectrum in Figure 5.17b shows that the iron-gall ink contains other vitriolic satellites elements of iron, namely copper and zinc. No variation can be observed in the concentration of manganese between the support and the ink. However, the carbon ink (see Figure 5.17c) does not contain any vitriolic metallic components. Given our inability to detect tannins with the current protocol, we cannot distinguish whether some tannins have been added to this carbon-based ink, which would make it an ink according to Maimonides' recipe; but we can at least confirm that no metallic elements have been added to this ink.



5.16a

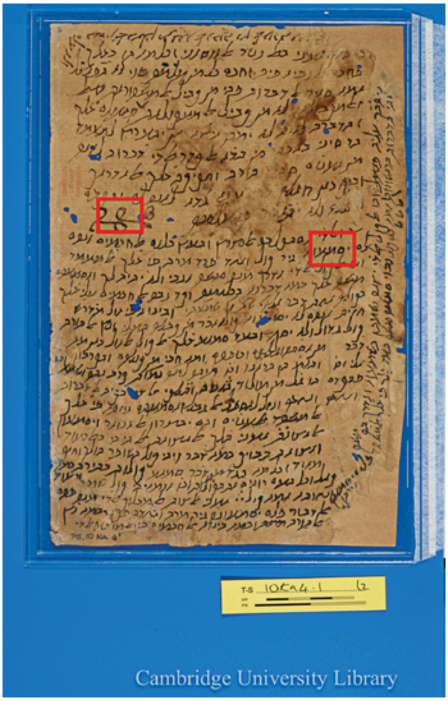


5.16b

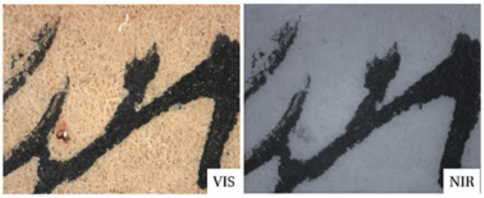


5.16c

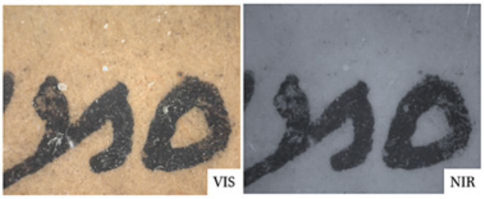
FIGURE 5.16 Presentation of the manuscript T-S 12.192; a) photograph of the manuscript reproduced by kind permission of the Syndics of Cambridge University Library, b) VIS/NIR micrographs of a portion of the signature of Maimonides, and c) XRF line scan on support and ink, displaying potassium (K, purple), calcium (Ca, grey), manganese (Mn, green), iron (Fe, red), copper (Cu, blue) and zinc (Zn, yellow)



