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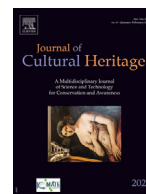
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Original article

Practices of the Mont Saint-Michel scriptorium in the use of parchment for manuscripts in the 11th century

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ABSTRACT

The Mont Saint-Michel abbey in Normandy, France, was an important pilgrimage site in Christianity, and its scriptorium produced numerous manuscripts between the end of the 10th and the middle of the 13th century. The present study investigates the practice of the Mont Saint-Michel scriptorium in the use of parchment to produce manuscripts in the 11th century, based on a corpus of 67 manuscripts produced between 980 and 1100. The combination of information gained from the codicological studies, proteomic analyses and thickness measurement of the parchments, revealed that copyists and/or artists deliberately select the type of skin depending on the content of the folio or the status of the manuscript. Thus, only sheep parchment is used for folios with text or only lightly illuminated manuscripts, while calf parchment is selectively used for the most valued part in the manuscript, such as full-page illuminations and often large ornate letters opening the manuscripts. For the most prestigious manuscripts, which concern four volumes in the corpus, calfskin is used in the entire manuscript, with the occasional addition in the Mont Saint Michel Sacramentary of goatskin, confirming the special status of these manuscripts for liturgical use. The demonstration of these practices constitutes for historians invaluable information on the parchment production at the time, as well as insight into the manuscript or folio significance.

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1. Introduction

The Mont Saint-Michel abbey in Normandy, France, was an important pilgrimage site in Christianity, and this monastery was also an influential spiritual, cultural and intellectual center. Its scriptorium produced numerous manuscripts between the end of the 10th and the middle of the 13th century, which are today conserved for the major part in the patrimonial library of Avranches in Normandy, as well as in other French libraries and archives (Paris, Rouen, Bordeaux, Caen) or abroad (Berlin, London, New York, Vatican...) (Table 1). Since 2017, more than one hundred of them are accessible online on the virtual library of Mont Saint-Michel [1]. This corpus has been preserved from the different historic events that often led to looting, dispersion or destruction of medieval manuscripts. This exceptional collection constitutes a testimony of the writing and illuminating practices over a large period of time,

for that reason a research project was started in France in 2018 to characterize the different constitutive materials, namely the parchment, the coloring materials and the inks, in order to retrace the copyists and the artists practices.

The present study focuses on manuscripts from the Romanesque period (end of 10th – 12th century), and in particular those dated before 1100. This corpus benefits from the previous codicology studies made by Alexander and Avril that allowed to define four group periods based on their layout, decoration and writings, proposed a chronological classification and attributed some manuscripts to known copyists (Table 1) [2,3]. For the *Early group* and the *Transitional group*, the decor is mainly made up of colored capital letters in titles and some beautiful ornate letters in Carolingian style (Fig. 1A and B). The *Middle group* corresponds to the Roman artistic apogee of the Mont Saint-Michel, with very rich full-page illuminations and a large color palette, as well as many beautiful ornate letters of Anglo-Saxon influence, in Winchester style (Fig. 1C and D). The *Late group* is also a very rich artistic period. If full-page illuminations are less frequent and the color palette is reduced compared to the *Middle Group*, the ornate letters

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Table 1

Listing of the 11th century manuscripts from the Mont Saint-Michel known in collections and grouping made by Alexander [2]. * Manuscripts which production was attributed to a different provenance based on this project.

