

## Watermark identification of early printed paper

How watermark investigation leads to date early Hebrew printed paper

Moshe ROSENFELD\* Chief bibliographer, Institute for Computerized Bibliography of the Hebrew Book, Jerusalem, Israel

Yishayahu VINOGRAD<sup>+</sup> Late chief bibliographer, Institute for Computerized Bibliography of the Hebrew Book, Jerusalem, Israel

Eyal NAIMY Algorithm specialist, Axicon Technologies A.N. Ltd., Bet Shemesh, Israel

Elyakim KASSEL, Ph.D., Investigator, Institute for Computerized Bibliography of the Hebrew Book, Jerusalem, Israel

Sara GREGORI Assistant Archivist, City Archive of Fabriano, Marche, Italy

**Abstract:** The Institute of Computerized Bibliography of the Hebrew Book is investigating an unknown printed work in Hebrew. The main clue to date this work is a watermark. This watermark, three mounts encircled within two rings with a cross sticking from the middle mount, is documented in many sources in Europe from 1418 to 1439. The Zhonghi collection stands out with such a watermark dated 1541. The origin of this watermark is from the City Archive of Fabriano.

The team investigated at the City Archive of Fabriano to reconcile this watermark with the time frame of the first half of the fifteenth century. It used as comparison watermark frequency in files from archives in Perpignan, France, from manuscripts from Ambrosiana Library in Milano and Austrian National Library in Vienna. The conclusion is that this paper from the Zonghi collection was most likely manufactured in the first half of the fifteenth century, like the other examples found.

Image processing of the printed Hebrew characters reveals also that fonts are quite non homogeneous. It is an additional clue that the paper was from the early years of printing and not from the middle of the sixteenth century.

Based on the date from the first half of the fifteenth century, there is a plausible origin of the Hebrew printed work from the well documented tentative of Hebrew printing that took place in Avignon, France, between 1444 and 1446. This would make those sheets of paper the first known work in the West printed with metal moving types.

**Keywords:** Fabriano, Avignon, Procope Waldvogel, Hebrew printing, watermarked paper

## Introduction

The Institute for Computerized Bibliography of the Hebrew Book received for expertise and investigation a set of two printed unfolded quires with Hebrew letters. This article focuses on a striking element found on one of the two pages, namely a very distinct watermark, that should help identify the time period of the printing of the two quires.

Before the description of the watermark, a description of the two sheets is given. The paper size is 20x28 cm. There are seven chain lines along the height of the sheet. Both unfolded quires are printed on both sides. Eight pages are printed on each side. The dimensions of the print area of the pages are 5 x 7.5 cm. The text is printed in semi-cursive Spanish Hebrew characters

Only one of the two quires bears a watermark that is figuring three mounts encircled within two rings, and from the middle of the center mount, a mast with a cross. See (Fig. 1) and (Fig.2). The chain line distance around the watermark is 42 mm.



Fig. 1 Watermark under investigation as seen in the printed Hebrew text



Fig. 2 Beta-radiography of the watermark under investigation

### 1. Watermark in reference works

This watermark design is reported in a number of reference works: Briquet (1907) [1], Harlfinger (1974) [2], Picard (1996) [3], Website [www.wzma.at](http://www.wzma.at) [4] and Zonghi (1953) [5]

See Table 1.

Source	Location	Year	Chain line distance (mm)
Briquet	Perpignan, Archives Départementales des Pyrénées Orientales	1418	58
Briquet	Palermo, Archivio di Stato	1424	60
Briquet	The Hague, Nationaal Archief	1420	59
Harlfinger	Milan, Ambrosiana Library		60
Picard	Constance	1418	59

Website www.zmat.at	Vienna, Österreichische Nationalbibliothek	1418	60
Website www.zmat.at	Vienna, Österreichische Nationalbibliothek	1439	61
Zonghi	Fabriano, Fondazione	1541	42

Table 1: List of three mounts in double ring watermarks found in the literature

## 2. Watermarks in their natural environment

The investigating team chose to see the original watermarks in Perpignan [6], Milan [7], Vienna [8] and Fabriano [9].

In the case of Perpignan, Milan and the two manuscripts in Vienna the relevant watermarks were found in thick volumes where variations of the three-mount watermarks were found as well. The design of the three mounts were similar and the variations appeared with one ring or no ring at all, sometimes without the cross. Similarly to the loss of the cross, in some cases the bottom of the three mounts is missing. With usage watermarks undergo wear and fine details may break and be lost.

