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The Vienna Genesis: An Example of Late Antique Purple Parchment

Die Wiener Genesis: ein Beispiel für spätantikes Purpurpergament

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Abstract: The investigation and conservation of the Vienna Genesis, a Late Antique manuscript on purple parchment, included the study of parchment

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production and purple dyeing in the sixth century. The process of parchment making and of purple dyeing was recreated and compared with the Vienna Genesis and other manuscripts from the sixth and eighth centuries. Parchment made from the hides of young lambs and dyed with orchil resembled the folios of the Vienna Genesis. The results of material analysis and the study of parchment technology influenced decisions for the conservation and storage of the manuscript. Fragile areas of ink and parchment were stabilised with strips of adhesive coated Japanese tissue paper. The single folios are stored in folders of Japanese paper and museum matboard within a sink mat.

Keywords: parchment, orchil dye, Vienna Genesis, purple dyed parchment

Zusammenfassung: Die Untersuchung und Konservierung der Wiener Genesis, einer spätantiken Purpurhandschrift, beinhaltete eine Studie zur Herstellung von Pergament und zur Purpurfärbung im sechsten. Jahrhundert. Der Prozess des Pergamentmachens und des Färbens mit Purpurfarbstoffen wurde in Experimenten rekonstruiert und die Ergebnisse mit der Wiener Genesis und anderen Handschriften des sechsten und achten Jahrhunderts verglichen. Aus den Häuten junger Lämmer hergestelltes und mit Flechtenfarbstoff gefärbtes Pergament ist den Folios der Wiener Genesis ähnlich. Die Erkenntnisse aus Materialanalyse und technologischen Studien beeinflussten Entscheidungen zur Konservierung und Aufbewahrung der Handschrift. Fragile Stellen in Tinte und Pergament wurden mit Brücken von beschichtetem Japanpapier stabilisiert. Die einzelnen Folios werden in Umschlägen aus Japanpapier und Museumskarton in versenkten Passepartouts aufbewahrt.

Schlüsselwörter: Pergament, Flechtenfarbstoffe, Wiener Genesis, Purpurpergament

1 Introduction

The Vienna Genesis (Austrian National Library, Cod. theol. gr. 31) is an illuminated Greek manuscript written with silver ink on purple parchment. The codex is dated to the first half of the sixth century and was produced in the Near East, possibly in the city of Antioch (Mazal 1980). Today, 24 single folios of a presumed total of 96 folios are preserved. The manuscript is famous for its unique cycle of 48 miniatures depicting scenes from the book of Genesis: from the fall of Adam and Eve to the funeral of Jacob. Figure 1 shows folio 2, page 4 with the miniature of the departure from the ark. Since 1664, the folios have been preserved in Vienna at the Court Library, which later became the Austrian National Library. We do not know how the manuscript arrived in Europe. Archduke Leopold Wilhelm of Austria presumably bought it from a collection in Northern Italy. When his nephew

Figure 1: Vienna Genesis, Cod. Theol. gr. 31, folio 2, page 4, the departure from the ark and Noah's sacrifice.

Leopold I. inherited his uncle's collection, the prefect of the Court Library Peter Lambeck asked the emperor to integrate the codex into the library. In a letter to Leopold I. in 1664, Peter Lambeck described the deterioration of the silver ink that had resulted in losses of the parchment and the text (Mazal 1980). This damage remains to be the main challenge for conservation.

The endangered condition of the Vienna Genesis prompted us to undertake a research project to study the materials, to assess the damage, and to provide solutions for its conservation. We did not want to change the 1975 encasement between polyacrylate sheets without better knowledge and options for improved preservation. In a three-year project supported by the Austrian Science Fund FWF, we investigated the history, materials, and production of the unique artefact from different perspectives and combined analysis, observation, and technological experiments. We assessed options for conservation and storage in trials and by artificial ageing studies. The results were discussed with diverse groups of experts in order to reach evidence-based and balanced decisions. This contribution summarizes the research findings and conservation of the Late Antique parchment and provides a synopsis of the results of our three-year project. For more details on the parchment and conservation as well as further information on the purple dyeing of parchment, the dye analysis, and the investigation of silver inks and pigments we refer to the book publication (Hofmann 2020) which is also available as free download at https://www.vandenhoeck-ruprecht-verlage.com/themen-entdecken/sozial-rechts-und-wirtschaftswissenschaften/natur-landschaft/55417/the-vienna-genesis?c=1824.

2 Research Questions for the Study of the Parchment

The parchment of the Vienna Genesis is thin and has a smooth, glossy surface on the flesh and on the hair side; these are typical characteristics of Late Antique parchment production from the fourth to seventh centuries. The extreme thinness of the parchment contributed to its degradation by ink corrosion. On all 24 folios of the Vienna Genesis, the parchment is of highest quality.

One question of our project was how the parchment could have been produced in such a consistent quality. Its appearance resembles that of other Late Antique codices and is significantly different from Medieval parchment. Few written sources exist on Antique parchment, and none describes its production. Antique manuscripts were usually written on sheep parchment; however, the knowledge of manufacture was not transferred to the Middle Ages. To bridge the gap of knowledge, experiments were set up in order to produce similar qualities to those of Antique parchment.

The process of dyeing requires the parchment to be uniform. Any flaws or irregularities appear prominently on dyed parchment. Did the parchment maker or the scribe dye the parchment? We do not have written sources on the process of purple dyeing. Ancient knowledge of the prominent shellfish purple dyes and their application was not transferred to subsequent centuries. Historically, it is presumed that purple manuscripts were dyed with the precious shellfish or Tyrian purple. Based on the analytical results reported elsewhere (Hofmann 2020), we needed to experiment with different dyes and application methods to achieve effects similar to those found on the Vienna Genesis.

An essential question was how to preserve the thin degraded parchment. Pressing the folios between sheets of polyacrylate was not a solution that we wanted to continue. What treatment does the parchment of the Vienna Genesis require? And regarding the future mounting, how can we factor in space for planar distortions and air exchange while preventing further degradation of weakened areas?

3 Methods and Materials

3.1 Analytical Methods

The 24 folios were studied under different lighting conditions (daylight, LED, raking, transmitted light, and UV-radiation) and with a stereo microscope (Wild M 400). The thickness of each folio was measured at 12 points on the blank margin with a Mitutoyo micrometer (MDC-SX) and averaged. The thickness was compared with the parchment of other sixth century manuscripts (see chapter 4.5) and the eighth century Dagulf psalter. We mapped damage like tears, losses, and holes and reconstructed the scheme of the bifolios.

Signs of the source animal and its anatomy as well as of production were studied under different lighting conditions and with a stereo microscope. The specific characteristics of Late Antique parchment were compared with those of other manuscripts from the sixth century, among them the Vienna Dioscorides (Austrian National Library, Cod. Med. gr. 1), two folios of Codex Purpureus Petropolitanus (Cod. Theol. gr. 31, fol. 25–26), Codex Rossanensis (Rossano, Calabro, Museo Diocesano) and Codex Sinopensis (Bibliothèque nationale de France, Supplément grec 1286). The results were referenced with a larger study of Late Antique manuscripts that have been preserved more completely than the Vienna Genesis (Vnouček 2019, 2021).

Attempts were made to identify the animal species with biomolecular analysis by means of electrostatic Zooarchaeology by Mass Spectrometry (eZooMS). The surface of all pages was gently rubbed on one spot in the blank margin area with a PVC eraser. The eraser crumbs were collected in a plastic tube for analysis (Appendix 1).

Selected spots of blank parchment were measured with micro-X-ray fluorescence spectroscopy (μ-XRF) on the Vienna Genesis and Codex Purpureus Petropolitanus (Appendix 2). Micro-samples of silver ink were analysed with X-ray-diffraction (XRD) and energy dispersive X-ray analysis in the scanning electron microscope (SEM/EDX) (Appendix 2).

The purple dyes, inks, and pigments of the Vienna Genesis, the Codex Purpureus Petropolitanus, the Codex Sinopensis, and the Dagulf Psalter were analysed with Fibre Optics Reflectance Spectroscopy (FORS), spectrofluorimetry and μ-XRF and compared with reference material (Appendices 2 and 3). Micro-samples of purple parchment were also investigated with micro-spectrofluorimetry and surface enhanced Raman spectroscopy (SERS) and the results compared with reference material to identify the dye by Maria J. Melo (Appendix 4) and Maurizio Aceto with their respective teams (Aceto et al. 2020a).