	<i>Early group (980–1020)</i>	<i>Transitional group (1015–1040)</i>	<i>Middle group (1035–1075)</i>	<i>Late group (1065–1100)</i>
Patrimonial library of Avranches	12 manuscripts Ms 35 part 2. (f. 194–316) Ms 50* Ms 69 part. 2 (f. 119–302) Ms 78 Ms 95 Ms 97 part. 1 (f. 1–257) Ms 98* Ms 109 part. 2 (f. 37–73) Ms 211 part. 2 (f. 156–210) Ms 229 part. 2 (f. 116–190) Ms 229 part. 4 (f. 193–230) Ms 240	10 manuscripts Ms 38 Ms 68 part. 1 (f. 1–112) Ms 70 Ms 79* Ms 91 Ms 99 Ms 105 part. 2 (f. 6–177) Ms 115 Ms 128 part. 1 (f. 1–270 + 280–284) Ms 129*	17 manuscripts Ms 51 Ms 59 Ms 61 part. 2 (f. 111–316) Ms 61 part. 3 (f. 317–343) Ms 72 part. 1 (f. 1–95) Ms 72 part. 2 (f. 96–149) Ms 72 part. 3 (f. 150–181) Ms 72 part. 4 (f. 182–199) Ms 75 Ms 76 Ms 77 Ms 86 part. 1 (f. 3–57) Ms 86 part. 2 (f. 58–135) Ms 90 Ms 97 part. 2 (f. 257–264) Ms 101 Ms 107	15 manuscripts Ms 9 Ms 35 part. 1 (f. 74–193) Ms 47 Ms 57 (f. 49–110) Ms 58 Ms 61 part. 1 (f. 1–110) Ms 73 Ms 82 Ms 86 part. 3 (f. 136–173) Ms 89 Ms 102 Ms 103 Ms 128 part. 2 (f. 271–279) Ms 146 Ms 163
Other french libraries	AD Calvados, Caen: 1 manuscript 6G/56 BnF, Paris: 3 manuscripts latin 5920 latin 8055 part. 2 (p. 141–178) latin 8070 part. 1 (f. 1–129)		BnF, Paris: 4 manuscripts latin 2055 latin 2088 latin 2639 part. 2 (f. 31–54) BM Rouen: 3 manuscripts mm 15 (suppl. CGM 116) A. 143 (CGM 427) A. 178 (CGM 425) BM Bordeaux: 1 manuscript (2 Vol.) BM1 (vol. I and II)	BnF, Paris: 1 manuscript latin 5290 part. 1 (f. 1–21) latin 8055 part. 1 (p. 1–140)
International libraries	Vatican: 1 manuscript Reg. lat. 2043	Vatican: 1 manuscript Vat. lat. 9668	Morgan Library & Museum, New York: 1 manuscript M.641	SB Berlin: 1 manuscript Phillipps 1854 BL London: 2 manuscripts Royal 13.A.XXII Royal 13.A.XXIII
Copists	<i>Hervardus, Martinus, Galtherius</i>	<i>Giraldus, Rannulfus, Warinus</i>	<i>Frotmundus, Gyraldus, Antonius</i>	<i>Osbernus, Ermenaldus, Mauritius, Nicholaus,</i>
	17 manuscripts	11 manuscripts	26 manuscripts	20 manuscripts

remain rich, beautiful and numerous (Fig. 1E and F). The objective of the research is to confirm and complement these attributions from the physico-chemical analysis of the constitutive materials, but also to provide chronological markers for the manuscripts produced in this scriptorium.

Parchment was the main writing support in Europe during the medieval period due to its exceptional qualities that are its strength, whiteness, thinness, stiffness, and flexibility. In contrast to papyri, writing can be applied on its both sides and the sheets can be bound into books. Parchment was prepared from an animal skin, that has been basically dried and scraped under tension, after removal of the hair and flesh, to obtain a thin and uniform material [4]. Parchment manufacturing process and animal type vary according to the geographical location and the historical period [5]. In Europe, the skin of domesticated animals, so that of calf, sheep or goat, were mostly used to make parchment, nevertheless the quality and thus the value of the obtained parchment greatly varied with the animal age and species. Calfskin gives the highest quality parchment, often named vellum in ancient text, as it was produced from the skin of young animal (6 weeks old max-

imum) and showing the less imperfection. Sheepskin and goatskin parchments instead had to be produced from adult animal, therefore the parchment often display marks of the life of the animal (scars, parasite or insect marks), especially on the side exposed to the environment (grain side, where the hair was). The skin of an adult sheep also contains more fat causing the parchment to become yellow if the fat has not been fully eliminated; as a result, sheepskin parchment was considered to be of lowest quality and was thus cheaper [6]. This type of skin, thinner and more fragile, is also more sensitive to tears during the preparation of the skins. Several analytical studies focused on the identification of the parchment animal species and evidenced the tendency to use sheepskin for ordinary parchment in non-religious texts and select specially calfskin parchments for the most sacred and valuable books such as biblical manuscript [6]. The study on the pocket bible produced in Europe in the 13th century is a good illustration of the use of calfskin for the manufacturing of these precious books [7]. The biocodological analysis of the medieval library and archive from Orval abbey, Belgium, revealed for its golden age in the 13th century, an equal representation of sheep and calf skins,