An example of a watermarked found in Perpignan is given in (Fig. 3). Another example of a watermark found in Vienna in Cod. 4597 is given in (Fig. 4).





Fig. 3 Three mounts in double ring in Perpignan

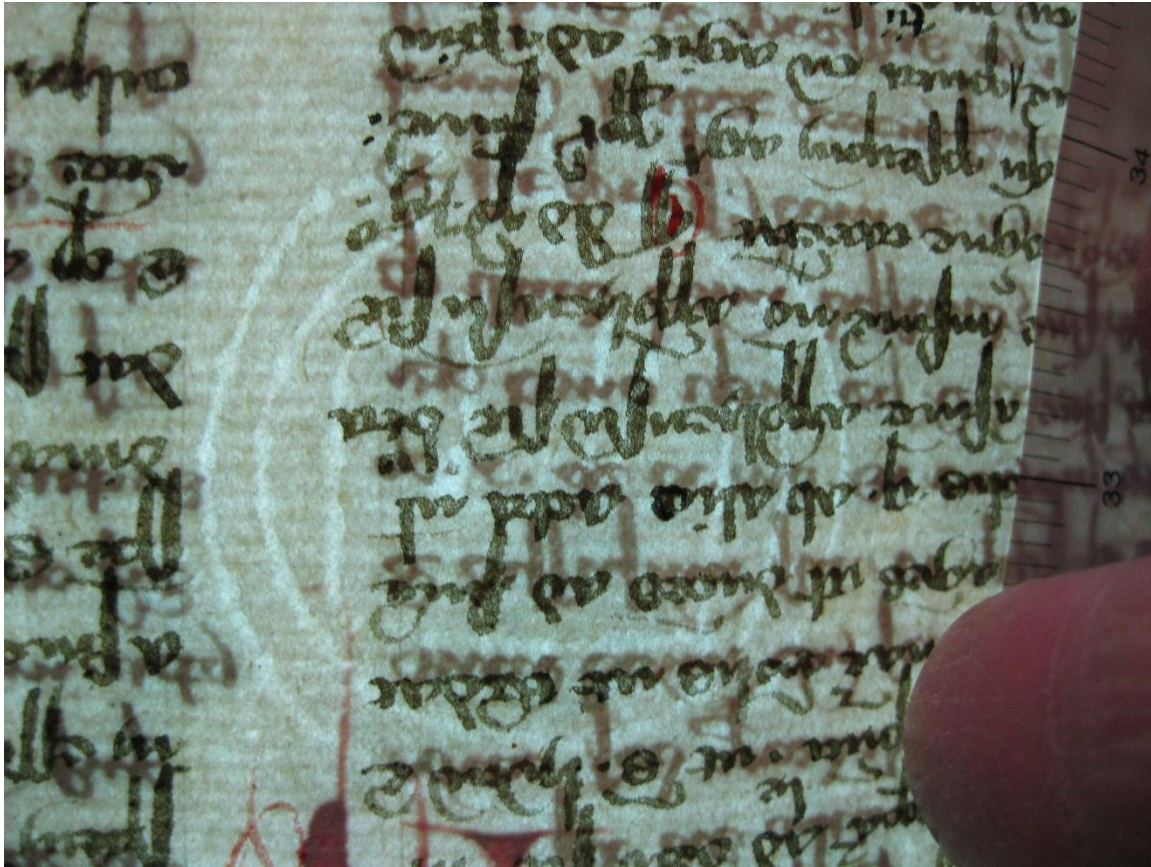


Fig. 4 Three mounts in double ring in Vienna

Overall, the various watermarks are all contemporaneous since they appear in the same bounded volume with some continuity in the content. In Perpignan those are notarial records covering the years 1418-1419. In Milan it is a set of Greek works copied by the same hand. In Vienna, the on-line catalog mentions different copyists. Cod. 4597 is one single theological work. Cod. 5091 is a collection of judiciary documents.

In Fabriano, the team met a different situation. The watermark collection organized and published by Augusto Zonghi is managed by the Fondazione Fedrigoni Fabriano (FFF). The watermark under investigation is on a blank sheet that Augusto Zonghi tore apart from a file at the Historical City Archive of Fabriano. See (Fig. 5). The horizontal bar of the cross is missing. As written earlier, this can happen after extensive use of the same mould that some part of the wire fell off and was not sewn back in place.



