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A Scribe and His Inks. An Interdisciplinary Approach to Byzantine Inks in the Manuscripts Coislin 330 and Vat. gr. 244

1 Introduction

The manuscript Paris, BnF, Coislin 330 (Diktyon 49471) is a codex well-known to Aristotelian scholarship. Traditionally dated to the eleventh century,[1] its text has played a primary role in the understanding of Aristotle's treatises on logic for the last 200 years. This *Coislinianus* is one of the witnesses on which I. Bekker based the first modern edition of the *Organon* and it was part of several other important editions of the collection ever since.[2] In spite of its undisputable relevance to our current understanding of Aristotelian philosophy, several features of Coisl. 330 have not been sufficiently investigated. This is especially true of the numerous notes that different hands wrote at various stages of the manuscript's life, mostly in the margins and between the lines of its core content.[3] This paper contributes to

1 A brief description of Coisl. 330 is available in R. DEVREESSE, Catalogue des manuscrits grecs, II. Le fonds Coislin. Paris 1945, 315.

2 Bekker gave Coisl. 330 the siglum C, which was kept by the subsequent editors of the *Organon*. See, among other important editions, I. BEKKER (ed.), Aristotelis Opera, I. Berlin 1831; T. WAITZ (ed.), Organon graece, I–II. Leipzig 1844–46; W.D. ROSS (ed.), Aristotelis Analytica Priora et Posteriora. *OCT*. Oxford 1964; R. BODÉÜS (ed.), Aristotle Catégories. Paris 2002; H. WEIDEMANN (ed.), Aristoteles De interpretatione. *Bibliotheca scriptorum Graecorum et Romanorum Teubneriana*. Leipzig 2014.

3 For some specific marginal and interlinear notes in Coisl. 330, see N. AGIOTIS, Inventarisierung von Scholien, Glossen und Diagrammen der handschriftlichen Überlieferung zu Aristoteles' De interpretatione (c. 1–4). *Working Paper-Reihe des SFB 980 "Episteme in Bewegung"*. Berlin 2015, 4–5; C. BROCKMANN, Helpful Interaction between Commentary and Text: Aristotle's Posterior Analytics and Important Manuscripts of this Treatise, in S. Boodts / P. De Leemans † / S. Schorn (ed.), Sicut Dicit. Reflections on Editing Commentaries on Authoritative Texts. *Lectio. Studies in the Transmission of Texts & Ideas*, 8. Turnhout 2019, 209–242, at 221; J. MAKSIMCZUK, Layers of Corrections, Scribal Practices, and the Transmission of Prior Analytics I 1–7 in the MSS Neap. III D 37, Ambr. Q 87, and Vat. 244. *MEG* 22 (2022) 221–245, at 236–238. For marginal notes in a different context see: R. TOCCI, Lesen und Schreiben im Freirand: Die Patriarchen(angaben) im Kodex Vindobonensis historicus graecus 99, in I. Grimm-Stadelmann / A. Riehle / R. Tocci / M.M. Vučetić (ed.), Anekdota Byzantina. Studien zur byzantinischen Geschichte und Kultur. Festschrift für Albrecht Berger anlässlich seines 65. Geburtstags. *BA*, 41. Berlin / Boston 2023, 717–735.

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the exploration of Coisl. 330's multi-layered dimension by focusing on one specific note containing a recipe for black ink, jotted down by a later user of the manuscript on the verso of the first folio. The palaeographical features of the hand that wrote the recipe allow us to identify it with the main hand of another important witness to the *Organon*, the codex Città del Vaticano, BAV, Vat. gr. 244 (late 12th century, Diktyon 66875). The study of this recipe provides us information about the interests of an anonymous scribe who hitherto was only known to have written logical texts and their commentaries. By using X-ray Fluorescence (XRF), Ultraviolet (UV), and Near Infrared (NIR) reflectography, we profile the ink that the scribe used to write the different layers in Vat. gr. 244. This approach that integrates methods of the humanities and natural sciences applied to the materiality of written artefacts is an essential part of the framework developed in the Centre for the Study of Manuscript Cultures (CSMC, Universität Hamburg) and its Cluster of Excellence 'Understanding Written Artefacts', which aims at overcoming traditional academic boundaries between disciplines. The interdisciplinary investigation carried out in this paper allows us to better understand the copying activity of an anonymous scholar who annotated and wrote two of the most relevant *Organon* manuscripts that were passed down to us.

2 The scribe and his recipe

Coisl. 330's first folio offers a ruled sheet of parchment in bad state of preservation: there are numerous small holes all over the folio and its margins are broken. The contents are difficult to read, not least because at several points the ink has faded. The recto and part of the verso were mainly written by a scribe different from those who wrote the text of the *Organon* in Coisl. 330 by the end of the eleventh century. The handwriting of the scribe who made most of the content on f. 1 can be dated to the second half of the twelfth century. According to Devreesse's catalogue description, "[à] travers l'écriture à peu près effacée du f. 1 apparaissent quelques lignes sur la chronologie de la vie d'Aristote et un fragment de logique (on y cite, au début, le Parménide)".[4] The biographical references to Aristotle are followed by a short note, difficult to decipher, whose incipit and desinit are Ση(μείωσαι) ὅτι Πλάτων τὴν λογικὴν … ἐν τῷ Παρμενίδῃ. The last text, i.e. the one that Devreesse described as "un fragment de logique", is a long excerpt from Philoponus, *Commentary on*

4 Devreesse, Catalogue (as footnote 1 above) 315.

Categories 32, 7–33, 30,[5] headed by a lemma that quotes *Categories* 1 a 24 (ὃ ἔν τινι μὴ ὡς μέρος…). For its part, the verso of f. 1 offers a rather chaotic patchwork of notes carelessly jotted down by different hands over centuries (Fig. 1). In the web of annotations that cover f. 1v, there is one note that features prominently due to its contents and extension. It covers the first ten lines in the middle of the folio – whereas the others have no more than two lines – and it can be identified as a recipe for black ink, as its title Σκευασία τοῦ μελανίου clearly announces; in turn, the other notes deal with logic. For the first time, we offer a transcription of the recipe text, reproducing the spelling of the original document and followed by our English translation. Some portions of the recipe were illegible to the naked eye and could be read only through multispectral imaging (Fig. 2).[6]

> Σκευασία τοῦ μελανίου· κικίδιν συντετριμμένον λεπτὸν καυκ[ία/ον…]
> καὶ ὕδωρ καυκία πέντ’ ἢ ἕξ· κομίδιν καυκίον ἕνα· καὶ ὕδωρ
> ζ΄ ἢ καὶ θ΄· ταῦτα ἀποβρεχέσθωσαν ἰδίᾳ καὶ ἰδίᾳ
> ἡμέρας ἕξ· εἶτα βρασάτω πρότερον τὸ κικίδιν ἄχρις
> γένηται ἁπαλὸν ὡς ζύμη· εἶτα σακελιζέσθω εἰς τὸ κομί[διν],
> πρότερον καὶ αὐτοῦ σακελισθέντος· καὶ πάλιν βρασάτω ἀμφότερ[α]
> ἱκανῶς· εἶτα σακελιζέσθωσαν ὁμοῦ· καὶ οὕτως ἐμβάλλεται
> τὸ καλάκανθον ὀλίγον ὀλίγον, ὅσον ἀρκέσει μελανῶσαι τὸν ζ[ωμόν·]
> πλεοναζέτω δὲ ἡ στύψις καὶ ἔστω ὁ ταύτης ζωμὸς παχύτερος ἐν τῷ βρά[σαι]
> πλέον·
>
> Preparation of black ink: (…) cup(s?) of gall nuts well pulverized and fine and five or six cups of water. One cup of gum and seven or even nine cups of water. Let these soak each for itself for six days. Then let us first boil the gall nuts until they become soft like a yeast dough. Then let us filter it into the gum, after having first filtered the dissolved gum itself. And then let us boil again both sufficiently. Then let them be filtered together. And then the vitriol is added very slowly, bit by bit, as much as will be sufficient for the sauce-like liquid to become black. Let the mixture be more abundant and let its sauce-like liquid become thicker by boiling it more.

