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1 PAST WORK

We are getting new members constantly and therefore I first would like to welcome the new members.

The two running projects (NanoKult and Affandi)

NanoKult
We continued our work on the NanoK©ult project and will soon be able to implement the new nano technology for mass deacidification on the market. (We also were invited to give a talk on it in the IPH congress in Valencia)
Paintings by Affandi
On 6th of September we had our interim report and dissemination of
results in the Asea Uninet project "Development of an integrated Restoration
Concept for the Art and Architecture in the Affandi Museum Yogyakarta". Prof.
Dr. Hanus was very kind to make the opening of the small get-together, O.Univ.Prof. Dipl.-Ing. Dr.techn. A Min Tjoa, head of Asea Uninet and Prof. Dr. Helmut Kortan and his wife, Mag. Susanne
Kortan were our most prominent guests.

ERASMUS

There were three ERASMUS students and two FFG voluneers with us during the last months. Monika Dzik and Magda Szymanska, students from Akademy of Fine Arts Warsaw, study conservation majoring in books and graphic art, Izabela Vajova from Slovak University of Technology in Bratislava is student in chemistry.
The university students were primarily involved in our recent research
project NanoKult (link http://www.donau-uni.ac.at/de/aktuell/news/archiv/24224/index.php)
(http://www.restauratorenohnegrenzen.eu/erc/Research/)
The project deals with the conservation of written heritage on wood pulp paper based on the use of nano-particles. To get an insight into the problem, various archives, namely with recent archival material were visited, for example, the Europa Nostra archive: http://www.donau-uni.ac.at/de/department/bauenumwelt/forschung/projekte/id/19874/index.php

Conservators without Frontiers

Conservators without Frontiers is an association, which was from the very start an initiative promoted by the European Research Centre for Book and Paper Conservation-Restoration
Conservators without Frontiers help to preserve an archive evacuated from Mosul
In the Iraqi town Mosul courageous people evacuated medieval archival and library material to save it from devastation. It was a private initiative. Since then these people have been trying to improve the interim storage situation of this heritage and get support by professional conservators. We were able to send a colleague to Iraq – for further information please visit our website: www.restauratorenohnegrenzen.eu

Representatives of the Research Centre

Our community of representatives of the Research Centre is growing. We have now representatives in 18 countries (Belgium, Bulgaria, Denmark, Germany, Estonia, France, Greece, Ireland, Italy, Lithuania, Norway, Poland, Portugal, Russia, Ukraine, Slovakia, Spain and Turkey). Representatives are not identical with the board members, who lead the Centre, but they act as our communication channels in the individual countries.

Alumni

We would like to inform you about our new „Alumni" link:
https://www.facebook.com/groups/150553258698594/

Summer school El´Manuscript

Summer school El´Manuscript which took place in Vilnius this year. There we did a workshop on conservation theory. Also this paper is finalised for print in English and Russian so that it can be accessed by a wider community. The paper suggests a systemic approach to conservation theory and demonstrates how the pattern language by Christopher Alexander can be used to overcome the missing elements in describing practical conservation in Brandi´s otherwise perfect "teoria del restauro".

Exhibition

16th of Nov. 2016 we had the pleasure to inaugurate, together with the Austrian Academy of Sciences and the Diocese Archive St. Pölten, an exhibition on watermarks.
The exhibition attracted a lot of experts and will be followed by a publication.

Conference

Bucharest with our contribution (Patricia Engel, "Systemic Approach Towards the Intangible Aspects in Tangible Heritage"; RESTIZUTIO Reclaiming the Tangible and Intangible Heritage-Conservation and Restoration Attitudes, Muzeul National al Satului Vol. 2, 10/2016 Bucharest, pp. 247-249 The printed book of the conference is already available.

New Publication

Historical Book Binding Techniques in Conservation
ISBN 978-3-85028-785-2

We got funding by the Lower Austrian government for publication of a book on historical book binding techniques in conservation. It is printed by Berger.
It is available under:
https://www.verlag-berger.at/alle-produkte/fachliteratur/detail/v/isbn-978-3-85028-785-2.html

MAECENAS Award

Berger Company and Gutmannsche Fortsverwaltung won a Maecenas prise

4th from left, representative of Berger company
This price is granted for the continuing support of the European Research Centre for Book and Paper Conservation-Restoration by the two enterprises since 6 years.

2 ARTICLES

This newsletter contains two articles.

Paper of Armenien Manuscripts – a Key to Stop Ink Corrosion?

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Abstract

A large number of Armenian manuscripts suffer from ink corrosion, a phenomenon due to oxidation and hydrolysis in which iron gall ink destroys the cellulose of the book's paper and the text is lost. Armenian manuscripts are not only the oldest Christian manuscripts in the world but also contain unique information on the history and culture of the Caucasus region; they also include antique texts translated into Armenian which have been lost in the original language. Therefore, these manuscripts represent a high value for European society in general and Armenian history in particular. An international interdisciplinary team set out to rescue these books. The composition of the ink and its individual capability to react with the paper is one source for the corrosive destruction. In Armenia various sorts of iron gall inks and soot inks as well as mixtures of both were used. The inks were subject of the first step of a survey to rescue the manuscripts. However, the text carrier - the paper - must be considered equally relevant in understanding the destruction, as it serves as reaction partner to the ink. The condition of the books varied widely, and was not explained by the type of ink used. The paper's composition, manufacturing process, and/or the surface treatment were suspected to be the reason for the condition of the text today. Thus the authors' second step was to survey the paper. The authors reviewed several known treatments, including the phytate treatment suggested by Reissland and Neevel, which is aqueous and has known disadvantages.

Keywords: Armenian Paper, Armenian Manuscripts, iron gall ink.

1 Introduction

Armenian manuscripts are not only the oldest Christian manuscripts in the world but also hold unique information on the history and culture of the Caucasus region as well as texts of classical ancient time in Armenian translation which are lost in the original form. A large number of Armenian manuscripts suffer from ink corrosion, a phenomenon where due to oxidation and hydrolysis so called iron gall ink destroys the cellulose of the paper of the book and the text is lost. Iron gall ink is composed of a metal salt and a tannin; however the concrete composition varies from ink to ink even if the recipe is the same, because the material is taken directly from plants and soil.
The manuscripts represent a high value for European society in general and Armenian history in particular.

An international interdisciplinary team set out to rescue these books under the „Armenian Ink Project", headed by Patricia Engel and Gayana Eliazyan. 100 Armenian ink recipes from the 12th to the 19th century had been brought together from manuscript-colophons and other historical Armenian texts. Inks were manufactured, applied to paper and aged artificially as to simulate the situation in the historical manuscripts. The resulting dummies served as test material in the try to stop ink corrosion.

The composition of the ink and its individual capability to react with the paper (parchment was not included in the first step of survey) is one source for the corrosive destruction. In Armenia various sorts of iron gall inks and soot inks as well as mixtures of both were used. The inks were subject of the first step of an ample survey on the way to rescue the manuscripts.[1] However the text carrier, the paper, must be considered equally relevant in understanding the destruction, as it is the material, which is decayed by the ink and can be called the reaction partner of the ink. It was obvious, that some books were in better and some in worse condition. The question why this was the case could not only be explained by the sort of ink used to write the text. Rather the composition and/or manufacturing procedure of the paper respectively possibly a particular so far not understood surface treatment of the paper were suspected to be the reason for the condition of the text today. It is self-evident that also the storage condition of the books play a role in the destruction process of the manuscripts, however as the changeful history of the manuscripts could not be verified in each and every case, this factor had to be estimated from traces such as water tide lines and conservation reports. Therefore a survey of the paper was the second step on the way to rescue the manuscripts.
Even if there are suggestions for treatment of ink corrosion in Europe there had been a great hope to find alternative methods in those manuscripts, which are in good condition, which, in best case, could be used as alternative and possibly nonaqueous ink corrosion inhibition measure. The phytate treatment suggested by Reissland and Neevel (Neevel 1995) is aqueous and brings with it all disadvantages water in conservation brings along.

2 Survey of Manuscripts

The first step was to survey the manuscripts by visual observation (visible light, transmitted light, and raking light) and microscopic analyses and register the data to get into the position to make comparison and draw conclusions. Mold structure, watermarks, formation, fillers, thickness, colour, sound and gloss (sort of polishing technique) as well as the measure of penetration of ink flow into the paper were registered.
As to understand the relation between paper composition and condition of the manuscript, the degree of destruction was correlated with the visible features of the inks. The composition of the inks was estimated on the background of the already gained experience with the performance of recipes
and appearance of the resulting inks and the destruction features. (Soot inks cannot cause ink corrosion, iron gall inks are not water soluble.)
To verify suspected wood pulp papers a Phloroglucin test for lignin was performed. To verify a calcium filler or surface treatment with calcium carbonate or as to correlate the pH value with the degree of ink corrosion, pH value was tested in case it seemed relevant. To verify iron content
of inks, free iron ions were detected by Bathophenanthrolin and, if needed, Ascorbic acid. Catalogue data and damages as well as past conservation measures were registered. The fifty codices surveyed were from the 14th to 19th century, the selection was random and decided on by the librarians. In the following paragraphs the surveys are presented century by century. Armenian codices often consist of several books bound together, which explains ununiform data.

2.1 14th Century Books

The two books surveyed from this time as well as observations on the books from the following century suggest that these early texts were written on grass mold-paper (no watermarks). The team was quite if not 100% sure to see that these papers were filled or treated with starch respectively
paste and were also calcium-compound filled. These papers came from the Western part of Old Armenia. The information about the provenience was taken from the catalogue.

2.2 15th Century Books

Amongst the six books from the 15th century seven papers were made on grass mold and two on wire mold. Armenian manuscripts often consist of several parts having been individual books before and the papers and inks change from book to book but also within one book in such a compiled codex. This means that the majority of these papers from the 15th century were made on grass mold. All of them but one were taken for

[1] Eliazyan (2009); Engel and Eliazyan (2006)

calcium-compound filled and/or surface sized with starch and smoothened. The codex Mat. 5985 should be revisited, because it is a Western paper and has a watermark, but this watermark is not described in the notes. The other Western paper with a grape, bowl or crown as watermark in codex Mat. 143 is inscribed with soot ink and thus not relevant for present research on ink corrosion in relation to paper-sort. Out of the six books from the 15th century, two were from the Western part, one from the East of Armenia and in three cases the origin is unknown. Conclusively it can be said that the papers in the 14th and 15th century seem to be grass-molded, calciumcompound filled, surface-treated with paste and smoothened (Oriental features).