Fig. 5 Three mounts in double ring in Fabriano

Zonghi left in his notes the reference of the file from which he tore apart that leaf [10]. So, we could go to the archive and have a look at the file. In this file there is one quire of three folded sheets with the special watermark of three mounts encircled in two rings. Unlike what was observed in the other cases, the rest of the manuscript folder does not contain any other watermark with any type of three mounts. It is written with different handwriting and unrelated paper. This manuscript file is dated 1541 and deals with a border dispute between the city of Fabriano and Genga, mostly dealing with tax levying. The specific document of three folded sheets bears inside the text the date of 1536.

### 3. Paper manufacturing dates

The Fabriano watermark stands out with a referenced date which is much later than the others. The gap is about a hundred years, an unusual situation. According to Zonghi (1911) [11], since Fabriano was a major paper manufacturing center, all the papers found at the City Archive are expected to be locally manufactured. We randomly surveyed files from the fifteenth century at the Archive. We did not find other pages with the same watermark, but as it happened at the other visited locations, we easily found papers with three mounts, one ring. See (Fig. 6). If we were not convinced that this is paper manufactured locally, we found such a watermark in the 1442 book keeping records of Antonio di Cicco, whose activity was to smooth out paper before selling it to paper merchants [12]. This activity is called in Italian *cialandratore*. Since he is selling smoothened paper to merchants, we can't imagine that he is importing paper from outside the city of Fabriano.



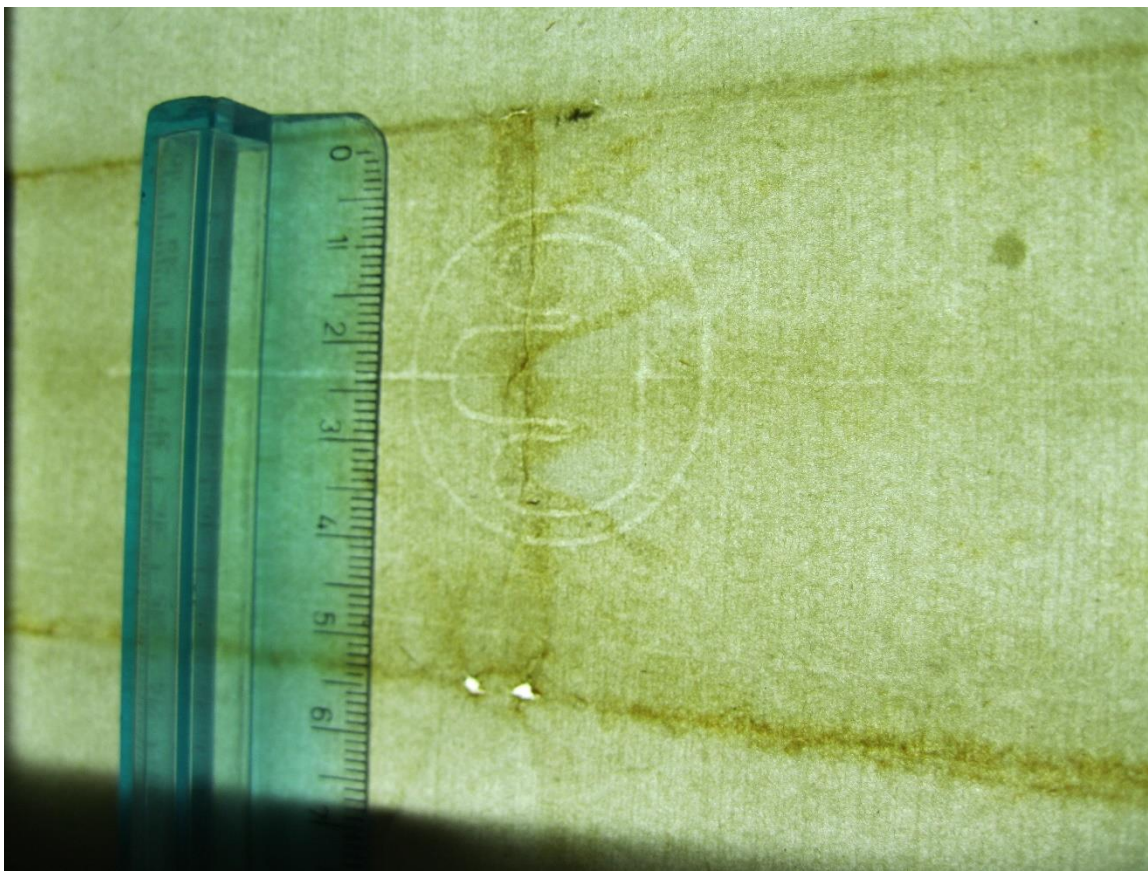


Fig. 6 Three mounts in single ring in Fabriano

We got the help of the State Archive of Ancona. They looked through notarial archives of Fabriano in the years 1415-1435. They also found three mounts watermark with one ring only.

