

Gaining Perspective into the Materiality of Manuscripts: The Contribution of Archaeometry to the Study of the Inks of the White Monastery Codices

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Abstract

An interdisciplinary approach to the study of manuscript traditions is here applied to the analysis of the leaves from the White Monastery, one of the greatest centres of literary production in Late Antique Egypt. In the framework of the 'PATHs' project, archaeometric analyses complement the information pieced together by a range of disciplines in the field of humanities. The use of different complementary analytical techniques provides information on the type of ink used and its elemental composition, unveiling interesting details regarding the materials and methodology of manufacturing of writing media. Moreover, this contribution takes a step forward and discusses the possible existence of a regional arrangement in the elemental composition revealed in the inks studied.

Keywords

archaeometry, ink analysis, interdisciplinary approach, Coptic studies, manuscript making.

1. Introduction

In November 2017 the CSMC (Centre for the Study of Manuscript Cultures, University of Hamburg), the BAM (Bundesanstalt für Materialforschung und -prüfung, Berlin), and the ERC Advanced grant project 'PATHs', based at Sapienza University of Rome, started an interdisciplinary project aimed at bringing new insights into the material study of manuscripts.¹ This collaboration is based on a dedicated PhD project, that addresses primarily the archaeometric analysis of writing materials in Coptic Egypt. The main purpose is to collect data on a statistically relevant number of manuscripts, trying to reconstruct the technological evolution of black inks and coloured pigments, while giving support to palaeography and codicology.² It is in this frame-

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1 GHIGO *et al.* 2018.

2 The corpus of manuscripts to examine is in constant development in accordance with the results obtained during the work. So far, we have analysed texts from six different collections. Among the papyrus collections, we examined some fragments from the 'Bodmer Library' and some codices from the library of the cathedral of Thi(ni)s (GHIGO - RABIN - BUZI 2020; GHIGO - TORALLAS in this volume). Among the parchment collections, we examined the codices from the Monastery of Apa Jeremiah, the heterogeneous Michaelides collection preserved at the Cambridge University Library, the parchment codices from the Monastery of Saint Macarius (GHIGO - RABIN 2019), and those from the library of the White Monastery presented in this work.

work that the material analysis of the inks used on the leaves from the library of the White Monastery has been developed.

The White Monastery, or better the confederation of monasteries that it coordinated, became one of the most relevant focal points of Coptic literary production under the strenuous guidance of Shenoute (ca. 350-465/66 CE), who himself became the most prolific Coptic writer.³ What remains of the library, however, dates back for the most part to a much later period, between the ninth-eleventh centuries CE, although a nucleus of earlier papyrus and parchment manuscripts might have survived.⁴ The codices from this ancient collection were often divided up while circulating the antiquity market. For this reason, their leaves are nowadays to be found in several European and non-European collections.⁵

The parchment leaves examined within the research described here date back to the tenth-eleventh centuries, and most of them are preserved at the Staatsbibliothek zu Berlin Preußischer Kulturbesitz, as part of a set of fragments bought in 1887. This purchase included 69 leaves, which, once at the Staatsbibliothek, were bound in eleven modern volumes.⁶ At the Staatsbibliothek we examined 25 parchment leaves originally belonging to 17 different codicological units. In addition, we also analysed 5 parchment leaves originally divided in 3 codicological units forming part of the Borgian collection at the Apostolic Vatican Library. These were brought to Europe on the initiative of Cardinal Stefano Borgia, who acquired them in 1778.⁷ Finally, we examined 2 leaves from a single codicological unit now preserved at the Cambridge University Library which, according to Catherine Louis, belong to a codex from the White Monastery.⁸

Table 1 lists the shelfmarks, number of folio and modern collection for each codicological unit examined. For sake of clarity, we added the CMCL sigla⁹ and the 'PATHs' IDs (CLM numbers, in the latter case)¹⁰ as a univocal way of determining a specific codicological unit, as it appears in the *Archaeological Atlas of Coptic Literature*.

It is fundamental to remark that the codices that formed part of this library were not produced exclusively in the scriptorium of the White Monastery. Some of their colophons reveal that, as a gesture to save their souls, some donors commissioned manuscripts to a *scriptorium* in Touton,¹¹ in the Fayyūm, far away from the White Monastery in Sūhāğ (Sohag). This seems to have been a professional *scriptorium* that spent part of the time producing codices to be donated to the White Monastery. Table 1 reports, where possible, the information available regarding the place of production of the leaves examined.

