

# Report on the Assessment and Survey of the Condition and Technique of the Vinland Map and the Bindings of the Tartar Relation and Speculum Historiale

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## ABSTRACT

*This paper reports on the result of the assessment of the state of condition of the Vinland Map (VM). The damage assessment was based on visual and simple nondestructive methods observing characteristics at the macroscopic and microscopic level mainly relating to the surface of the parchment including the ink. Additional damage assessment was performed on selected parchment sheets bound in the Tartar Relation (TR) and the Speculum Historiale (SH). The bindings of the TR and the SH were subjected to a technical examination of the book structure and a simple nondestructive damage assessment of the leather. The condition of the parchment and ink of the VM, SH and TR as well as the book bindings are reported and recommendations and precautions for their future storage and treatment presented. Moreover, the authenticity of the VM, dating of the rebinding of the SH and TR as well as the relations between the three objects are discussed on the basis of our observations and our recommendations for future studies are presented.*

The purpose of the assessment and examination was first of all to determine the state of damage and the techniques used for production and to try and decide whether any restoration techniques have been used on the Vinland Map. Damage assessment of parchment sheets from the TR and the SH allowed a comparison of the three populations of results. The purpose of examining the bindings of the TR and the SH was to determine the extent of leather damage. The purpose of a technical examination of the bindings of the TR and the SH, so-called book archaeology, was to shed light on the binding and restoration history. However, we hope the new information that we put forward in this report may contribute to the history and dating of the Vinland Map.

The Danish research effort was inspired by a Vinland Map Debate held in Copenhagen in May 2004 with participation of leading international experts and organised by Director Jørgen D. Siemonsen in cooperation with the Danish National Museum.

Further aspects of the research were discussed during the Improved Damage Assessment of Parchment (IDAP) Seminar in Copenhagen 23-26 August 2005.

The actual assessment and examination were performed by Dorte V. Poulsen and Marie Vest and took place at the Beinecke Rare Book & Manuscript Library at Yale University (Yale) from 29 November to 1 December 2004.

We are grateful to Yale University for their great hospitality, openness and support. We are grateful to Professor Michael McBride for loan of a microscope, without which this project would not have been possible, and to Jørgen D. Siemonsen who made contact to, arranged and took part in the visit to Yale University.

We are also very grateful to Dr. Soghomon Boghosian, Foundation for Research & Technology - Hellas Institute of Chemical Engineering & High Temperature Chemical Process, Greece for performance of the FT-Raman analyses of European inks on parchment samples. Furthermore we are grateful for his contribution to the discussion of the ink of the Vinland Map. Finally, we are grateful to Jana Kolar, National and University Library, Ljubljana, Slovenia, for her contribution to the discussion of the ink and ink analysis; And to Christina Lund and Karen Borchersen, School of Conservation, Denmark, for proof reading and editing of this report, respectively.

The planning of the project and subsequent analysis of the data obtained from the assessment and examination were performed by the following group of scientists:

René Larsen, Rector, PhD, School of Conservation, Denmark (coordinator of the project)

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The report contains the chapters "damage assessment", "equipment and methods", "results and discussion" and "conclusions".

Methods not applied due to restrictions imposed by Yale:

- IR reflectrometry
- Shrinkage temperature measurements (reflecting chemical/physical condition) of leather fibres from the bookbinding of the SH and the TR.
- Shrinkage temperature measurements (reflecting chemical/physical condition) of parchment fibres from the VM, SH and TR.

Items not examined:

- Watermarks in the paper leaves of the SH and the TR
- Various unrelated parchment and paper leaves annexed to the SH and TR
- Recent discovery of the SR and TR manuscripts in the Luzern Zentral und Hochschulebibliothek<sup>7</sup>.

### *DAMAGE ASSESSMENT*

Parchment is a skin-based material composed primarily of collagen. Therefore, any damage to a parchment document at the molecular level is normally caused by chemical and microbiological deterioration of the collagen. This deterioration typically takes the form of chemical modification of individual amino acid residues and cleavage of collagen peptide chains, causing changes in the physical properties and stability of the parchment at other levels in the structural hierarchy.

Damage assessment concerns the whole object including its physical attributes as well as more immaterial cultural traits. For a parchment manuscript this includes the physical and chemical state of the parchment itself and any associated ink, dyes and pigments. Theoretically, damage at the molecular level should affect the properties of the parchment at all other structural levels. At the macroscopic level, these changes may manifest themselves as decreasing hydrothermal stability and tear strength, changes in colour, flexibility, transparency, etc.<sup>1</sup>.

Assessment of damage to a parchment is a very complex affair, and it is not possible to define only one state of deterioration. The chemical and physical state, surface colour and other characteristics vary from one spot to another across the surface of the parchment. Moreover, the damage may be superficial or penetrate part of or the whole structure from the outside in, and a well-preserved parchment may appear intact macroscopically but may have significant damage at the molecular level. Therefore, the state of deterioration of a parchment can be defined as a population of local

conditions which may be called the damage picture. For conservation purposes it is of interest to know both the full damage picture (at least the high and low end of the deterioration range) as well as which part of the deterioration range that is predominantly represented over the area of the parchment.

The establishment of a correlation between simple assessment and advanced analysis of state of deterioration was investigated by a European research group within the framework of the research project IDAP (EVK4-CT-2001-00061). These simple assessment methods were applied to the parchment sheets of the VM, TR and SH.

### *Equipment and methods*

The conservation assessment included measurement of colour, transparency, flexibility, thickness, discolorations, biological deterioration, deposits of calcite, fixation of the ink and visible signs of other characteristics which may relate to the condition, production and later conservation treatment and repair of the VM and selected parchments bound in the TR and the SH. Moreover, the condition, style, technique and restoration/repair of the TR and the SH were observed and described. Finally, modern ink made according to historic European formulas applied to modern handmade parchment as well as the ink of a sample of historic European parchment were analysed visually and photographically in the same way as the ink on the VM, TR and SH parchments. In addition, the ink of the historic European parchment was analysed by FT-Raman.

The two sides of the parchments were labelled recto and verso as the grain layer has been removed from most of the samples by the manufacture or by other treatments of the surface. On the VM, recto is the upper side with ink drawings and text. The parchments bound in the books were labelled so that



Figure 1 The position of the specific areas on the Vinland Map.

the recto is on the right hand side and the verso is the reverse of the recto.

The assessment consisted of two parts. First an overall visual assessment was performed including signs of previous conservation treatment, identification of animal origin, description of the overall colour of the parchment, description and categorization of the damage<sup>2</sup>. This was followed by measurement and assessment of colour, transmission, thickness, calcite deposits, glasslike layer, discoloration, surface appearance, surface contamination etc. (examples, see tables 1 and 4). These were performed on both sides (recto and verso) of so-called specific areas chosen to be uniform in colour, damage and other characteristics in order to obtain valid measurements and to analyse for possible correlations between data of the different characteristics measured<sup>2</sup>. The number of specific areas was in most cases five, in few cases three, for each parchment sheet. For relocation of the specific areas, templates were made out of paper with holes marking the position of the specific areas. Figure 1 shows the position of the five specific areas on the VM. Due to restrictions in handling of the VM in connection to assessment and measurements, these are all positioned at the edges of the sheet.

#### *Signs of previous conservation treatment*

Based on a visual examination it was assessed whether the parchment had been subjected to any kind of conservation or surface treatment e.g. whether it has been coloured, polished, treated with oil, pasted or glued or treated with calcite as a surface treatment for writing.

#### *Animal species*

During the process of parchmentmaking the hairs are removed and a pattern of hairholes is left on the grain side of the skin. Hair roots can be left in the fibre structure and if remains of the grain layer are present on the parchment, a recognisable pattern of hairholes may permit the identification of the animal species.<sup>2</sup>

#### *Overall colour of the parchment*

Defining the exact colour of a parchment is difficult, as the colour often varies due to for instance remains of hair, stains or dirt. The “overall colour of the parchment” was the average colour impression obtained after only a short look at the whole parchment. The overall colour of the parchment was assigned one or more of the following colours: *white, light yellow, yellow, dark yellow, light brown, brown, dark brown, red brown.*

#### *Colour*

As parchment may be very inhomogeneous with respect to colour, the colours of the specific areas were determined by the using a Gretag Macbeth SpectroEye spectrophotometer. The measured L\*, a\* and b\* values represent the brightness, green-red shift and blue-yellow shift, respectively. The L\* values range from 0-100, the higher the value, the brighter the colour. Low and negative a\* values represent a colour shift towards the green area of the colour spectrum and increasing positive values represent a shift towards the red area. Low and negative b\* values represent a shift to the blue and increasing positive values a shift to the yellow colours.