As our transcription reflects, the decipherment of the text is hampered by the folio's poor state of preservation and the rather loose structure of the recipe, which was evidently written for personal use. The ink has faded at certain points, making it impossible to read some signs with the naked eye but thanks to the multispectral images that were provided by our colleagues of the CSMC at a later stage of our investigations, we were able to recover a few of these illegible text portions

5 M. Wallies (ed.), Philoponi (olim Ammonii) In Aristotelis Categorias Commentarium. *Commentaria in Aristotelem Graeca*, 13/1. Berolini 1898.

6 Multispectral images of Coisl. 330, f. 1v were kindly produced by our colleagues Kyle Ann Huskin and Ivan Shevchuk in September 2023. They were processed by Kyle Ann Huskin in December 2023.

(especially at the the second line: καυκίον ἕνα· καὶ; and at the third line: the ending -σαν and ἰδίᾳ καὶ ἰδίᾳ). Moreover, words or signs at the very end of some lines became illegible when they were covered by the volume's modern binding. At the end of the eighth line, we read ὅσον ἀρκέσει μελανῶσαι τὸν. After τὸν, we can still distinguish part of the first letter of a word that was written very much inside the inner margin and today has almost completely disappeared into the fold. The same occurs in the following line, the ninth, whose last visible letters are βρά. The latter signs belong to a word that we conjectured to be βράσαι (cooking). In the case of the eighth line, a conjecture is harder. The first and only distinguishable sign after τὸν is a ζ. Thus, it is possible that the last word in the eight line is ζωμόν, a common term used to indicate a liquid, which appears also in the ninth line of our recipe.[7]

Despite the difficulties mentioned above, it is clear that Coisl. 330, f. 1v offers a typical recipe for iron-gall inks, which were the most common types of inks in the Middle Ages in the Western and Byzantine worlds.[8] They were obtained from the reaction between tannins and iron II ions in an aqueous solution, with the addition of a binder. Judging from the numerous medieval recipes that came down to us, our recipe prescribes the most typical ingredients for iron-gall inks.[9] The source of tannins is gallic acid extracted from pulverized gall nuts (κικίδιον); the source of iron ions in our recipe is vitriol (καλάκανθον);[10] the binder is gum (κομίδιον).

The recipe prescribes that the pulverized gall nuts and the gum be put in two different recipients together with water. Then, it is necessary to leave them to macerate for six days. The gall nuts must be boiled and filtered into the gum. The mixture must be boiled again. After filtering it, the vitriol (i.e. the component that will provide the black colour by reacting with the gallic acid from the gall nuts) is added. It is interesting to note that the author of our recipe suggests adding the vitriol carefully, little by little (ὀλίγον ὀλίγον), until the black color is obtained. Thus, it

7 The reading ὅσον ἀρκέσει μελανῶσαι τὸν ζωμόν finds further support through a comparison with the contents in other preserved recipes. Compare: τὸ δὲ καλάκανθον μαυρίζει τὸν ζωμὸν τῶν κικιδίων (C.M. Mazzucchi, Inchiostri bizantini del XII secolo. *RSBN* 42 (2005) 157–162, at 159).

8 See an overview of recipes of black ink in M. Zerdoun Bat-Yehouda, Les Encres Noires Au Moyen-Âge (Jusqu'à 1600). Paris 1983, 143–214 (for Medieval Europe) and in P. Schreiner / D. Oltrogge, Byzantinische Tinten-, Tuschen- und Farbrezepte. *Veröffentlichungen der Kommission für Schrift- und Buchwesen des Mittelalters / Reihe IV: Monographien*, 4. *Denkschriften der philosophisch-historischen Klasse*, 419. Wien 2011, 33–44 (for the Byzantine world in particular).

9 See Zerdoun Bat-Yehouda, Les Encres Noires (as footnote 8 above) 16–20.

10 The term vitriol designates hydrated sulphates of metals, namely iron, copper, magnesium, and zinc. Ancient sources for vitriol are usually found within the weathering zones of copper and iron mines. They contain a mixture of several metallic salts (V. Karpenko / J.A. Norris, Vitriol in the History of Chemistry. *Chemické Listy* 96 [2002] 997–1005).

transpires that he was aware that inks with an excessive proportion of vitriol could corrode the writing support, a well-documented phenomenon.[11]

In Byzantium, the most common term for vitriol was καλάκανθον or καλακάνθιν.[12] From the different metallic sulphates present in the sources of vitriol known to the Byzantines, only iron sulphate will react with tannins to form the black complexes that give the ink its characteristic colour. Although other vitriol sources will always contain some iron sulphate, and probably even enough to make ink, green vitriol (whose main component is melanterite, i.e. iron sulphate) would be the most suitable for our recipe.[13] Unfortunately, the author of our recipe did not specify what type of vitriol he recommends using. The recipe only reads καλάκανθον.[14]

The last two lines in our recipe (9–10) appear to have been introduced rather loosely. They stop with an interpunct instead of a period, which may indicate that the recipe was left incomplete. Furthermore, the meaning of those lines is somewhat puzzling to us. While alum (gr. στύψις) is attested in several medieval Byzantine and Syriac recipes for coloured inks, mainly for red inks made from lakes,[15]

11 See for example M.A.P.C. DE FEBER / J.B.G.A. HAVERMANS / P. DEFIZE, Iron-Gall Ink Corrosion: A Compound-Effect Study. *Restaurator* 21/4 (January 2000) 204–212; V. ROUCHON-QUILLET / C. REMAZEILLES / J. BERNARD / A. WATTIAUX / L. FOURNES, The Impact of Gallic Acid on Iron Gall Ink Corrosion. *Applied Physics* A 79/2 (July 2004) 389–392; B. KANNGIEßER / O. HAHN / M. WILKE / B. NEKAT / W. MALZER / A. ERKO, Investigation of Oxidation and Migration Processes of Inorganic Compounds in Ink-Corroded Manuscripts. *Spectrochimica Acta Part B: Atomic Spectroscopy* 59/10–11 (October 2004) 1511–16; U. HENNIGES / R. REIBKE / G. BANIK / E. HUHSMANN / U. HÄHNER / T. PROHASKA / A. POTTHAST, Iron Gall Ink-Induced Corrosion of Cellulose: Aging, Degradation and Stabilization. Part 2: Application on Historic Sample Material. *Cellulose* 15/6 (December 2008) 861–870.