2.3. 16th Century Books

From the 16th century four books were surveyed, 50% of them had Oriental features, 50% Western (i.e. wire mold and watermarks, respectively unfilled and collagen based surface sizing). However one of the two Western papers seemed surface treated according to Eastern tradition, while the other one appears unfilled and unsized. The latter has a very low pH while the first is around neutral pH. The origin of the books are from Ganzagar (Gandzasar-Nagorny Karabach), Selo Abndants (Avndants, a village in Western Armenia), Kara Kala (which one of is in Armenia and one in Azerbaijan) and Aghtamar (which is in the East). In the 16th century there seems to be a change from the Oriental paper to the Western paper.
Possibly trade with Europe started. However the data from these four relevant books are very inhomogeneous, one information is not useful, because the notes taken in Yerevan are contradictive and one codex was poured with ink, which is also impossible to line into the other observations, as the amount of ink is too high and therefore not representative. The eldest codex however in terms of material fits well into the tradition of the previous century with a grass mold paper and good state of the ink. The second interesting observation is that one of the codices indicates what will come in later centuries, i.e. the European glue-sized papers leaving codices in bad condition.

2.4. 17th Century Books

Nineteen codices observed were from the 17th century. Six papers in those codices were made on grass mold and thirty-four on wire mold, which clearly is a majority. Twentyeight watermarks were registered. While the earlier papers seem to be surface treated with starch the later papers show the Western glued surface. The pH (five in average) is in general two numbers lower (more acidic) than in the grass-mold papers, where it is seven in average. However pH value was altered in five of these books, respectively eight of these papers by conservation measures between 1989 and 1990 and included Bariumhydroxide-, Ammonia-, Ethanol and Methylcellulose application. This information was taken from documentation sheets in Matenadaran conservation-centre. While in previous centuries the Oriental paper seems to be responsible for the good condition of the texts, it seems that in the books of the 17th century the composition of the inks become more important for the good or bad state of the text, than in the time before. Inks, which are stoechiometrically even are not destructive and an ink which comes close to such even state is less destructive than an ink with large number of free metal ions. Western type of paper without an Oriental treatment seems to result in the worse state of the manuscript today while Oriental or similarly treated papers seem to have a tendency to cause a better state of the books. The paper might hold a sort of buffer against ink corrosion, while Western papers are exposed to any potency of ink attack.

2.5. 18th Century Books

Seventeen codices from 18th century contained fifty-eight obviously different papers in the book blocks. The flyleaves were not taken into consideration in the cause of these observations, as they are often from rebinding and are both elder and later papers. No paper of these books was produced on a grass mold. However one is described as on bamboo and one on textile, both not making the majority of the very book. They might have been added from elsewhere. In seventeen cases the watermark is clearly visible.
Interesting seems the fact that while these papers are not so heavily coated with starch any more, the mechanical surface treatment seems to have increased; a large number of pages is not only smoothened but really polished. This fits well to the fashion in Arabic book production at this time – book producers also followed environmental habits. Armenian books made in Moscow and in St. Peterburg are made of European paper, unfilled, glue sized with “rough” unpolished surface. This is very much true for Diaspora manuscripts too. In the Austrian National Library a larger number of Polish Armenian books on Western papers are kept.

Codex 5880 includes both quires of heavily filled paper and quires of not filled pages and the damage of the text decreases immediately from one page to the other where these papers change while the ink seems to be the same. This clearly demonstrates how the filling helps against the aggression of the ink. Furthermore it should be mentioned that conservation was executed in nine of these books. Conservation treatments included Formaldehyde-, Ethanol-, Ammonia-, Bookkeeper- (30°C inert carrier (untoxic FKW) Perfluoro-Heptan (100% recycled) + Alkylester (against lumping) and magnesium oxide (Suspension)) and Bariumhydroxidetreatments.

2.6. 19th Century Books

Seven manuscripts from the 19th century contained eight different papers. Three were handmade on wire molds, the others machine made. Five books were treated by the conservators, which is actually a high percentage indicating the need for such conservation treatment. The treatments included Calciumcarbonate - application (four times), Bariumhydroxide (once) and a combination of CaCO3, Methylcellulose and Ammonia (once). The treatments were executed in the years 1997 and 1998. Wood pulp paper and alum sizing, seemed to explain the bad state of the books from the 19th century, while the composition of the inks seem to play a minor role.

2.7. Conclusion on the Observations

The observation calcium-compound filled or starch-filled was made mainly for the papers in the elder manuscripts. According to Karabacek [2] and Loveday [3] Oriental papers were made by starch sizing and chalk treatment. The fact that no watermarks were registered in this survey for paper used before the 15th century fits well to the hypothesis that Oriental papers were calcium-compound-starch sized and had features of grass molds without watermarks. This was also the conclusion of an e-mail conversation of Patricia Engel with Paul Hepworth and Karin Scheper in winter 2011.

However, there seemed to be papers with clear Western features such as wire mold and watermarks, but with Oriental fillers, surface sizing and polishing. The condition of the inks seemed to be better in the presence of such Oriental features.

Two questions arose from this survey:

1. Were our observations on the chemical composition of the papers correct or disguised by parameters the team was not aware of?
2. Is there source literature about the surface treatment of imported papers in the region?

As to verify these observations they were compared with results of Fourier transform infrared spectroscopy (FTIR) and X Ray Fluorescence spectroscopy (XRF) and fibre analyses performed on samples from these papers. Research on the watermarks should help identify the region of the origin of the Western papers and give further information about paper material. The FTIR and XRF analyses were made in the course of a cooperation between the European Research Centre for Book and Paper Conservation-Restoration and the Academy of Fine Arts, Vienna. Erasmus students, Emilia Domazet und Rafaela Burmeta under Mirna Willer University of Zadar were able to make the work, which was conducted under the supervision of Manfred Schreiner and Wilfrid Vetter. Firbre analysis was superwides by Helmgard Holle, also Akademy of Fine Arts Vienna and watermark survey was superwised by Emanuel Wenger, Austrian Academy of Sciences.

Reproduction of historical surface treatment recipes was performed as to understand the influence of these methods and materials on inks. It was suspected that natural complex builders might be amongst the plant materials described to be used for the treatments. Reproduction of the historical surfaces was done under the supervision of Patrica Engel by Erasmus students, Emilia Domazet und Rafaela Burmeta under Mirna Willer, University of Zadar.

[2] Karabacek (1887, 1888)

[3] Loveday (2001)

3 Instrumental Analysis, Fibre Analysis and Watermarks

FTIR and XRF spectroscopy and after this fibre analyses should verify or falsify the observations made so far and gain further understanding of the paper material. Four samples of the books from the 14th century (one of one codex and three of another codex), five samples out of three books of the 15th century, two samples of two books of the 16th century, six samples all out of different books from the 17th century, fourteen samples out of four books from the 18th century and two samples out of two different books from the 19th century were available.

3.1. FTIR Spectroscopy

Twenty-eight samples (five were lost) were analyzed in the FTIR spectrometer Alpha with ATR unit of Bruker Optics. FTIR spectroscopy allows the identification of organic and inorganic components of paper. The resulting charts must be estimated with care, as some of the samples were very small.
Nevertheless some clear data could be found. Cellulose was detected in 94% of the samples, which was to be expected, as all pages of these books were made of paper. Traces of lipids, which were found in several samples, can be taken for grease which was definitely available from the use of the books over centuries. More interesting were the data for chalk and glue as well as the try to discriminate cellulose from starch, as both materials show relatively similar spectral features. Chalk was found in three manuscripts; Mat. 7954, Mat. 908, and Mat. 6447. Visual observation on the paper had already given
a similar estimation. It had been noted for signatures Mat. 7954 and Mat. 908. In manuscript Mat. 6447 the presence of chalk was not observed. The reason for this might be the way of application. That the technique of application plays a role for the visible appearance of the surface was clearly
observed during or paper recreation described in chapter 4.The utmost interesting result of the IR spectroscopy was, that glue could be detected in nearly every sample no matter from what century it came. This was in pronounced contrast to what was written down during the visual survey and lead to the wish to prepare the surface treatments according to the old recipes. If glue was present in all papers, it could not influence the state of the ink, unless there is a difference in the way it sits on the paper.
A clear distinction between starch and cellulose was not possible due to band interferences and did not allow a conclusion on the materials surveyed.

3.2. XRF Spectra

By means of XRF spectra the elements phosphorus (P), potassium (K), calcium (Ca), iron (Fe), copper (Cu), zinc (Zn), lead (Pb), manganese (Mn) were detected. The instrument used was a Spacetrace 5000 by Noran Instruments.
All the metals, i.e. iron, copper, zinc, lead and manganese are suggested to derive from the ink. Ink always comes off the text and distributes as small particles all over the paper, however in an amount that it is virtually invisible. Iron and also copper are the two main elements in iron gall ink while the other metals may either come from the mineral ores or they derive from the jugs and pots in which the inks were made. In Armenian museums kitchen devices of copper with inner walls of zink can be seen. It is very probable that the same dishes were used for ink production. [4]
The elements calcium and potassium should come from a surface treatment or possibly they are deposits from the water, which was used to produce the paper. As the analysis is not quantitative, it is difficult to further specify this. The phosphorus most probably derives from the glue.
Both IR and XRF analyses pointed towards a strong use of collagen based glue in paper making. According to recent understanding this not necessarily supports the hypothesis of a European surface sizing with glue, but could very well also derive from an Oriental surface treatment where glue and starch were mixed as in one of the Iranian recipes which are described in chapter 4 or possibly from a mixture of glue and chalk as in Western paper primers.

[4] Engel and Eliazyan (2006)

3.3 Fibre Analysis

According to Karabecek, fibres of Oriental paper are of cotton [5], later this was dimmed being wrong. Recently the possibility of cotton in use for paper making is at least taken into consideration again which was confirmed also by a personal comment of Gangolf Ulbricht [6]. The opportunity to see the fibres of these Oriental papers was hoped to give additional insight into Armenian paper production. A Microscope ZEISS Discovery.V20 SteREO with a magnification from 7.5 to 150 in transmitted, raking and normal light and a light microscope Axioplan 2 from Carl Zeiss (magnification between 50 and 200) were used. The fibres were first put into water as to detect their physiognomy and later stained by Herzberg and Herzog solutions. [7] The assumption was that the fibres could be flax, hemp and/or cotton. Wood pulp was suggested for the 19th century, as lignin test with Phloroglucine and watermarks "WHATMAN" pointed into this direction.