#### *Thickness*

The thickness of the parchments was measured with a micrometer. The values were recorded in mm.

#### *Flexibility*

The flexibility of the specific areas was determined by comparison to four different references of plastic folios (Rianyl seriegrafifolie, gul 755, Rias, Denmark). The folios differ in thickness: *A-0.14 mm, B-0.20 mm, C-0.30 mm or D-0.40 mm.* The flexibility was determined by flexing the plastic folios (references) with the thumbs and forefingers and comparing with the parchment sample. The reference that resembles the parchment was chosen.

#### *Transmission of light*

The transparency was measured as the transmission of light through the parchment using a photographic light metre. The light metre was a Sekonic Flashmate Model L-308B with a mounted Lumidisc. The light source was a hand lamp with a bulb releasing very little heat (Philips Ecotone 9 W) in order not to damage the parchment. The light was channelled through a cardboard cone mounted on the lamp. The parchment was placed under the hole made in the tip of the cone, and the light metre was placed underneath the parchment. The transmission is measured relative to a reference (Riacryl SE 10.11, cast acrylic, 3.0mm, white 044 (Rias, Denmark)).

The reported values were calculated as :

$$T_{\text{parchment}} = (T_{\text{reference}} / M_{\text{reference}}) * M_{\text{parchment}}$$

$T_{\text{parchment}}$  = calculated transmission of light through the sample



Figure 2 The parchment of the VM suffers from deformation and waving.

$M_{\text{parchment}}$  = measured value (EV = electric value) through the parchment

$M_{\text{reference}}$  = measured value (EV) through the reference

$T_{\text{reference}}$  = the defined transmission of light through the reference set at 90.00

### *Damage assessment and categorization of the parchments*

The overall condition assessment of the parchment is based on a visual examination of the parchment as a whole and of the specific areas. The damage assessment includes information on transparent areas, deformations/mechanical damage, surface contamination, blood colouring, discoloration, biological deterioration (microorganisms), biological deterioration (insects, rodents), water damage, heat or fire damage, fibres sticking out of the damaged areas, remains of hair, deposits of calcite and ink writing.

### *OVERALL DEGREE OF DAMAGE*

The immediate impression of the overall degree of damage to the parchment was categorized to one of the following:

*No damage* - uniform, good condition with no visible signs of damage over the parchment surface.

*Slightly damaged* - uniform, good condition with one or a few small areas showing signs of minor visible biological, chemical and/or physical damage.

*Damaged* - uniform, progressing visible signs of damage on a larger part of the parchment and/or several minor areas with serious visible biological, chemical and/or physical damage.

*Heavily damaged* - uniform, progressing visible signs of damage on most parts of the parchment and/or several minor areas with serious visible biological, chemical and/or physical damage.

### *DAMAGE IN THE SPECIFIC AREAS*

The impression of damage in the specific areas was categorized to one of the following categories

*No damage* - uniform, good condition with no visible signs of damage.

*Slightly damaged* – signs of minor visible biological, chemical and/or physical damage.

*Damaged* - uniform, progressing visible biological, chemical and/or physical damage.

*Heavily damaged* - uniform, progressing heavy visible biological, chemical and/or physical damage.

### *FT-Raman*

Raman spectra have been recorded with the FT-Raman FRA-106-S module of an Equinox 55 Bruker FT-IR spectrometer using NIR excitation at 1064 nm wavelength with a total power of 450 mW.

### *RESULTS AND DISCUSSION*

The results of the visual assessment and measurements of colour are given in tables 1-12.

### *Vinland Map*

A visual examination of the VM clearly reveals ten holes that have been covered with small square patches. Moreover, one of the possible wormholes penetrates the legend text of “montes inferiores abrupti”. Part of the “s” at the end of the word

“samogedos” and the whole word “et” is missing in the second line and in the translation in reference 3 (text 39, p. 133) this is marked by putting the “et” in brackets. The same is the case for the text “magnus ka..” (text 41) where the missing letter/-s according to reference 3 may have been a “n”. These features are clearly seen on the picture of the map in reference 3. This supports the assumption that the wormholes appeared after the text was written.

A more thorough examination seems to show remains of hairholes. However, an examination with a magnifying glass did not verify this. It has been put forward that the VM once was in one piece.<sup>3,4</sup> The perfect alignment and match of map lines across the centre folding and the form of the lacunas from the possible traces of 4 sewing holes on each side of the centre folding strongly indicate that the VM once was in one piece and prepared to be incorporated into a book. Moreover, this is further supported by the fact that there are no inscriptions close to or overlapping the centre folding on the two parts of the map. On the other hand, the map has been drawn in a way that could only have been done on the flat parchment and not on a parchment folded and bound in a book.

In general, the parchment feels very thin and flexible. Moreover, the parchment suffers from deformation



Figure 3 Discoloration due to moisture (lower left from the centre) and part of the restoration of the centre fold at the lower part of the VM.

and waving (see Figure 2). Both recto and verso sides are characterized by some surface contamination, signs of biodeterioration and deposits of calcite. The overall colour of both sides of the parchment is light yellow-green. The latter is confirmed by the spectrophotometric colour measurements of both sides of the five specific areas. In addition, the map suffers from damage and slight discoloration from moisture; this is especially the case around the centre folding of the sheet. Most probably this is due to contact with water, either by an accidental exposure to a high moisture level or as a result of a restoration treatment (see Figure 3).

Although there are no clear and objective signs proving that the VM has undergone any kind of conservation treatment at an earlier stage in its history, the physical characteristics like the more flat and flexible character of the VM parchment indicate that it may have been exposed to a flattening in humid conditions. Moreover, in general the VM parchment is less bright in colour and has a lower light transmission than the TR and SH parchments. This may also be explained by a humid or water-based treatment of the VM including when the patches were placed to keep the two parts together and to cover the wormholes.

Based on the visual assessment the VM parchment may be categorized as “damaged” according to the overall visual assessment and the assessment of the five specific areas. Three of the five specific areas are categorized as “damaged”, whereas the TR sheets are categorized as “slightly damaged” and the SH as “undamaged” (see below). This difference is to be expected as the latter have been protected inside the books and the VM has, at least for some decades, been more openly exposed to its surroundings as a single sheet.

After an examination by A.D. Baynes-Cope and A.E. Werner at The British Museum in 1967 they concluded that the VM had possibly undergone some chemical treatment as it had a washed-out appearance. However, they could not detect possible residues of any chemical bleaching agent in the test carried out.<sup>4</sup>

These possible treatments may have harmed the parchment and the damage may increase on the long term as indicated by the assessment data and the gelatinization of the parchment fibres at the uneven edges of the wormholes (see Figure 4).<sup>5</sup> The yellow glasslike edge most probably originates from a water-based binding medium, e.g. wheat starch used to apply the squared patch to cover the hole.



Figure 4 Gelatinized (yellow glasslike) fibres on the edge of a wormhole.

The assessment of the specific areas confirms the overall observations which indicate that the condition of the parchment can be classified to a damage category ranging between 2 and 3 (from “slightly damaged” to “damaged”). All specific areas can be characterized as half mat. Specific areas 3-5 have fixed dark surface

contamination on both sides probably originating from human handling. The major part of the calcite is found on the recto side bearing the text and drawing. This is in concordance with the fact that calcite has been used in parchment making to make the parchment surface suitable for writing. Moreover, in most cases the flesh side was used for writing and illuminating. We therefore assume the recto side of the VM to be the flesh side.

The parchment is very flexible (A) in all specific areas apart from area number one which is categorized as B and as such less flexible. However, this is within the variation to be expected.

The thickness of the specific areas varies between 0.08 and 0.13 mm and the transmission of light between 91.96 and 95.22 %, but there is no relation between the variations in these figures. Visually, the parchment colour was estimated to be yellow-green. This is confirmed by the measured low and mainly



Figures 5 a) The west side of the lake at Vinland. b) A detail from Greenland, a little northeast of Qaanaaq. c) The beginning of Dacia written across the northwestern part of Jutland, Denmark. d) The end of Dacia, the northeastern part of Jutland, Denmark.

negative  $a^*$  values (average = -0.10) in combination with the positive  $b^*$  values (average = 11.3). The brightness is relatively high with an average  $L^*$  of 82.7 (ranging from 73.0 to 86.8).

### *The ink of the VM*

The ink drawing and writing are heavily damaged suffering from extended partial loss of ink pigment, whereas the binding media have apparently penetrated into the parchment surface causing a yellowing. This damage may have been introduced or increased by the possible earlier humid treatment. As seen from Figure 5a-d, there is no difference in the characteristics of the ink from the four different areas of the VM. This strongly indicates that the same ink has been used for all text and drawings. A minor degree of off-flaking of ink is also observed for SH 224.