2. Analytical protocol

The analytical protocol applied on the leaves from the White Monastery consists of a primary screening to determine the type of the ink and a subsequent in-depth analysis using several spectroscopic techniques: X-ray Fluorescence (XRF), Fourier Transformed Infrared Spectroscopy (FTIR), and Raman spectroscopy.¹² The primary screening is carried out by means of near-infrared reflectography. Strictly speaking, optical differences between carbon, plant and iron-gall inks are best recognized when comparing their response to the infrared light: carbon ink has a deep black colour, iron-gall ink becomes transparent above 1200 nm and plant ink disappears at ca. 750 nm.¹³ We performed the analysis using a small USB microscope equipped with a NIR light at 940 nm, an UV light at 390 nm and an external white light source. Working at 940 nm we determined the ink typology, observing the changes in the opacity of the ink. Here, car-

3 ORLANDI 2002; BUZI 2016.

4 BUZI 2014, 64.

5 On Shenoute's and the manuscripts of the White Monastery, see above all EMMEL 2004.

6 BUZI 2014, 61-63.

7 BUZI 2009, 7-8; LOUIS forthcoming, 7.

8 LOUIS forthcoming, 365 (n. 919).

9 Corpus dei Manoscritti Copti Letterari (CMCL): www.cmcl.it.

10 'PATHs' – Archaeological Atlas of Coptic Literature: <https://atlas.paths-erc.eu>. The *siglum* CLM stand for Coptic Literary Manuscripts.

11 NAKANO 2006.

12 RABIN *et al.* 2012.

13 MRUSEK - FUCHS - OLTROGGE 1995.

Preservation place	Shelfmark	Folio(a)	CMCL	CLM	Production place
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1348	ff. 1-3	MONB.LN	502	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1350	f. 1	MONB.AB	264	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1350	f. 3	MONB.OO	576	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1605	f. 1	MONB.IB	427	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1605	f. 2	MONB.IE	430	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1605	f. 3	MONB.NL	547	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1605	f. 6	MONB.KH	476	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1606	f. 3	MONB.NT	555	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1607	ff. 1-2	MONB.DN	343	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1607	ff. 9-10	MONB.GC	400	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1608	f. 3	MONB.EZ	375	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1609	ff. 1-2	MONB.VG	3350	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1609	f. 3	MONB.AW	283	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1609	f. 4		1572	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1611	f. 1		1710	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1612	ff. 1-3	MONB.AR	278	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1613	f. 1	MONB.DQ	346	Unknown
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1614	f. 1	MONB.CR	325	Unknown
Apostolic Vatican Library	<i>Borg.copt.</i> 109 cass. 16, f. 57	f. 2	MONB.KM	480	Fayyūm (?)
Apostolic Vatican Library	<i>Borg.copt.</i> 109 cass. 26, f. 131	ff. 2-3	MONB.CE	314	Touton - Fayyūm
Apostolic Vatican Library	<i>Borg.copt.</i> 109 cass. 29, f. 166	ff. 1-2	MONB.NC	538	Fayyūm
Cambridge University Library	<i>Or.</i> 1699	ff. M1-M2	MONB.LY	511	Touton – Fayyūm

Table 1. List of the leaves analysed. The information on the production place was extracted from the section 'Manuscripts' of the *Archaeological Atlas of Coptic Literature*: <https://atlas.paths-erc.eu/manuscripts> (last accessed 13.02.2019). Further details are discussed in the following paragraphs.

bon-based inks show no change in their opacity, while the opacity of iron-gall inks changes considerably, and plant inks become transparent. The in-depth investigation includes micro-XRF analysis to detect the elemental composition of the ink. In the case of iron-gall inks we sometimes establish the so-called fingerprints, i.e. the characteristic ratios of the metallic elements contained in the ink.¹⁴

3. Preliminary results

We focused our analysis on both the black inks and the coloured pigments displayed in the leaves of the codices.