3.3.1 Morphology

As there are no modern reference samples of such papers, or systematic survey [8], the results can rather give an overview and not go into depth. The Fibre Atlas by Ilvessalo-Pfäffli and Harders-Steinhäuser [9] was used as a first step followed by further examination with optic methods after Herzog [10] and by using a dying method according Herzberg [11]. The first impression under the microscope under 100 to 200 times magnification showed that the fibres are partly quite damaged from the grinding procedure. Furthermore the hypothesis that mixtures of fibres might be found was immediately confirmed. The predominant fibres however were bast fibres, which mainly came from linen or hemp fibres (Figs. 1-4, Fig. 5). Due to the small size of the samples it was not possible to detect the characteristic features of cotton linters, of hard fibres such as Espartogras (Fig. 6) and of bast fibres with the accompanying cells of crop-species. However they might be present. Some fibres such as the one depicted in Figs. 7, 8 could not be identified.
Physiognomy of the fibres in water showed that no cotton fibres were involved. To distinguish between hemp and flax especially in paper with reused and regrinded fibres, was not easy.

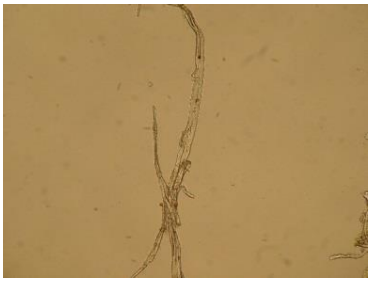

Fig. 1 Linen fibres 200x transmitted light taken from codex Meh.7954 page 8, 1483

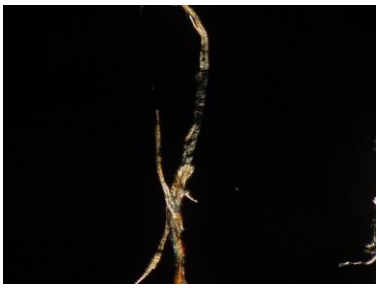

Fig. 2 Linen fibres 200x resolution by orthogonal position between crossed polarisators, taken from codex Meh.7954 page 8, 1483

[5] Karabacek (1887, 1888); Wiesner (1887)
[6] Ulbricht, pers. comm.
[7] Herzberg (1921), pp. 79-81, 114-115; Herzog (1940)
[8] Wiesner (1902); Collings and Milner (1984)
[9] Ilvessalo-Pfäffli (1995), pp. 79-359; Harders-Steinhäuser (1974), pp. 13-106
[10] Wülfert (1999), pp. 290-292
[11] Jayme and Harders-Steinhäuser (1970), pp. 83; Franke (1993), pp. 66-67

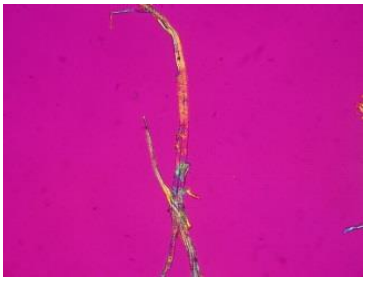

Fig. 3 Linen fibres 200x middle lamdaplates NS position: orange taken from codex Meh.7954 page 8, 1483

Fig. 4 Linen fibres 200x middle lamdaplates OW position: indigo taken from codex Meh.7954 page 8, 1483

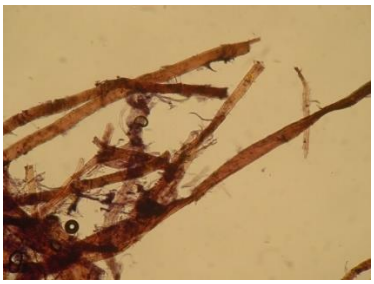

Fig. 5 Hamp fibres and unidetified twisted fibre (cotton or Esparto) rod-brown colour by Chlor zink iodine 200x middle lamdaplates NS position: orange taken from codex Meh.6589 page30, 18th cent.

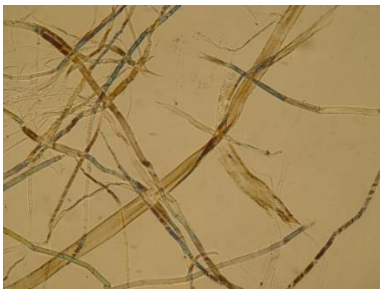

Fig. 6 Espartogras (sample from collection of Technical University Graz). Polarisation, 200x

Fig. 7 Unidentified bundle of fibres, died with Chlor zink iodine, 200x, Meh. 7954 taken from page 9, 1483

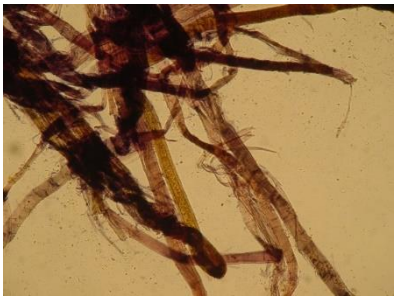

Fig. 8 Unidentified fibres between bast fibres, died with Chlos zink iodine, 200xMeh. 4992, taken from page 246, 1475

3.3.2 Dying Tests

In the dying tests which were used in the frame of the project, every material containing lignin appears yellow-orange and thus can be distinguished easily from the blue cellulose fibres (from the 19th century on both conifer and broad leafed trees can be found) and the light Bordeaux red to blue-violet rag fibres (Figs. 9, 10), such as linen, hemp and cotton. As the iodine in the dying substance causes also a blue reaction of the starch, respectively starch paste in or on the paper can influence the colour. A surface sizing with starch paste may be suggested for Mat. 7334 (fig. 11).

Besides of old clothes as a source for the early paper production, one should in this case also take into consideration the rich flora of Armenia. For example Triticum Urartu and Triticum Araticum are plants from which today´s grains were developed and it is known that in the Ararat region cotton was grown in the old days. [12]Furthermore paper was traded which means that other plant fibres might have been used, in particular in the case of later paper.

It can be concluded that hamp and flax were found as fibre material in the samples and also wood pulp was identified. However, there are still many open questions, which clearly ask for further research, mainly due to the circumstance that the samples were extraordinary small. The observation under iodine staining confirmed the observations made directly in the books.

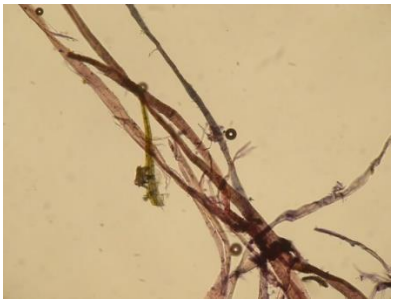

Fig. 9 Dark red or violet colour by Chlor zink iodine on hamp fibres, yellow-green colour of a wood fibre, 200x Mat. 7954 taken from page 9, 1483

[12] Höhnel (1893)

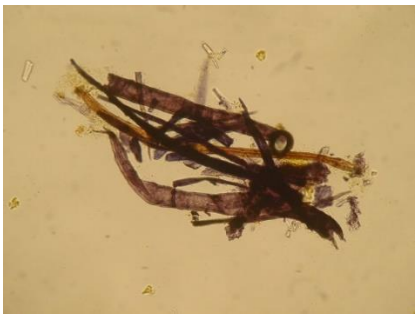

Fig. 10 Blue colour by Chlor zink iodine on a pine tree fibre with Tüpfel, yellow a wood fibre of unidentified sort, 200x, Meh. 5046, 17th cent.

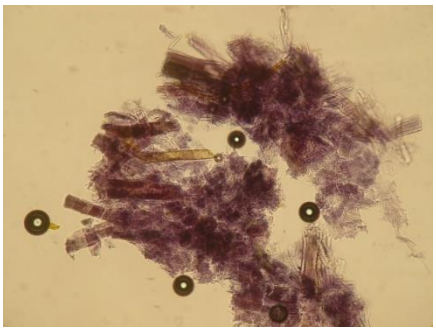

Fig. 11 Blue colour of starch (sizing) by iodine oft he reagens after Herzberg, 200x Meh. 7334, 17th cent.

3.4 Watermarks

Some of the papers involved in the survey have watermarks. On one hand the question: did Oriental papers have watermarks despite the existing viewpoint arose, on the other hand there was the wish to draw conclusion on the origin of the papers used in Armenian manuscripts by identifying the mills.
It is often brought forward as an argument that oriental, i.e. grass mold papers have no watermarks, as the fixing of the features would not be possible. This is not necessarily true, as it would easily be possible to sew for example a thicker thread onto the flexible mold. The question is rather, was it done?
In any case it is worth observing, sorting and searching for the watermarks available in the Armenian papers and to try to find their origin.
Practically nothing is published on this topic and also this contribution is by no means sufficient. It rather is a start for a larger project which should follow. In Armenia watermarks were partly described, partly traced and in a few cases photographed. In table 1 an overview of the watermarks found in the codices in Matenadaran is given in chronological order; the naming of the watermark motifs follows the English terminology and hierarchical classification of the "Bernstein" project [13] in those cases where it was possible. A colloquial description was chosen in the other cases. Bernstein has developed a hierarchical classification for watermark motifs in six languages with three levels of hierarchy so far. This classification system has been adopted, modified, and extended up to ten levels of hierarchy by the project Wasserzeicheninformationssystem. [14]

Signature	Date	Watermark motif
Mat. 143	14th, 15th, 17th century	flora >> fruit >> grape, with additional motif crown
Mat. 658	1601	mountains/luminaries >> star, coat of arms >> shield with letter(s) >> with one letter M
Mat. 4405	1631	p.1, p.9: coat of arms >> shield with lily >> with three lilies and on top crown; p.163: fabulous creature >> dragon (wyvern) >> detached, entire figure with additional motif?
Mat. 10735	1631	some watermarks, but their motifs are identifiable
Mat. 153	1671	p. 12: fauna >> bird >> head; p. 14: flora >> leaf/blossom/tree >> flower (other forms)
Mat. 3109	1680	complicated and not describable crown

[13] Rückert, Hodecek, and Wenger, (2009); Wenger (2010)
[14] Frauenknecht and Stieglecker (2012)