According to Zonghi (1953), with the exception of this watermark dated 1541, all the rest of the three-mount family, with one ring or no ring at all, spans the years 1385 -1492. Then we turned to the 1530-1550 time frame and browsed in Fabriano Archive through a sample of files. We did not find any watermark from this family of three mounts. This and Zonghi's collected watermarks essentially exclude that Fabriano paper mills came back to use those watermarks in the sixteenth century.

Zonghi (1911) [13] claims that in general the use of paper was very close to the manufacturing date, since paper was available in large quantities in Fabriano. It did not make sense to store old paper. However, he documents that a limited stock of unused sheets was found in Municipal Archive of Fano a few centuries after their fabrication. So, this seems to be a similar situation for our three sheets with the watermark under investigation.

The FFF performed a dimension comparison between their scanned picture of the watermark Z01764 , which corresponds to the referenced number 1315, and the scan of the beta- radiography of the investigated watermark. They found out that by aligning the

two watermarks on the left edge of the outer ring, the chain lines coincide exactly and have the same distance of 42 mm. The difference of the watermark drawing is 4mm both in horizontal and vertical direction. From Stevenson (1967) [14] we learn that moulds and their chain lines would be kept on a longer period, while the watermarks would be deformed along the usage of the same mould. So the slip of 4mm is quite compatible with the assumption that these two watermarks were manufactured in the same place around the same time.

So far this watermark design is documented only in the time frame between 1418 and 1439.

As said earlier, Zonghi was aware that some time a limited stock of paper is kept for a long period of time. We believe this is the explanation for the three sheets found in the Archive of Fabriano. Now we need to raise the question regarding the printed sheets. Was the printer holding also a stock of paper for tens of years before printing the book under investigation?

#### **4. Type homogeneity**

In order to get some information from the printed text, we followed the approach pioneered by Agüera y Arcas (2003) [15], a computer scientist and Princeton graduate, who collaborated with Paul Needham librarian of Princeton University's Scheide Library. He showed that unlike common assumptions, in the early years of printing, in the late 1450's, the standard punch-matrix method of preparing types was not used. His demonstration is based on image processing of printed letters from Gutenberg's texts which exhibit large non-homogeneity that can't be reconciled with the idea that each type is cast from matrices originating from the same punch.

In a different study and without the help of a computer, Stevenson (1967) [16] claimed that the printer of the "Missale speciale" "worked without punches or apparently even matrices or resources for making any; but he did have abrasive devices for modifying types already made". The main claim of Stevenson is that this book was printed in 1473 by a less experienced worker. This is the reason for the non-homogeneity that was observed by eye.

We tried the image processing approach on the printed sheet under investigation. We used a scanner as a platform for digitizing the examined image, getting high uniformity of white-balance of examined image. The scanning performed in RGB in very high-resolution imaging - 1200 dpi (equivalent to 130 Mpixels). Scanning in high resolution allows us to downscale to preferable analyzing resolution.