The XRF analysis of red, green and yellow pigments found on some of the leaves of this collection led to their identification, showing a palette composed of minium (Pb_3O_4) for the red-orange tones, orpiment (As_2S_3) or realgar (As_4S_4) for the yellow hues, and copper-based greens whose mineralogical composition was not possible to investigate further. These results were not surprising as these pigments occur in nature and are widely distributed. Furthermore, the use of arsenic-based pigments is documented in Egypt since Pharaonic times¹⁵ while evidence of minium is recorded from the Greco-Roman period onwards.¹⁶

In contrast, interesting results were obtained while investigating the black inks. The examination using NIR reflectography revealed that the main body of the text, the titles and the colophons of all the leaves analysed were written using iron-gall ink. Furthermore, XRF analysis revealed a difference in their elemental composition. After comparing the data obtained from all the codicological units studied, we observed two different clusters: inks containing only iron (Fig. 1), and inks also containing copper and, in some cases, a little zinc (Fig. 2), as reported in Table 2.

¹⁴ RABIN *et al.* 2012.

¹⁵ LEE - QUIRKE 2000; DANIELS - LEACH 2004; DI STEFANO - FUCHS 2011.

¹⁶ AHMED AFIFI 2011.

Preservation place	Shelfmark and folia	Elements detected		
		Fe	Cu	Zn
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1348	*	*	*
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1350, f. 1	*		
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1350, f. 3	*		
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 160, f. 1	*	*	
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1605, f. 2	*		
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1605, f. 3	*		
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1605, f. 6	*		
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1606, f. 3	*		
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1607, ff. 1-2	*		
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1607, ff. 9-10	*		
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1608, f. 3	*		
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1609, ff. 1-2	*	*	*
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1609, f. 3	*	*	
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1609, f. 4	*	*	
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1611, f. 1	*		
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1612, ff. 1-3	*		
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1613, f. 1	*	*	*
Berlin, Staatsbibliothek	<i>Ms.or.fol.</i> 1614, f. 1	*	*	
Apostolic Vatican Library	<i>Borg.copt.</i> 109 cass.16.57, f. 2	*		
Apostolic Vatican Library	<i>Borg.copt.</i> 109 cass.26.131, ff.2-3	*		
Apostolic Vatican Library	<i>Borg.copt.</i> 109 cass.29.166, ff.1-2	*		
Cambridge University Library	<i>Or.</i> 1699 ff. M1-M2	*		

Table 2. Elemental composition of the black inks from the codicological units studied.

A variety of mediaeval recipes mention the use of vitriol in the manufacturing of iron-gall inks. The term itself referring to a mixture of sulphates appeared during the late Middle Ages.¹⁷ Vitriol has been commonly equated to the Greek term *chalcanton*, a copper-based substance often mentioned in ancient treatises.¹⁸ According to Pliny, *chalcanton* could be obtained during Antiquity from crystallization of drain waters proceeding from mines containing sulphates,¹⁹ and we can suppose that throughout history it could have been directly extracted from those mines as well. Either way, the resulting salt will most likely contain a mixture of different sulphates, typically iron, copper and zinc, as has been supported by the analysis of the inks of mediaeval European manuscripts.

The absence of a variety of metallic elements in the inks of some of the manuscripts from the White Monastery collection might be an indication that other materials, such as common iron nails or iron filings, were used instead of vitriol to prepare this type of iron-gall ink. Arabic recipes from the Middle Ages onwards corroborate this possibility.²⁰ Alternatively, vitriol may have been purified before being used in the preparation of the ink: the addition of solid iron to the vitriol solution to obtain pure iron sulphate is reported in literature.²¹ In any case the two groups of inks revealed through elemental analysis reflect differences in the materials and methodology of manufacture of the inks.

Generally, we tend to assume that manuscripts belonging to the same collection show a certain degree of homogeneity in the materials used for the preparation of the ink. However, this is not the case for

¹⁷ KARPENKO - NORRIS 2002.

¹⁸ We must recognise, though, that to date we have no direct proof of the correspondence between *chalcanton* and vitriol before the early Middle Ages.

¹⁹ Pliny, 34.32.

²⁰ COLINI forthcoming.