Mat. 10998	1691	Ring with lily (counter.) frame and round inner part with vertical lines
Mat. 5866	17th. century	sort of flower, crown and grape, “CTPCB” + crown + grape, countermark “LARDOND”
Mat. 1489	17th. century	letters/digits >> two letters >> I B, p.210: fauna >> bird >> entire figure >> in oval, countermark: letters/digits >> two letters >> PG; mountains/luminaries >> moon >> three moons; letters/digits >> three letters >> IAS, second line: letters/digits >> one letter >> G
Mat. 5778	17th. century	circle and shell shapes, wings? unclear
Mat. 1691	17th. century, 1765	letters/digits >> word >> “...GA…”
Mat. Syrisch9	17th. century	mountains/luminaries >> moon >> three moons and three small circles on a stick
Mat. 5046	17th. century	gear on twisted stick, decoration of sort of frame (only part visible), p. 1,2: coat of arms >> shield with lion >> in entire shield and crown above, p. 395: fauna >> bird >> heraldic eagle, letters/digits >> three letters >> GFA
Mat. 5691	17th century	p. 36: fauna >> tetrapod >> lion
Mat. 3300	17th century and 1834	letters/digits >> two letters >> BS in a circle; p. 170: big lion with flag, p. 186: flora >> leaf/blossom/tree >> flower (other forms)
Mat. 1575	17th and 18th century	mountains/luminaries >> moon >> three moons
Mat. 7856		mountains/luminaries >> moon >> three moons; and sort of flower and VG
Mat. 3287	1728	volute
Mat. 6945	1758	lion and person with stick and moon (like in sign. 6412 and sign. 6252)
Mat. 3281	1759-1774	letters/digits >> three letters >> CASTRES LANGVEDOC; flowers, letters/digits >> two letters >> DV, other motifs
Mat. 1212	1773	letters/digits >> one letter >> E
Mat. 2896	1781	“flower and part of frame”; flora >> leaf/blossom/tree >> lily
Mat. 6274	1782	p. 407: flora >> fruit >> grape with crown above; p. 395: letters/digits >> word >> “CALCINA TOSCOLANO”
Mat. 6613	1799	letters/digits >> word >> Pieter de Vries
Mat. 5880	18th century	unclear and partial watermarks; letters/digits: P 9 and X , p. 144: coat of arms?; p. 152: mountains/luminaries >> moon >> three moons? and many others, unspecific and not well visible
Mat. 6276	18th century	fauna >> serpent (snake) and crown
Mat. 6452	18. century	p.1: letters/digits >> word >> Le lune; flora >> fruit >> grape
Mat. 7654	1819	letters/digits >> word >> 1817 RUSE & TURNERS
Mat. 5337	1827	letters/digits >> three letters >> DMC, p. 21: mountains/luminaries >> star >> with six rays; p. 81: unidentifiable letters,
Mat. 5788	1833	X vase?
Mat. 10930	19th century	letters/digits >> word >> “Whatman TURK 1839”
Mat. 5408	19th. century	letters/digits >> word >> “Whatman”, “1853…”, coat of arms
Armen 1		realities>>arms, weapons >> crossbow (Briquet 708, 1354 Troyes)
Armen 2		mountains/luminaries >> moon >> several moons >> three moons
Armen 3		hard to identify, large complicated watermark like a basket with scroll
Armen 4		letters/digits >> two letters >> which first letter U/V; coat of arms (hardly visible), 16 laid lines per 2cm, chain line distance: 2.5 cm
Armen 5	1631	coat of arms? chain line distance: 2.7 cm
Armen 7		coat of arms >> shield with eagle?
Armen 8		no watermarks
Armen 11	1608	figures, anthropomorphic >> entire figure, male >> man in a circle
Armen 12		fol. 2: letters/digits >> word/name >> “C &… HONIG“ with beehive above the text: chain line distance: 2.7 cm, coat of arms >> shield, above crown
Armen 13	1580	coat of arms >> shield, above crown and three tools
Armen 14	1645	fauna >> tetrapod >> lion in circle; realities >> structures >> tower >> two towers, in between archway consisting of two lines without merlons; letters/digits >> one letter >> letter W
Armen 16	1613	mountains/luminaries >> star; letters/digits >> one letter >> letter M; figures, anthropomorphic >> entire figure, male >> man in a circle
Armen 17	1617	fauna >> serpent (snake) >> consisting in two lines with letter H on one side and S on the other; figures, anthropomorphic >> entire figure, male >> man in a circle
Armen 18	1702	coat of arms?; figures, anthropomorphic >> head >> fool, letters/digits >> two letters >> MH; chain line distance: 2.2 cm
Armen 19	1635	huge letters/digits >> two letters >> WM but hardly identifiable: maybe coat of arms >> shield with lamb, above crown? height: 13 cm
Armen 21	1687-1698	figures, anthropomorphic >> entire figure, male >> others (rider with horse); fleur-de-lis; three balls on a stick with two S; huge coat of arms
Armen 22		fauna >> bird >> heraldic single-headed eagle with crossed hammers at the chest; SM; chain line distance: 2.4 cm; double-headed eagle; laurel leaves and three fleurs-de-lis and lion below in a shield
Armen 23	1616	letters/digits >> two letters >> MS and single-headed eagle like Armen 22
Armen 23*		fauna >> bird >> heraldic eagle? chain line distance: 2.2 cm: coat of arms >> shield with posthorn below 4 and WR ; counter mark HD or JD
Armen 26		realities >> anchor >> in circle, with additional motif >> star; chain line distance: 2.7 cm
Armen 27	1664	mountains/luminaries >> star >> with six rays >> moon and cross on top; Fol. 2, 3,5,20

Armen 28		bowl and star; counter mark: flora >> leaf/blossom/tree >> cloverleaf with moon; chain line distance: three cm, 14 laid lines per two cm; another cloverleaf but smaller is in the 4th quire; chain line distance: 2.7 cm
Armen29		fol. 213 distorted grass mold; e.g. fol. 291 no chain lines visible
Armen34		very fine sieve; coat of arms >> shield with mitre on top; height: 19cm; letters/digits >> A V H B… VC? chain line distance: 2.4cm

Table 1 Watermarks found in the Armenian Manuscripts kept in Matenadaran in Yerevan (Mat. and number) and in the Austrian National Library (Armen. and number)

It is significant that the findings are mainly in those codices, which the catalogue dates between 17th and 19th century. Additionally to the stock of data on watermarks collected in Yervan (signatures with "Mat." ahead the number; table 1), the team made a survey on watermarks in the Armenian manuscripts held by the Austrian National Library (signatures with "Armen." ahead the number; table 1). This was done to have more material to draw conclusion on. In the Armenian manuscripts kept in the Austrian National Library more watermarks could be found. The following table 2 lists them in chronological order. These codices were mostly written in today´s Poland and other central European countries.
Several of these watermarks could be identified using mainly the watermark portal 'Bernstein – The Memory of Paper' which includes the catalogues of Briquet and Piccard among others. The investigation of watermarks has been incomplete and does not allow to make any well-grounded conclusions so far. It only can be said, that European papers were used for Armenian manuscripts not only in diaspora, where the use of local paper can be estimated, but also in the mother land (see table 2). There is the need for deeper research on this topic.

Signature	Watermark	Found in	Country
Armen 1	realities >> arms, weapons >> crossbow (Briquet 708, 1354 Troyes)	http://www.memoryofpaper.eu	/
Armen 3	flora >> leaf/blossom/tree >> lily	http://www.memoryofpaper.eu	/
Armen 26	realities >> anchor >> in circle, with additional motif >> star	http://www.memoryofpaper.eu	/
Mat. 5046	fauna >> bird >> heraldic eagle with crown	http://www.memoryofpaper.eu	Italy, Czech
Armen 19	fauna >> tetrapod >> lamb with a cross	http://www.memoryofpaper.eu	Italy
Armen 17	fauna >> serpent (snake) >> consisting in two lines	http://www.memoryofpaper.eu	Germany
Mat. 6274	letters/digits >> word >> Calcina Toscolano		Italy
Armen 14	realities >> structures >> tower >> two towers, in between archway consisting of two lines without merlons >> towers with windows >> without additional motif	http://www.memoryofpaper.eu	
Armen 28 Mat.5866	flora >> leaf/blossom/tree >> cloverleaf without stipe >> trifoliate	http://www.memoryofpaper.eu	
Armen 16	figures, anthropomorphic >> entire figure, male >> man in a circle		
Mat.5408	letters/digits >> word >> Whatman, "1853…"; coat of arms		England
Mat.10930	letters/digits >> word >> Whatman TURK 1839		England
Mat.7654	letters/digits >> word >> 1817 RUSE & TURNERS		England
Mat.3281	letters/digits >> word >> "CASTRES LANGVEDOC", flowers, "CV", other things		France
Mat.6613	letters/digits >> word >> "Pieter de Vries"	http://www.gravell.org	Netherlands

Table 2 List of watermarks found in various databases

4 Recreation of Paper Surface According to Historical Recipes

The observations made on the original manuscripts (described in chapter 2) matched to a high number with the results of the instrumental analysis and fibre observation (described in chapter 3) however in some cases they differed. Namely the presence of collagen glue was not fully detected by visual observation. The reason why the glue was not identified was suspected to lay in the way it was applied. A homogeneous layer of surface sizing with collagen glue can be seen, but study of source literature on paper treatment reviled, that in the relevant region and time mixtures of various materials were applied to paper surfaces before writing.
As the surface treatment of a paper might play an important role for the condition of the manuscript, as it might hinder or open access of the ink to the cellulose, and as to understand the paper production in Armenia better, recipes found in the literature were performed.
A stock of old rag paper was washed to clean it from both dust and sizing (10 hours in cold water and then in hot water for about one hour and dried at ambient conditions) and allowed to dry. A series of recipes of

Iranian paper surface treatments collected and published by Barkeshili (Barkeshili 2003) was prepared and applied. It can be estimated that Iranian and Armenian paper treatments did not differ strongly, as local plants and minerals are used. Isfahan and New Julfa are given as examples for origins of Armenian manuscripts in the catalogue of the manuscripts observed. Both places are in today´s Iran where the source literature comes from. General knowledge about paper preparation might have been circulated in the region. As European rag papers were usually surface sized, this fact was artificially recreated by sizing 50% of the washed and dried rag paper samples with animal glue.
This represented probably the state in which the papers reached Armenia from Europe. To see the difference the surface sizing might mean, the other 50% were left without glue. The recipes were executed. In all cases where no measures or exact procedure was mentioned, an estimation on the basis of experience with both the paper and the preparation of historical advises was made. The same holds true for the application technique and amount of applied material. In the following paragraphs the recipes are given first in original words, then the exact measures which were used for the preparation in the course of the survey and this is followed by an interpretation. Besides the description of the appearance in visible light, a UV fluorescence lamp was used. It was presumed that observation under UV might gives additional features, which could help identify such surface treatment in the original manuscripts later.