12 Other words to refer to the vitriol such as βεντριόλον or βιτρίολον are rare and attested in manuscripts from the fifteenth century (e.g. Paris, BnF, grec 2327, f. 295r [Diktyon 51958] and grec 2419, f. 118v [Diktyon 52051]).

13 Recent publications revealed that, in some cases, the vitriol used for the inks was not green vitriol, as the main metallic compound was copper or zinc instead of iron. See for example O. HAHN / T. WOLFF / H.-O. FEISTEL / I. RABIN / M. BEIT-ARIÉ, The Erfurt Hebrew Giant Bible and the Experimental XRF Analysis of Ink and Plummet Composition. *Gazette du livre médiéval* 51/1 (2007) 16–29; S. BOSCH / C. COLINI / O. HAHN / A. JANKE / I. SHEVCHUK, The Atri Fragment Revisited I: Multispectral Imaging and Ink Identification. *manuscript cultures* 11 (2018) 141–156; N. GORDON / O. BONNEROT / I. RABIN, Inks Used to Write the Divine Name in a Thirteenth-Century Ashkenazic Torah Scroll: Erfurt 7 (Staatsbibliothek zu Berlin, Ms. or. Fol. 1216). *manuscript cultures* 15 (2020) 163–184; G. NEHRING / O. BONNEROT / M. GERHARDT / M. KRUTZSCH / I. RABIN, Looking for the Missing Link in the Evolution of Black Inks. *Archaeological and Anthropological Sciences* 13/71 (April 2021).

14 In other recipes that were passed down to us, types of vitriols are specified. Examples are Alexandrine vitriol (καλακάνθιν ἀλεξανδρινόν) and vitriol from Cyprus (ἐκ τῆς Κύπρου). See SCHREINER / OLTROGGE, Tinten-, Tuschen- und Farbrezepte (as footnote 8 above) recipes 13, 16, 22.

15 In the red ink recipes, alum precipitates the organic dye into a lake, i.e. an insoluble pigment (see J. DACCACHE / A. DESREUMAUX, Les textes des recettes d'encres en syriaque et en garshuni, in

and for silver and golden inks, it is barely attested as an ingredient for black ink in the published recipes. In one Byzantine recipe, Schreiner and Oltrogge recipe 5, the related term στυπτηρία, which the *LSJ* renders as "name of any of a group of *astringent substances* containing (a) alum or (b) ferrous sulphate", is used to refer to the mixture resulting from combining the different prescribed ingredients.[16] In our opinion, the word στύψις in the recipe on Coisl. 330, f. 1v should be interpreted in the same way as στυπτηρία in Schreiner and Oltrogge recipe 5 – namely, as the mixture obtained by combining gall nuts, gum, and vitriol. Accordingly, it seems that the last two lines in our recipe give further optional steps to make the ink even thicker and more concentrated.

Let us now focus on the script of the scribe who wrote down the recipe in the first verso of Coisl 330. Despite the fact that there is a pronounced change of ductus, it transpires that the notes on logic in Coisl. 330, f. 1r and the recipe on f. 1v were written by the same hand. Decisive palaeographical evidence that invites the identification are the following: lambda minuscule in small format almost resembling an uncial alpha (Fig. 1, l. 1 λεπτὸν); rho in small format with a short lower bar (Fig. 1, l. 3 ἀποβρεχέσθω); delta with the bar descending to the right (Fig. 1, l. 1 κικίδιν); the compendium for sigma-alpha (Fig. 1, l. 6 σακελισθέντος); the ligature for tau-alpha at the end of a word (Fig. 1, l. 3 ταῦτα); the ligature for epsilon-rho (Fig. 1, l. 4 πρότερον).

The script of the anonymous scribe is also found in the margins of some folios in the middle of Coisl. 330: f. 17v–22r (*Categories*), 43r–44v (*De Interpretatione*), and 45v–46r (*De Interpretatione*). Some of the notes he inserted have attracted the attention of scholars in the past, who identified him as the scribe who wrote the important *Organon* manuscript Vat. gr. 244.[17] This *Vaticanus* is a complex, paper manuscript written by a late twelfth-century scribe.[18] The layers of paracontent he

F. Briquel Chatonnet / M. Debié (ed.), Manuscripta Syriaca. *Des sources de première main. Cahiers d'études syriaques*, 4. Paris 2015, 195–246, at recipes 58 and 81; Schreiner / Oltrogge, Tinten-, Tuschen- und Farbrezepte (as footnote 8 above) recipes 47–52, 54–56). See also Schreiner / Oltrogge, Tinten-, Tuschen- und Farbrezepte (as footnote 8 above) recipe 28, with orpiment. In this case, the editors suggest that alum is used as a fungicide.

16 Schreiner / Oltrogge, Tinten-, Tuschen- und Farbrezepte (as footnote 8 above) 35.

17 The identification was first proposed by N. Agiotis. This proposal was accepted and complemented by other scholars (see the bibliographical items referenced in footnote 3 above). When this paper was already in proof stage, Ch. Brockmann and J. Maksimczuk identified a further *Organon* written and annotated by the same anonymous scribe: Città del Vaticano, BAV, Vat. gr. 1020 (Diktyon 67651).

18 See the catalogue description in G. Mercati / P. Franchi de' Cavalieri, Codices Vaticani Graeci. Vol 1. Codices 1–329. Rome 1923, 313–317. The catalogue dates Vat. gr. 244 to the thirteenth century;

inserted in different subsequent production processes testifies to his intensive scholarly activity. Vat. gr. 244 contains all the treatises of the *Organon* and Porphyry's *Isagoge*. The texts of those treatises occupy the central part of the folios while the upper, outer, and lower margins were covered with exegetical notes written by the same scribe who made the core text (= the *Isagoge* and the *Organon*).[19] Many notes consist of Leon Magentinos' commentaries. On several folios, two or even three blocks of marginal annotations, written by the same hand, can be visually distinguished. The first block is placed around the core text, and both appear to have been written during the same production process; the second and third blocks surround the first block of notes and consist of later supplementations.[20] The notes that are part of the first block of paracontent exhibit a script identical to the one the scribe used for the core text. In turn, the notes that belong to the second and third blocks were written in a fast and rather careless script, closer to the one the scribe used to annotate different parts of Coisl. 330 (cf. Fig. 3).

3 The scribe and his inks

Vat. gr. 244 can be perceived as the scribe's personal volume of Aristotle's *Organon* and Magentinos' commentaries on the collection. It must also have been his working or study manuscript, as exposed by the several layers of annotations that he inserted over time. In January 2023, Olivier Bonnerot and José Maksimczuk carried out a chemical analysis of the ink used to produce the different layers of writing in Vat. gr. 244. What can the results of this research tell us about the inks the scribe used in the different production processes? Can we draw conclusions regarding the

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the twelfth-century dating was proposed by recent scholarship (cf. Brockmann, Helpful Interaction [as footnote 3 above] 220 n. 35–36, where further bibliographical references are indicated).