²¹ KARPENKO - NORRIS 2002

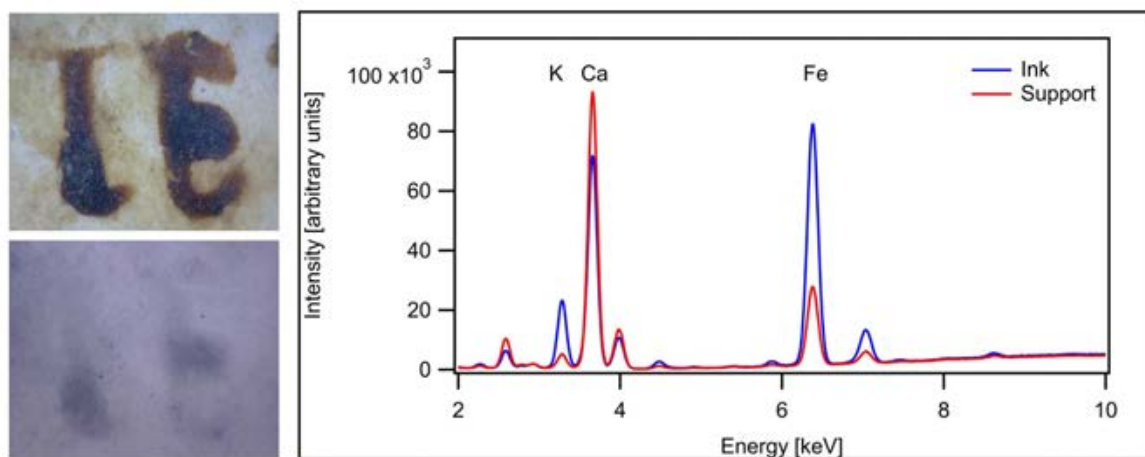


Fig. 1. Visible and near-infrared micrographs (left top and bottom, respectively) and XRF spectra (right) of the inked (blue) and non-inked (red) area on Berlin, Staatsbibliothek, *Ms.or.fol.* 1350, f. 1.

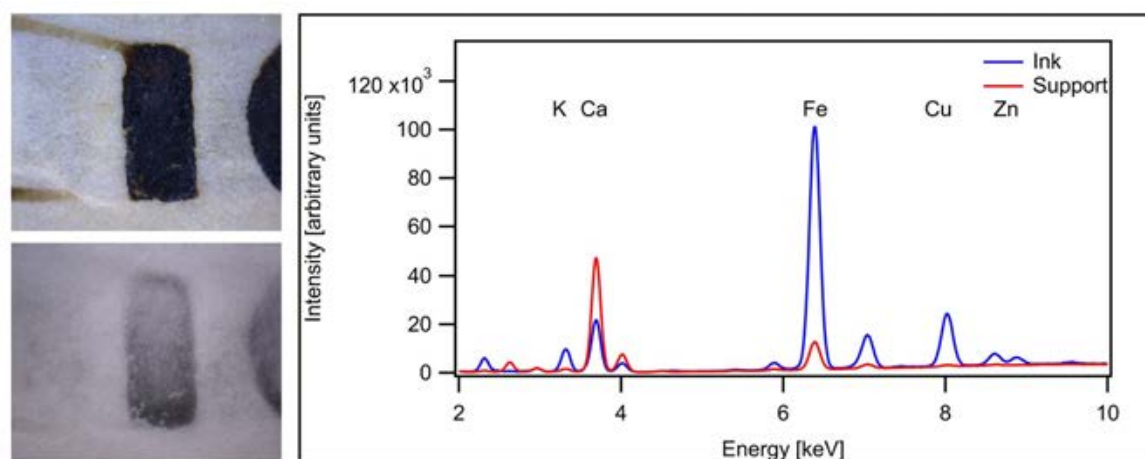


Fig. 2. Visible and near-infrared micrographs (left top and bottom, respectively) and XRF spectra (right) of the inked (blue) and non-inked (red) area on Berlin, Staatsbibliothek, *Ms.or.fol.* 1609, f. 1.

the manuscripts from the White Monastery. We should not forget though, that the codices forming part of this collection were most probably produced in at least two different places: the Touton *scriptorium*, in the Fayyūm region, and the White Monastery itself. Trying to gain further insight, we focused our attention on the few codices available that were attributed to Touton or more generally to the area of the Fayyūm, and therefore produced in the north of Egypt rather than in the area of Sūhāġ, where the White Monastery was located. According to palaeographical and codicological studies, the leaves at the Cambridge University Library, *Or.* 1699 and those preserved at the Apostolic Vatican Library, *Borg.copt.* 109 *cass.* 26, f. 131 were originally part of codices produced in Touton (respectively MONB.CE = CLM 314 and MONB.LY = CLM 511). In fact, as it has been pointed out by Francesco Valerio,²² both are decorated in the so-called 'Touton Style', which was identified and defined by Petersen²³. Moreover, Apostolic Vatican Library, *Borg.copt.* 109 *cass.* 29, f. 166 (MONB.NC = CLM 538) can be generically attributed to the area of the Fayyūm according to some dialectal forms typical of this region,²⁴ while *Borg.copt.* 109 *cass.* 16, f. 57 (MONB.KM = CLM 480) may have

²² Personal communication (26th June 2019).