Starch and Glue
Original text: "Prepare the size from starch. Make a paste, then pour in water, then boil it for a moment or two on a hot fire. Add to thin starch some glue (serish). Strain neither too thin nor too thick, spread it on the paper and see. When you are applying size to your paper moisten the paper slightly with water."
25 g of wheat starch were mixed with 200 ml of cold tap water and stired well. The mixture was put onto the oven. Cooking time was utmost short. Then animal glue swollen in water over night and warmed up in a water bath was added. There was about 4:5 of starch paste and 1:5 glue in the mixture. The mixture was well applicable with a brush, the paper became very wet and stayed wet for a long time.
The result after drying was a slightly shiny surface and the entire paper was quite stiff; actually a sort of paper which had not be seen in the Armenian manuscripts. In UV light the surface appears quite yellowish, this is the colour of the animal glue.

Wheat Starch
Original text: "Make some wheat starch paste. Then filter it followed by cooking. Take a wooden board and cover it with felt (namad) or a muslin cloth. Take two bowls; put the starch in one and some water in the other. Moisten a cotton ball with starch and rub it over the paper. Finally take another piece of clean cotton ball, moisten it with water and rub it over the starched paper."
A part of the paste which had been prepared for the recipe discribed above was set onto fire again to allow it for a bit longer cooking, however only for approximately one minute more. Then a tampon of nylons was made by filling the stocking with still hot paste. When applied in small circles the paste was rubbed into the paper and gave a mother of pearls like shine on its surface. Interestingly the paper did not become wet, thus it also did not really expand. Going over it with water was done too, seemed however to make not much difference.
The resulting paper was soft, the surface shiny and closed, which makes inks well applicable, namely soot inks. This surface came close to many surfaces observed in the manuscripts. It is interesting that this recipe not only comes close to the "not fully boiled paste" mentioned by Karabacek (Karbecek 1887), but that in this recipe the way of application plays an important role in the preparation of the paper surface. The same material brushed onto paper gives a different appearance. Under UV the starch appears slightly whitish.

Rice Starch
Original text: "Take best quality of white rice, rub it with salt, wash it until it becomes clean and the taste of salt disappears. Then add some water and keep it for one full day until it becomes very soft. Boil it on a slow fire; stir it with a wooden stick until it becomes pasty. Let's get it cold. Spread a piece of cloth in the sun and put the paper over it till it dries up. Brush the paper till it becomes very smooth. Dyes can be added to the paste to get coloured paper."
100 g rice was mixed with 10 g of salt and washed. It can be taken for granted that this was a cleaning and disinfection procedure of the old days, however it could have resulted in salt residues, therefore the recipe

was executed as suggested. 300 ml water was added to the rice then and this mixture was left for 30 hours in room temperature. Then the mixture was cooked slowly and the paste occurred.
It was a smooth fine rice paste, which gave a very slight shiny surface and left the paper soft. The paste was brushed onto the paper.

Mucilage of Rice
Original text: "Cook rice on fire until its mucilage is obtained. Make sure the rice and vessels used are free of oil. Size the paper with it."
100 g of rice were boiled in 700 ml of water for 10 minutes. The relation between water and rice was not proper, however the resulting gel was applied onto the paper with a brush.
Also this recipe left the paper soft and gave a slightly, nearly not visible surface gloss.

Fleawort Seed
Original text: "Pour some fleawort seed until you get its mucilage. Leave the paper in the mucilage for one hour and then take it out. OR size the paper sheet with mucilage or fleawort at one time. Then let it dry."
7.46 g fleawort seeds were given into 60 ml cold water and stayed there for 30 hours in room temperature. The mass was than swollen that much, that it could not be sifted or filtered by household measures or methods of the old paper makers. The mass was given into a nylon stocking and squeezed while rubbing over the paper surface. The mass was very sticky.
This fleawort seeds treatment left the paper as if nothing had been applied. Possibly the treatment should be repeated with less seeds in relation to water.

Cucumber Seeds
Original text: "Keep the cucumber seeds in water until its mucilage is obtained.
Dip the paper into it for some time and then take it out."
17.19 g cucumber seeds stayed for 30 hours in 40 ml cold water before applying on paper the resulting liquid. The extract was quite liquidish and made water stains on the paper on the wet-dry edges. It gave the paper no special surface appearance. The tide line however is bright orange under UV.

Mucilage from Marshmallow
Original text: "Keep marshmallow in some water for one night and one day. Heat it over fire until you get the mucilage. Dip the paper into it for some time and then take it out."
3.40 g Marshmallow-leaves were given into 150 ml of cold water and stayed for 30 hours in water before cooking them. The result was a greenish watery brew, which gave a greenish surface on the paper. No mucilage occurred.
After this experience it might be suggested that the roots not the greens of the plant should have been taken; this recipe needs to be repeated.
The paper was greenish after treatment but no sizing effect appeared. Under UV the tide line was somewhat orange-coloured and the overall application appeared purple-orange.

Grape Syrup
Original text: "Filter grape syrup. Apply it on the paper for sizing. Grape should be seedless."
White grapes from the supermarket were squeezed to get the juice and the juice was brushed onto the paper. However this recipe will be repeated, as it might be that "syrup" means cooked and thus condensed grape juice, which is then far denser.
The grape juice made a strong tide line and there the paper became transparent, but it did not result in a paper surface seen in Armenian manuscripts so far.

Juice of Sweet Melon
Original text: "Take the juice of sweet melon and dip the paper into it for sizing."
There are different sorts of sweet melons. One of them offered in the super market was chosen, squeezed and the juice was applied onto the paper. It was quite liquid and orange and resulted in a nice apricot coloured paper.
The melon made tide lines even stronger then the grapes and no sizing effect could be witnessed. The lines might come from the sugar, which might have the same reflection index as the cellulose.

Fish Glue
Original text: "Soak a small amount of fish glue in water. Change the water and refill fresh water for three days until it clears thoroughly. Heat the fish glue until it melts, then filter it with a piece of muslin cloth. Apply the fish glue on paper as a sizing material. Let it dry in the sun carefully."
This recipe was not executed because fish glue is very similar to the glue we used for surface sizing.

Gum Arabic
Original text: "Melt the gum Arabic and size the paper with it."
9 g gum Arabic was given into 80 ml water and let swell over night. The gum was applied. It gave a virtually transparent and stiff paper.
The gum showed a faint orange tide line in UV light.

Serish [15]
Original text: "Mix serish with a thin starch."
This recipe was not executed because we got the information only after we had finished the research.

Modification of paper surface seemed to have been a wide spread habit. While Europeans beat and primed the paper, surface coating and polishing appear to have been the preferred oriental habits. The recipes which were performed in the frame of the research presented here altered the papers in gloss, stiffness, density, and colour. Polishing with an obsidian as another step in recreation of the surface-appearance resulted in shiny papers.
Grape juice and Gum Arabic-treated papers could not be polished; cucumber and both recipes based on rice starch as well as both recipes containing wheat starch could be polished nicely.
A chart which was drawn during the survey of the manuscripts in Yerevan showed that all earlier papers were surface treated, while the late papers were not surface treated. Especially in the 18th century polishing seems to have been fashionable while in the 17th century a large variety of surfaces was found.
However the most interesting result of the recreation of the traditional surface treatment was, that there were mixtures of starch and glue, which appear to the naked eye as if they were starch only. This explained well why glue could not be detected in the initial survey (chapter 2) on the manuscripts, while collagene glue was found by instrumental analysis (chapter 3).
As some of the surface treatments left the paper with altered colour the colour was measured before and after the application of the various recipes.
It was hoped to be able to identify a certain surface treatment by colour measure in the original books. The differences in colour are however not conclusively representative; more tests should be done. It is worth mentioning, that the original Armenian papers show a large variety of colours, from nearly white to dark brown.
This feature could be created in a next step. The surface treated papers were inscribed with iron gall ink and artificially aged.
Another interesting result of the recreation of the recipes was, that none of the recipes resulted in the hazy appearance of the mold lines so often seen in Armenian papers. Therefore a mixture of wheat starch and Calciumcarbonate was made and applied onto paper. The result was a quite stiff paper, which allowed for polishing, but again did not give any result comparable to the original papers taken for typical Armenian.
Finally a traditional European primer of chalk and animal glue was brushed onto the paper surface. This treatment made the mold structure of the paper appear unclear, gave a polishable surface and was not visually distinguishable as a separate priming layer along tears. This was actually the feature observed in the original manuscripts.
As to see whether or not there would be a surface treatment amongst the Iranian recipes, which would hinder ink corrosion, iron gall inks were applied to the paper samples. The inscribed samples were aged artificially according to ÖNORM A 1116.

[15] Sirish-i-safid, *Eremurus auchierianus* - Boiss. Is an Iranian plant. "A glue is made from the mucilage contained in the root and is used with leather and in book-binding" (Accessed July 7, 2012. http://server9.web-mania.com/users/pfafardea/database/plants.php?Eremurus+auchierianus/)

Alteration of the paper was namely concerning colour and brittleness quite strong in the case of the grape and the melon recipe. (83.24;16.08;82.43 before and 41.25;20.92;62.10 after aging for grape and 89.55;9.12;89.97 before and 67.03;25.37; 72.16 after aging for melon). (Colorimeter X-Rrite 508)
The inks showed strong aggression on rice starch and cucumber treated surface, however especially strong ink corrosion appeared on gum Arabic surface. Marshmallow left the paper in a grayish tone and seemed to have protected the ink.

5 Results

The initial idea of the research on Armenian manuscripts was to find a key to stop ink corrosion of Armenian inks, i.e. hinder the loss of texts and rescue this valuable heritage.
While in the first approach the inks were focused, the second approach concentrated on the paper. It was presumed that the damages is a result of an interaction of *all* material involved. Other parameters such as thickness of lines, position of text in the book block, history of individual codex and damage flooding etc. were discussed elsewhere. [16]
By understanding the composition of the paper used in Armenian manuscripts and correlating it with the composition and condition the inks are in today, it was hoped to possibly detect a historical conservation material, for example a natural chelate builder which might have been involved in paper production and can be possibly used by todays conservators. Especially it was hoped to find a non aqueous agens, as so far suggested phytate treatment [17] contains water and therefore rules out in many cases in praxis, as water damages soot ink written texts and water soluble paper fillers and colours.
After visual observation of the original papers, instrumental analysis of both organic and inorganic compositions and elements present in the papers, fibre analysis and research on the watermarks were made.
These results gave a hint to a surface sizing, which could not be seen with the naked eye easily. FTIR and XRF spectra seemed to confirm the observations made by the naked eyes and under the microscope in many cases. This means that training of the conservator helps considerably in material detection. However the glue which was found by FTIR and XRF was not seen by the researchers, which means that instrumental analysis is an important supplement in material understanding. It is suspected, that in the cases where glue was not observed the glue was intermixed with starch before applied and not applied as individual layer.
That glue was mixed with other material and than used as surface sizing became evident from the study of historical sources on paper making in the region.
Fibre analysis showed that no cotton was present in none of the samples. Hemp and flax seem to be the main fibre material of the paper used by Armenian scribes. That this often was paper of European origin could be shown by the watermarks found. Even if Samarkand and Damascus are named as being places of origin of "Armenian" papers. This survey showed that from the 16th century on an increasing number of papers with European origin were used for books which have been written in Armenia mainland. Italy must be suggested as one of the places where the paper came from. From the 19th century on also machine made papers were used in Armenia, manuscripts, which left the text in especially bad state.