A comparison of the VM ink with ink from a historic Spanish parchment dating from 1575 owned by the Royal Library, Denmark (see Figure 6) was performed at the microscopic level. Some characteristics are found to resemble each other.

The type of damage to the ink indicates that the ink pigment has very little affinity to the collagen which may be expected from a carbon ink. Carbon particles, suspended in liquid, will remain on the surface. An iron gall ink is an iron-tannin complex pigment of which both the iron complex and the tannin are known to have great affinity to the collagen. The iron gall ink is a solution when applied and will partly penetrate into the fibre structure. This together with the high affinity to the collagen normally leads to strong fixation through stable chemical binding of the ink pigment to the parchment.



Figure 6 Document from the Gerona Archive, dated 1575 (Royal Library, Denmark).

### *Tartar Relation*

Three of the examined parchment sheets are found to be slightly damaged. The colour of all the parchments is light yellow with a half mat to mat appearance (Tables 5-8). Moreover, TR3 is transparent and a glasslike layer is seen above one of the wormholes. The specific areas of TR3 show no sign of visual damage. Calcite layer appears at specific areas 4 and 5. TR18 shows transparent areas, signs of biodeterioration from microorganisms and rodents, deformation and signs from blood and veins.

The ink of the TR seems also to be of a carbon ink type according to its colour and fixation to the parchment. Moreover, the ink on some of the pages suffers from loss of pigments due to the low degree of fixation (see Figure 7). However, there is no sign of remains of binding media on the parchment surface as for the VM and the European parchment mentioned above. This may be due to less exposure to humidity.

### *Speculum Historiale*

The overall colour of SH7 and SH8 is light yellow and the general state of deterioration is judged to "no damage". SH7 has ink writing on both sides. The upper corner of SH8 is missing (may have been cut off). SH224 is overall light yellow with a dark yellow lower edge. Moreover, it has a wormhole and the ink writing flakes off slightly. The colour of SH239 ranges from light yellow to yellow. It appears slightly damaged with transparent areas, signs of biodeterioration and the ink from the next page colours the parchment brown. Moreover, it has a hole probably originating from its production.

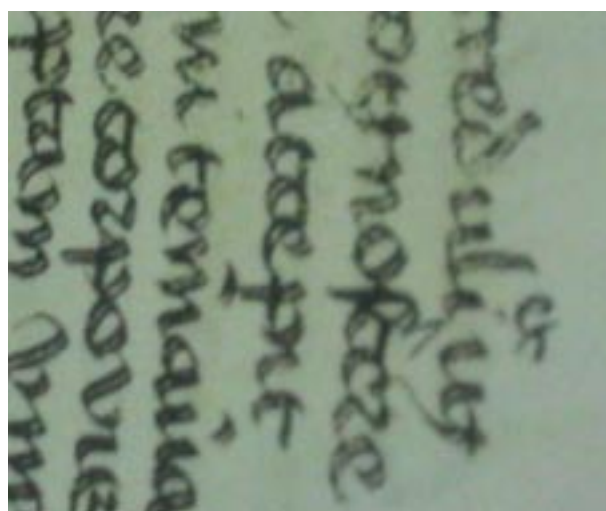


Figure 7 Partial loss of ink layers on a TR parchment leaf.

The specific areas of SH7, SH8, SH224 are all found in the category “no damage” and they all appear mat and the measured colours are close to each other. The SH239 is categorized as “slightly damaged”. It has the same colours as above, however, specific area 3 verso and specific area 4 recto and verso are all half mat. Apart from specific area 3 of SH7 and 5 of SH239 which have a flexibility of category B, the flexibility of all specific areas are categorized as A.

## *THE BINDINGS OF SPECULUM HISTORIALE AND TARTAR RELATION*

### *Speculum Historiale*

The manuscript *Speculum Historiale* is bound in a dark brown full leather cover, but the book has been rebaked at some later stage (see Figure 8). The leather on the boards is vegetable tanned, based on the observation that the brown colour is present throughout the full leather structure and taking into account the estimated age of the leather covered boards. The animal origin of the leather is presumably wool sheep according to a visual examination of the very few areas with an intact hairhole pattern. This observation agrees with previous examinations.<sup>3</sup> A visual examination of the leather showed that the leather is destroyed by wear and tear and chemically deteriorated, too. The degree of deterioration could not be determined specifically as no sampling from the leather was allowed. Testing of fibre coherence and shrinkage temperature was not performed as it requires sampling from the leather.



Figure 8 The binding of SH with the original medieval boards and a later rebacking.

The full leather on the wooden boards is covered by small figures in blind stamping. Marston et al.<sup>3</sup> concluded that the binding is contemporary with the text, a conclusion with which we concur. However, later alterations of the binding structure have reversed the front and back cover, and the



Figure 9 Remains from the previous headband of SH.

conclusion made by Marston that they were reversed by a modern binder is by far the most likely conclusion. Either it could be a mistake or, more probably, it was done on purpose to present a much nicer first-hand impression because the back board is in a far better physical condition than the front board.

The text block consists of 15 quires, which are all arranged in the same way, the outer and inner leaves being of parchment and the rest of the leaves in between of paper. At some pages (for example 17, 28, 38) the text written in the margin is slightly cut away. A trimming of a sewn book block should produce even edges but today each quire is displaced compared to the next one. This suggests that a resewing of the book block took place. The sewing thread is too thick to suit the large book block and has a quality which resembles normal bookbinder sewing thread used within the last hundred years. It is dirty and due to its thickness it has pressed marks into the leaves. The sewing thread is found in the middle of each quire and a contemporary headband was sewn onto the text block. The headbands were fixed to the book block by sewing the thread into each quire at the top and at the bottom of the book block (see Figure 9).

At some later stage in the history of the binding the headbands were cut away, but the thread which fixed them to the top and bottom edges of the book block could not be removed from the middle of each quire. They were left in the quires and today only the small loose ends at top and bottom reveal that the present headbands are later additions.

A new leather backing and leather repairs are the most significant signs of a modern rebinding. The new leather is goat leather which is strikingly different in appearance from the original leather.





Figure 10 New backing of the book block fixed to the inner side of the wooden boards of the SH.

Furthermore the edges of the leather repairs are put on the top of the original leather. In general, this gives the overall impression of a quickly performed conservation job with the lack of quality standards.

At the inner board there are no endleaves glued to the wood. It leaves the structure open and strips of parchment glued over the back of the book block are visible. The backing of the book block at top and bottom is made of some modern material and also a strip of canvas is visible throughout the full height of the book (see Figure 10). A split in the wood is filled with paper and some synthetic material, which could be white glue, for example polyvinyl acetate. This suggests that the dating of the rebinding should be no earlier than the 1930's.

Remains of a written text are visible on the inner side of the board which is placed as the front board today. Written text is also found on the thick cords which are inlaid in the boards. This points to the presence of a previous parchment endleaf with text that was glued onto the board with animal glue, remains of which is still found on the board. Strips to support the back were glued onto the inner boards after removal of the endleaf as no text is found on them.

#### *Tartar Relation*

The TR is bound in a light brown full leather cover (see Figure 11). The leather binding is decorated with an outer gold-tooled frame and is most likely a late 19th or early 20th century binding. At the inner side of the boards are found two layers of endleaves: an original one in white paper and a later addition of marbled paper. The book block and the boards with leather cover are joined as two independent pieces; this can be seen in the hollow back. This technique enables the production of two independent pieces: a book block and a leather cover which are then glued



Figure 11 The leather binding of TR.

together. The book is tightly bound and therefore the sewing cannot be inspected. Headbands are placed at top and bottom of the book block and a visual inspection reveals that the headbands are sewn on thin red sticks of a synthetic material. This suggests a rebinding of the book to have taken place in the late 1940's or early 1950's.

#### *GENERAL DISCUSSION*

##### *Assessment*

Three of the five specific areas fall into the same category (lower right corner and in the middle of the recto part of the map). The two specific areas on the top right corner are categorized as "slightly damaged". This distribution of damage is seen also for the specific areas of TR18 and SH239 ("no damage" to "slightly damaged") and may indicate that these are the areas which are touched the most by human handling of the sheets. A very strong example of this is Japan on the VM, which tends to be exactly where thumbs are placed while handling the map, resulting in a very blurred almost invisible image of the borders of Japan.

It has been suggested that the VM could be a palimpsest. In that case one would expect the parchment to be significantly different and thinner than the other parchments. The parchment with the highest variation in thickness is SH239, where the thickness differs from 0.06 mm to 0.16 mm. The average thickness of VM is 0.11 mm.