3.2 Parchment

Parchment was produced from lamb hides in numerous experiments with the aim of achieving physical characteristics similar to sixth century parchment (Vnouček 2020). Only materials that would have been available in the sixth century were used for the manufacture. The new parchment was compared with the reconstructed bifolios of the Vienna Genesis.

3.3 Dyes

Samples of the new lamb parchment were dyed purple (Rabitsch, Boesken Kanold, and Hofmann 2020a). Based on a literature search and the results of the dye analysis (Aceto et al. 2020) we selected orchil dyes (obtained from *Lasallia pustulata* and *Roccella tinctoria* species), folium (obtained from *Chrozophora tinctoria* fruits), and shellfish purple (obtained from *Hexaplex trunculus* snails). The orchil dyes were applied by brush, cotton swab, and immersion in a bath. Samples of parchment were immersed in a solution of folium and in a vat of shellfish purple. The dyed samples were dried under tension with pins on soft fibreboard.

3.4 Mending

We evaluated conservation materials for mending and adhesives in a series of screenings (Rabitsch, Hofmann, and Sonderegger 2020c). The first screening of materials for mending included thin sanded parchment, reconstituted parchment, goldbeater's skin, and Japanese tissue papers (RK0, RK00, KR4C, Berlin Tissue). The materials were evaluated on new sheep parchment with the following adhesives: gelatine, isinglass, parchment glue, Klucel® G (hydroxypropyl cellulose), Methocel® A4M (methylcellulose), and wheat starch paste. The adhesives were evaluated individually and in mixtures. The selection criteria were:

- sufficient mechanical support for degraded ink and parchment
- low tension
- low moisture content
- visual integration on purple parchment and dark ink
- removal of mending without causing further damage

In the second screening, a selection of Japanese tissue papers was coated with Klucel® G, gelatine, isinglass, parchment glue, and mixtures of gelatine with Klucel® G and isinglass with Klucel® G. The dry adhesive film was activated with ethanol in the case of Klucel® G, and with a solution of ethanol and water (1:1) for all the other adhesives. The remoistened tissue papers were applied on new samples of sheep parchment. One set of samples was artificially aged for 10 days at 80 °C and 65% relative humidity (RH) in a climate chamber (Vötsch VC 4034). The aged and unaged samples were evaluated visually and mechanically by peeling the tissue papers from the parchment.

To be less visible on the purple parchment, the tissues had to be coloured in advance. The Japanese tissue papers RK0, KR4C and Berlin tissue were coloured with dry pigments suspended in water (Kremer), watercolours (Schmincke Horadam), and cold-water dyes (Procion MX Dye). The evaluation criteria were:

- ease of application
- even colour tone
- visual integration on the purple parchment

The most promising materials were submitted to Oddy Tests (Appendix 5).

3.5 Mounting

After a survey and discussions with conservators and curators, we selected three different methods of mounting: a double-sided window mount, a sink mat, and pockets of Japanese tissue or silk gauze in a double-sided window mount (Quandt 2011). Parchment samples the size of the original folios were mounted as prototypes using these three methods. Valerio Capra provided a fourth model: parchment suspended with Japanese tissue paper and adjustable springs in a metal frame. We discussed the selected conservation and mounting methods at a meeting of experts at the Austrian National Library. With the feedback received, we modified the mounts.

4 Results and Discussion

4.1 Source Animal

From the fourth to seventh centuries, parchment was primarily made of sheep hides. Visual observation indicated that the source animal of the parchment for the Vienna Genesis was indeed sheep. Hair follicles found in a few areas, like on folio 11, page 22, resemble the hair follicle of sheep. However, the results of eZooMS analysis were not consistent (Vnouček et al. 2020). They indicated sheep, goat, and calf. In one case, sheep and goat were identified on a single folio. In 1975, the folios were treated with parchment glue, which was made in the conservation department from scraps of modern parchment. We assume that the glue layer on the parchment surface is responsible for the different animal sources detected by eZooMS. Visual observation in combination with the experience gained during manufacture confirmed sheep as the source animal (Vnouček et al. 2020).

4.2 Manufacture of Parchment

The substantial step in preparing Late Antique parchment is the removal of the epidermis layer. Experiments showed that the epidermis can be peeled more easily from the skin of very young lambs, especially new-born or stillborn lambs (Vnouček et al. 2020). The hide of a new-born lamb was used to produce one bifolio (double leaf) for example in the Codex Bezae (Vnouček 2021). In the case of the Vienna Genesis, parchment made from the hide of a two-month-old lamb precisely matched the size of two bifolios (Figure 4). We assume that modern lambs are larger than lambs in the sixth century. Sheep until the age of one year is considered a lamb. The hides of young lambs gave the best results in recreating the qualities of Late Antique parchment in the following process.

Fresh or previously frozen pelts of lambs were washed in running water and then soaked in a lime bath for several days. The hair was removed on a wooden beam, and the flesh side was cleaned. The wet skin was stretched on a circular wooden frame. At this stage, the epidermis layer of the skin was gently peeled off the hair side (Figure 2). After this step, fat lipocytes located at the papillary-reticular junction could be removed, making it possible to completely clean the

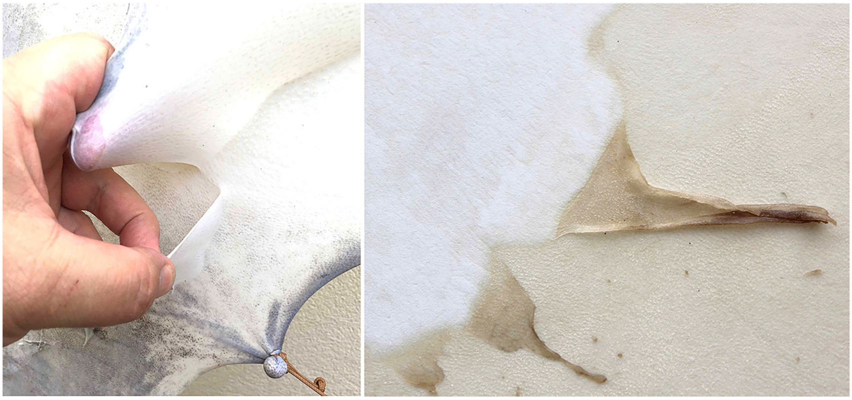

Figure 2: Left. Peeling off the epidermis layer on the hair side of a sheepskin; Right. Hair side of dried sheep parchment in Late Antique style with unpeeled parchment and residues of epidermis.

dermis surface. On the flesh side, residues of fat and other impurities were removed which was easier from the skins of very young or stillborn animals. With some practice, a homogenous surface layer with an even colour on both sides could be obtained. By peeling away the epidermis and cleaning the papillary layer, the thickness of the parchment was halved. The qualities of Late Antique parchment were achieved entirely during the wet processing of the hides. Once the parchment was dry, the production was finished, the hide could be removed from the frame (Figure 3) and was ready for writing or painting. For dependable results, it was necessary to use the hides of lambs of the same breed and age. We assume that the Late Antique parchment makers had a lot of experience in making these choices. The high quality of parchment of all folios of the Vienna Genesis is a testimony to the advanced technological knowledge of the craftsmen that produced it.

In Medieval parchment production, from the eighth century onwards, calfskins were the preferred raw material. The major difference in the preparation is that the final surface treatment of the hides was conducted in the dry stage. Skins from calves were usually preferred, because they are thicker than sheepskins and can withstand mechanical surface treatment. The evenness and the thickness of the parchment were achieved in the dry stage by pouncing both sides while the hide was still stretched on the frame. A surface with a fine velvety nap that easily absorbs ink is characteristic for Medieval calf parchment. Medieval calf parchment is also thicker than that produced from sheep during the Late Antique period. The unique properties of Late Antique parchment impact its ageing characteristics and long-term preservation.

Figure 3: The finished parchment (hair side) on the circular frame.