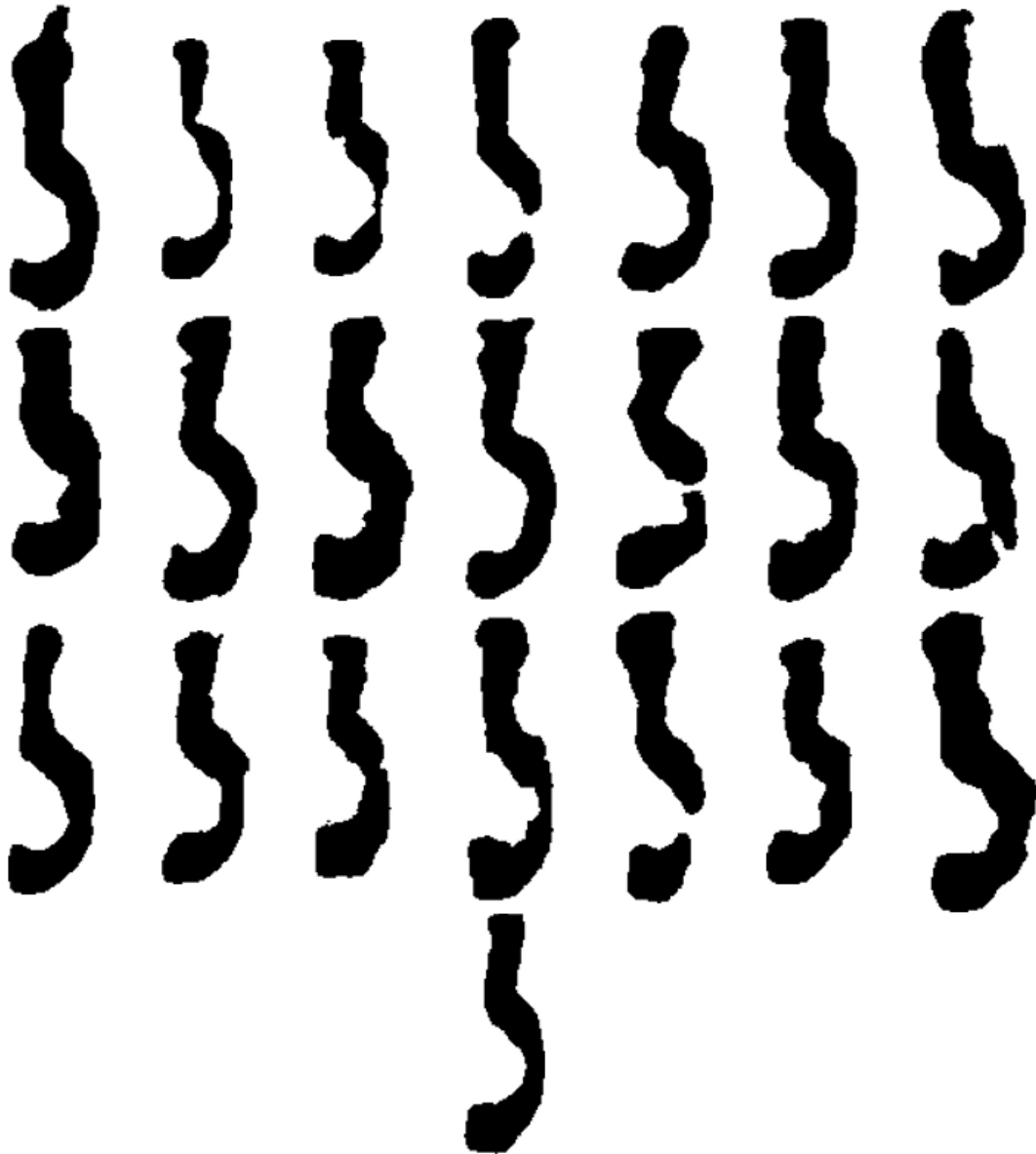
We defined an orderly process starting with the RGB image acquisition and finishing with a glyph image. The images pass through customized automatic stand-alone image preprocessing before being analyzed. The preprocess contains the following operations in the following procedure:

Adaptive RGB to gray conversion, histogram equalization, cropping (layers removal), lines detection, roll correction, inhomogeneity filtering (Bilateral filter), re-histogram equalization, splitting by automatic tool especially built especially for this purpose and finally binarization – thresholding to a glyph.



At the end of the preprocess, we get the entire characters split, cleaned of noises and aligned. The next step is to rescale it to reasonable sampling resolution so we downscale from 60 x 180 to roughly 50 x 150 pixels. which is enough getting high morphologic information. The rescaling was performed globally for keeping the size anomaly between characters.

For this publication we selected the *lamed* Hebrew letter. The same methodology and results would apply to any letter. We extracted 22 such letters. The split glyph characters are presented in (Fig. 7).



---

Fig. 7 Set of 22 *lamed* Hebrew letters extracted from investigated printed text

We performed cross-correlation between each pair of split characters getting the best Euclidean concentric match. We setup a code to find the best shift match for all possible pairs. Once a pair of characters is located at best positioned match of each other, we divide a character's surface area by the other's surface area, so the higher value results in the higher matched surface. The value of '1' gives the best perfect match.

In order to overcome mismatch when a surface of one character is less or higher than the other, we normalized the subtracted surfaces results by dividing twice the joint surface area of the two characters by the sum of the surface areas of the two characters separately.

Examples after best cross correlation are shown in (Fig. 8). In light blue is the overlapping area between the two glyph characters. In dark blue is the area outside of the overlap for one of the glyphs and in green is the area outside of the overlap for the other glyph of the pair.