²³ PETERSEN 1954.

²⁴ LOUIS forthcoming, 373-375.

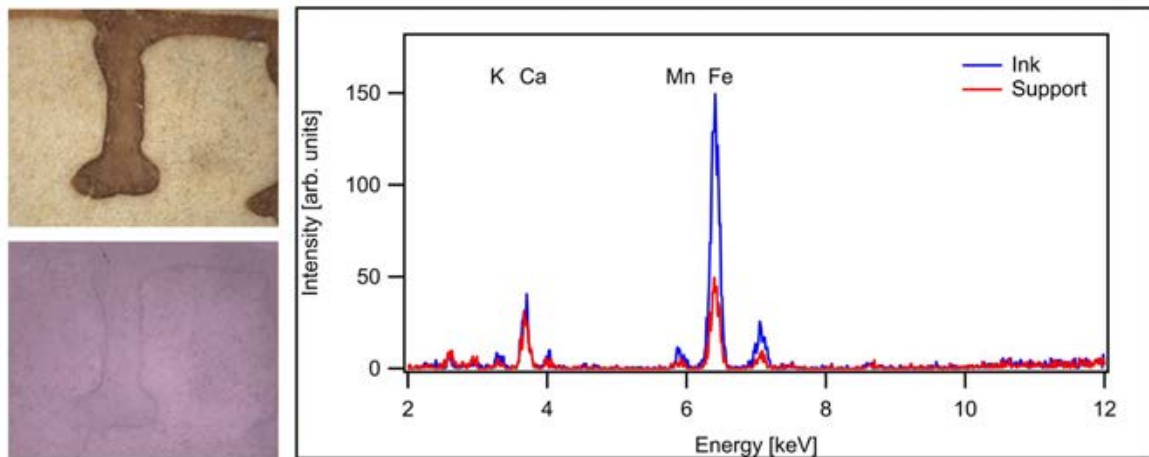


Fig. 3. Visible and near-infrared micrographs (left top and bottom, respectively) and XRF spectra (right) of the inked (blue) and non-inked (red) area on Apostolic Vatican Library, Borg.copt. 109 cass. 26, f. 131.

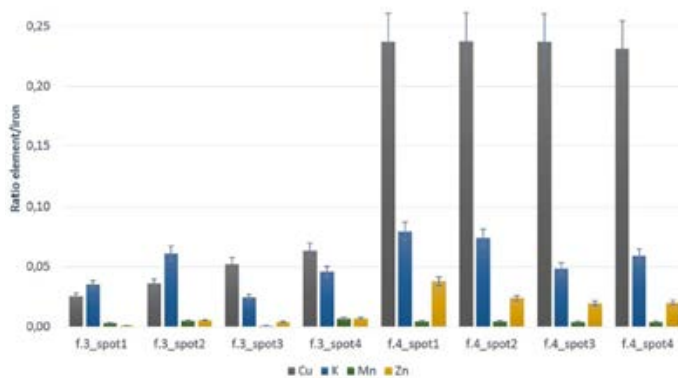


Fig. 4. XRF elemental analysis on four spots of ink from f. 3 and four spots of ink from f. 4 of Berlin, Staatsbibliothek, Ms.or.fol. 1609. The results are reported as ratio of each element to iron (i.e.: fingerprint).

been produced in the same region according to the typology of superline strokes used.²⁵

It was interesting to note that the inks found on all these four different codicological units contained exclusively iron, with no trace of copper or zinc (see for instance the results obtained on *Borg.copt.* 109 cass. 26, f. 131 in Fig. 3). Despite the fact that the number of manuscripts from Touton and the Fayyūm that have been investigated is far from being statistically meaningful, the consistency in the result obtained seems to suggest there