19 Certain folios are fully occupied by notes (e.g. f. 141v, 142v–143r). For a more detail analysis of the complex formatting of Vat. gr. 244, see S. Ebbesen, Commentators and Commentaries on Aristotle's Sophistici Elenchi. A Study of Post-Aristotelian Ancient and Medieval Writings on Fallacies. 3 vol. *Corpus Latinum Commentariorum in Aristotelem Graecorum*, 7/1–3. Leiden 1981, vol. 1, 315; C. Brockmann, A Multilayered Greek Manuscript of Learning. Some Glimpses into the Scribal Practices Evident in the Aristotelean Codex Vaticanus graecus 244, in J.B. Quenzer (ed.), Exploring Written Artefacts. Objects, Methods, and Concepts, II. *Studies in Manuscript Cultures*, 25. Berlin / Boston 2021, 603–622.

20 S. Kotzabassi (ed.), Byzantinische Kommentatoren der aristotelischen Topik. Johannes Italos und Leon Magentinos. *Etaireia Byzantinon Ereunon*, 17. Thessaloniki 1999, 50; Brockmann, Helpful Interaction (as footnote 3 above) 217; and Brockmann, A Multilayered Manuscript (as footnote 19 above).

way he worked based on the ink analysis? Is it possible to relate some of them to the recipe he wrote on Coisl. 330, f. 1v? These and other relevant questions are addressed in the next pages.

3.1 Method and equipment

Christian Brockmann and José Maksimczuk selected relevant spots in Vat. gr. 244 for the ink analysis. On the basis of palaeographical and codicological criteria, they identified different phases, in which the scribe worked on this manuscript. This is illustrated by Fig. 4, showing the spots analyzed for the different phases on f. 303r. The inks from Vat. gr. 244 were then investigated following the non-destructive and non-invasive two-step procedure developed by the Centre for the Study of Manuscript Cultures (CSMC, Universität Hamburg) and the Bundesanstalt für Materialforschung und -prüfung (BAM) over the last two decades.[21] The first step consisted of checking the ink typology and selecting areas for further elemental analysis with X-ray fluorescence (XRF). This preliminary screening was performed with a USB microscope (Dino-Lite AD4113TI2V USB) equipped with ultraviolet (UV, 395 nm), visible (VIS), and near-infrared (NIR, 940 nm) light. We took pictures of a selection of spots representative of the different writing phases identified at x50 magnification under the different illuminations. Each ink class has distinct optical properties which allow their differentiation: the colour of soot ink/carbon ink is independent of the wavelength between 300 and 1700 nm; iron-gall ink loses opacity towards long wavelengths in the infrared region (i.e. 750–1000 nm) and becomes transparent at 1200 nm, while plant ink is transparent already at ~700 nm. That means that under the NIR light of the Dino-Lite microscope, plant inks will not be visible, iron-gall inks will appear faded, and carbon ink will be as opaque as under visible light. During this stage, attention is paid to select spots of inks that are accessible to the XRF instrument (i.e. not too close to the binding), large enough for the spot size of the XRF instrument (1 mm), and free from ink on the opposite side of the folio in order to avoid contamination in the XRF spectrum.

The second step consisted of elemental analysis of the ink with XRF. When the emitted X-ray beam interacts with an atom in the sample, an electron is ejected

21 O. Hahn / W. Malzer / B. Kanngiesser / B. Beckhoff, Characterization of Iron-Gall Inks in Historical Manuscripts and Music Compositions Using X-Ray Fluorescence Spectrometry. *X-Ray Spectrometry* 33/4 (July 2004) 234–239; I. Rabin / R. Schütz / A. Kohl / T. Wolff / R. Tagle / S. Pentzien / O. Hahn / S. Emmel, Identification and Classification of Historical Writing Inks in Spectroscopy: A Methodological Overview. *Comparative Oriental Manuscript Studies Newsletter* 3 (January 2012) 26–30; Gordon / Bonnerot / Rabin, Inks (as footnote 13 above).

from the atom's inner shell, creating a vacancy that is then filled by another electron from an outer shell. In the process, the electron from the outer shell releases energy in the form of emitted X-ray fluorescence. The emitted radiation has an energy characteristic of the atomic element. The analysis results in a spectrum (intensity against energy) with peaks whose position allows the identification of atoms present in the sample, and whose intensity is related (among other factors) to the amount of the element in the sample. It must be noted, however, that the technique is only suitable for the reliable analysis of elements heavier than aluminum. Furthermore, the X-rays penetrate deep inside the material, meaning that spectra on inked areas have contributions from both the ink and the paper. Therefore, spectra on paper without ink were taken in addition to spectra on inked areas, and the folios analyzed were lifted 2–3 cm above the following pages during analysis to avoid contamination from the underlayers. The X-Ray analysis was performed with Elio (Bruker / XGLab), a small portable XRF spectrometer with a 4W rhodium tube and an interaction spot of 1 mm. All measurements were conducted under the following experimental conditions: t=90s, excitation parameters of 40 kV and 80 μA. Following the analysis, the spectra were processed with Spectra (ARTAX) software from Bruker to identify the elements and determine their net peak intensities. The contribution of the paper was then subtracted, and the intensities of the different elements were normalized to that of iron, following the semi-quantitative adaptation of the method described by Hahn et al.[22]

3.2 Results

All the black inks investigated fade under NIR light but remain visible, strongly suggesting that they are iron-gall inks. Furthermore, tannins present in the inks quench the fluorescence of the paper support and appear dark under UV illumination (Fig. 5). This identification is unequivocally confirmed by the presence of iron in the inks, as detected by XRF. Furthermore, various amounts of copper and zinc and some sulphur were detected on every spot, indicating the vitriolic nature of the iron-gall ink.

All the inks have similar compositions, with only a little copper and traces of manganese and zinc. As an example, XRF of inks from the core content (ink A), first block of paracontent (ink C), and second block of paracontent (ink B) in f. 303r are shown in Fig. 6. The intensities of the different peaks vary. However, the differences

22 Hahn / Malzer / Kanngiesser / Beckhoff, Characterization of Iron-Gall Inks (as footnote 21 above).

observed probably reflect different thickness of the ink. Indeed, after normalization to the iron peak intensity, differences between the three inks are minimal, as shown in the table below:

¥	S*	Mn*	Cu*	Zn*
Ink A	0.03	0.00	0.04	0.01
Ink B	0.06	0.01	0.04	0.01
Ink C	0.06	0.01	0.04	0.00

From our analysis, it transpires that the scribe used the same kind of ink for the different stages of writing Vat. gr. 244, namely, a vitriolic iron gall ink. According to the visual impression, inks A and C (core content and first block of paracontent) look different from ink B (second block of paracontent, which is a later addition). Inks A and C exhibit a lighter shade of brown whereas ink B appears darker. This difference might arise from the use of different binders (different gums or oils or animal glue) or sources of tannins (gall nuts, bark, or other plants extracts). It can also, more simply, come from different levels of dilution of the inks in the water solvent. None of these hypotheses can be tested by the non-destructive analysis we carried out. Be that as it may, inks A, B, and C are all of the same type (vitriolic iron-gall ink) and were most probably prepared with the same source of vitriol. All in all, inks A, B, and C, as well as the ink described in the recipe from Coisl. 330, f. 1v are vitriolic iron-gall inks, which should not come as a surprise, as such inks were the most common at that time. Unfortunately, since the latter recipe contains only generic and typical ingredients for iron-gall ink (namely, gall nuts, gum, and vitriol), we cannot conclude with certainty whether the inks in Vat. gr. 244 were prepared according to this recipe.