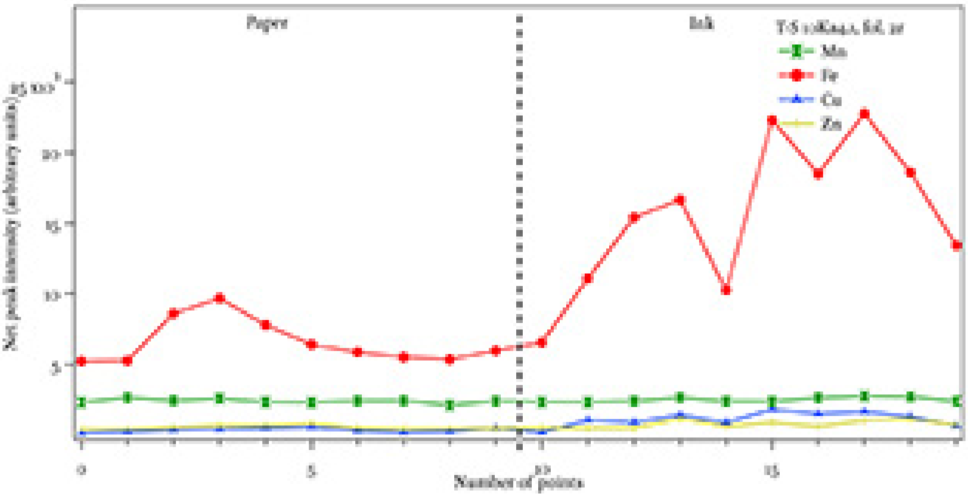
5.17a



5.17b

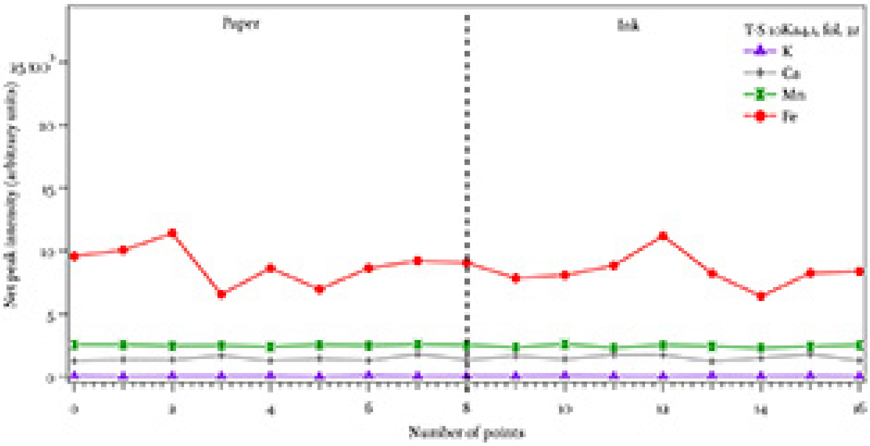


5.17d



5.17c

FIGURE 5.17 Presentation of the manuscript T-S 10Ka4.1, fol. 2r; a) photograph of the manuscript reproduced by kind permission of the Syndics of Cambridge University Library, b)–c) VIS/NIR micrographs and the element profiles calculated from line scans conducted on the two regions of interest. The inked and non-inked areas are indicated by vertical dotted lines



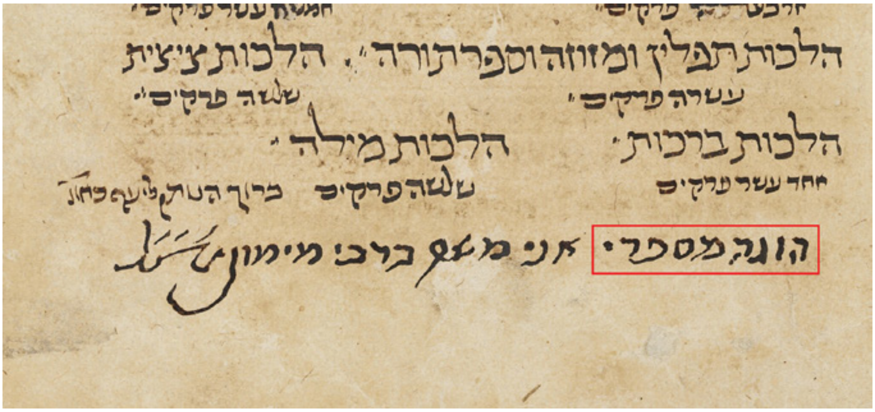
5.17e

During a visit to the Bodleian Library, I was able to analyse the manuscript Huntington 80, which is a copy of Maimonides' *Mishneh Torah*.[41] This manuscript, copied by Yefet b. Solomon, contains at the end an autograph from Maimonides, on folio 165r, certifying that the book was proofread and corrected based on his own copy. As one can observe in Figure 5.18, the ink used to write this autograph faded away under NIR light, which is characteristic of an iron-gall ink. XRF analyses on both the main text of the folio, written by Yefet b. Solomon, and on the autograph of Maimonides, show that two different inks were used. The ink used by Yefet b. Solomon contains very little copper (Cu) – considered as a trace according to our standards – while the one used by Maimonides contains 9% of copper. The ink used by Maimonides was therefore not the one used by Yefet b. Solomon and was probably his own.