The size of the Vienna Genesis folios ranges from 257 × 238 mm to 328 × 268 mm. The folios were trimmed irregularly on the edges during past treatments. We assume that damaged parts of the blank margins were cut off. Two reconstructed bifolios fit within the hide of a contemporary lamb that is two months old (Figure 4). Transmitted light reveals signs of the animal's anatomy like the spine and neck area. The parchment folios were folded in the spine area. Multiple re-bindings of the manuscript have caused considerable damage to the original centrefolds, where the spine of the animal was located. Although the folios are preserved as singletons, it is still possible to reconstruct the former bifolios and to identify the hair and flesh sides. The thin parchment reacts strongly with humidity. Left unrestrained, the hair side is convex and the flesh side concave. The average thickness of the parchment folios measures 0.108–0.168 mm in the blank margin areas. Various treatments like the application of glue have changed the surface texture of the parchment. Since the end of the 19th century, the folios were stored between glass plates and since 1975 between polyacrylate sheets (Hofmann and Rabitsch 2020). The long storage under pressure has further

Figure 4: Comparison of new parchment with two bifolios of the Vienna Genesis in transmitted light.

modified the original appearance of the folios. Transparent areas in the parchment were probably caused by exposure to water or high humidity. We think that the transparency of the parchment has increased with ageing and with the application of adhesives to consolidate the ink and miniatures. An original edge on folio 2 shows signs of re-stretching. We assume that the parchment was dyed after production and the skins were re-stretched after application of the liquid dye, in order to retain the unique properties of the material. This work was presumably conducted by the parchment maker and not by the scribe.

4.3 Purple Dyeing

Prestigious biblical documents were often written with silver and gold ink on purple-dyed parchment. The ancient appreciation for the colour purple remained strong in Late Antiquity and the Byzantine Empire. During the Carolingian and Italian Renaissance, this connection was revived especially in book art. For a long time, researchers believed that purple manuscripts were dyed with shellfish or Tyrian purple. Recent investigations proved that parchment was mostly dyed with orchil or folium. On the Vienna Genesis an orchil-based dye was identified as the main purple dye by Maria J. Melo and Maurizio Aceto with their respective teams

(Aceto et al. 2020a). Our experiments (Rabitsch, Boesken Kanold, and Hofmann 2020a) showed that parchment can be dyed with orchil, folium, and shellfish purple (Figure 5). The purple colours differ in shade and light stability. Orchil (*L. pustulata*, *R. tinctoria*) results in a warm reddish purple, folium (*C. tinctoria*) in a pale rose, and shellfish purple (*H. trunculus*) in a cool bluish purple depending on the type of parchment and the method of application. Orchil dyes can be applied

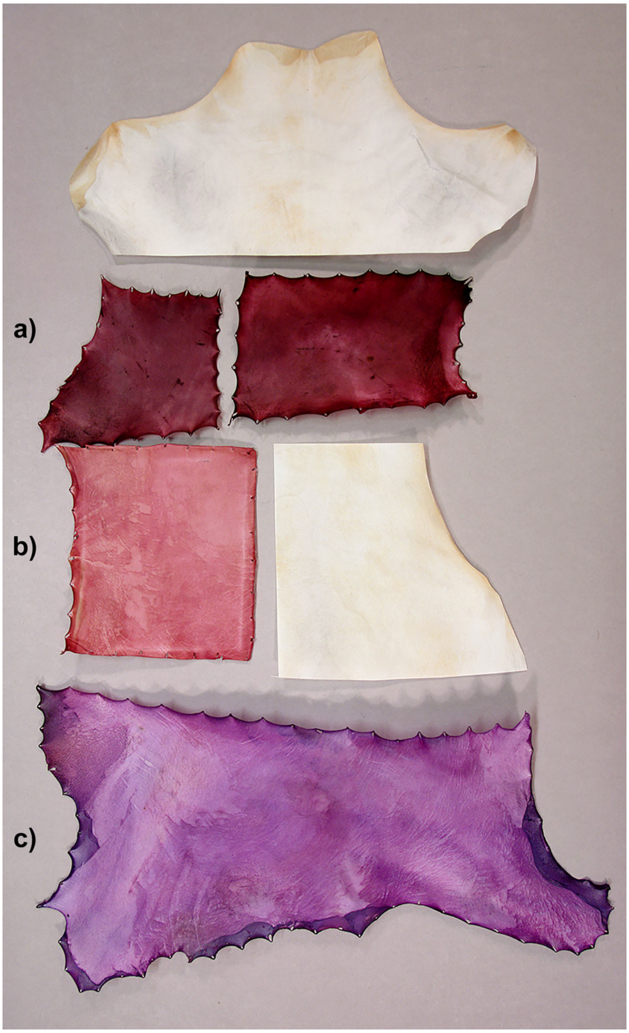

Figure 5: The parts of sheep parchment in Late Antique style dyed with (a) orchil, (b) folium and (c) shellfish purple.

cold with brushes, swabs, or by immersion in a bath. Immersion or a transfer cloth impregnated with the dye are the method of choice for folium (Denoël et al. 2018). Shellfish purple is a vat dye. The temperature of the vat must be lowered to 25 °C at the end of the fermentation process to prevent denaturation of the parchment (Rabitsch, Boesken Kanold, and Hofmann 2020a).

The shades of unaged and light aged parchment samples dyed with orchil resembled most of the tones of the Vienna Genesis (Figure 6). The experiments confirmed the analytical results (Aceto et al. 2020a). Orchil is exceptionally light

Figure 6: Comparison of light-aged orchil samples with folio 4, page 7 and folio 7, page 14 of the Vienna Genesis.

sensitive. Folios of the Vienna Genesis were exhibited at various occasions in the *Prunksaal*, the baroque hall of the Austrian National Library, between 1846 and 1916 (Hofmann and Rabitsch 2020). Depending on the amount of light exposure, the shades differ from light brown to deep reddish purple. The flesh side is paler than the hair side, on which more dye is deposited. Orchil dyes are relatively easy to prepare and to apply compared to shellfish purple (Rabitsch, Boesken Kanold, and Hofmann 2020a). We assume that the finished parchment was first cut into smaller pieces which were formatted to the approximate size of the future bifolios, and only then dyed. In our experiments, we dried the parchment samples under tension by pinning them to soft fibreboard. We observed semi-circular patterns between the pins as well as higher concentrations of dye at the edges, similar to that observed on the original outer edges of the Vienna Genesis, especially on folio 2.

4.4 Condition

To assess the condition of the manuscript and conduct further analysis, we had to open the polyacrylate mounting. The folios were temporarily stored between non-woven polyester (Bondina®) and museum board. The parchment showed planar distortion especially in the text area. We observed horizontal undulations that could have resulted from burnishing the parchment before writing. Many folios have small tears in margin areas. Some long tears measure up to 25 cm. Round holes are the signs of insect activity and can be found in folios that had been close to the wooden boards of the former cover. Losses of the parchment due to ink and copper corrosion are the most pronounced damage. The silver ink has migrated through the parchment, thereby making the text less legible. Parts of the miniatures containing azurite (Hofmann et al. 2020) are visible as dark areas on the other side of the parchment. The ink layer is cracked and corroded. The colour of the silver ink has turned grey or black. Degradation of the ink has resulted in small to large losses of parchment as seen on Figure 7 in transmitted light. On some folios, the parchment in the text area appears like lace. This damage makes the folios extremely vulnerable. Tide lines and stains are caused by exposure to water in liquid form or as water vapour. Paint deposits have been transferred to other folios during exposure to high humidity.