4 The scribe and his manuscripts

As palaeographically demonstrated, it is sure that certain links exist between Coisl. 330 and Vat. gr. 244, for the scribe of the latter wrote down several notes in the former. The nature of the relationship between the two manuscripts was philologically established: several parts of the core text of the *Vaticanus* were copied from the *Coislinianus*. This was well established for the *First* and *Second Analytics*.[23]

23 See C. Brockmann / J. Maksimczuk, The Codex Reg. gr. 107: Some Codicological and Textual Remarks on a Multilayered Manuscript of Aristotle's Organon, in Grimm-Stadelmann / Riehle / Tocci

However, this theory does not hold true for all the sections of the *Organon*, as revealed by our ongoing investigation of the text of Porphyry's *Isagoge* in around 115 manuscripts. According to our collation of a representative part of the Porphyrian treatise (i.e. 7, 22 – 12, 10),[24] Vat. gr. 244 depends on Coisl. 330 only up to *Isagoge* 9, 18, but not from that point onwards. The following list provides all the variants that both manuscripts share against the printed text of the *Isagoge* 7, 22 – 9, 18 (not all of them are stemmatically relevant):[25]

7, 22–23: ἐπ' ἄλλου] τινὸς add.
7, 23: γένοιτο] τῶν κατὰ μέρος add.
7, 24: τῶν κατὰ μέρος γένοιντο ἂν αἱ αὐταί] γένοιντο αἱ αὐταὶ τῶν κατὰ μέρος
8, 5: καὶ τίνα καὶ γένη] καὶ τίνα τὰ γένη
8, 5: τίνα τε] καὶ τίνα
8, 6: τὸ εἶδος, εἴρηται] τὸ εἶδος λέγεται, εἴρηται
8, 11: αὐτός γε ἑαυτοῦ] αὐτὸς ἑαυτοῦ
8, 12: πῶς ἔχειν] πῶς ἔχει (sed πῶς ἔχειν Vat. gr. 244, p. corr.)
8, 13–14: τὸ ἕτερον τοῦ ἑτέρου διαφέρῃ] **τοῦ ἑτέρου διαφέρῃ τὸ ἕτερον**
8, 14–15: οἷον γλαυκότης ἢ γρυπότης ἢ καὶ οὐλὴ] οἷον γρυπότης γλαυκότης ἢ οὐλὴ
8, 16: ὥσπερ ἄνθρωπος] ὥσπερ ὁ ἄνθρωπος
8, 21: διαφορὰ προσελθοῦσα] προσελθοῦσα διαφορά
9, 3: διαφοράς] om.
9, 5: μόνον ἀλλοῖον] ἀλλοῖον μόνον
9, 5: αἱ ἑτερότητες μόνον] αἱ ἑτερότητες μόναι
9, 7-8: χωριστὰς εἶναι] εἶναι χωριστὰς
9, 9: ἐστιν] εἰσι
9, 10: ἢ σιμὸν] ἢ σιμὸν ἢ γλαυκὸν
9, 14–15: λόγῳ λαμβάνονται] λάμβανονται λόγῳ

On one occasion, Vat. gr. 244 has a text *more correct* than Coisl. 330; however, it lacks any stemmatic value. At *Isagoge* 8, 18, Coisl. 330 alone reads μὲν οὖν whereas all the other manuscripts, Vat. gr. 244 included, have the correct μέν. Tellingly, Vat.

/ M.Vučetić (ed.), Anekdota Byzantina (as in footnote 3) 47–70, here at 52–59 (with further bibliographical references).

24 A. Busse (ed.), Porphyrii Isagoge et In Aristotelis Categorias commentarium. *Commentaria in Aristotelem Graeca*, 4/1. Berolini 1887.

25 We left out from the list only variants in spelling and accentuation, provided that they do not imply changes of meaning (e.g., αὐτό and ἑαυτό). We print in bold the variant found solely in Coisl. 330 and Vat. gr. 244 (and its descendants) and in no other manuscript.

gr. 244 exhibits an erasure covering the extension of three letters after μέν. This physical feature of Vat. gr. 244 suggests that its original text was most likely μὲν οὖν (as is the case in Coisl. 330) and that a correction was performed at a certain point in the manuscript's life (see Vat. gr. 244, f. 17v, 7–8).[26]

From the above discussion, it transpires that Coisl. 330 and Vat. gr. 244 provide identical texts of the *Isagoge*, sharing several poor variants[27] and two particular readings[28] for the section comprised between 7, 22–9, 18 in the printed edition of the treatise. This result is completely in line with the conclusions reached for other treatises of the *Organon*, namely that Vat. gr. 244 is an apograph of Coisl. 330.

But as mentioned above, from *Isagoge* 9, 18 onwards,[29] Coisl. 330 and Vat. gr. 244 exhibit clear textual divergences, as an analysis of *Isagoge* 9, 18–22 demonstrates. At *Isagoge* 9, 18, Coisl. 330 and Vat. gr. 244 provide different variants, each of which is attested in numerous manuscripts within the tradition:

Coisl. 330 et al.: ἐπίτασιν λαμβάνουσι καὶ ἄνεσιν
Vat. gr. 244 et al.: ἐπίτασιν καὶ ἄνεσιν λαμβάνουσι

One line further, 9, 19, we see the same phenomenon:

Coisl. 330 et al.: ἂν ᾖ γένος
Vat. gr. 244 et al.: ἂν εἴη γένος

At 9, 21, Coisl. 330 and Vat. gr. 244 again follow different versions of the *Isagoge*:

Coisl. 330 et al.: οὔτε ἄνεσιν οὔτε ἐπίτασιν
Vat. gr. 244 et al.: οὔτε ἐπίτασιν οὔτε ἄνεσιν

26 The fact that the manuscript Paris, BnF, grec 1972 (early 14th century, Diktyon 51599), a faithful apograph of Vat. gr. 244, reads μέν and not μὲν οὖν is a clear indication that the correction in Vat. gr. 244 was introduced before the 14th century.

27 From the list above, consider, especially, *Isagoge* 8, 5; 8, 6; 9, 3; 9, 5; 9, 10.

28 *Isagoge* 8, 13–14 (τοῦ ἑτέρου διαφέρῃ τὸ ἕτερον) and 8, 18 (μὲν οὖν).

29 The last variant that Coisl. 330 and Vat. gr. 244 share against the printed text of the *Isagoge*, before 9, 18 is found at 9, 14–15 (λόγῳ λαμβάνονται instead of λαμβάνονται λόγῳ). However, the reading in question has little, if any, stemmatic significance. Furthermore, it is shared by another twenty-five manuscripts and is not sufficient evidence to prove any type of relationship between Coisl. 330 and Vat. gr. 244 still at 9, 14–15. In our opinion, the dependence of Vat. gr. 244 on Coisl. 330 can be surely perceived until 9, 10, where both manuscripts read ἢ γλαυκόν after ἢ σιμόν. The addition of ἢ γλαυκόν is a variant attested in the family headed by Coisl. 330 and only seven other manuscripts.