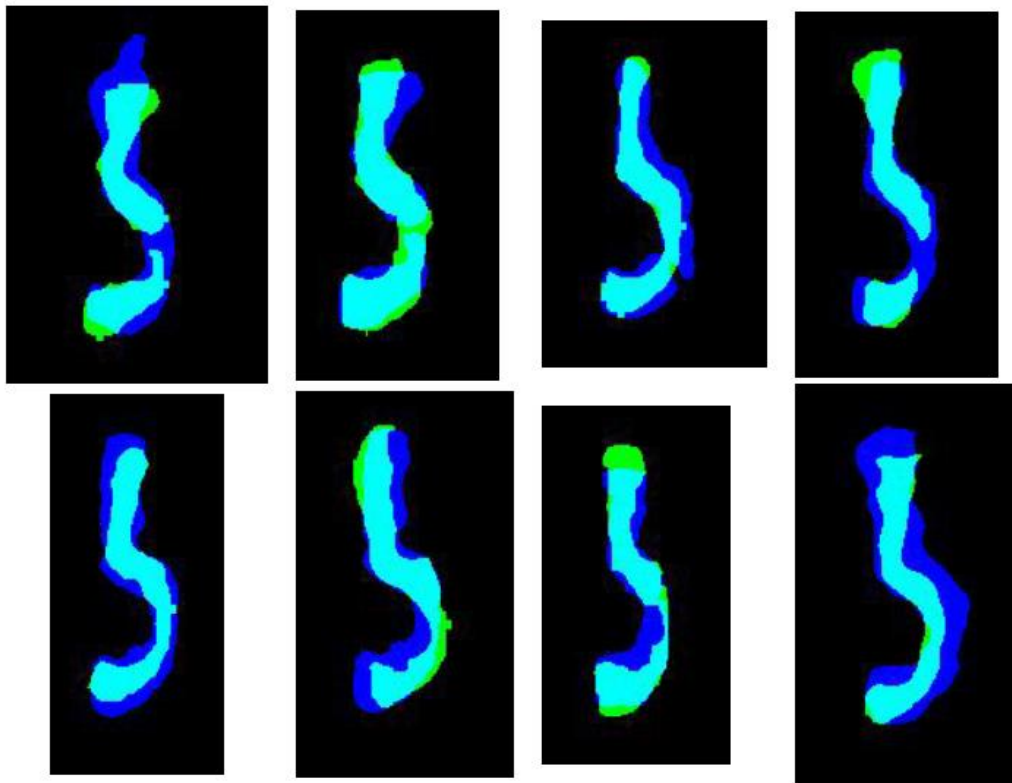


Fig. 8 Examples of correlated pairs of *lamed* Hebrew letters

By checking all possible pairs, most of all pair cases got a score less than 0.87 which means low correlation rate. The highest correlation coefficient was 0.91. This translates into the conclusion that all *lamed* letters of the sample are different.

It would be difficult to date this text from 1541, period of time when printing was a mastered craft and when types were already uniformly printed.

## 5. Early semi-cursive Spanish Hebrew type

We need to try to match this text with printers of the early years of the printing craft, bearing in mind that it is printed in semi-cursive Spanish Hebrew characters. According to Tishby (1983) [17] the earliest known printed Hebrew books are from Rome in the years 1469 to 1472. They all use square Hebrew types. The first known Hebrew book with semi-cursive Spanish Hebrew types was printed in 1475 in Reggio di Calabria. It is followed by a book printed in 1476 in Guadalajara. Tishby (1988) [18] provides a table with the fonts from both places. From this work we can see that the none of those two places has fonts similar to the one we investigate.

Hurvitz (1985) [19] identified incunabula pages as Maimonides' Mishne Torah printed in 1481 in Toledo. It is mostly using square Hebrew types. It has only one chapter set with semi-cursive Spanish Hebrew types. Here also we could not find similarity with what we are investigating.

We had access to quality scans from books printed with semi-cursive Spanish Hebrew types in Hjar in 1487 [20] and in Lisbon in 1489 [21]. We could also see that those fonts are different than ours. See (Fig. 9) and (Fig. 10). Other Iberic printing shops used square Hebrew types.