We observed various efforts to treat and stabilise the manuscript in the past: residues of different adhesives and repair strips (Hofmann and Rabitsch 2020). Tears had been mended with pieces of silk gauze, transparent paper, paper fibre, and pressure sensitive tape. Gaps in tears were filled with paper fibres. We compared the current condition of the folios with the three facsimile editions from

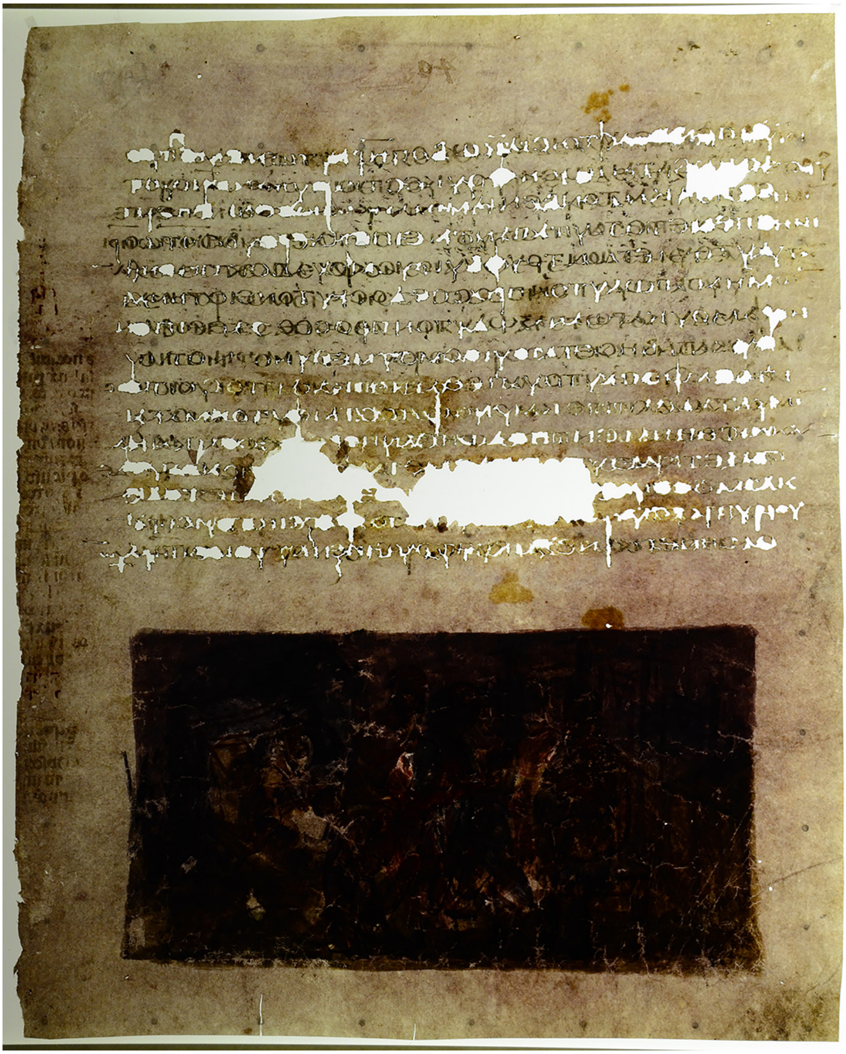

Figure 7: Cracks and losses on folio 20 in transmitted light.

1895, 1931, and 1980. The parchment was flattened especially during the treatment in 1975. We could see compression folds that were probably caused by the application of parchment glue followed by pressing under weight.

The colours of the miniatures are abraded. Losses have occurred especially in areas with white pigments such as in the faces or other flesh tones, but we discovered few loose colour particles. Azurite and orpiment were identified by

FORS and XRF (Hofmann et al. 2020). The painters used azurite as a blue colour and in a mixture with orpiment to make a green colour. The use of this copper-containing pigment resulted in migration of copper ions and darkening of the other side of the folio as well as in losses of parchment like on folio 14 (Figure 8).

XRF analysis detected silver and copper as the main ingredients of the ink (Rabitsch et al. 2020). Chromium, gold, and mercury are present as trace elements. XRF spectra revealed intense signals of chlorine in the ink and in the parchment. The peaks of chlorine are higher than on the two folios of Codex Purpureus Petropolitanus that have been stored with the Vienna Genesis since 1664. XRD analysis detected silver chloride as the main corrosion product of the ink micro-sample from the Vienna Genesis. EDX results showed that chlorine is present in samples taken from the surface and in cross-section ranging from 1 to 20%. Sulphur is present only at about 2/3 of total positions and in half of these positions with a percentage of less than 1%. By SEM/EDX no metallic silver has been found in the silver ink samples. Silver is always accompanied by chlorine, most likely as silver chloride. Araújo et al. suggest in a study on silver paints in manuscripts that in the first step of oxidation of silver, silver oxide (A_2O) is formed as an

Figure 8: Miniature on folio 14, page 28, Joseph's dream of sheaves, dark migration and degradation of the parchment caused by azurite.

intermediate, and the final products are then formed by ligand exchange. In the case of a chloride ion and/or radical, the possibility of a direct reaction must also be considered (Araújo et al. 2018).

By observation and by interpreting the analytical results, we assume that the degradation of silver ink was promoted by elevated levels of humidity in combination with elevated levels of chlorine (Rabitsch et al. 2020). Chlorine could originate from ingredients of the ink like sodium chloride used as a grinding aid for metallic silver. Salty seawater or air saturated with seawater could be further sources for chlorine in the ink and parchment. Copper ions are contained in the ink and in the blue pigment azurite. High humidity enhances the mobility and the catalytic activity of copper ions (Ahn et al. 2014). Both silver chloride and copper ions presumably degraded the protein fibres of the parchment. Over time, the thin parchment of the folios became very weak and broke away in thicker areas of silver and of azurite.

4.5 Comparison with Four Sixth Century Manuscripts and One Eigth Century Carolingian Psalter

4.5.1 Codex Purpureus Petropolitanus (Austrian National Library Cod. Theol. Gr. 31, fol. 25–26)

Two folios of the sixth century Codex Purpureus Petropolitanus have been preserved with the Vienna Genesis under the same shelf mark since 1664, though the bulk of the manuscript is kept at the Russian National Library in St. Petersburg. The text from the gospel of Luke is written in silver ink on purple parchment. Visual observation and eZooMs identified the animal source as sheep. The parchment shows the characteristics of Late Antique production. The average thickness of the blank margin areas of fol. 25 is 0.122 mm and of fol. 26 0.119 mm. The purple dye was identified as orchil by FORS (Aceto et al. 2020a). XRF analysis showed that the silver ink is of similar composition as that on the Vienna Genesis with a comparable ratio of silver to copper (Rabitsch et al. 2020b). The levels of chlorine in the ink and parchment are significantly lower. The ink is corroded but has not degraded the parchment carrier.

4.5.2 Codex Rossanensis (Museo Diocesano, Rossano, Italy)

For stylistic reasons, the Codex Rossanensis, an illuminated Greek Gospel book written in silver and gold ink on purple parchment, is considered to be closely related to the Vienna Genesis (Mazal 1980). The sixth century manuscript is kept at the Museo Diocesano in the Calabrian town of Rossano in southern Italy. One hundred eighty eight folios from a presumed total of 400 folios are preserved as bifolios. A fire and high humidity severely damaged the manuscript. In the early 20th century, gelatine and cellulose nitrate were applied to the first 20 pages. On the last 15 pages the silver ink had corroded and was conserved with gelatine and silk gauze. The codex was recently investigated, conserved and re-bound (Bicchieri 2014; Di Majo, Fiddyment, and Pascalicchio 2020; Quandt, Colaizzi, and Pinzari 2020). Visual observation and eZooMS determined the parchment as sheepskin. The thickness varies between 0.05 and 0.19 mm. The purple dye was identified as orchil by FORS. XRF spectra showed that the silver ink contained copper. The quality of the parchment is similar to that of the Vienna Genesis with all the characteristics of Late Antique methods of production (Vnouček et al. 2020). The purple colour shows more variation in tone. This might simply be due to the larger number of folios that are preserved. The general pigment palette is comparable to the Vienna Genesis (Bicchieri 2014; Hofmann et al. 2020). The size of the animals appears to be similar to those used for the Vienna Genesis. In most cases, two bifolios seem to have been cut from one skin, with the animal's spine located in the centrefold of the quire. Aside from the last 15 pages, the silver ink is in better condition than in the Vienna Genesis and has caused less degradation of the parchment.