The plot in Figures 12 a and b compares the combination of transmission of light, the measured

colour brightness ( $L^*$ ) and the thickness of the specific areas of the parchments. The plotted VM data cluster together with a subpopulation of TR data deviate from the SH and remaining TR data (Figure 12 a). In general the VM samples are less bright in colour, have a lower transmission and are among the thinnest. Figure 12 b shows the same plot, but the data are labelled with the damaged category assigned to the specific areas by the visual assessment. The trend is that the more the damage the lower the colour brightness and transmission of light.

As seen in Figure 13, the VM deviates from the SH and the TR with respect to colour by its general lower brightness and  $a^*$  (towards green) and  $b^*$  (towards the blue). Two sample t-test show that the average  $L^*$  value of the VM (82.7) is significantly lower than that of the TR (86.1), and that that of the TR is significantly lower than that of the SH (89.4). See Annex I for more details.

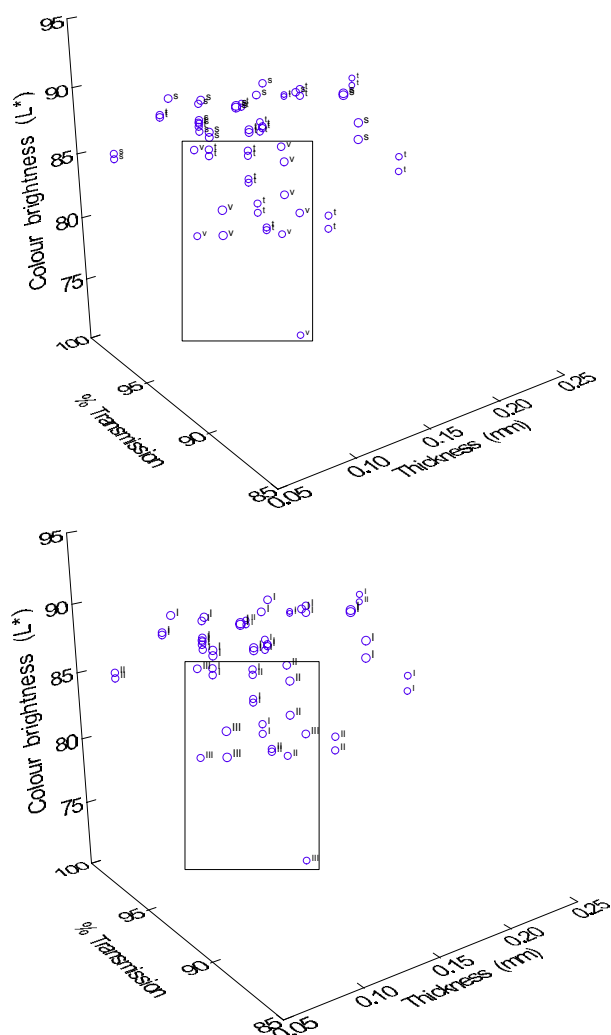


Figure 12 a and b Plot of transmission of light, the measured colour brightness ( $L^*$ ) and the thickness of the specific areas of the parchments. Figure 12 b is the same as plot 12 a, but the data are labelled with the damage category assigned to the specific areas by the visual assessment.

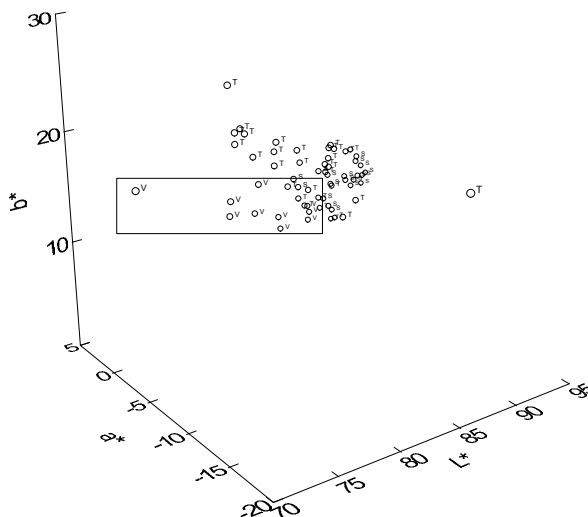


Figure 13 Plot of  $L^*$ ,  $a^*$  and  $b^*$  colour values from the VM, SH and TR.

### Ink analysis

The results of the microscopic assessment of the ink showing it to be heavily damaged by loss of pigments confirm earlier findings published in reference 3 and 6. The identification of anastase in connection with the ink of the VM has previously been reported by Thomas and Kusko.<sup>3</sup>

The identification of the ink as a carbon type is confirmed by the FT-Raman analysis by Brown and Clark.<sup>6</sup> Their identification of anastase is based on two bands appearing at  $143\text{ cm}^{-1}$  and  $398\text{ cm}^{-1}$ . However, our study of their paper shows that they have obtained another two bands indicating anastase at  $509\text{ cm}^{-1}$  and  $630\text{ cm}^{-1}$ , respectively.

The FT-Raman analysis performed by Boghosian on six iron gall inks produced according to historic prescriptions using analytical grade chemicals and on two commercial carbon inks applied to parchment showed differences between the inks, but no traces of anastase. However, both carbon ink and iron gall ink were commonly used in the Middle Ages. Therefore, comparative FT-Raman analysis of medieval inks and study of the physical adherence of these inks to the parchment surface would be of interest. Moreover, FT-Raman analysis of the areas of the VM parchment not covered by text and drawings would be of interest to see if these areas contain anastase too.

### Book bindings

The SH is bound in a binding contemporary with the manuscript, but the book has undergone restoration at least twice. The most recent restoration can be attributed to a date which is later than that of the invention of synthetic glues in the early 1930's.

The TR is covered in a leather binding, presumably late 19th century. As technically the leather cover is produced independently of the text block, the joining of binding and text block could have been made much later. This is supported by the presence of the synthetic material in the headbands which indicates that a rebinding took place no earlier than 1940's.

### *The possible connection between the SH and the TR*

It has been speculated whether the SH and the TR were previously bound in the same binding. Some of our findings presented above clearly indicate that both the SH and the TR, as they appear today, were previously bound together with other book pages. Based on the examination of the bindings and the book blocks we have no direct or physical evidence for saying that these two manuscripts have been bound together in the past. However, the recent discovery<sup>7</sup> in Luzern, Switzerland, of a copy of the *Speculum Historiale* that contains a copy of the *Tartar Relation*, both dating from 1338-40 and written by the same hand, is a strong indication supporting this possibility.

It is interesting that the Luzern copies of the SH and TR appeared around 100 years after the first original SH by Vincent of Beauvais. SH describes the mission of Carpini and of San-Quinton to the Mongols ("Tartars") and the TR is based on the records of the same Carpini from another mission to the Mongols.

### *CONCLUSIONS*

The major purpose of the assessment was to establish the state of condition of the VM, SH and TR. However, even if this report contributes new knowledge on the conditions, materials and techniques used, this is not sufficient to verify if the VM is authentic or a forgery.

The perfect alignment and match of map lines across the centre folding and the form of the lacunas from the possible traces of four sewing holes on each side of the centre folding strongly indicate that the VM was once in one piece and prepared to be incorporated into a book. This is further supported by the fact that there are no inscriptions close to or overlapping the centre folding on the two parts of the map. Despite the presence of what seems to be traces of hairholes, these are not sufficient for identifying the animal origin or which side is the flesh and grain side of the VM. However, the major part of the calcite observed on the surface is found on the recto side (which bears the drawing and text) on both pieces. Therefore we

assume the recto side of both VM pieces to be the flesh side as this side was normally used for writing.

The VM parchment may be categorized as "damaged" according to the overall visual assessment and the assessment of the five specific areas. The damage and characteristics of the parchment seem to derive from surface contamination, biodeterioration, deposits of calcite and moisture damage which may originate from the restoration, especially on what may have been the centre folding of the sheet. The overall light yellow-green colour of both sides of the parchment may originate from some kind of conservation treatment at an earlier stage in its history. Although there are no clear and objective signs proving that the VM has been exposed to a process of flattening in humid conditions, the physical characteristics such as the more flat and flexible character of the VM parchment strongly indicates that this is so. The gelatinization of the parchment fibres on edges of the wormholes probably originates from the moisture introduced to the parchment by attachment of the patches to cover the holes. Moreover, in general the VM parchment is less bright in colour and has a lower light transmission than the TR and SH parchments. These differences may also be attributed to a humid or waterbased treatment of the VM.