Fig. 9 Typical glyph of *lamed* Hebrew letter from work printed in Hjar in 1487



Fig. 10 Typical glyph of *lamed* Hebrew letter from work printed in Lisbon in 1489

We finished the survey with two places where Hebrew printing was brought from the Iberic Peninsula and where semi-cursive Spanish Hebrew types as well. We received quality scans from a book printed in Fez [22] in 1517 and one in Constantinople [23] attributed in 1494, but possibly from 1504. None of them is a fit for our investigation



## 6. Avignon's printing shop

To try to find a printer for those sheets, we turned to historians of previous generations, Friedberg (1937) [24], Roth (1962) [25] and Haberman (1968) [26] to see what they write about the earliest Hebrew printing efforts. It turned out they all mention an indication of an early printing endeavor which took place in Avignon, France, in the years 1444-1446.

This endeavor was first discovered by Pierre Henri Requin at the end of the nineteenth century [27]. Requin surveyed notarial archives at Archives Départementales de Vaucluse and found out about Procope Waldvogel. Waldvogel who was a silversmith from Prague who conceived a new method called *ars scribendi artificiler*, the art of artificial printing. He is known through notarial contracts he signed with people he recruited as partners, apprentices and money lenders. The contracts mention sets of metal letters, tools and equipment like a screw. For Requin and those who followed him [28], there is no doubt that Waldvogel's invention was printing.

The part that is relevant to our investigation is the fact that Waldvogel also recruited a local Jew, Davin de Caderousse. Waldvogel prepared for Davin Hebrew types in metal. After the dissolution of their partnership in 1446, Waldvogel leaves Avignon and relinquishes the Hebrew types in the hands of Davin. This is the first mention in History of Hebrew metal moving types.

French historians like Stein (1890) [29] and Blumenkrantz (1975) [30] envisioned as quite likely that, one day, Hebrew printed sheets from Avignon would be discovered.

We'd like now to connect the Hebrew sheets of paper originating from Fabriano in the years 1418-1439 with the Hebrew printing endeavor of 1444-1446. This connection is not far-fetched. Alibaux (1926) [31] mentions importation into France of Fabriano paper.

Specifically, Alibaux (1926) [32] quotes documents showing the purchase of Italian paper in Avignon in 1432. The paper is defined by its bull's head watermark. Alibaux looked for this watermark in Archives Départementales de Vaucluse and found it in the years 1434-1436. It is there still around in 1446.

Those are years parallel to the dates we met in our investigation making it plausible, as far as dates, that Fabriano paper was used in Avignon for printing.

## 7. Summary of a possible interpretation

The investigation started with a printed watermarked paper, whose design is known in the time frame between 1418 to 1439. The text is printed in Hebrew.

One similar watermark is dated 1541 and has the same chain line width that the watermark under investigation.

The similar watermark is from a paper that most likely was manufactured in Fabriano.

By performing a sample survey of the Historical City Archive of Fabriano, it is also very likely that this watermark design was not used in Fabriano in the sixteenth century.

The first temporary conclusion is that the watermark under investigation was used in Fabriano and was manufactured in the reported time frame between 1418 to 1439.

The analysis of the Hebrew letters shows a total inhomogeneity in the shapes of the printed shapes. This points to an early period of the printing craft.

The analyzed printed Hebrew letters, whose style is called Spanish semi-cursive, do not fit any known Hebrew printing shop.

History of Hebrew printing records the collaboration in Avignon between the silversmith Procope Waldvogel and the local Jew Davin de Caderousse which led to the first set of Hebrew metal moving types in History. This happened in the time frame between 1444 to 1446.

Some historians are convinced that Waldvogel was successful in actually printing even though, so far, no printed evidence could be found.

Our proposed interpretation is that the Fabriano-made paper was used in Avignon to print a Hebrew book, making this the first evidence of printing with metal moving types in the West.

### **Conclusion**

As a conclusion, we present a plausible assumption that the investigated sheets of paper were manufactured in Fabriano between 1418 and 1439 and that the printing took place in Avignon between 1444 and 1446. It provides a new perspective to the history of Hebrew printing and is relevant to the general history of printing in the West, namely suggesting that Procope Waldvogel in Avignon achieved book printing before Gutenberg.