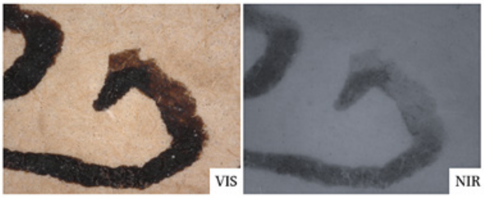
A summary of the results gathered so far on Maimonides' ink use is presented in Table 5.4.[42]

41 I would like to thank Cesar Merchan-Hamann for allowing me to access the document and authorising analyses on it.

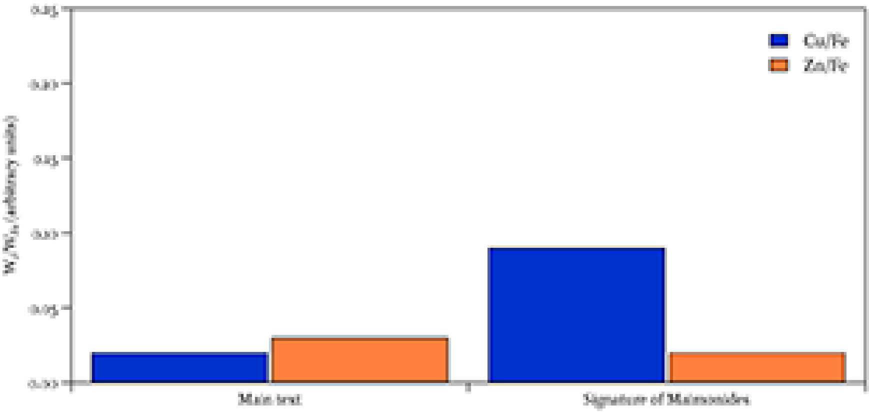
42 The Genizah contains hundreds of documents written by, or including autographs of, Maimonides; I therefore think it would be interesting to conduct a systematic study of his autographs, using reflectography at least.



5.18a



5.18b



5.18c

FIGURE 5.18 Presentation of the manuscript Bodleian Libraries, University of Oxford, Huntington 80, fol. 165r; a) detail of the signature, b) VIS/NIR imaging of the signature of Maimonides, and c) fingerprint values w(i)/w(Fe) (i= Cu and Zn) obtained by XRF analyses, on both the main text and the autograph of Maimonides

TABLE 5.4 Ink characterisation of Maimonides' autographs

Classmark	Type of manuscript	Conservation place	Technique	Ink used
T-S 12.192	Letter	CUL	Reflectography + XRF	Carbon ink
T-S 10Ka4.1	*The Guide for the Perplexed*	CUL	Reflectography + XRF	Carbon ink (doodle) and iron-gall ink (text)
Huntington 80, fol. 165r	*Mishneh Torah*	Bodleian Library, Oxford	Reflectography + XRF	Iron-gall ink
Heb. 5703/2[a]	Commentary on the Mishnah	National Library of Israel, Jerusalem	Reflectography	Iron-gall ink

a This manuscript is discussed in Beit-Arié, *Hebrew Codicology. Historical and Comparative Typology of Hebrew Medieval Codices Based on the Documentation of the Extant Dated Manuscripts Using a Quantitative Approach*, 280. I would like to thank Ira Rabin and Malachi Beit-Arié for kindly sharing with me the results of the reflectographic studies made on this manuscript.

Table 5.4 shows that Maimonides did not have any preference for a specific ink type in the writing of the documents gathered here. It is especially clear from the analysis of the draft of *The Guide for the Perplexed*, in which both carbon and iron-gall ink were detected. It seems that Maimonides was using any black ink that was available at the location he was writing. The difference between fresh carbon and iron-gall inks is not apparent since the discolouration of iron-gall ink is the result of the deterioration of the ink.