4.5.3 Codex Sinopensis (Bibliothèque national de France, Supplément grec 1286)

Scholars have grouped the sixth century illuminated Greek Gospel book, Codex Sinopensis (Bibliothèque national de France, Supplément grec 1286) together with the Codex Rossanensis and the Vienna Genesis (Mazal 1980). All three manuscripts are believed to originate from the Near East. The Codex Sinopensis is written in gold ink on purple parchment; from a presumed total of 490–500, only 43 folios are preserved. The illuminated folios are housed in folders and mounts. All text folios are sandwiched between glass in wooden frames. The parchment was visually identified as sheep. The thickness of the parchment on four accessible folios measured 0.08–0.16 mm and shows the characteristic features of Late Antique production. The purple dye was identified as orchil by FORS (Aceto et al. 2020b). The pigment palette is similar to the Vienna Genesis (Aceto et al. 2020b; Hofmann et al. 2020). The border of the scrolls held by the prophets was painted with silver which has corroded and now appears dark grey. Silver corrosion products have mechanically damaged the parchment. XRF spectra indicate the presence of sulphur and copper in the silver (Aceto et al. 2020b).

4.5.4 The Vienna Dioscorides (Austrian National Library, Cod. med. gr. 1)

The Vienna Dioscorides is a manuscript made for Princess Juliana Anicia around 512 in Constantinople (Austrian National Library, Cod. med. gr. 1). In 1664, Peter Lambeck dated the Vienna Genesis to the sixth century comparing it with the Vienna Dioscorides which comprises 485 folios with 496 images of plants and animals preserved as a bound volume (Mazal 1980). The text is written in iron gall ink on undyed parchment (Aceto et al. 2012). The pigment palette of the miniatures is similar to the Vienna Genesis (Aceto et al. 2012). Otto Wächter conserved the manuscript in 1960 (Wächter 1962) and rebound the folios in three new volumes with leather binding. Visual observation and eZooMS analysis determined the parchment as sheepskin with the characteristic features of Late Antique production. The skins of larger and smaller animals measure 0.104–0.181 mm in thickness. The size of the folios varies considerably. There are colour differences between the hair and flesh sides with the hair side being more yellow. The skins are of lower quality than the ones of the Vienna Genesis. They have numerous repairs made with patches of membrane during manufacture (Vnouček 2019; Vnouček et al. 2020). Vnouček describes these repairs in detail in his contribution in this topic issue of Restaurator. The condition of parchment, inks, and pigments seems to be stable. The Vienna Dioscorides is an example of a Byzantine parchment manuscript that points towards a forthcoming technological change (Vnouček 2019).

4.5.5 Dagulf Psalter (Austrian National Library, Cod. 1861)

During the Carolingian Renaissance, the use of gold and silver ink and purple dyes was revived. An early example of Carolingian book art is the so-called Dagulf Psalter (Austrian National Library Cod. 1861). The scribe Dagulf wrote the psalter between 782 and 795 while working at the court school of Charlemagne (Holter 1980). The small manuscript of 161 folios (190 × 120 mm) was re-bound in the early 19th century. The ivory plaques of the original cover are preserved in the Musée du Louvre in Paris. Visual observation identified the parchment as calfskin. The thickness varies between 0.155 and 0.268 mm. The parchment demonstrates the characteristics of Medieval production. It is thicker than Late Antique parchment. Striation marks made by the parchment maker's knife are visible. The surface of the hair side is rougher than that of the flesh side. A uniform quality of the surface and thickness was achieved in the dry process while the parchment was still stretched on the frame. The text is written in gold ink. Purple is used as a colour in initials and as background on the decorative page on folio 25r. It was probably applied with a brush on primed parchment. The paint layer appears translucent. The dark reddish-purple tone is still visible. Originally, it might have been darker and the brush strokes on fol. 25r less visible. In the initials the scribe combined purple with indigo and ultramarine. The purple colour was identified as orchil by FORS. On the decorative folios (fol. 25r, fol. 67v, fol. 108v) silver was used in letters and in the framework. The silver has corroded and turned grey. The migration of silver through the parchment has left dark stains on the other side of folios. The parchment carrier shows no signs of mechanical degradation. The silver ink was investigated using µ-XRF on folio 108v and on the initial of folio 120v (Malissa, internal report, 2017). Here, again, substantial chlorine peaks were present, and sulphur was detected in blackened areas. Copper, iron, gold, and lead were detected as minor or trace elements, varying significantly in their ratio. Further investigations with XRF confirmed silver with a significant amount of chlorine. Stereo microscopy showed different patterns of silver corrosion and a primer layer on the decorative pages (Jembrih-Simbürger and Hofmann, internal report 2022). A low proportion of copper in the silver ink, a primer coat, and the thicker Medieval parchment could have prevented mechanical damage. The scribe used a range of blue tones (ultramarine, indigo) in combination with purple, silver, and gold. Overall, the parchment, the inks, and the pigments are in stable condition. Abrasion can be observed on layers of ultramarine and indigo. Pigments like ultramarine, indigo, and orpiment that we identified on the Vienna Genesis continued to be used. The knowledge of the preparation of orchil seems to have been passed down to Medieval craftsmen, although the parchment is no longer dyed purple. Instead, purple is locally applied as a colour by brush. The animal source for parchment and the methods of manufacture have changed by this period. An ongoing project in cooperation with the Institute of Art History at the University of Zurich and the Institute for Natural Sciences and Technology in the Arts (INTK) of the Academy of Fine Arts Vienna further investigates the manufacture of the Dagulf psalter.

4.6 Conservation and Storage

The aim of the conservation treatment was to stabilise the folios in their current condition and to preserve them in the full richness of their authenticity (Janis 2005). Old mending materials were left in place as long as they were stable and did not pose a risk to the manuscript. We decided to remove the pressure sensitive tapes as they would potentially yellow and release adhesive into the parchment. Based upon our research, we concluded with the Director of the Collection of Manuscripts and Rare Books, Andreas Fingernagel, that the Vienna Genesis should remain with limited access to the original. Due to the light sensitivity of the orchil dye and the fragility of the ink, the folios should not be displayed, thus maintaining the policy since 1916. New digital images and a new facsimile edition offer advanced forms of access to the manuscript (Gastgeber, Hofmann, and Zimmermann 2019). The results of material analysis and condition assessment showed that the degraded parchment is very reactive to humidity; therefore, the impact of humidity on both, the parchment and the ink, must be minimised. Materials brought into contact with the manuscripts during treatment and storage must be chemically stable to avoid further corrosion. The future storage system should be air permeable and not exercise pressure on the parchment. The movement and flexing of the folios must be strictly limited to prevent deterioration of the inks and paint layers. When access to the original is allowed, it should be possible to view the material aspects of the codex as well as its full range of colours.

Pressure sensitive tapes that had been used to secure the folios in the polyacrylate sheets and to mend tears were mechanically removed. In keeping with the concept of our predecessors, we stabilised tears, fragile ink areas, and losses in the parchment with strips of remoistenable tissue bridging the endangered areas. During the testing phase, Berlin Tissue (2 g/m^2, *mitsumata* and *kozo* fibres) proved to provide sufficient support while integrating most subtly with the purple parchment and darkened ink (Rabitsch, Hofmann, and Sonderegger 2020c). Gangolf Ulbricht made the paper for us with *Aloe vera* as forming aid. The paper was coated with 5% Klucel® G in water. Klucel® in water is easier to apply by brush than Klucel® in ethanol. The Klucel® G layer can be activated with ethanol, thus minimising the impact of moisture. During testing, Klucel® G showed sufficient adhesive strength and minimal colour change after ageing (Rabitsch, Hofmann, and Sonderegger 2020c).

Small pieces of Berlin Tissue were tinted with watercolours (Schmincke Horadam) by brush to better integrate the repairs with the purple parchment and the dark ink. The watercolours are easier to apply to the thin tissue than chemical dyes, which are applied by immersion. The coloured Berlin Tissue passed the Oddy Test for permanent use. Klucel® G (5%) in water was brushed on a 5 mm thick silicon mould that had been made on the matt surface of frosted glass (Hofmann et al. 2015). A tinted piece of Berlin Tissue was placed on the wet adhesive layer and left to air dry. The textured surface of the silicon mould decreased the coating's gloss. For mending, small strips of remoistenable tissue (5 × 2 mm) were cut with a scalpel. A sponge cloth (10 × 10 cm) was immersed in a solution of 37 mL of ethanol and water, 3:1 v/v (Jacobi et al. 2011). The addition of one part water prevents the reactivated tissue from drying too quickly. Two sheets of blotting paper were put on the saturated sponge cloth on a water-resistant support. One strip of tissue paper at a time was reactivated on the sandwich of blotting paper and sponge cloth. The strip was placed on the parchment with tweezers, adhered under the slight pressure of a brush and dried under blotting papers and light weight

(Figure 9). In general, the tissue strips were applied on the rougher hair side of the folios. If necessary, the mend can be mechanically removed after moistening with ethanol. On the samples, the Klucel® G mends could be removed easily after ageing. The strips of coloured Berlin Tissue proved to be visually unobtrusive on the purple parchment and silver ink.