No manuscript before the Ottoman empire was surveyed. The eldest papers of Armenian manuscripts included into this research were form the 14th century. At this time the paper production was well developed all over Europe, including the habit of putting watermarks into them. The watermarks found should be further analysed.
Besides this research to stop the ink corrosion new insight into paper used in Armenian manuscripts was gained. European papers were not only used in diaspora manuscripts, but also in motherland Armenia. These papers were often further processed with local surface treatments; first application of substances and then polished. The latter could be observed in the manuscripts. The polishing stone left creases and characteristic pressed areas.

[16] Eliazyan (2009)
[17] Neevel (1995)

Although in the meanwhile the phytate treatment was applied to Armenian manuscripts, it requires special techniques and skills to overcome the damaging potence the water. [18] It would be worth to survey further the historical sizings.
Marshmallow might have been a natural conservation agent for iron gall inks; at least this can be concluded from the research presented here.
However it must be said, that marshmallow application did not result in a paper looking like these often seen in Armenian manuscripts.

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Fa. Merck, D-6100 Darmstadt, www.merck.de
Phloroglucin zur Analyse Nr. 107069
Salzsäure 37% zur Analyse Nr. 113386
Zinkchlorid zur Analyse Nr.108816
Kaliumjodid zur Analyse Nr. 105043
Jod zur Analyse Nr. 104761

(Colorimeter X-Rrite 508)

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New Developments in Watermark Research

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Abstract

In many fields the research on watermarks in paper is of interest to get answers when and where paper was used, apart from aspects of production, trade and distribution. For a long time, printed sources were the only tools for identifying watermarks.Modern times brought modern methods, not only in reproducing watermarks but also in administrating images and metadata in databases. The portal BERNSTEIN as a platform for many smaller and larger collections with various backgrounds is showing the need and interest for presentation on the web. Two of the databases are shown as examples of what happens backstage like imaging technologies or the gathering of data from manuscripts. But not only is there the need for good cooperation between conservators, researchers and watermark specialists, but during conservation-restoration, it is often the only chance to get a good glance on watermarks hidden in gatherings or covers.

New Developments

In many fields the research on watermarks in paper is of interest to paper historians, scholars doing research on manuscripts and incunabula, art historians, musicologists, archivists, antiquarians, paper conservators. In many ways they need an expertise on watermarks to get answers when and where paper was used, apart from aspects of its production, trade and distribution. The analysis of watermarks is connected not only with the history of paper but also gives answers to questions on texts and other information such as music notes or illuminations and illustrations found on the paper being studied. [19] For example, art historians are interested if an etching or a drawing was done by a particular artist or by someone of his school. Musicologists hope to get, via watermarks, information in which period in the life of a composer, a composition was written down or to reorganize the chronology of the genesis of various pieces of music. Incunabulists and cartographers have similar interests: The printing history of incunabula, and the study of maps or atlases can be verified by the examination of the paper used.

[19] A first survey on various fields of watermark research is found in Rückert et al. (2009), with an extended edition (in Spanish) by Rückert et al. (2011). For literature on paper, paper history, and watermarks see also the bibliography on BERNSTEIN

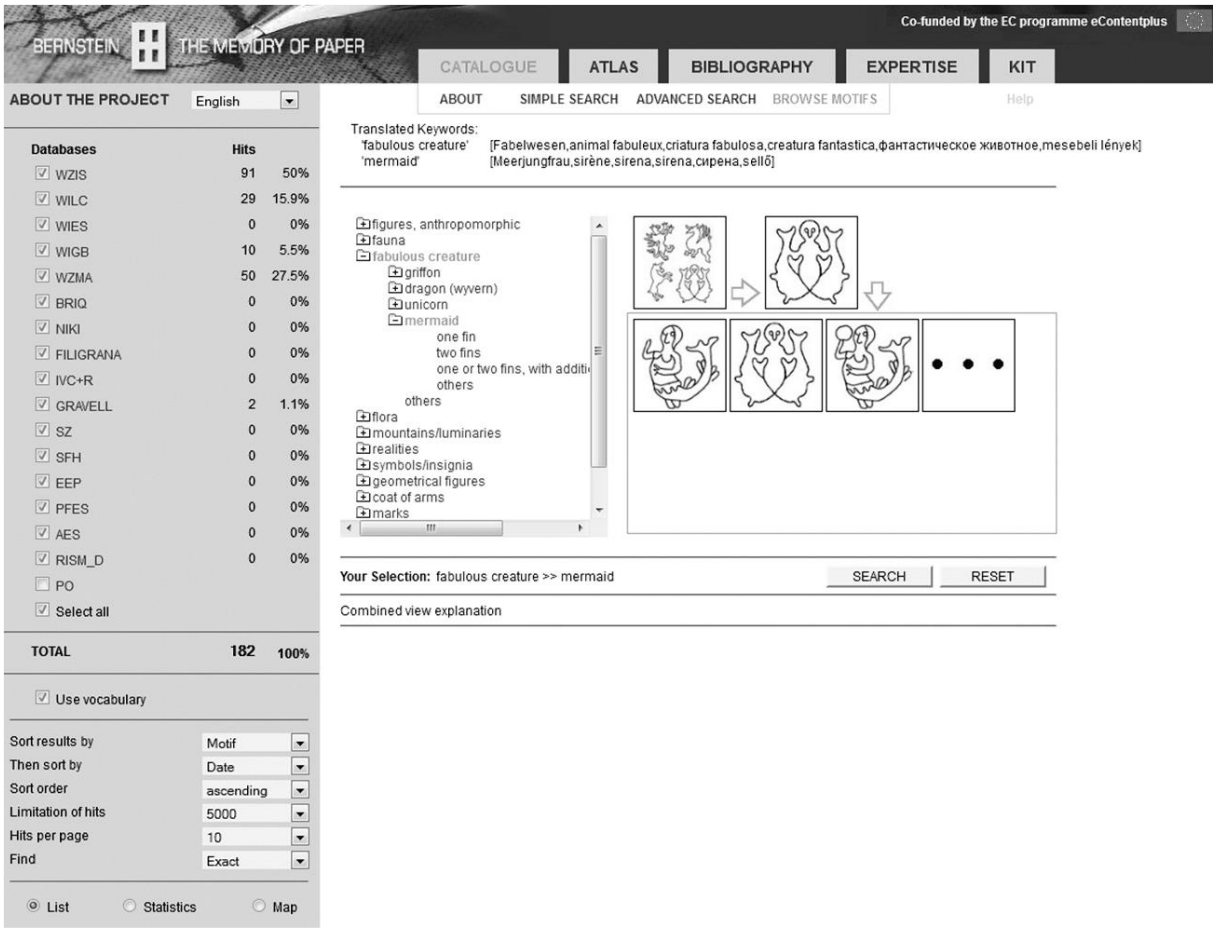

Fig. 12 The portal BERNSTEIN (www.memoryofpaper.eu): catalogue with the list of included databases.

For a long time printed sources of watermarks – like the well-known ones from Gerhard Piccard[20] or Charles-Moïse Briquet[21] – were the only tools for identifying watermarks. Modern times brought modern methods not only in reproducing watermarks but also in administrating images and metadata in databases. In the last 15 years large collections have been digitally recorded and since 2009 they are presented together as a joint watermark portal on the internet by the EU-funded project "Bernstein – The memory of paper"[22] (Fig. 12). Started by a few databases, this portal now is the platform for a lot of smaller and larger collections with various backgrounds, thus showing the need and interest for presentation on the web. Besides the possibility of searching in all databases for a special watermark simultaneously, specialists can search on their particular interests. Researchers on incunabula for example will have a special interest in WILC[23], WIES[24], or WIGB[25]. On the other hand musicologists will prefer RISM_D[26] or AES[27], and paper historians, the collections of the collectors Piccard or Briquet mentioned above. But also smaller and new compilations from Europe (and around the world) can be reached via Bernstein as there are EEP[28], PFES[29],

[20] Piccard (1961–1997), also available online: PPO
[21] Briquet (1968), also available online: BO
[22] BERNSTEIN
[23] Watermarks in Incunabula printed in the Low Countries, WILC; van Delft (2009)
[24] Watermarks in Incunabula printed in España, WIES; van Thienen (2009)
[25] Watermarks in Incunabula printed in Great Britain, edited by Paul Needham, Princeton and Koninklijke Bibliotheek, Den Haag, available via the Bernstein-Portal
[26] A selection of watermarks collected by Répertoire International des Sources Musicales, Working Group Munich – Bayerische Staatsbibliothek, available via the Bernstein-Portal
[27] A selection of watermarks collected by Répertoire International des Sources Musicales, Working Group Salzburg and the Archive of the Archdiocese Salzburg, available via the Bernstein-Portal
[28] Early Estonian Prints, EEP
[29] Papel y Filigranas en España, available via the Bernstein-Portal; Macias (2012)