5 Conclusions and Outlook

This study deals with the correlations between writing surfaces and inks and their use by the Jewish communities of Fusṭāṭ in the first half of the 11th century. To this aim, I have investigated a corpus of 391 manuscripts found in the Cairo Genizah – 498 documents – produced by scribes known to be from different communities.

Different types of inks coexisted and were in use at the time: those based on carbon particles, iron-gall inks, mixed inks and even possibly plant inks.

With respect to the iron-gall inks, I found that 159 ink samples – including 53 in main texts – did not contain vitriolic metals. 118 ink samples – including 46 in main texts – were written with carbon inks, 49 – including 26 in main texts – with mixed inks and 7 samples – with only 1 to write a main text – with what seems to be a plant ink. Despite the limitations of the current protocol, the overall picture of the inks correlates well with the multitude of recipes available in medieval Arabic sources. It is not surprising, therefore, that no identical iron-gall ink fingerprints based on the content of vitriolic metals could be found across different documents separated in time. However, identical fingerprints were found within single documents – whether religious manuscripts or legal documents. Therefore, material analysis can be used as an additional criterion for joining fragments into a single manuscript.

Though some personal preferential use of one ink type rather than another was observed for some individual scribes, it seems that generally speaking scribes indiscriminately used any ink that was available, at least for everyday use and for legal documents. Any personal preferences of scribes were not driven by the community to which the scribe belonged, nor could ink type be correlated with the type of support being used. In any case, no single ink (based on its fingerprint) could be associated with an individual scribe. To establish a link between a scribe and a certain ink, one would need to have followed his production over a short period of time, and such a corpus is not available, at least not in the Cambridge University collection. Therefore, I was limited to considering correlations based over a larger period of time. Overall, the observations suggest that scribes were buying their inks rather than making them. It is not even clear whether they were aware of the formulation of their inks; most probably, inks were chosen purely on the basis of cost.

Neither of the two Rabbanites communities examined during this project shows a preference for a specific ink type, at least in dealing with non-religious documents. The small number of documents attributed to the Karaite community, on the other hand, show a coherent corpus of documents written with carbon ink. It is noteworthy that where scribes do show a certain preferential though not exclusive use of one ink type, this is regardless of the community to which they belong.

The type of support chosen was mostly dictated by the type of document which needed to be written and therefore most probably by the price the scribe was willing to put into copying the document. There is a correlation between religious documents and skin-based materials, whereas almost all legal documents were written on paper. In the case of religious documents, a tendency within the Palestinian community to use parchment and iron-gall inks is contrasted to the use of leather but with any type of ink by the Babylonian community.

The investigation of the inks within a single document has resulted in a important new insight. First, it seems that there is a correlation between the number of signatures, the inks that they were executed with and the importance of the document. Moreover, using ink analysis it has possible to reconstruct the production timeline of some documents. Furthermore, similar results were obtained from a (rather limited) corpus composed of Arabic legal documents.

The results of this study seem very promising, for they lay the foundations for future studies. Although the fingerprints obtained from the inks did not provide information about their attribution to a scribe or a manufacturer, several interesting results have been obtained during the course of this study. It would be interesting, for instance, to investigate other legal documents of the Cairo *bet din* and extend the analysis to a more extensive corpus of Arabic legal documents for comparison. The study of other corpora, including a corpus of biblical scrolls, would allow for more insight into the use of writing materials in the case of religious documents. In addition, it would be relevant to conduct a study focusing on a later scribe, such as Maimonides, to compare his entire scribal production, dated and undated documents alike, mixing religious, private and working documents. It was our primary idea before beginning that a reflectographic study of the inks used to write these manuscripts would gather sufficient data. Now, however, after conducting this project, we have the feeling that a multidisciplinary study is necessary due to the multiple aspects of the inks that were used in this corpus. In order to be able to fully understand their diversity and the breadth of types, it seems that restricted studies that do not take into account the organic part of their composition would be prejudicial for future research in this field. The study of black inks now needs to include and encompass the large variety of carbon inks and the different types of mixed inks. In addition, it seems that a study measuring and studying the distribution of inorganic compounds – especially iron – on the surface of paper is necessary to increase our knowledge about scribal practice and the techniques used at the time.