In general, the VM is significantly thinner than the SH and most of the TR parchments, but of the same thickness as a subpopulation of the thinnest of the TR parchments. The latter is characterized as slightly damaged and has  $L^*$  values and a light transmission close to that of the VM. Therefore, the possibility that the VM and TR parchment leaves have been placed together in the same book or even may originate from the same parchment production cannot be excluded. On the other hand, the suggestion that the VM could be a palimpsest indicated by its small thickness is not supported by our findings. That the TR sheets can be categorized as only slightly damaged and the SH as undamaged may be due to the fact that these have been protected inside the books.

The ink drawing and writing of the VM are heavily damaged and suffer from extended partial loss of ink pigment all over as previously reported by others. Apparently the binding media penetrated into the parchment surface causing a yellow shadowlike effect. This strongly indicates that the ink used for all the text and drawings is a carbon ink. Moreover, the damage is the same all over and there is no evidence that the ink of Vinland and Greenland differs from the ink on other parts of the map. Furthermore, the characteristic ink damage is found also on a

historic parchment document dating from 1575. Moreover, the colours and characteristics of inks of the SH parchments resemble those of carbon ink. In addition, the colour of the ink indicates that the ink on the TR parchments is a type of carbon ink. This is supported by the fact that some of the TR parchments also suffer from partial loss of ink pigment due to bad fixation, but without the yellow colour of what may be remaining binding media ingrained in the parchment surface.

The identification of the ink as a carbon type is confirmed by the FT-Raman analysis by Brown and Clark. In addition, our study of their paper shows that they have obtained another two bands indicating anastase. Our FT-Raman analysis of six iron gall inks produced according to historic prescriptions and two commercial carbon inks applied to parchment showed differences between the inks but no signs of anastase traces. Therefore, comparative FT-Raman analysis of ink on historic European parchment would be of interest.

The SH is bound in a binding contemporary with the manuscript, but the book has undergone restoration at least twice. Moreover, the original vegetable tanned leather clearly suffers from chemical deterioration, but the degree cannot be verified without further analysis. The restoration can be attributed to a date which is later than the invention of synthetic glue, i.e. no earlier than the 1930's. However, the new leather backing and leather repairs are the most significant signs of a modern rebinding. The new goat leather differs strongly in appearance from the original leather and the edges of the leather repairs are put on top of the original leather. This gives the overall impression of a quickly performed restoration job lacking aesthetic quality and professionalism.

The TR is bound in a light brown full leather cover decorated with an outer gold-tooled frame. Materials and style indicate that the leather cover is a late 19th or early 20th century binding. However, the headbands at the top and the bottom of the book block are sewn on thin red sticks of synthetic origin. This suggests that the rebinding of the book took place no earlier than the late 1940's. The binding technique indicates that the leather cover may have been taken from another book and reused for the book block of the TR at the same time as the headband was applied.

Our findings presented above clearly indicate that both the SH and the TR, as they appear today, were previously bound together with other book pages. Moreover, a recent discovery in Luzern, Switzerland,

of a 100 year earlier copy of the SH containing a copy of the TR strongly supports this possibility.

In "The Vinland Map and the Tartar Relations"<sup>3</sup> it is assumed that the Yale TR is the only known copy. The existence of another copy in Luzern opens up for - perhaps decisive - new research. There was no map attached to the Luzern copy.

The fact that the VM map cannot have been produced on the parchment bound in a book, and that no evidence can be found of any interventions to the books have been made in the 20th century prior to the rebinding, points towards that, if a recent forgery, the map must have been produced after the 1940's. However, if the VM was originally bound together in front of the SH, as indicated by the match of the wormholes, the two wormholes penetrating part of the text of the map points towards a much earlier production of the map, as it would have been difficult to avoid the ink to bleed by writing over the wholes. Signs of this cannot be observed and have not been reported by others.

#### *RECOMMENDATIONS FOR FUTURE WORK*

We highly recommend doing a dating of the paper and parchment of the SH and TR in order to make sure that the existing watermark dating is correct. In addition we recommend doing comparative studies of ink, parchment, binding techniques as well as paleographic studies of the two sets of manuscripts of the SH and the TR at Yale and Luzern, respectively, to establish the relation of the two Yale manuscripts. Moreover, comparative FT-Raman and XRD analysis of ink and study of the physical adherence of ink to the parchment surface on medieval parchment manuscripts including the Luzern SH and the TR would be of interest to establish any relation between the Yale manuscripts and the VM. Finally, the origin of the anastase present in connection with the ink of the VM should be the subject of further studies.

Comparative examinations of the distances and placement of the sewing holes within and between the Yale SH, TR and VM may establish if all the object materials (without saying anything with respect to the authenticity of the VM drawing and text) have originally been bound together in the same book. This would entail opening the TR binding at one side between the book block and the non-authentic binding to be able to study and measure the sewing holes on the back. However, such an operation can be done and the binding be restored by a professional book conservator-restorer without harming the original materials in the TR.

## *PRECAUTIONS AND RECOMMENDATIONS IN CONNECTION WITH THE STORAGE, EXHIBITION AND CONSERVATION AND RESTORATION OF THE PARCHMENT OBJECTS*

### *Introduction*

In connection with the storage, exhibition and conservation and restoration of parchment objects, it is important to focus on factors and actions which may initiate or accelerate the deterioration of either text, paint layers or the parchment support. Light, heat and pollution may cause damage as does corrosion of iron gall inks or fading and colour changes to paints. However, in many cases damage to the text and paint layers is directly related to damage of the parchment structure (e.g. cracking, flaking etc.). Parchment degradation tends to develop from an intact fibre structure of high hydrothermal stability through different stages of fibre structure changes and decreasing physical and hydrothermal stability. The degradation may progress to a terminal stage with a considerably disintegrated fibre structure that is transformed into a gelatinous substance by contact with water or storage in moist conditions or into small fibre fragments without any detectable hydrothermal activity. At the macroscopic level these changes may be reflected in characteristics such as colour, stiffness, thickness, transmission of light etc. of the parchment.

Parchment is extremely sensitive to changes in relative humidity and temperature. Even minor variations in these factors may cause changes in its dimensions (area and thickness) resulting in curling and waving of the structure. Moreover, dimensional changes of the parchment may cause damage to text and paint layers.

High relative humidity may speed up chemical degradation like hydrolysis of especially parchment acidified by pollution and other chemical reactions and attack of microorganisms on the parchment structure. In this damage category it may be expected that several fibres are so damaged that they may shrink, gelatinize, melt and/or fragmentize irreversibly at room temperature by exposure to a high relative humidity or moist treatment. In some cases the fibre transformation may even take place at normal relative humidity conditions (50-55 %).

High temperature and light accelerate oxidative reactions leading to degradation of the parchment fibres, binding media and paint including fading of paint colours. High temperature may also dry

out the parchment structure which will cause the parchment to stiffen.

Low temperature in combination with a high relative humidity may cause condensation of water on the surface of the parchment. Particular attention should be paid to closed showcases where condensation may happen when the temperature of the surroundings drops. This situation may create an ideal microclimate for microorganisms and accelerate chemical reactions etc.

The general precautions and recommendations which follow are based on the present state of knowledge of and experience with parchment and the influence of damaging environmental factors or conservation treatments. New knowledge and experiences may therefore lead to detailing or modifications of the precautions and recommendations. In this connection we would like to recommend trials to test and establish the optimum conditions with respect to relative humidity and temperature for storage of parchment at different stages of deterioration. This should include the effect of freezing heavily damaged parchment to stop the process of gelatinization.

### *Storage and exhibition of parchment*

It is recommended to use the IDAP EWS<sup>8</sup> parchment sensor system and data logger for measurement of relative humidity and temperature to control the environment and warn against damaging factors in the surroundings. This could be supplemented with other types of more specific sensors to ensure early warning of damaging factors like acidic and oxidative pollutants.

In general, all parchment should be kept in a clean, dark and stable environment in protective boxes or with other forms of protection from direct exposure to the environment of the storage room in accordance with the recommended parameters in the table below. Parchment in this damage category should be kept cold under very stable conditions of temperature and relative humidity.

Only short term exhibition (or research) in a well regulated and controlled environment should be allowed for parchment in the “damaged” category. Storage and exhibition conditions should be the

same with respect to temperature and relative humidity.

It is recommended to make safety copies of the parchment with text and illuminations for research and exhibition purposes. Take care not to expose the parchment to damaging conditions during the copying.

	Light (max), lux	UV (max), $\mu\text{W}/\text{lm}$	Temperature ( $^{\circ}\text{C}$ )	%RH	Note
Storage	0	0	2-15	50-55	Control regularly
Exhibition	50	75	2-15	50-55	Only short time exposure

ISO 11799 (2003)<sup>9</sup> recommends temperatures between 2-18 $^{\circ}\text{C}$  and RH between 50-60%. However, some microorganisms thrive at 60% RH. We therefore recommend not to go higher than 55%. In mixed collections containing acid papers, it may be advisable to keep the RH as low as 45 %.