## References:

- [1] Briquet, Charles Moise *Les Filigranes: Dictionnaire historique des marques du papier*, Genève: A. Jullien 1907, vol. 4, no. 11898.
- [2] Harlfinger, Dieter & Johana *Wasserzeichen aus griechischen Handschriften*, Berlin: N. Mielke 1974, I,
- [3] Picard, Gerhard *Wasserzeichen Dreiberg*, Stuttgart: W. Kohlhammer 1996, Teil I, p.13 no. 1593
- [4] Website [www.wzma.at](http://www.wzma.at) search “ Berge/Himmelskörper / Dreiberg / im Kreisring / Kreuz (einkonturig) / ohne weiteres Beizeichen”
- [5] Zonghi, Aurelio, Zonghi, Augusto, Gasparinetti, A F *Zonghi's Watermarks* Hilversum : Paper publications society, 1953., no. 1315
- [6] Archives Départementales des Pyrénées Orientales (ADPO), Notules de Guillaume Roue, 1B212
- [7] Biblioteca Ambrosiana, Ms B128 sup
- [8] Österreichische Nationalbibliothek (ÖNB), Cod. 4597 dated 1418 and Cod. 5091 dated 1439
- [9] Fondazione Fedrigoni Fabriano (FFF), watermark code Z01764
- [10] Archivio Storico Comunale Fabriano, 13-E.Z. 1358
- [11] Zonghi, Augusto *Segni della carta. La loro origine et la loro importanza*, Fabriano: Premiata Tipografia Economica, 1911, p.21
- [12] Archivio Storico Comunale Fabriano, 11-EL Cartai 1360
- [13] Zonghi *ibid.* p31
- [14] Stevenson, Allan *The problem of the Missale Speciale*, London: The Bibliographical Society, 1967, ch. IV, ch. VII and Excursus IV
- [15] Agüera y Arcas, Blaise “Temporary matrices and elemental punches in Gutenberg’s DK type” in Jensen, Kristian (ed.) *Incunabula and their readers. Printing, Selling and Using Books in the Fifteenth Century*, London: The British Library, 2003, p.1-12
- [16] Stevenson, Allan *ibid.*, p.239
- [17] Tishby, Peretz. “Hebrew Incunabula Italy-Rome” *Kiryat Sefer*, vol. 58, 1983, p. 807-857 [In Hebrew]
- [18] Tishby, Peretz. “Hebrew Incunabula Spain and Portugal (Guadalajara)” *Kiryat Sefer*, vol. 61, 1986/7, p. 521-546 [In Hebrew]
- [19] Hurvitz, Elazar *Rambam’s Mishne Torah*, New York: Yeshiva University, 1985 [In Hebrew]
- [20] Yakov ben Asher *Tur Hajar*: Eliezer ben Alantasi, 1487
- [21] Nahmanides *Hiddushei ha Torah* Lisbon: Eliezer Toledano, 1489
- [22] Abudarham, David ben Yosef *Sefer Fez*: Samuel Nedivot, 1517
- [23] Yakov ben Asher *Tur* Constantinople: David ibn Nachnias, 1494 [?]



- [24] Friedberg, Haim Dov *The History of Hebrew Printing in Europe (Avignon)*. Antwerp: Friedberg. 1935. p. 91 [In Hebrew]
- [25] Roth, Cecil *The Jews in the Renaissance*. Hebrew edition Jerusalem : Mossad Bialik. 1962. p155-7
- [26] Haberman, Abraham Meir. *Hebrew Printing in Development*. Jerusalem : Am Israel Rubin Mass, 1968. p74 [In Hebrew]
- [27] Requin, L'Abbé *Origine de l'imprimerie en France (Avignon 1444)*, Paris: Cercle de la librairie, de l'imprimerie, de la papeterie, 1891
- [28] See Claudin, Anatole *Les origines de l'imprimerie en France. Premiers essais à Avignon en 1444*, Paris : Librairie A. Claudin, 1898 or Labande, Léon-Honoré " L'imprimerie en France au XVe siècle " in Otto Hartwig (ed.), *Festschrift zum fünfihundertjährigen Geburtstage von Johann Gutenberg*, Leipzig : Otto Hassarowitz, 1900, p.432-487
- [29] Stein Henri. *L'Imprimerie à Avignon en 1444*, par l'abbé Requin; *Les Origines de l'imprimerie à Avignon*, par L. Duhamel.. In: Bibliothèque de l'école des chartes. 1890, tome 51. pp. 315-319;
- [30] Blumenkrantz, Bernhard *Auteurs juifs en France medieval*, Toulouse : Edouard Privat, 1975, p. VI.
- [31] Alibaux, Henri *Les premières papeteries françaises*, Paris : Les Arts et le Livre, 1926, p.84
- [32] Alibaux, Henri, *ibid.* p.107-109

All pictures were taken by the authors