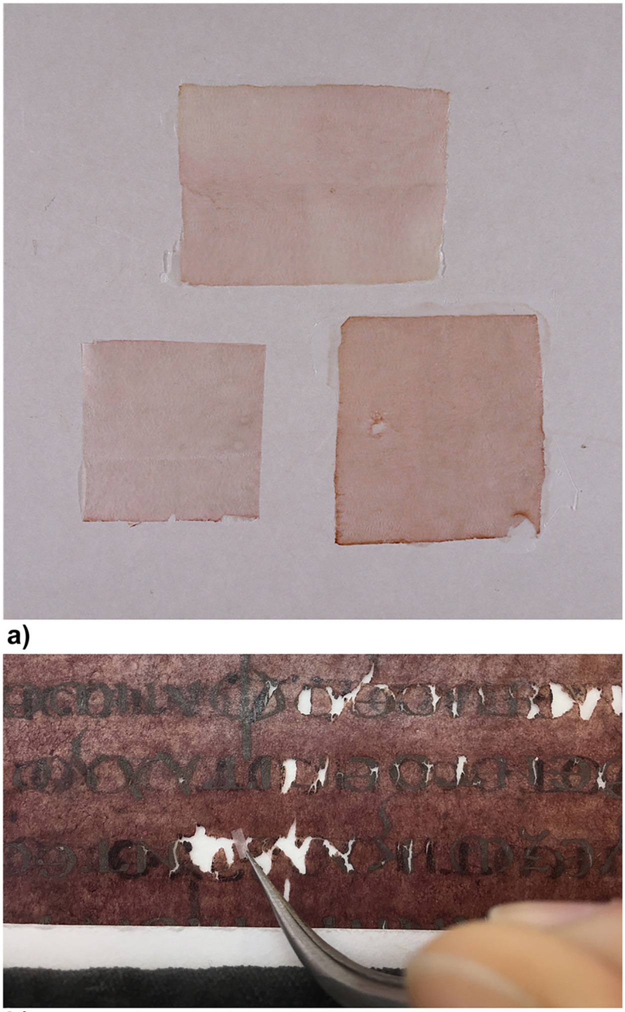

Figure 9: (a) toned and coated Berlin Tissue, (b) application of strips with tweezers.

Loose paint particles were consolidated with 1.5–2% isinglass. After pre-wetting with ethanol, isinglass was applied to the edge of the paint layer with a thin brush (00, Winsor Newton, Series 7) under the microscope. If necessary, the flaking paint layer was put down with a fine colour shaper (0, flat chisel, Royal Sovereign Ltd. UK) with a polyester interleave.

We limited the Japanese paper strips to the endangered parts to avoid changing the visual appearance of the manuscript and refrained from filling losses in the parchment. As a result, the folios remain fragile. In discussions about the storage system, we assumed that any kind of suspension of the folios in a double-sided window mount or in a frame would be too risky. In addition, we wanted to avoid gluing strips of Japanese paper on the margins of the parchment. The folios are preserved unbound. We wanted to maintain the possibility to visually reconstruct the former bifolios. The impression of the miniatures should not be changed by material covering the surface like a gauze or shiny plastic films. The direct contact of materials that could build up electric charges had to be avoided. These thoughts guided our decision for storage.

We opted for a folder in a sink mat. After discussions with colleagues, we modified and improved the model that was made of the storage system (Rabitsch, Hofmann, and Sonderegger 2020c). Each folio was stored in two folders of Japanese paper slightly larger than the folio. The inner folder was made of *Mitsumata* paper (6.5 g/m^2) and opens on the right side. The *Mitsumata* paper that is in direct contact with the folio has a smooth surface. The outer folder was made of *Mino* paper (18 g/m^2) and opens on the left side. The *Mino* paper is thicker and offers more support. The high-quality papers were handmade for us at the Association for Successors of Traditional Preservation Techniques in Japan (Appendix 6). The folios in the Japanese folders were put into individual folders made of museum matboard (Canson 1.8 mm). On the inside of the folders, frames of matboard (Canson 1.2 mm) function as spacers who were adjusted to the size and the amount of planar distortion of each folio (Figure 10). A click system of board was applied to keep the folders close (Figure 10). A piece of board on the left frame fits into a hole on the right frame. The matboard folder is stored in a sink mat with a cover. For diagrams of the construction see Rabitsch, Hofmann, and Sonderegger (2020c). The sink mat was made of museum board and archival corrugated board measuring 50 × 40 cm. With the help of cotton straps, the matboard folder can be easily removed from the sink mat. The folder can be turned around to view the folios from the verso while providing support. All access, if at all necessary, is to be overseen by a conservator. Three sink mats are stored in archival boxes made of corrugated board (Klug-Conservation). All materials used for storage passed the Oddy Test (Appendix 4) and can be used permanently in contact with sensitive

Figure 10: Matboard folder with frame and click system.

objects. Similar to the Oddy Test procedure, coupons of polished silver, copper, and lead were included in the three boxes for long term monitoring of pollutants. The Vienna Genesis is stored at 20 °C and 45% RH. In 2021, we monitored the condition of the folios by visual comparison with the digital images. The metal coupons were evaluated by Sabine Stanek from the Conservation Science Department of the Kunsthistorisches Museum Vienna and showed no unexpected signs of corrosion. The condition of the manuscript is considered stable. In the following yearly controls, we will monitor the purple colour of the parchment with a spectrophotometer.

5 Conclusion

Studying the Vienna Genesis from different points of view and with various techniques helped us to gain a deeper understanding of its components. Analysis, technological experiments, and comparison with other related manuscripts complemented one another. The results supported decisions for conservation. The exchange with experts from different fields was valuable in discussing results and adjusting decisions. The unique qualities of the Late Antique parchment should be preserved by allowing air exchange without the presence of pollutants. In the sink mats, the folios have space to remain without restraint. The soft surface of *Mitsumata* paper prevents abrasion. Contrary to the former polyester sheets, the paper folders do not build up electric charges. The solid museum board gives support and protection. In the folders the folios are accessible from both sides. Stabilisation of endangered areas in inks and paint layers will prevent further losses. We will continue to monitor the condition of the Vienna Genesis and if necessary, adjust our concept. Our treatment allows for improvements and further research.

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Appendices

1 Identification of the animal species with biomolecular analysis, eZooMS

Sarah Fiddyment and Matthew Collins developed electrostatic Zooarchaeology by Mass Spectrometry (eZooMS) in collaboration with conservators at the Borthwick Archive at the University of York. eZooMS uses the principle of Peptide Mass Fingerprinting (PMF) through ZooMS analysis. However, it has been adapted to cultural heritage objects with the addition of non-invasive sampling based on triboelectric extraction developed by Fiddyment and Collins (Fiddyment et al. 2015). The method involves gently wiping the surface of the parchment with a PVC eraser and collecting the resulting eraser crumbs to be analysed. Fiddyment analysed eraser crumb samples from all 24 folios of the Vienna Genesis and from one folio of the Codex Purpureus Petropolitanus. Eraser crumb samples were extracted in a saline solution with trypsin and incubated at 37 °C for 4 h. Samples were then desalted using a C18 filter tip before being spotted onto steel plates for subsequent Matrix Assisted Laser Desorption/Ionization – Time of Flight mass spectrometry (MALDI-TOF) analysis. Resulting spectra were analysed using PMF to determine the species of origin of the parchment.