#### Conservation and restoration

It is recommended to perform visual assessment according to the IDAP parchment damage assessment program part 1-4 prior to and after the treatment of the parchment.<sup>2</sup>

Cleaning, even with a small amount of moisture, may cause changes to the surface (e.g. colour, transparency). Moistening, even stepwise, may increase the stiffness of the parchment, accelerate hydrolysis in acidic parchment and cause irreversible shrinkage, gelatinization, melting and/or fragmentation at room temperature of a large proportion of the fibres.

Press or heavy load on damp or moist parchment may very probably lead to significant damage of the parchment.

Use of moisture-based binding media in restoration may lead to immediate gelatinization (glasslike layer) and/or fragmentation of the part of the parchment which is in contact with the binding media. Load or press on the treated area (e.g. the overlap of original parchment and restoration material treated with binding media) will very

probably lead to immediate formation of glasslike layer in this area.

Avoid the use of moisture in connection with cleaning, flattening and restoration of the parchment. Flattening should only be done in very exceptional cases where this treatment is the only access to the historical information stored on the parchment.

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Table 1 The results of the visual assessment and measurements of colour, transmission and thickness for the Vinland Map (V), the specific areas are numbered 1-5, and recto and verso are given as r and v respectively.

	Transmission	Thickness	Colour card	L-value	a-value	b-value
V1_r	91.96	0.12	2010-10	86.61667	-0.45222	10.62333
V1_v	91.96	0.12	2010-10	84.19222	-0.16778	10.14667
V2_r	93.26	0.13	2010-10	86.76889	-0.31	9.164444
V2_v	93.26	0.13	2010-10	80.13	-0.10111	12.81556
V3_r	91.96	0.13	2010-10	72.954	0.629	15.592
V3_v	91.96	0.13	2010-10	82.52556	-0.10333	13.72778
V4_r	95.22	0.09	2010-10	80.11333	0.04	11.36556
V4_v	95.22	0.09	2010-10	86.63333	-0.65667	10.12111
V5_r	91.96	0.08	2010-10	82.46556	0.362222	10.79556
V5_v	91.96	0.08	2010-10	84.31111	-0.23444	9.028889

Table 2. The results of the visual assessment and measurements of colour, transmission and thickness for the Tartar Relation (T), the specific areas are numbered 1-5, and recto and verso are given as r and v respectively.

	Transmission	Thickness	Colour card	L-value	a-value	b-value
T3_1_r	95.29	0.10	1005-20	85.86	-0.35667	11.52667
T3_1_v	95.29	0.10	1005-20	86.34778	-0.46444	10.74556
T3_2_r	96.62	0.08	1005-20	88.78667	-0.96	9.024444
T3_2_v	96.62	0.08	1005-20	88.61222	-0.71111	8.858889
T3_3_r	95.96	0.14	1005-20	86.255	-1.0625	12.51125
T3_3_v	95.96	0.14	1005-20	87.02667	-4.29	11.02
T3_4_r	91.99	0.20	1010-10	83.55444	-0.66222	15.38667
T3_4_v	91.99	0.20	1005-20	84.69333	-0.68667	13.12667
T3_5_r	94.63	0.13	1005-20	87.45778	-0.68556	11.26667
T3_5_v	94.63	0.13	1005-20	87.59667	-0.67333	10.23
T18_1_r	93.97	0.12	1005-20	82.39889	0.353333	16.12778
T18_1_v	93.97	0.12	1005-20	81.68	0.281111	18.47333
T18_2_r	94.63	0.12	1005-20	83.89333	-0.14667	16.40667
T18_2_v	94.63	0.12	1005-20	83.62333	-0.81333	17.6
T18_3_r	93.31	0.12	1010-10	80.95	0.453333	17.63
T18_3_v	93.31	0.12	1010-10	80.74	0.11	18.86667
T18_4_r	91.99	0.15	1010-10	81.67	0.85	18.74333
T18_4_v	91.99	0.15	1010-10	80.64667	0.756667	22.90333
T18_5_r	94.63	0.12	1010-y	86.04444	-0.30333	14.87778
T18_5_v	94.63	0.12	1005-20	85.65778	-0.50111	16.20667
T11_1_r	95.37	0.20	1010-10	89.16333	-15.4333	17.12
T11_1_v	95.37	0.20	1010-10	88.60667	-1.07667	15.77333
T11_2_r						
T11_2_v						
T11_3_r	93.36	0.11	1010-10	88.50667	-0.92333	12.22333
T11_3_v	93.36	0.11	1005-20	88.31333	-4.12	12.16333
T11_4_r						
T11_4_v						
T11_5_r	96.04	0.10	1010-10	87.67333	-1.27	13.90333
T11_5_v	96.04	0.10	1010-10	87.98	-1.26667	14.31667
T10_1_r	94.03	0.15	1010-10	89.62	-1.15	15.29667
T10_1_v	94.03	0.15	1010-10	90.11667	-1.08667	15.32
T10_2_r						
T10_2_v						
T10_3_r	97.39	0.17	1010-10	87.56667	-1.82	16.40667
T10_3_v	97.39	0.17	1010-10	87.72333	-1.82667	16.62667
T10_4_r						
T10_4_v						
T10_5_r	97.39	0.14	1005-20	87.46667	-1.49333	14.77667
T10_5_v	97.39	0.14	1010-10	87.78333	-1.46333	15.25



Table 3 The results of the visual assessment and measurements of colour, transmission and thickness for the Speculum Historiale (S). The specific areas are numbered 1-5, and recto and verso are given as r and v respectively.

	Transmission	Thickness	Colour card	L-value	a-value	b-value
S7_1_r	90.00	0.14	1005-20	91.78667	-0.3	11.30333
S7_1_v	90.00	0.14	1005-20	91.92238	-0.63143	12.46048
S7_2_r	92.61	0.10	1005-20			
S7_2_v	92.61	0.10	1005-20			
S7_3_r	91.96	0.11	1005-20			
S7_3_v	91.96	0.11	1005-20			
S7_4_r	90.00	0.12	1005-20			
S7_4_v	90.00	0.12	1005-20			
S7_5_r	90.00	0.13	1005-20			
S7_5_v	90.00	0.13	1005-20			
S8_1_r	90.65	0.10	1005-20			
S8_1_v	90.65	0.10	1005-20			
S8_2_r	91.96	0.09	1005-20	91.29333	-0.86	13.39333
S8_2_v	91.96	0.09	1005-20	91.40762	-0.89714	12.41619
S8_3_r	91.96	0.09	1005-20			
S8_3_v	91.96	0.09	1005-20			
S8_4_r	92.61	0.09	1005-20			
S8_4_v	92.61	0.09	1005-20			
S8_5_r	93.91	0.08	1005-20			
S8_5_v	93.91	0.08	1005-20			
S224_1_r	93.91	0.12	1005-20			
S224_1_v	93.91	0.12	1005-20	90.48667	-1.05	12.28333
S224_2_r	93.26	0.14	1005-20			
S224_2_v	93.26	0.14	1005-20	90.48	-1.27	14.18667
S224_3_r	94.57	0.13	1005-20			
S224_3_v	94.57	0.13	1005-20	90.78667	-0.96667	14.44667
S224_4_r	94.57	0.09	1005-20	90.56667	-1.40667	12.80333
S224_4_v	94.57	0.09	1005-20			
S224_5_r	95.87	0.08	1005-20	90.33667	-0.87333	11.7
S224_5_v	95.87	0.08	1005-20			
S239_1_r	90.00	0.15	1005-20	88.39444	-0.94333	12.44333
S239_1_v	90.00	0.15	1005-20	89.58444	-1.06222	12.89222
S239_2_r	94.00	0.09	1005-20	88.55667	-0.89667	9.845556
S239_2_v	94.00	0.09	1005-20	88.17222	-0.99	10.37667
S239_3_r	96.00	0.10	1005-20	87.90778	-0.69889	11.06333
S239_3_v	96.00	0.10	1005-20	87.33	-0.88333	13.93
S239_4_r	98.00	0.06	1005-20	85.34778	-0.50333	13.58889
S239_4_v	98.00	0.06	1005-20	85.75667	-0.49333	12.70333
S239_5_r	96.00	0.10	1005-20	88.18556	-0.83556	13.31667
S239_5_v	96.00	0.10	1005-20	89.385	-1.465	12.735

Table 4. Vinland Map: Assessment of specific areas. R = recto; V = verso; X = observed; empty cell = nothing observed. ND = not possible to detect.