may be a trend in the composition of the inks used in northern Egypt. This hypothesis was corroborated by the analysis of four codices from the Monastery of Saint Macarius in Wādī al-Naṭrūn that revealed the use of iron-gall inks containing exclusively iron, but of course it will be necessary to make more tests before reaching trustable conclusions.²⁶ This analytical evidence, together with the textual information demonstrating that the manuscripts from the White Monastery were produced in different places, poses some interesting questions: is it possible that the inks produced in the north of Egypt in a period between the ninth and eleventh centuries all contained exclusively iron? Could this have been a peculiar trait characteristic only of the inks produced in that area? And if so, what implication would this have for the analytical results obtained on the collection from the White Monastery? Is it possible that the manuscripts whose inks contain only iron were produced in the north of Egypt, while those whose inks contain other elements were produced elsewhere, for instance inside the same monastery? These matters are of great importance. If further analysis could confirm that a consequential number of manuscripts produced in northern Egypt were penned with inks containing only iron, while a significant number of manuscripts produced inside the monastery were written with inks containing also copper and zinc, that would indicate the existence of local differences in the materials and methods used in the manufacturing of writing

²⁵ LOUIS forthcoming, 145-147. Archaeometric studies often rely on few pieces, given the limited access that it is possible to obtain to the collections when it comes to perform scientific analysis. Therefore, every piece of information that is possible to obtain matters, even in case of manuscripts whose historical context is still unclear. For sake of clarity, it is pointed out that the attribution to a specific geographic location is, in this case, dubious.

²⁶ GHIGO - RABIN 2019.

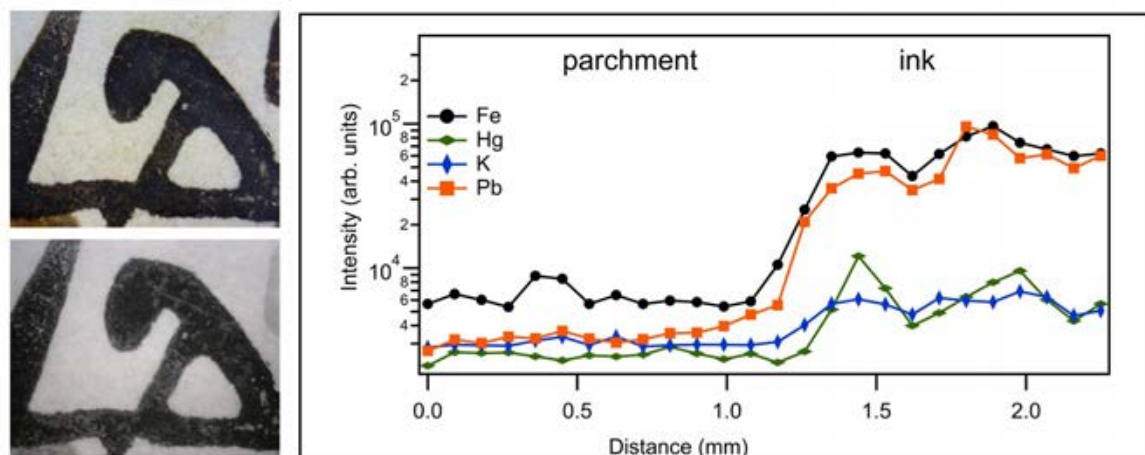


Fig. 5. Visible and near-infrared micrographs (left top and bottom, respectively) and XRF intensity profiles (right) of different elements extracted from a line-scan connecting non-inked and inked areas on Berlin, Staatsbibliothek, Ms.or.fol. 1605, f. 6.

media. Most importantly, this typological diversity could be exploited to establish the place of production of a certain codex.

Archaeometric analysis, at least in some cases, can support palaeographical and codicological studies, providing them with additional tools to gain insight on the production of manuscripts in a certain scriptorium. It is the case of Berlin, Staatsbibliothek, *Ms.or.fol.* 1609, ff. 3 and 4 (CLM 283 and 1572). In her catalogue of the Coptic manuscripts at the Staatsbibliothek,²⁷ Buzi suggests that these two leaves may come from the same codicological unit, since the hand is very similar, if not the same. After performing XRF analysis, we calculated the fingerprint (i.e.: the ratio of each element to iron) of the ink used on both these leaves. In Fig. 4 the result of this calculation is displayed. Here we observe a diversity in the ratio of copper to iron in folio 3, where is around 5%, and in folio 4, where is around 25%. Although on this basis we cannot claim that these two leaves belong to different codicological units or were written by different persons, we can certainly assess that they come from different writing phases. In fact, even when the same ink is used for a certain period, and it is left to rest in the inkwell or in any other storage place for some time, it might change its fingerprint due to deposition and drying processes. Alternatively, every new batch of ink displays a slightly different fingerprint. Such differences in the fingerprint have been successfully used in the past to discriminate between several writing phases on a certain codex.²⁸ The case study on Berlin, Staatsbibliothek, *Ms.or.fol.* 1609, ff. 3 and 4 was presented at the University of Hamburg during the summer school dedicated to Coptic literature that took place in September 2018,²⁹ in the presence of scholars who had directly studied these leaves. According to Diliانا Atanassova, despite the similarity in the handwriting, the two leaves were written indeed by two persons. Alin Suciú added that these two hands very likely belong to a teacher and a pupil who worked closely in the same *scriptorium*, thus explaining the similarity in the handwriting.