At 9, 22, we find a further instance:

Coisl. 330 et al.: τὸ δὲ γρυπὸν ἢ σιμὸν εἶναι,
Vat. gr. 244 et al.: τὸ δὲ γρυπὸν εἶναι ἢ σιμόν

Considered all together, the four cases presented here unambiguously indicate that Coisl. 330 and Vat. gr. 244 belong to two different branches within the *Isagoge* tradition in this section of the text. The independence of Vat. gr. 244 vis-à-vis Coisl. 330, starting roughly here, continues until at least 12, 9; this is clearly shown by mistakes found in Coisl. 330 but not reproduced in Vat. gr. 244. See:

10, 14: μὲν] om. Coisl. 330
10, 18: μὲν] om. Coisl. 330
10, 20: καὶ εἰς τοὺς ὁρισμούς] καὶ τοὺς ὁρισμούς Coisl. 330
11, 3: οὔτε δὲ πάσας τὰς ἀντικειμένας ἔχει] οὐκ ἐνεργείᾳ ἀλλὰ δυνάμει add. Coisl. 330
12, 9: ἄν] om. Coisl. 330

We do not know the reason why the scribe of Vat. gr. 244 changed models in the middle of the *Isagoge*. The change must have occurred around the text passage *Isagoge* 9, 18, which appears in Coisl. 330 on f. 8v (= *Isagoge* 9, 7–9, 24). As far as we can see on our digital reproduction of the manuscript, there is nothing on that folio that would have made this change necessary (e.g., a textual lacuna, an illegible passage, etc.). Neither do we perceive any type of discontinuity in the middle of Vat. gr. 244, f. 18v, which contains *Isagoge* 9, 12–22. Nor did we yet have the opportunity to examine more closely at what point of the *Organon* and for what reason the scribe of Vat. gr. 244 decided to come back to Coisl. 330 as the model for his manuscript. Certainly, for the *First Analytics*, he followed again the text in Coisl. 330.[30]

5 Conclusions

It is rare to find a note sheet from an important scribe and scholar, let alone a note sheet that gives us clues about the writing material he used. One such document has survived as the first folio in Coisl. 330. Among other things, the scribe had jotted down an ink recipe on this leaf. The rapid style of writing, which is difficult to decipher, indicates that he addressed the note about the ink to himself or to his closest

30 MAKSIMCZUK, Layers of Corrections (as footnote 3 above) 234–238. A promising line of research to elucidate the second model of Vat. gr. 244 is to perform a close comparison with the text of the *Isagoge* in Vat. gr. 1020, i.e. the third *Organon* manuscript that can be palaeographically connected to the scribe of Vat. gr. 244 (cf. footnote 17 above).

co-workers. He recorded the recipe on what is now the verso of the leaf, while he wrote down some notes relevant to the Aristotelian content of the manuscript Coisl. 330 on the recto. Later the single note sheet was incorporated as a flyleaf in this codex. That the anonymous scribe had this book in his hands and on his desk, is clearly proven, because he left numerous annotations on its margins and used it as one of the main models of his *opus magnum* as a scribe and scholar, namely the Vat. gr. 244. During the intensive production process of Vat. gr. 244, he obviously used separate sheets for notes, one of which has been preserved, as it was bound into the model manuscript. This probable scenario suggests that the recipe is likely to reflect ingredients and procedures that were used to produce the inks needed to create the new manuscript. A comparison with other Greek ink recipes has shown that the recipe in the Coislin 330 is of the usual standard. The different ingredients are exactly what one would expect from an iron gall ink. More specific information – for example about the vitriol used – is missing. Nevertheless, we gained further insights into the working materials of our scribe through the ink analysis of Vat. gr. 244. While no definite connection between the inks he used in this manuscript and that of the recipe can be established, it is significant that the same ink composition was found in all the layers of Vat. gr. 244. Analysis of the inks used in Coisl. 330 will hopefully provide additional precious information about the scribe's writing practices. This paper is a primary attempt to profile the craft of an important Byzantine scribe and scholar, combining evidence from historical, philological, palaeographical, and chemical analyses. After all, to the best of our knowledge, it is the first time that a meaningful link can be drawn between a particular recipe, a particular scribe, and a particular manuscript.[31]

31 The research for this paper was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC 2176 'Understanding Written Artefacts: Material, Interaction and Transmission in Manuscript Cultures', project no. 390893796. The research was conducted within the scope of the Centre for the Study of Manuscript Cultures (CSMC) at Universität Hamburg. Kyle Ann Huskin proofread the English of our paper and made valuable remarks on its contents. Kyle Ann Huskin and Ivan Shevchuk produced for us multispectral images of Coisl. 330, f. 1v, which were crucial to deciphering some parts of the ink recipe. Alessandra Palla checked *de visu* some parts of Coisl. 330, f. 1v that were illegible in our digital reproductions; Ciro Giacomelli and Raimondo Tocci discussed with us the recipe in Coisl. 330. The three of them provided several good ideas and fresh insights. Claudia Montuschi, Director of the Manuscript Department of the Biblioteca Apostolica Vaticana, allowed us to perform the needed analysis on the Vat. gr. 244. Ángela Núñez Gaitán and the team of the Conservation Workshop of the Library assisted us during our research stay. Our thanks go to all these colleagues. The images of Città del Vaticano, BAV, Vat. gr. 244 are reproduced by the permission of the BAV, with all rights reserved. Further data on the chemical composition of the inks in Vat. gr. 244 can be found in the Research Data Repository at Universität Hamburg. https://doi.org/10.25592/uhhfdm.13215.

Figures

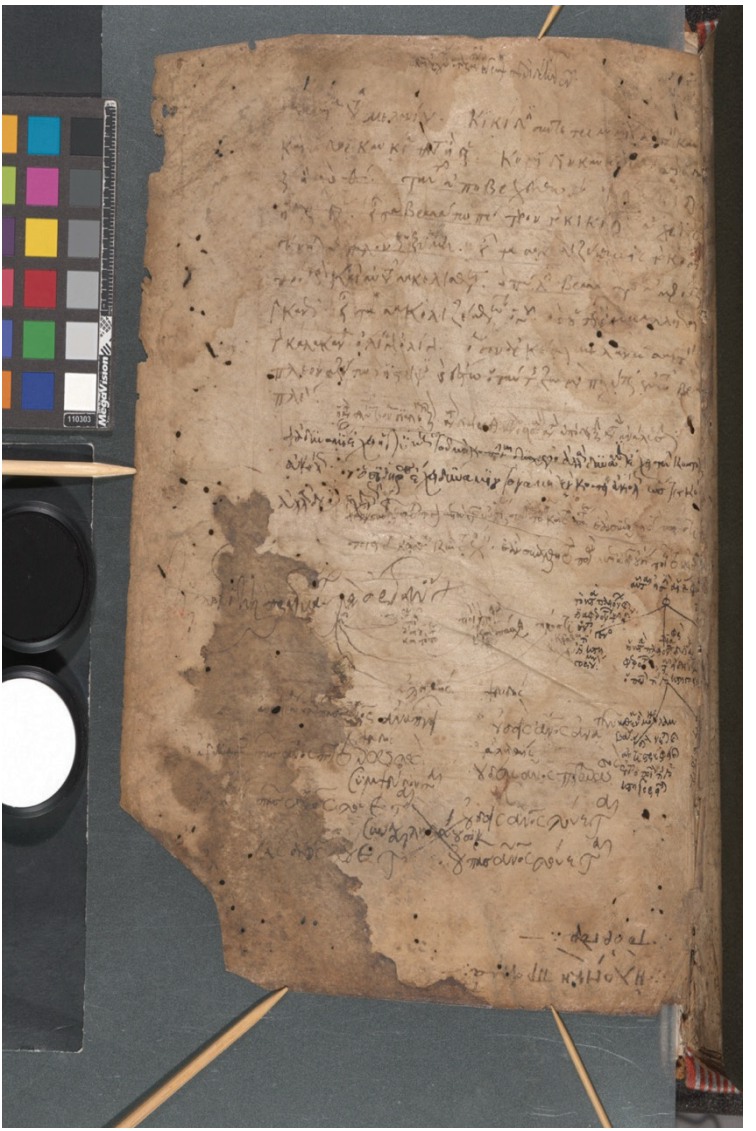

Fig. 1: Paris, BnF, Coisl. 330, f. 1v © BnF (Natural light photograph taken by Kyle Ann Huskin and Ivan Shevchuk)