Animal:	No hairholes				
Damage properties:	Surface contamination, biodeterioration, calcite, ink writing, ink is flaking of				
Visual damage	Slightly damaged				
Overall colour	Yellow-green light				
Specific area no.	1	2	3	4	5
Visual damage category	slightly damaged	slightly damaged	damaged	damaged	damaged
Colour R	2010-10	2010-10	2010-10	2010-10	2010-10
Colour V	2010-10	2010-10	2010-10	2010-10	2010-10
Surface treatment R	none	none	none	none	none
Surface treatment V	none	none	none	none	none
Surface appearance R	half mat	half mat	half mat	half mat	half mat
Surface appearance V	half mat	half mat	half mat	half mat	half mat
Surface contamination R	none	none	dark fixed	light fixed	dark fixed
Surface contamination V	none	light fixed	dark fixed	dark fixed	dark fixed
Hairholes R					
Hairholes V					
Remains R					
Remains V					
Veins and blood R					
Veins and blood V					
Calcite deposits R	X				
Calcite deposits V		X	X	X	X
Glasslike layer R					X*
Glasslike layer V					
Discoloration R					
Discoloration V					
Bio R					
Bio V					
Micro R					
Micro V					
Moulds R					
Moulds V					
Rodents R					
Rodents V					
Water R					
Water V					
Flexibility	B				

\*Slight deposit on the fibre surface.

Table 5. Tartar Relation 3: Assessment of specific areas. R = recto; V = verso; X = observed; empty cell = nothing observed. ND = not possible to detect.

Animal:	Unknown				
Damage properties:	Glasslike layer above hole, calcite layer, transparent				
Visual damage:	Slightly damaged				
Overall colour:	Light yellow				
Specific area no.	1	2	3	4	5
Visual damage category	none	none	no	no	no
Colour R	1005-20	1005-20	1005-20	1010-10	1005-20
Colour V	1005-20	1005-20	1005-20	1005-20	1005-20
Surface treatment	none	none	no	no	no
Surface appearance R	half mat	mat	mat	mat	half mat
Surface appearance V	mat	half mat	mat	half mat	mat
Surface contamination R					
Surface contamination V					
Hairholes R					
Hairholes V					
Remains R					
Remains V					
Veins and blood R					
Veins and blood V					
Calcite deposits R					
Calcite deposits V				X	X
Glasslike layer R					
Glasslike layer V					
Discoloration R					
Discoloration V					
Bio R					
Bio V					
Micro R					
Micro V					
Moulds R					
Moulds V					
Rodents R					
Rodents V					
Water R					
Water V					
Flexibility					

Table 6. Tartar Relation 10: Assessment of specific areas. R = recto; V = verso; X = observed; empty cell = nothing observed. ND = not possible to detect.

Animal:	?				
Damage properties:					
Visual damage	Slightly damaged				
Overall colour	Light yellow				
Specific area no.	1	2	3	4	5
Visual damage category R	none	none	none	slightly damaged	none
Visual damage category V	none	none	none	none	slightly damaged
Colour R	1010-10		1010-10		1005-20
Colour V	1010-10		1010-10		1010-10
Surface treatment	No	no	no	no	no
Surface appearance R	Mat	half mat	mat	mat	mat
Surface appearance V	half mat	half mat	mat	mat	half mat
Surface contamination R					
Surface contamination V					
Hairholes R					
Hairholes V					
Remains R					
Remains V					
Veins and blood R					
Veins and blood V					
Calcite deposits R					
Calcite deposits V					
Glasslike layer R					
Glasslike layer V					
Discoloration R					
Discoloration V					
Bio R					
Bio V					
Micro R					
Micro V					
Moulds R					
Moulds V					
Rodents R					
Rodents V					
Water R					
Water V					
Flexibility					

Table 7. Tartar Relation 11: Assessment of specific areas. R = recto; V = verso; X = observed; empty cell = nothing observed. ND = not possible to detect.

Animal:	?				
Damage properties:					
Visual damage	No damage				
Overall colour	Light yellow				
Specific area no.	1	2	3	4	5
Visual damage category R	none	none	none	none	none
Visual damage category V	none	slightly damaged	none	none	none
Colour R	1010-10		1010-10		1010-10
Colour V	1010-10		1005-20		1010-10
Surface treatment	no	no	no	no	no
Surface appearance R	mat	mat	half mat	half mat	mat
Surface appearance V	mat	mat	mat	mat	half mat
Surface contamination R					
Surface contamination V					
Hairholes R					
Hairholes V					
Remains R					
Remains V					
Veins and blood R					
Veins and blood V					
Calcite deposits R					
Calcite deposits V					
Glasslike layer R					
Glasslike layer V					
Discoloration R					
Discoloration V					
Bio R					
Bio V					
Micro R					
Micro V					
Moulds R					
Moulds V					
Rodents R					
Rodents V					
Water R					
Water V					
Flexibility					

Table 8. Tartar Relation 18: Assessment of specific areas. R = recto; V = verso; X = observed; empty cell = nothing observed. ND = not possible to detect.

Animal:	?				
Damage properties:	Transparent areas, signs of biodeterioration (microorganisms, rodents), signs of blood and vein, deformations				
Visual damage	Slightly damaged				
Overall colour	Light yellow				
Specific area no.	1	2	3	4	5
Visual damage category R	none	none	slightly damaged	slightly damaged	no
Visual damage category V	none	none	slightly damaged	slightly damaged	slightly damaged
Colour R	1005-20	1005-20	1010-10	1010-10	1010-y
Colour V	1005-20	1005-20	1010-10	1010-10	1005-20
Surface treatment	none	none	no	no	no
Surface appearance R	half mat	half mat	half mat	half mat	half mat
Surface appearance V	half mat	half mat	half mat	half mat	half mat
Surface contamination R					
Surface contamination V					
Hairholes R					
Hairholes V					
Remains R					
Remains V					
Veins and blood R					
Veins and blood V					
Calcite deposits R					
Calcite deposits V					
Glasslike layer R					
Glass like layer V					
Discoloration R					
Discolouration V					
Bio R					
Bio V					
Micro R					
Micro V					
Moulds R					
Moulds V					
Rodents R					
Rodents V					
Water R					
Water V					
Flexibility					

Table 9. *Speculum Historiale* 7: Assessment of specific areas. R = recto; V = verso; X = observed; empty cell = nothing observed. ND = not possible to detect.

Animal:	No hairholes				
Damage properties:	Ink writing both sides				
Visual damage	No damage				
Overall colour	Light yellow				
Specific area no.	1	2	3	4	5
Transparent	none	none	no	no	no
Deformations	none	none	no	no	no
Visual damage category	none	none	no	no	no
Colour R	1005-20	1005-20	1005-20	1005-20	1005-20
Colour V	1005-20	1005-20	1005-20	1005-20	1005-20
Surface treatment r + v	none	none	no	no	no
Surface appearance R	mat	mat	mat	mat	mat
Surface appearance V	mat	mat	mat	mat	mat
Surface contamination R					
Surface contamination V					
Hairholes R					
Hairholes V					
Remains R					
Remains V					
Veins and blood R					
Veins and blood V					
Calcite deposits R					
Calcite deposits V					
Glasslike layer R					
Glasslike layer V					
Discoloration R					
Discoloration V					
Bio R					
Bio V					
Micro R					
Micro V					
Moulds R					
Moulds V					
Rodents R					
Rodents V					
Water R					
Water V					
Flexibility	A	A	B	A	A

*Deformation: drawn a little at the bottom, in the middle of the book, left, but not in the specific areas*

Table 10. *Speculum Historiale* 8: Assessment of specific areas. R = recto; V = verso; X = observed; empty cell = nothing observed. ND = not possible to detect.

Animal:	No hairholes				
Damage properties:	Upper corner missing (cut out)				
Visual damage	No damage				
Overall colour	Light yellow				
Specific area no.	1	2	3	4	5
Transparent	none	none	no	no	no
Deformations	none	none	no	no	no
Visual damage category	none	none	no	no	no
Colour R	1005-20	1005-20	1005-20	1005-20	1005-20
Colour V	1005-20	1005-20	1005-20	1005-20	1005-20
Surface treatment r + v	none	none	no	no	no
Surface appearance R	mat	mat	mat	mat	mat
Surface appearance V	mat	mat	mat	mat	mat
Surface contamination R					
Surface contamination V					
Hairholes R					
Hairholes V					
Remains R					
Remains V					
Veins and blood R					
Veins and blood V					
Calcite deposits R					
Calcite deposits V					
Glasslike layer R					
Glasslike layer V					
Discoloration R					
Discoloration V					
Bio R					
Bio V					
Micro R					
Micro V					
Moulds R					
Moulds V					
Rodents R					
Rodents V					
Water R					
Water V					
Flexibility	A	A	A	A	A

Calcite deposits V: Perhaps at specific area 4 + 5



Table 11. *Speculum Historiale* 224: Assessment of specific areas. R = recto; V = verso; X = observed; empty cell = nothing observed. ND = not possible to detect.