The results gathered would come to enrich the database we created for the purpose of this study and for the study of black inks. Through this database, we aim to gain insights in a possible evolution in the medieval technologies concerning writing materials and especially on inks. We hope to be able, in a near future, to publish the database online, to make it accessible for further studies.

These different projects listed here would also allow a better understanding of the economics of ink. Although several studies claim that carbon inks are the most expensive type, as they take the longest to produce, our observations on this extensive corpus have give numerous hints that disagree with this statement. Evidently, it is possible that different inks belonging to the same type would display different levels of quality and would have been produced with different degree of care concerning their manufacture. We would like, in the near future, to conduct a study on the manufacture of inks and the price of inks. So far, no research has been conducted to compare the different costs of ink-making in medieval Egypt. Ashtor has compiled different prices gathered from several Genizah fragments – prices of day-to-day items, such as food, housing and clothing, but also prices that are more focused on scribal practices, including different prices of books, and wages for different scribes and judges.[43] That compilation gathers data from different places and different times, but does not include the price of inks or of writing surfaces. A close look at the documents of the Genizah shows not only the different degrees of paper quality and of care in the layout and in the writing, but also the use of inks of different qualities. Although these general features cannot be used to determine the ink type used to write a particular document, they can provide indications of the contemporary value of the document at the time it was written and therefore, one hopes, would allow insights into the relative value of different types of ink.

43 Ashtor, 'Le coût de la vie dans l'Égypte médiévale'; Ashtor, *Histoire Des Prix et Des Salaires Dans l'Orient Médiéval*.

Documents Studied

Add. 4320, fols. a-d
L-G Arabic 2.154
L-G Misc.107
L-G Misc.124
L-G Misc.25
L-G Misc.6
Michaelides (charta) A169
Michaelides (charta) B48
Mosseri Ia.13.2
Mosseri Ia.2
Mosseri Ia.27
Mosseri Ia.4
Mosseri Ia.5
Mosseri Ia.9
Mosseri II.137.1
Mosseri II.141.1
Mosseri II.141.2
Mosseri IV.10
Mosseri IV.33.3
Mosseri IV.5
Mosseri IV.64.3
Mosseri V.366.1
Mosseri VI.208.2
Mosseri VII.136.1
Mosseri VII.37.2
Mosseri VII.4.1
Mosseri VII.43 + T-S Ar.53.53
Mosseri VII.45.2
Mosseri VII.58.1
Mosseri VII.76.1
Mosseri VII.89.4
Or.1080 1.39
Or.1080 1.8
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Or.1080 4.65a+b
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T-S AS 149.180
T-S AS 149.60
T-S AS 150.11
T-S AS 150.8
T-S AS 151.241
T-S AS 151.4
T-S AS 152.236 + T-S AS 152.269
T-S AS 152.303
T-S AS 178.233
T-S AS 181.163
T-S AS 4.161
T-S AS 4.162 + T-S AS 78.389
T-S AS 62.511
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T-S AS 62.524
T-S AS 62.525
T-S AS 62.526
T-S AS 74.324
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T-S AS 78.397
T-S AS 78.400

T-S AS 78.402 + 410
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T-S AS 93.524
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T-S B13.16
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T-S K 21.95s
T-S K21.84
T-S K25.189
T-S K5.108 f.1+2
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T-S Misc.26.53.17
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T-S NS 320.17
T-S NS 320.29
T-S NS 320.45
T-S NS 320.50C
T-S NS 320.76a+b + T-S NS 323.35
T-S NS 329.844-845
T-S NS J149
T-S NS J449
T-S NS J51
T-S NS J86

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