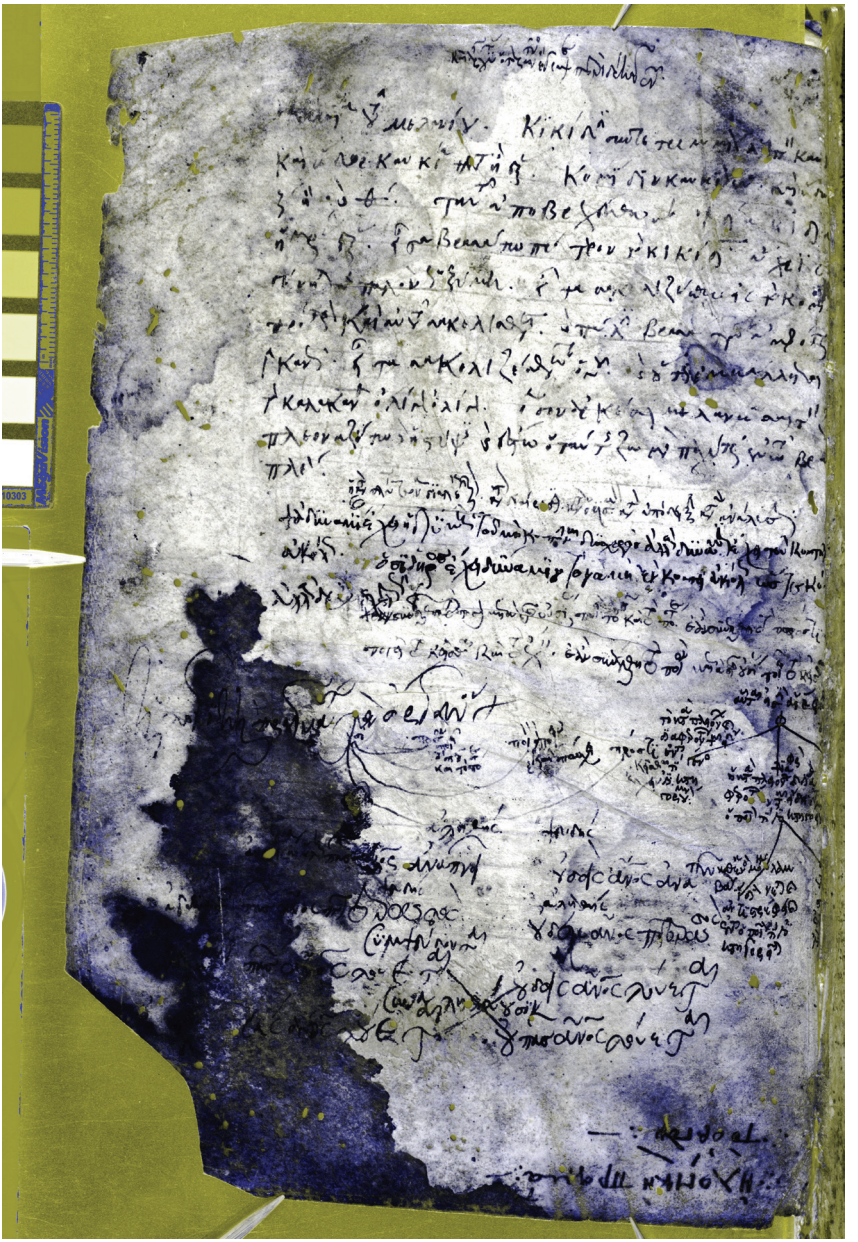

Fig. 2: MSI of Paris, BnF, Coisl. 330, f. 1v © BnF (Multispectral photograph processed by Kyle Ann Huskin)

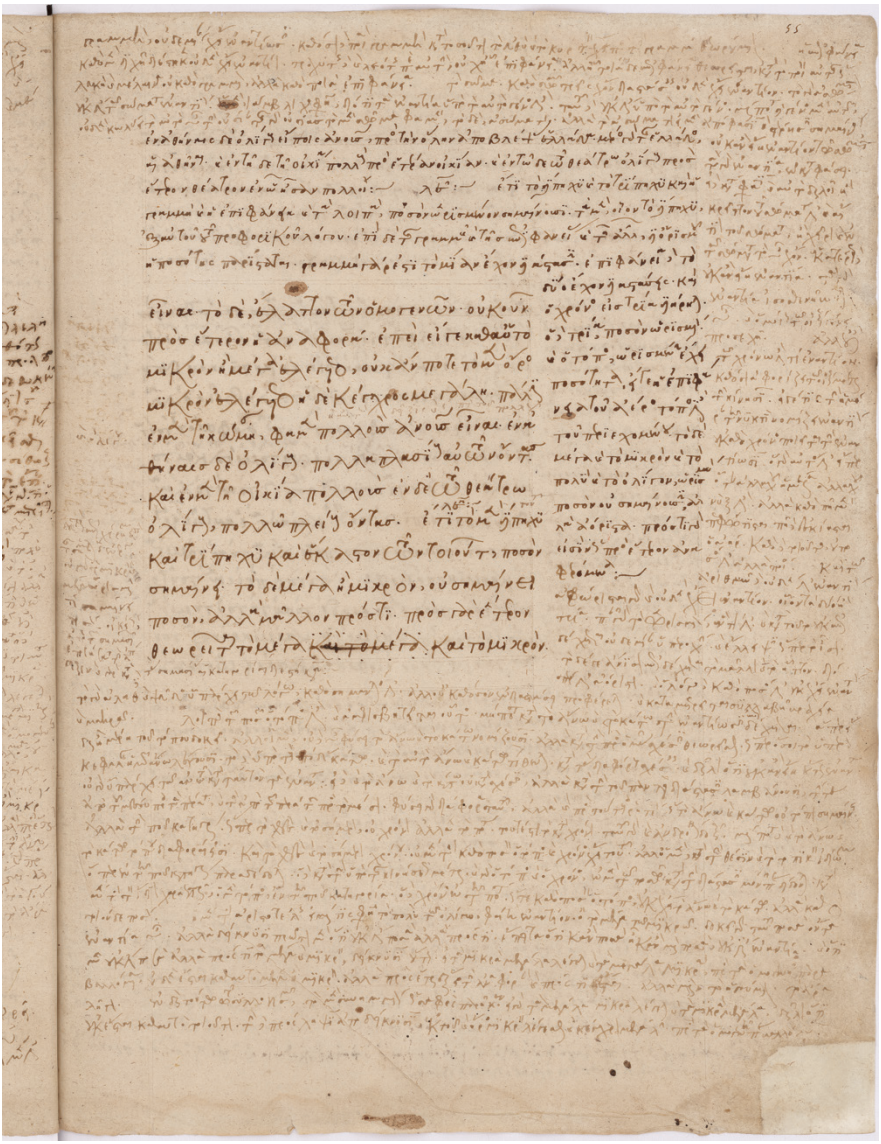

Fig. 3: Città del Vaticano, BAV, Vat. gr. 244, f. 55r © Biblioteca Apostolica Vaticana