Animal:	No hairholes				
Damage properties:	Wormhole, dark yellow lower edge, ink flakes off slightly				
Visual damage	No damage				
Overall colour	Light yellow				
Specific area no.	1	2	3	4	5
Transparent	none	none	no	no	No
Deformations	none	none	no	no	No
Visual damage category	none	none	no	no	No
Colour R	1005-20	1005-20	1005-20	1005-20	1005-20
Colour V	1005-20	1005-20	1005-20	1005-20	1005-20
Surface treatment r + v	none	none	no	no	no
Surface appearance R	mat	mat	mat	mat	mat
Surface appearance V	mat	mat	mat	mat	mat
Surface contamination R					
Surface contamination V					
Hairholes R					
Hairholes V					
Remains R					
Remains V					
Veins and blood R					
Veins and blood V					
Calcite deposits R					
Calcite deposits V					
Glasslike layer R					
Glasslike layer V					
Discoloration R					
Discoloration V					
Bio R					
Bio V					
Micro R					
Micro V					
Moulds R					
Moulds V					
Rodents R					
Rodents V					
Water R					
Water V					
Flexibility	A	A	A	A	A

*Deformation: drawn a little at the bottom, in the middle of the book, left, but not in the specific areas*

Table 12. *Speculum Historiale* 239: Assessment of specific areas. R = recto; V = verso; X = observed; empty cell = nothing observed. ND = not possible to detect.

Animal:	No hairholes				
Damage properties:	Transparent areas, signs of bio deterioration., hole from production, ink from next page colours parchment brown, red spot				
Visual damage	Slightly damaged				
Overall colour	Light yellow to yellow				
Specific area no.	1	2	3	4	5
Transparent	no	no	no	yes	no
Deformations	no	no	no	no	no
Visual damage category	no	no	no	slightly damaged	no
Colour R	1005-20	1005-20	1005-20	1005-20	1005-20
Colour V	1005-20	1005-20	1005-20	1005-20	1005-20
Surface treatment r + v	no	no	no	no	no
Surface appearance R	mat	mat	mat	half mat	mat
Surface appearance V	mat	mat	half mat	half mat	mat
Surface contamination R					
Surface contamination V					
Hairholes R					
Hairholes V					
Remains R					
Remains V					
Veins and blood R					
Veins and blood V					
Calcite deposits R					
Calcite deposits V					
Glasslike layer R					
Glasslike layer V					
Discoloration R					
Discoloration V					
Bio R					
Bio V					
Micro R					
Micro V					
Moulds R					
Moulds V					
Rodents R					
Rodents V					
Water R					
Water V					
Flexibility	B	A	A	A	B

## ANNEX I : TWO SAMPLE T-TEST L\* FROM CIELAB COLOUR MEASUREMENT

The two-sample t test (independent t test) to compare the mean of one variable for two groups of cases. The test was performed in SYSTAT<sup>®</sup>. The programme automatically provides three graphical displays combined in one graph: a box plot displaying the sample median, quartiles and outliers (if any), a normal curve calculated using the sample mean and standard deviation, and a plot displaying each observation.

### Two-sample t test on L\* for VM vs. TR:

Group	N	Mean	SD
VM	10	82.6711	4.2236
TR	32	86.0630	2.8196

#### Separate Variance

$t = -2.3793$ ,  $df = 11.6$ ,  $Prob = 0.0354$

Bonferroni Adjusted Prob = 0.0354

Difference in Means = -3.3919, 95.00%

CI = -6.5094 to -0.2744

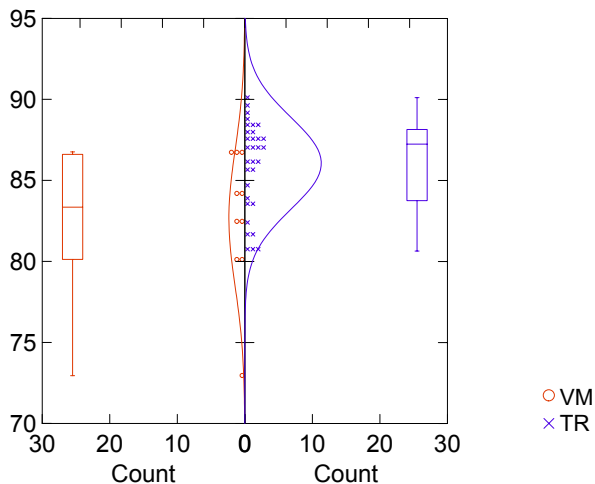
#### Pooled Variance

$t = -2.9351$ ,  $df = 40$ ,  $Prob = 0.0055$

Bonferroni Adjusted Prob = 0.0055

Difference in Means = -3.3919, 95.00%

CI = -5.7275 to -1.0563



The p values (Prob) for both tests indicate a significant difference in the average L\* values of VM and TR. That is, for the separate variance test,  $t = -2.3793$  with 11.6 degrees of freedom and an associated probability of 0.0354. The values for the pooled test are  $t = -2.9351$ ,  $df = 40$ , and p value = 0.0055. The pooled test should be used when you are comfortable that the population variances in the two groups are equal. The graphic displays different shapes and please note that the more the sample variances differ, the more the degrees of freedom

for the separate variance test drop. You pay a penalty for unequal variances - diminished degrees of freedom mean that the effective sample size decreases. In this case we have used the separate variance t test making the test condition stronger.

The average L\* value for TR is 4.3919 more than that for VM (86.0360 versus 82.6711). The standard deviation (SD) for VM (4.2236) is larger than that for TR (2.8196).

The difference in means is -3.3919. The separate variances estimate of the 95% confidence interval for this mean difference extends from -0.2744 to -6.5094. Note that the interval using the pooled variance estimate is shorter.

### Two-sample t test on L\* for SH vs. TR:

Group	N	Mean	SD
SH	19	89.3520	1.9305
TR	32	86.0630	2.8196

#### Separate Variance

$t = 4.9326$ ,  $df = 47.9$ ,  $Prob = 0.0000$

Bonferroni Adjusted Prob = 0.0000

Difference in Means = 3.2890, 95.00%

CI = 1.9482 to 4.6297

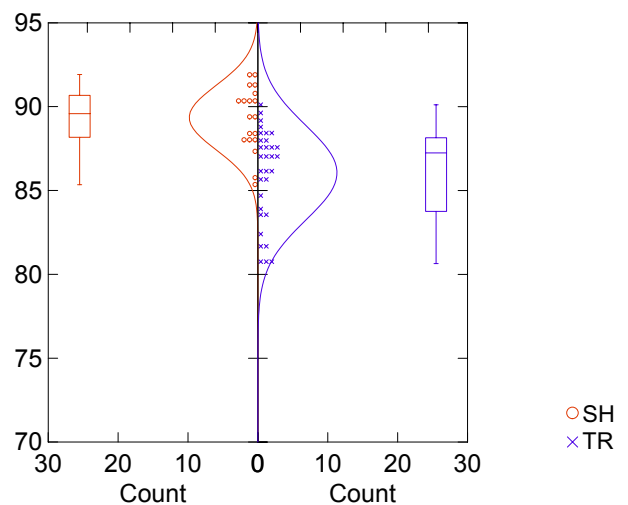
#### Pooled Variance

$t = 4.4893$ ,  $df = 49$ ,  $Prob = 0.0000$

Bonferroni Adjusted Prob = 0.0000

Difference in Means = 3.2890, 95.00%

CI = 1.8167 to 4.7613



The p values (Prob) for both tests indicate a strongly significant difference in the average L\* values of SH and TR. That is, for the separate

variance test,  $t = 4.9326$  with 47.9 degrees of freedom and an associated probability of  $< 0.0000$ . The values for the pooled test are  $t = 4.4893$ ,  $df = 49$ , and  $p$  value  $< 0.0000$ . In this case the difference between pooled and separate variance  $t$  can be ignored.

The average  $L^*$  value for SH is 3.2990 more than that for TR (89.3520 versus 86.0630). The standard deviation (SD) for SH (1.9305) is smaller than that for TR (1.9305).

The difference in means is 3.2890. The separate variances estimate of the 95% confidence interval for this mean difference extends from 4.6297 to 1.9482. Note that the interval using the pooled variance estimate is longer.