2 XRF, XRD, and SEM/EDX

Micro X-ray fluorescence spectroscopy (µ-XRF)

Silver inks, pigments, and blank parchment were analysed with energy dispersive µ-X-ray fluorescence spectroscopy (µ-XRF) with a portable instrument, provided by the International Atomic Energy Agency (IAEA), Seibersdorf Laboratories, Nuclear Science and Instrumentation Laboratory. In order to minimize absorption losses of excitation and X-ray fluorescence radiation by air and thus provide an elemental range from sodium (Na) onwards, a vacuum chamber that can be evacuated 0.1 mbar forms the centrepiece of the spectrometer. Additionally, the spectrometer is equipped with a low-power Pd tube, which was run with an acceleration voltage of 50 kV, a current of 1 mA and a measuring time of 100 s for each measurement position. The spot size is 160 µm in diameter when focused using the polycapillary of the instrument, which is placed inside the compact vacuum chamber. The chamber is sealed with a Kapton window that allows positioning of the measurement head in front of the spot analysed using two laser pointers, which cross at about 1–2 mm distance in front of the spectrometer, at the focal spot of the polycapillary. For this procedure, an internal camera is used. The fluorescence radiation emitted by the investigated sample is collected by a Si drift detector (SDD) with an active area of 10 mm^2. Since an upright positioning of the folios was required by the arrangement of the spectrometer, each folio was mounted on a polyester foam with paper corners and fixed vertically on a perforated plate using a custom-made setup. The measurements were performed and evaluated by Katharina Uhlir and Antonia Malissa, the qualitative interpretation of the XRF-spectra was supported by the comparison with reference spectra of natural and synthetic pigments provided by the Conservation Science Department Kunsthistorisches Museum Vienna (KHM).

X-ray diffraction (XRD)

Micro-samples were taken from the silver ink of the Vienna Genesis to investigate the corrosion products. The analysis of the silver corrosion phases was performed by micro-X-ray diffraction (µ-XRD), i.e., with beam diameters of about 100–300 µm in contrast to the beam sizes in the mm-range for conventional X-ray diffraction techniques. For the investigation, a Malvern/PANalytical B.V. powder diffractometer EMPYREAN was used in symmetric θ -θ -geometry, where both the X-ray tube and the 2-dimensional GaliPIX photon detector are rotated symmetrically during the detection process of photons around the sample. A focusing reflection mirror, mounted in the primary beam, provided a monochromatic X-ray beam of a copper anode at the sample position with a wavelength of 0.15405 and 0.15443 nm,

$CuK_{\alpha1}$ and $CuK_{\alpha2}$, respectively. The energy of the X-ray beam allowed a penetration depth in the range of a few 10 µm, dependent on the material under investigation and the incident X-ray beam angle. Hence, the phase analysis was restricted to the near surface region in contrast to the bulk analysis by e.g., neutron diffraction methods with penetration depths about one order of magnitude higher. A 300 µm slit in horizontal direction ensured a small beam on the sample position. Thus, in principle a locally restricted phase analysis on the sample is possible. The xyz-table of the instrument allowed a scan range of ±28 mm in two directions, parallel to the sample surface, and 20 mm perpendicular to the sample surface to cover the different measured positions on the samples without remounting and re-adjusting of the whole sample set-up. Klaudia Hradil and her team at the X-ray centre of the Vienna University of Technology conducted the XRD measurements.

Energy dispersive X-ray analysis in the scanning electron microscope (SEM/EDX)

Micro-samples of silver ink from the Vienna Genesis were investigated by SEM/EDX. The samples were investigated in a FEI Quanta FEG 250 SEM in high vacuum mode unless specified otherwise. X-ray micro-analyses were performed with an EDAX system equipped with an Apollo X SDD detector. The samples were investigated in their state as delivered: no sample preparation was applied. Since in all samples from the Vienna Genesis the surface of the silver ink was contaminated with material consisting mainly of organic matter mixed with mineral particles, only point analyses were performed on spots where the surface of the silver ink appeared to be clean in BSE images. The results of EDX analysis were normalized to 100% wt%. The figures of detected elements were given in percentage per weight. Rudolf Erlach conducted the investigation with SEM/EDX at the Institute of Art and Technology of the University of Applied Arts Vienna.

3 Fibre Optical Reflectance Spectroscopy (FORS)

UV-visible diffuse reflectance spectrophotometry with optic fibres (FORS) analysis was performed with an Avantes (Apeldoorn, The Netherlands) AvaSpec-ULS2048XL-USB2 model spectrophotometer and an AvaLight-HAL-S-IND tungsten halogen light source. Detector and light source were connected with fibre optic cables to an FCR-7UV200-2-1.5x100 probe. In this configuration, light is sent and retrieved with a single fibre bundle positioned at 45° with respect to the surface normal, in order to exclude specular reflectance. The spectral range of the detector was 200–1160 nm. According to the features of the monochromator (slit width

50 μm, grating of UA type with 300 lines/mm) and of the detector (2048 pixels), the best spectral resolution was 2.4 nm calculated as FWHM (Full Width at Half Maximum). Diffuse reflectance spectra of the samples were referenced against the WS-2 reference tile provided by Avantes and guaranteed to be reflective at least at 98% within the investigated spectral range. Blank correction was not efficient on both the extremes of the spectral range, therefore the regions 200–350 and 1100–1160 were not considered in the discussion. The diameter of the investigated area on the sample was 1 mm. In all the measurements, the distance between the probe and the sample was kept constant at 2 mm, corresponding to the focal length of the probe. To visualise the samples, the probe was equipped with a USB endoscope. The instrumental parameters were as follows: 10 ms integration time, 100 scans for a total acquisition time of 1 s for each spectrum. The system was managed by means of AvaSoft v. 8 dedicated software, running under Windows 7. Maurizio Aceto and his team investigated the pigments and dyes of the Vienna Genesis, the Codex Sinopensis and the Dagulf Psalter.

4 Microspectrofluorimetry, surface enhanced Raman spectroscopy (SERS)

For microspectrofluorimetry, fluorescence excitation and emission spectra were recorded with a Jobin Yvon/Horiba SPEX Fluorog 3-2.2 spectrofluorometer hyphenated to an Olympus BX51 M confocal microscope, with spatial resolution controlled with a multiple-pinhole turret, corresponding to a minimum 2 μm and maximum 60 μm spot, with 50× objective. Standard dichroic filters used at 45° were used to collect the excitation spectra (570 and 620 nm) and emission spectra (540 and 570 nm). Emission spectra were acquired exciting at 530 and 560 nm, while excitation spectra were recorded collecting the signal at 590 and 630 nm. This enables the collection of both the emission and excitation spectra with the same filter holder. Spectra were acquired on a 30 or 8 μm spot (pinhole 8 and 5, respectively) with the following slits set: emission slits = 3/3/3 mm, and excitation slits = 5/3/0.8 mm. The optimization of the signal was performed for all pinhole apertures through mirror alignment in the optic pathway of the microscope, following the manufacturer's instructions. Spectra were collected after focusing on the sample (eye view) followed by signal intensity optimization (detector reading). Emission and excitation spectra were acquired on the same spot whenever possible. Maria J. Melo and her team analysed most of the reference samples *in situ*. The Vienna Genesis was analysed using micro-samples.

SERS analysis was undertaken by Maria J. Melo and her team using a Labram 300 Jobin Yvon spectrometer, equipped with a HeNe laser operating at 632.8 nm

(17 mW). Spectra were recorded as an extended scan. The laser beam was focused with 50× and 100× Olympus objective lens. The laser power at the surface of the sample varied with the aid of a set of neutral density filters (optical densities 0.6 and 1). The laser power at the surface of the samples was between 4.25 and 1.7 mW. No evidence of sample degradation was observed during spectra acquisition. More than three spectra were collected from the same sample and a silicon reference was used to calibrate the instrument. Silver colloids for SERS were prepared by chemical reduction of silver nitrate with sodium citrate, following the synthetic protocol published by Lee & Meisel (Lee and Meisel 1982). SERS analysis was performed after deposition of 0.8 µL of the silver colloid and 0.1 µL of 0.5 mol L^{-1} KNO_3 aqueous solution onto the microsample. All spectra were collected by focusing the laser beam onto the microaggregates that formed inside the dye-colloid droplet a few seconds after the deposition of the silver nanoparticles and KNO_3. Spectra were acquired continuously until the droplet dried out.