Lastly, we will discuss the case of the peculiar type of ink found on f. 6 of Berlin, Staatsbibliothek, *Ms.or.fol.* 1605 (MONB.KH = CLM 476). Right in the middle of this leaf there is evidence of a marginal note added later, that corresponds to the numbering of chapters of biblical works according to the Greek system.³⁰ Fig. 5 reports the results on this spot. Near-infrared reflectography shows that there is no change in opacity when the ink is illuminated using 940 nm light. This clearly indicates that it contains carbon. However, XRF analysis detected the presence of iron, lead and mercury together with potassium, that could be attributed to the binder. The intensity profiles of each element detected along a line that connects non-inked and inked areas reveal that iron and lead intensities increase significantly moving from the support to the inked area, indicating that we are probably dealing with one of the

²⁷ BUZI 2014.

²⁸ For instance HAHN - HEILES - RABIN 2018.

²⁹ See https://www.manuscript-cultures.uni-hamburg.de/register_coptic2018.html.

³⁰ SCHÜSSLER 2007, 81.

rare examples of mixed inks recorded so far. Moreover, potassium and mercury are present in lesser amounts. The pattern of the intensity profiles is very similar in the case of potassium, iron and lead, and suggests that they were all contained in the ingredients employed, together with carbon, in the ink manufacturing. The high iron content may suggest that carbon was mixed with iron-gall ink, although the presence of tannins that need to react with iron to produce this type of ink could not be identified using the current analytical protocol. While potassium can normally be attributed to the binder, lead is generally not contained in vitriol or iron filings used to prepare iron-gall inks, and therefore could have a different origin. There exists the possibility that this ink was prepared by mixing carbon, iron-gall and red lead (minium), to give a warmer hue to the black colour. Or, simply, that lead was introduced from contaminated water. Finally, the line profile of mercury, appears slightly different from the one characterising the other elements. This suggests that the trace of ink was contaminated by something containing mercury, for example the same pen was first used to apply a mercury-based red ink (cinabar) and then used to write this marginal note.

At present, the evidence we have on mixed ink produced by blending carbon and iron-gall ink consists of different recipes contained in Arabic treatises from the ninth century onwards describing its preparation, and a Syriac manuscript from the fourteenth century where a mixture of iron-gall and carbon ink was unequivocally identified.³¹ Unfortunately, we do not have any information on the period in which this marginal note was added. It was definitely after the tenth-eleventh centuries CE, when this codex was first produced, and surely before its dismemberment. In fact, Francesco Valerio pointed out that such chapter numbers, all written by the same hand, are detectable in all the extant leaves belonging to this codicological unit.³² According to him, as a lower chronological term for the addition of such numbers, a reasonable date is the thirteenth-fourteenth century CE, when Coptic 'monolingual' manuscripts ceased to be produced and used, having been replaced by the bilingual Copto-Arabic ones.³³

5. Conclusion

The results obtained on the leaves from the White Monastery seem to suggest that there may exist local trends involving different materials and methods used in the manufacture of black inks in Egypt between the ninth and eleventh centuries, encouraging further investigation in this direction. If such trends could be systematically demonstrated, the chemical composition of the inks may serve to complement palaeographical and codicological information on the place of production of certain codices. Moreover, the archaeometric analysis of inks on Berlin, Staatsbibliothek, *Ms.or.fol.* 1609, ff. 3 and 4 revealed interesting details regarding the production of the manuscript, offering new insights on the different phases involved in the writing process. Finally, this study unveiled one of the first experimental proof of the existence of a mixed ink probably obtained by adding carbon to iron-gall ink, although further investigation is needed to support this conclusion.

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³¹ COLINI 2018; COLINI *et al.* 2018.

³² See the table dressed by SCHÜSSLER 2007, 81.

³³ Personal communication with Francesco Valerio, 27 June 2019.

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