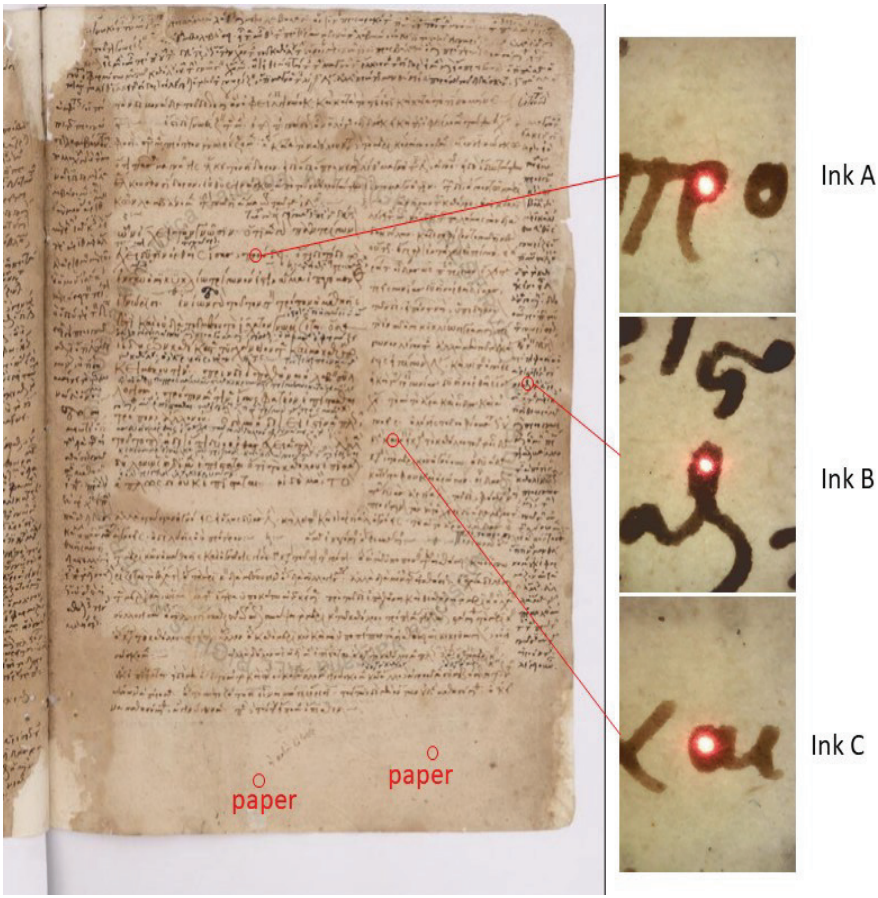

Fig. 4: Città del Vaticano, BAV, Vat. gr. 244, f. 303r (spots analyzed) © Biblioteca Apostolica Vaticana

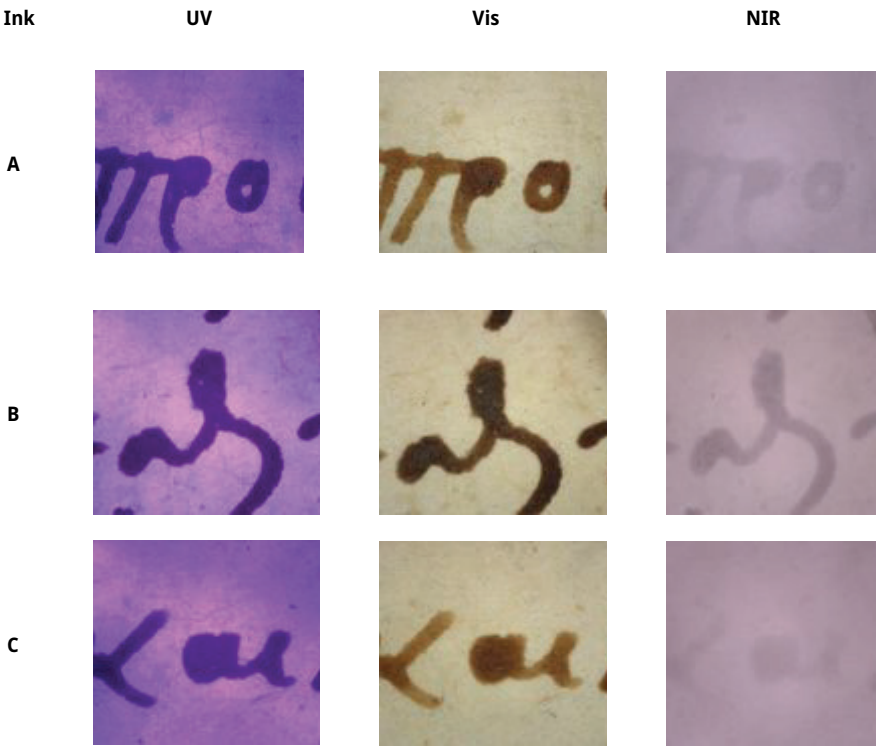

Fig. 5: UV (left), visible (middle), and NIR (right) pictures of the spots corresponding to ink A, B and C (from top to bottom) analyzed on Vat. gr. 244, f. 303r.

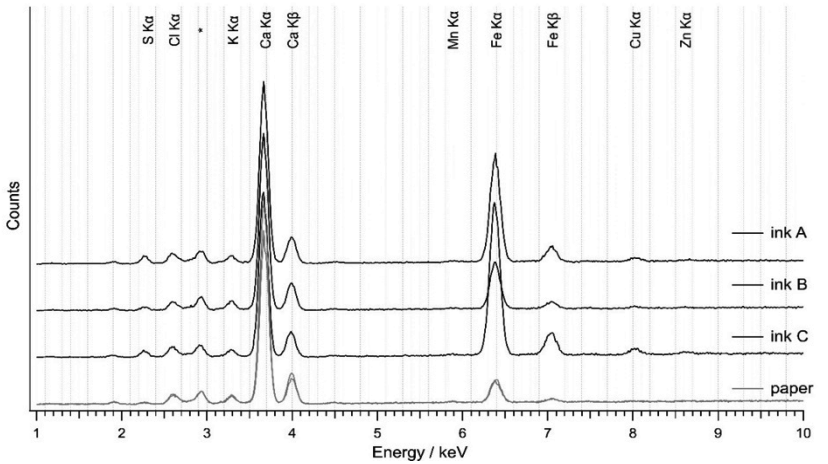

Fig. 6: XRF spectra corresponding to ink A, B, C and paper support (from top to bottom) analyzed on Vat. gr. 244, f. 303r. The asterisk corresponds to Ar detected because the analysis was performed in the air.