5 Oddy Test

The materials for storage were evaluated with the Oddy Test, a method developed by Andrew Oddy at the British Museum in 1970s. The Oddy Test is an accelerated corrosion test that observes the effect of pollutants emitted by the materials to be evaluated on three metal coupons (silver, copper, lead). The materials to be evaluated are exposed to 60 °C and 100% RH for 28 days. The roughened surface of the metal coupons enhances reactivity. The materials are classified in three groups:
P – materials for permanent exhibition use
T – materials for temporary use (maximum 6 months)
U – materials unsuitable for contact with valuable objects

Sabine Stanek conducted the Oddy Tests at the Conservation Science Department, Kunsthistorisches Museum Vienna (KHM).

6 Japanese Papers

Mitsumata and *Mino* papers were hand and custom made by Eikan Ebuchi in Kochi, a paper maker who is a member of the Association of Successors of Traditional Preservation Techniques in Japan. The fibres were cooked with soda ash (sodium carbonate, Na_2CO_3 decahydrate). Natural *neri* from *tororo-aoi* was used as mucilage. The papers were dried on wooden panels.

References

Aceto, M., A. Angelo, G. Fenoglio, P. Baraldi, P. Zannini, C. Hofmann, and E. Gamillscheg. 2012. "First Analytical Evidences of Precious Colourants on Mediterranean Illuminated Manuscripts." *Spetrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 95: 235–45.

Aceto, M., M. João Melo, E. Calà, P. Nabais, and R. Araújo. 2020a. "Identification of the Purple Dye on the Vienna Genesis." In *The Vienna Genesis: Material Analysis and Conservation of a Late Antique Illuminated Manuscript on Purple Parchment*, edited by C. Hofmann, 103–18. Wien: Böhlau Verlag.

Aceto, M., E. Calà, A. Angelo, G. Fenoglio, M. Labate, C. Förstel, C. Denoël, and A. Quandt. 2020b. "Non-Invasive Study on the Sinope Gospels." *Heritage* 3: 1269–78.

Ahn, K., A. Hartl, C. Hofmann, U. Henniges, and A. Potthast. 2014. "Investigation of the Stabilization of Verdigris-Containing Rag Paper by Wet Chemical Treatments." *Heritage Science* 2: 12–4.

Bicchieri, M. 2014. "The Purple Codex Rossanensis: Spectroscopic Characterisation and First Evidence of the Use of the Elderberry Lake in a Sixth Century Manuscript." *Environmental Science and Pollution Research* 21: 14146–57.

Denoël, C., P. R. Puyo, A. Brunet, and N. Poulain Siloe. 2018. "Illuminating the Carolingian Era: New Discoveries as a Result of Scientific Analyses." *Heritage Science* 6 (1): 1–19.

Di Majo, A., S. Fiddyment, and F. Pascalicchio. 2020. "Pergamene a nudo: indagini sulla specie animale." In *Il Codex Purpureus Rossanensis*, Vol. 2, edited by M. L. Sebastiani, and P. Cavalieri, 25–37. Quaderni Ottanta di storia dell'Istituto. Roma: Gangemi Editore.

Fiddyment, S., B. Holsinger, C. Ruzzier, A. Devine, A. Binois, U. Albarella, and R. Fischer. 2015. "Animal Origin of 13th-Century Uterine Vellum Revealed Using Non-Invasive Peptide Fingerprinting." *Proceeding of the National Academy of Sciences of the United States of America* 112 (49): 15066–71.

Gastgeber, C., C. Hofmann, and B. Zimmermann. 2019. *Die Wiener Genesis*. Luzern: Quaternion Verlag.

Hofmann, C., ed. 2020. *The Vienna Genesis: Material Analysis and Conservation of a Late Antique Illuminated Manuscript on Purple Parchment*. Wien: Böhlau Verlag.

Hofmann, C., A. Hartl, K. Ahn, I. Faerber, U. Henniges, and A. Potthast. 2015. „Studies on the Conservation of Verdigris on Paper." *Restaurator* 36 (2): 147–82.

Hofmann, C., and S. Rabitsch. 2020. "The History of the Vienna Genesis and Former Interventions Since 1664." In *The Vienna Genesis: Material Analysis and Conservation of a Late Antique Illuminated Manuscript on Purple Parchment*, edited by C. Hofmann, 11–34. Wien: Böhlau Verlag.

Hofmann, C., S. Rabitsch, A. Malissa, M. Aceto, K. Uhlir, M. Griesser, E. Calà, A. Angelo, and G. Fenoglio. 2020. "The Miniatures of the Vienna Genesis: Colour Identification and Painter's Palettes." In *The Vienna Genesis: Material Analysis and Conservation of a Late Antique Illuminated Manuscript on Purple Parchment*, edited by C. Hofmann, 201–46. Wien: Böhlau Verlag.

Holter, K. 1980. *Der goldene Psalter, Dagulf Psalter*. Graz: Akademische Druck- und Verlagsanstalt.

Jacobi, E., B. Reissland, C. Phan Tan Luu, B. Van Velzen, and F. Ligterink. 2011. “Rendering the Invisible Visible. Preventing Solvent-Induced Migration During Local Repairs on Iron Gall Ink.” *Journal of Paper Conservation* 12 (2): 25–34.

Janis, K. 2005. *Restaurierungsethik im Kontext von Wissenschaft und Praxis*. Stuttgart: Martin Meidenbauer.

Lee, P. C., and D. Meisel. 1982. “Adsorption and Surface Enhanced Raman of Dyes on Silver and Gold Sols.” *Journal of Physical Chemistry* 86: 3391–5.

Mazal, O. 1980. *Kommentar zur Wiener Genesis*. Frankfurt am Main: Insel Verlag.

Quandt, A. 2011. “Conserving the Archimedes Palimpsest.” In *The Archimedes Palimpsest, 1: Catalogue and Commentary*, edited by R. Netz, W. Noel, N. Wilson, and N. Tchernetska, 128–71. Cambridge: Cambridge University Press.

Quandt, A., P. Colaizzi, and F. Pinzari. 2020. “Reperti microscopici e un’ ipotesi archeologica riguardante il Codex Purpureus Rossanensis.” In *Il Codex Purpureus Rossanensis*, edited by M. L. Sebastiani, and P. Cavalieri, 45–95: Quaderni Ottanta di storia dell’Istituto, volume n. 2, dell’Istituto Centrale per il Restauro e la Conservazione del Patrimonio Archivistico e Librario. Roma: Gangemi Editore.

Rabitsch, S., I. Boesken Kanold, and C. Hofmann. 2020a. “Purple Dyeing of Parchment.” In *The Vienna Genesis: Material Analysis and Conservation of a Late Antique Illuminated Manuscript on Purple Parchment*, edited by C. Hofmann, 71–101. Wien: Böhlau Verlag.

Rabitsch, S., A. Malissa, K. Hradil, R. Erlach, K. Uhlir, M. Griesser, and C. Hofmann. 2020b. “The Silver Inks of the Vienna Genesis.” In *The Vienna Genesis: Material Analysis and Conservation of a Late Antique Illuminated Manuscript on Purple Parchment*, edited by C. Hofmann, 119–200. Wien: Böhlau Verlag.

Rabitsch, S., C. Hofmann, and J. Sonderegger. 2020c. “Conservation of the Vienna Genesis and the New Storage System.” In *The Vienna Genesis: Material Analysis and Conservation of a Late Antique Illuminated Manuscript on Purple Parchment*, edited by C. Hofmann, 247–86. Wien: Böhlau Verlag.

Vnouček, J. 2019. “The Language of Parchment. Tracing the Evidence of Changes in the Methods of Manufacturing Parchment for Manuscripts with the Help of Visual Analyses.” PhD diss., Department of Medieval Studies, University of York.

Vnouček, J. 2021. “Not all that Shines like Vellum is Necessarily So.” *Care and Conservation of Manuscripts* 17: 27–59.

Vnouček, J., S. Fiddyment, A. Quandt, S. Rabitsch, M. Collins, and C. Hofmann. 2020. “The Parchment of the Vienna Genesis: Characteristics and Manufacture.” In *The Vienna Genesis: Material Analysis and Conservation of a Late Antique Illuminated Manuscript on Purple Parchment*, edited by C. Hofmann, 35–69. Wien: Böhlau Verlag.

Wächter, O. 1962. “The Restoration of the Vienna Dioscorides.” *Studies in Conservation* 7 (1): 22–6.