SFH[30], or GRAVELL[31]. Not all of them provide a full database system but offer tables and images to make their collections searchable via the portal. The stand alone databases such as WZMA[32], WILC, or WZIS[33] are remaining at their institutions, but although they aren't copied, they can be accessed via a SRU gateway. The integrated workspace of the Bernstein portal also allows access to advanced analysis and expertise modules like the visualization of the distribution of watermarks or various statistics. Furthermore, the well-respected bibliography on all aspects of paper documented by The German Book and Scripts Museum of the German National Library (DNB) in Leipzig was implemented as a database in the portal.[34] One of the larger integrated databases is WZIS – Wasserzeichen-Informationssystem: a project funded by the Deutsche Forschungsgemeinschaft to create a central database for various watermarks collections held by diverse institutions all over Germany. In 2010 the State Archive of Baden-Württemberg, the State Library of Baden-Württemberg in Stuttgart, the Bavarian State Library in Munich, the University Library in Leipzig and the Commission for Palaeography and Codicology of Medieval Manuscripts at the Austrian Academy of Sciences in Vienna started this joint cooperation. Meanwhile in the second phase of the project, the State Library in Berlin and the German National Library in Leipzig joined in as new partners. At these libraries and archives there exist collections of watermarks as results of various projects for cataloguing manuscripts. For a sustainable use of these collections and for easier access, the idea was born to join them in a common database. An existing program for the administration of watermarks developed at the Austrian Academy of Sciences was adapted especially for the needs of a multi-client system. The result is the so-called "Wasserzeichen Studio". So now there exists a common database held at the State Archive of Baden-Württemberg in Stuttgart and the input takes place in each of the libraries. Concerning the content, the starting point is the collection of Piccard as presented in Piccard-Online which is integrated in this new database. Part of the project is the development of a new classification and terminology of watermarks in order to bring together the various existing systems as uniform as possible; a classification which is organized dynamically so new upcoming motives of watermarks can be included at any time. Here a special challenge is the paper and watermark collections of the new partners in Berlin and Leipzig who are bringing a large quantity of material from later periods. After the 16th century, motives of watermarks got much more complex and aren't as simple to describe as medieval ones. Besides, more information exists concerning the history of the paper like name and location of paper mills or paper makers; information which will be also searchable in WZIS (Fig. 13).[35]

[30] Collection Stefan Feyerabend (industrially-produced watermarks 1870–2010), SFH
[31] The Thomas L. Gravell Watermark Archive, GRAVELL; Mosser/Sullivan (2000)
[32] Wasserzeichen des Mittelalters, WZMA; Haidinger (2009)
[33] Wasserzeichen-Informationssytem, WZIS; Frauenknecht/Stieglecker (in print 1).
[34] For detailed information about the project "Bernstein – The memory of paper" see – beside the mentioned website – Rückert et al. (2009), pp. 99–113
[35] For further information on the project see Wolf (2009) or Frauenknecht/Stieglecker (in print 2)

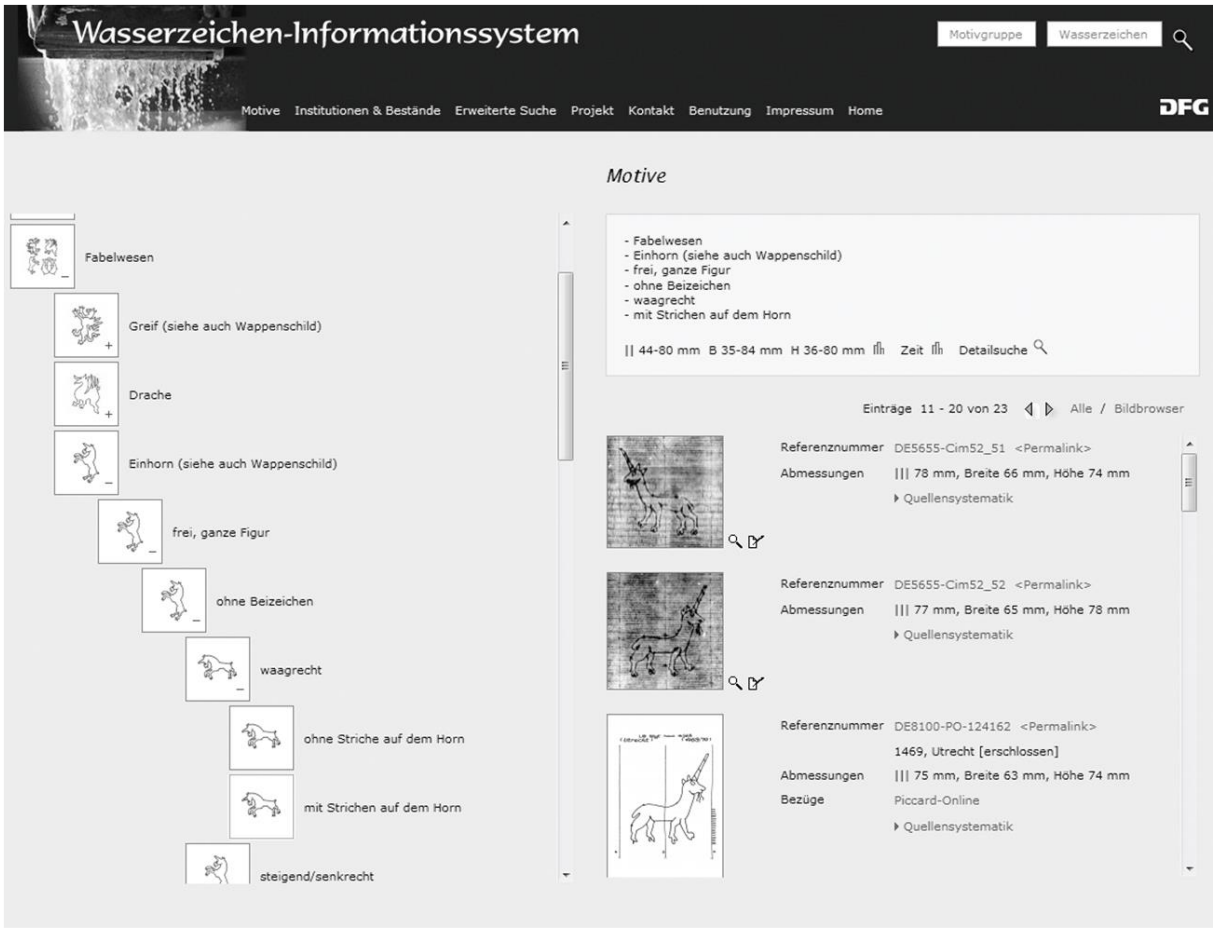

Fig. 13 WZIS (www.wasserzeichen-online.de): search watermarks by motive.

From a methodological and technical aspect, the database WZMA is prototypical for WZIS. The Division on Palaeography and Codicology dedicates itself to the scientific classification of the medieval manuscripts that are stored in Austrian libraries.[36] In addition to the identification of authors and texts as well as the description of material or dimensions, the important question is when a manuscript was produced. For manuscripts written on paper, the analysis of the watermarks often gives the most precise answer. Because the comparison with watermark reproductions in printed sources is time consuming and often of meagre result, the database WZMA was developed, based on the synthesis that comparing watermarks of paper used in the same region would be more successful. The content focus of WZMA is currently on watermarks of medieval manuscripts stored in libraries in the region of Vienna and Lower Austria as well as in the region of Tyrol. Already these two examples show the correctness of this assumption: in both regions we find comparable paper but there are only few references to each other. Not only there cannot be found any or only a small number of related watermarks[37], but the examined papers are showing entirely different groups of motives. Depending on different trade routes from Italy Austria paper was imported from different paper mills and regions. [38] The method to analyze the watermarks of a manuscript as done for WZMA is the following. Every folium of a codex is looked up and every location of a watermark is registered; a procedure which is nowadays much easier thanks to the invention of slimlight. Examining them only by chance (meaning looking up only a small number of leaves) can falsify the result because often the paper of a manuscript is mixed with single sheets or whole quires of older paper. By dating with

[36] ASBW

[37] There are distinguished equal watermarks (being identical), variants of watermarks (watermarks from the same wire figure which gradually changed its form during the paper production process) and types of watermarks Frauenknecht/Stieglecker (2009); Haidinger (2004) pp. 6–12, Stieglecker (2011); another example for the spread of paper is shown e. g. by Zaar-Görgens (2004). (groups of watermarks that are the same with regard to their motive, form, and size); Haidinger (2004), Frauenknecht/Stieglecker (2009)

[38] Haidinger (2004) pp. 6–12, Stieglecker (2011); another example for the spread of paper is shown e. g. by Zaar-Görgens (2004)

this older paper, one can be deceived by dozens of years. After this survey of each group of identical watermarks, a hardcopy is produced. Here the method of beta radiography is used, besides the method of rubbing and (in seldom cases) by using digital photography.[39] The reproductions of watermarks, created in one way or the other, and also the corresponding metadata have to be managed and organized in some way. The definition of the motive, the determination of the measurements, or compilation of relations is required. Therefore at the Austrian Academy of Sciences, in cooperation with the Russian Academy of Sciences, the so-called „Watermark Processing and Database Management Toolkit was developed "[40], the prototype of the above mentioned „Wasserzeichen Studio" now also used for WZMA. This program provides features for improving the quality of watermark images. It allows, for example, to rotate images, to invert them, or to enhance their quality (Fig. 14). Via a treeview-structure, the motive of the watermark is defined; this classification is organized hierarchically and dynamically so new motives can be added.[41] The measurements of the marks are done semi-automatically so at least the parameters for width, height and the distance of the chain lines are recorded. Of course each watermark is connected to the metadata of the manuscript it was taken from, such as library, shelfmark, or date and origin. To meet the main purpose of the database (to date undated manuscripts by their watermarks), it is necessary to connect related watermarks: the more equal marks in different but dated manuscripts are available, the more reliable is the dating. Therefore it is possible to superimpose one image transparency on the other so that the images can be compared easily (Fig. 15). In order not to burden the system with additional information and to keep the contents homogeneously, links to external references like papermaker, manuscript databases, and so on can be set.

Fig. 14 Wasserzeichenstudio: features for image enhancement (rotating, inverting, contrast enhancement).

[39] Haidinger (2004) p. 6

[40] The software was realized by Victor Karnaukhov, Institute for Information Transmission Problems, Russian Academy of Science, Moskow on ideas of Alois Haidinger, Commission of Palaeography and Codicology of Medieval Manuscripts, Austrian Academy of Sciences. For a description of the main features see Stieglecker (2007)

[41] One of the work packages of the project WZIS is the development of a new standard for the classification of watermarks. This standard will also be used in the future by BERNSTEIN and WZMA

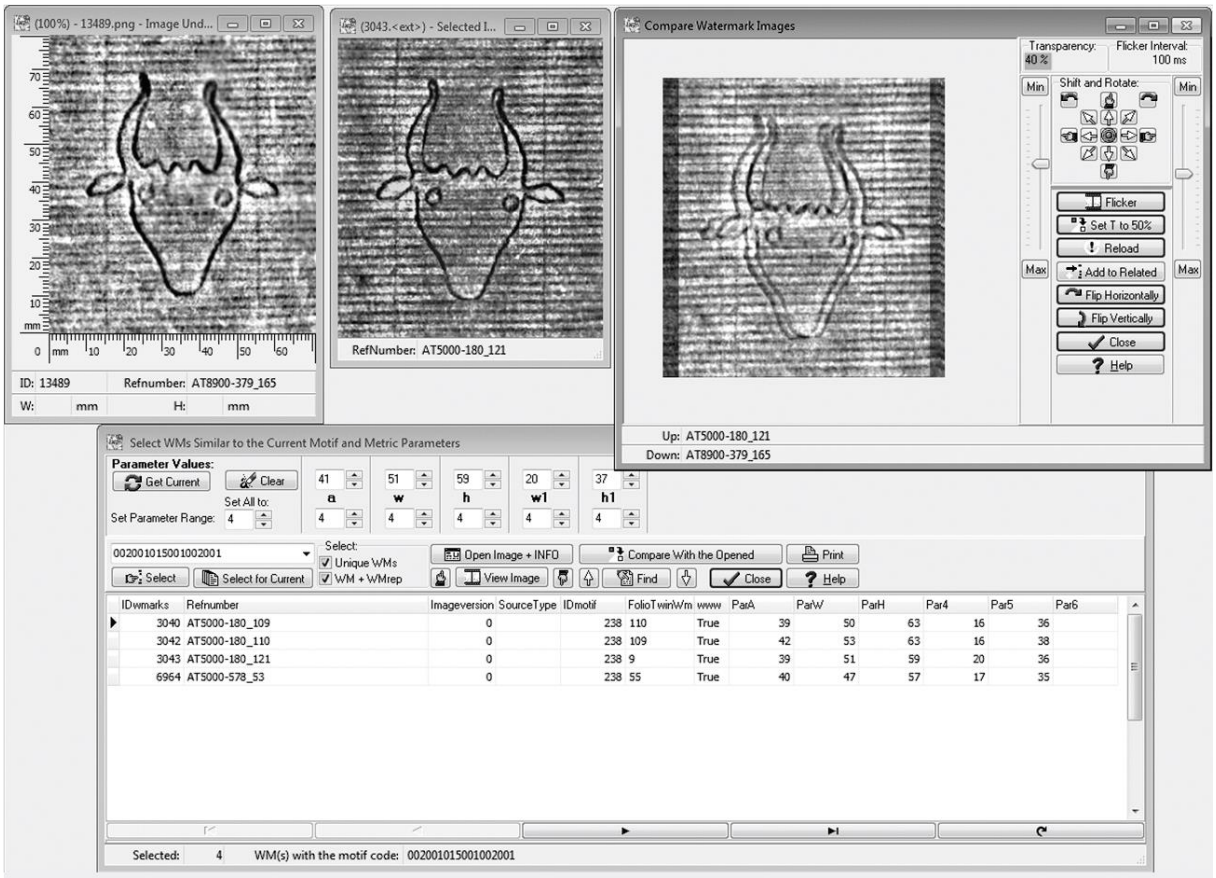

Fig. 15 Wasserzeichenstudio: comparing images by superimposing one image transparent on the other.

So eventually for each watermark, the following information is connected (Fig. 16): on the one hand information on the watermark such as motive description, measurements, or twinmark, and on the other hand information on the source such as library, shelfmark, or date and origin. At the bottom, there is the list of related watermarks, meaning paper used in other sources which was produced with the same mould. To visualize the above-mentioned method to date manuscripts, paper with this pair of a mermaid was located in 13 different sources, all dated or dateable between 1390 and 1400. So paper showing this pair of a mermaid was almost certainly used in the last decade of the 14th century.[42]

[42] The mentioned method for the dating of medieval manuscripts is described in detail in Haidinger (2004)

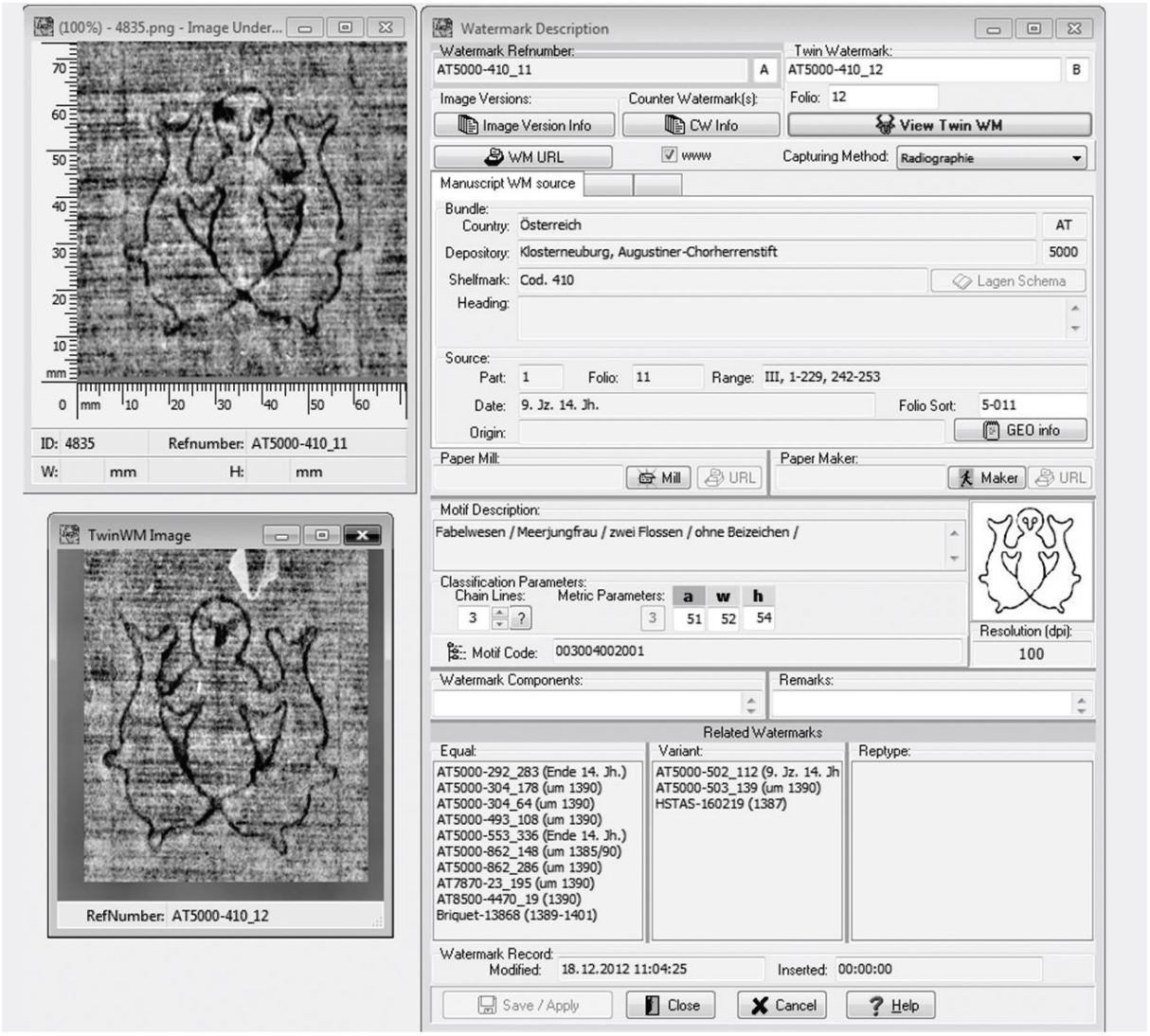

Fig. 16 Wasserzeichenstudio: information to a watermark and its source.

There is a wide range of techniques to reproduce watermarks.[43] The cheapest and most simple are of course tracing and rubbing needing only a pencil and thin paper (and a slimlight). But tracing can never give an exact image. In some way it will be always interpreted by the one who is tracing. Rubbing on the other hand depends on the quality of the paper; sometimes the contrast in the paper structure is too low to get a clear image. Also easy is the use of digital photography depending only on a digital camera, a slimlight, and a ruler. Of disadvantage is the irritating writing on the paper and the necessary post processing of the images to get a true to scale reproduction. Another photographical method with better results, is the image subtraction or backlight method. Here a transmitted light image is subtracted digitally from a reflected light image thus deleting great parts of the applied ink or colour. This method is a good alternative for single-sheet items and thus of interest for example for art historians. The best results can be achieved with radiographic technologies like soft-x-ray radiography, electron radiography, or especially beta radiography. But here special and expensive equipment is needed and various regulations for handling of radioactive material are to be considered. For these technologies, special x-ray-films are used, and they have to be developed and scanned before research on the watermarks can start. Less time-consuming because the recordings are immediately available in digital form, and with fewer health risks for the users, is the recently-established method of thermography. This method is based on the fact that many different inks are transparent in the infrared wavelength range and besides, this radiation on paper and watermarks is absorbed and scattered differently. So using a hotplate and a thermographic camera visualizes

[43] An overview of techniques for reproducing watermarks is found in Rückert et al. (2009) pp. 67–69; for radiographic methods see also Schreiner/Holle (2011)

watermarks.[44] All these techniques have one in common: it is easy to use them on single sheets of paper or on folio-sized manuscripts or incunabula because the watermark is placed more or less in the middle of the leaf and can be seen in its entirety. It is more difficult if it is a small format book where the sheets of paper were folded several times with the effect that the watermarks are "cut" in two or more parts, within the fold or at the edge of the leaf. Especially hard to reproduce are those within the fold, in particular if the binding is tight. Most difficult and impossible is the reproduction of watermarks on paste-downs or on sheets which are stuck together as well as – to mention all possibilities – on paper used for stays in the centrefolds, for covering, for support of the spine or back. Information might be hidden which can provide insights into the history of a manuscript like when or where the binding took place, whether the binding is original or of later times, or perhaps an owner who can be identified because a paper with a coat of arms was used. Only during the process of restoration when paste-downs are removed from the cover, or when bindings of small format books are renewed, it is possible to detect any existing watermark and see it as a whole. Knowing that this may be a vision, as time and money are short in the field of conservation and also knowing that the connection between conservators, researchers on manuscripts and watermark experts may be rare, the necessity for documentation in these cases needs to be emphasized.

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[44] Meinlschmidt et al. (2010) pp. 214–221. This method of thermography is applied at the Bavarian State Library in Munich as part of a project for the digitization and cataloguing of block books, see results: BLOCKBÜCHER

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