Fig. 1. Example of decors encountered in the studied corpus for each group: Early group (A, Ms97f223v), Transitional group (B, Ms91f2r), Middle group (C, Ms86f4r and D, Ms72f97r), Late group (E, Ms89f96r and F, Ms58f3v).

with calfskin reserved for biblical manuscripts [6]. Although it provided high quality parchment, the occurrence of goatskin is very limited in medieval manuscripts, and its use appears virtually absent in the North of the Alps [6].

Animal species identification can be accessed from visual observation of the hair follicles pattern on the parchment grain surface, however these follicles are not always visible, especially if the parchment has been heavily prepared through scraping and pouncing, as it is the case for calfskin parchment, or may be too limited and distorted to allow a reliable identification. As a result, the large development of proteomic analyses in the cultural heritage laboratories in the recent years, has opened up a new study area, as it offers a simple, low-cost and unambiguous method to identify animal species of materials in heritage collections [7–13]. This approach that relies on the analysis of the collagen protein, main constituent of parchment, only requires a minute sample of few fibres of parchment. These tiny samples can be collected directly using a fine pair of tweezers or through rubbing the parchment surface, to take advantage of the triboelectric effect [8]. This technique has been applied to large corpus of medieval manuscripts to investigate the practice in the use of parchments in a specific location (region, abbey), period in time or type and status of the document [6–10]. By extending combined studies of coherent manuscript collections by proteomic analysis and codicological examination, it will be possible to better understand the different scriptorium practices and possibly draw a geographical map of the parchment production in Europe in the Middle Ages.

2. Research aim

The aim of this research is to investigate the Mont Saint-Michel scriptorium practice in the use of parchment to produce manuscripts in the 11th century. The paper discusses the results obtained from the identification of the animal species of the parchments in a coherent corpus of 67 manuscripts produced in the Mont Saint-Michel scriptorium between 980 and 1100 (54 con-

served in Avranches, 12 conserved in other French libraries and archives and 1 conserved abroad). From the combination of the animal species and the thickness of the parchment folios with codicological data of each manuscript, we are able to evidence a specific practice in the choice of this support material for illumination and writing in this scriptorium over the period.

3. Materials and methods

3.1. Corpus of manuscripts and sampling

The parchment folios were analysed in a corpus of 67 manuscripts all produced, or thought to be produced initially, at the Mont Saint-Michel scriptorium between 980 and 1100. The corpus includes:

- Fifty-four manuscripts contained in 46 volumes conserved at the Avranches library
- Seven manuscripts contained in six volumes conserved at the French national library (BnF) in Paris: latin 2055, latin 2088, latin 2639, latin 5290, latin 5920, latin 8055 (part. 1 and 2).
- One manuscript contained in two volumes conserved in Bordeaux library: BM1 (vol I and II)
- One manuscript conserved in the Calvados departmental archive (AD) in Caen: 6G/56
- Three manuscripts conserved in the Rouen library: mm15 (suppl CGM 116), A.143 (CGM 427), A.178 (CGM 425)
- One manuscript conserved at the Morgan Library and Museum in New York (NYC): M.641

The dating and classification of these manuscripts according to Alexander's group can be found in Table 1. Full description of the manuscripts and digital images can be accessed from the virtual library of the Mont Saint-Michel [1]. The Sacramentary of the Mont Saint-Michel was split in two manuscripts at some point in its life, the highly decorated part that includes twelve full page illuminations is conserved in manuscript M.641 at the Morgan Library and

Museum in New York and the other 45 leaves are conserved in manuscript mm15 in Rouen library.

For the proteomic analyses, samples of few parchment fibres (~10 µg) are taken from the manuscript's parchment folio using a fine pair of tweezers and then stored in 500 µL Eppendorf tubes. Sampling areas are chosen so as to avoid writings, decorations, weakened or damaged zones, as well as heavily manipulated areas. In most of the manuscripts a minimum of 3 folios originating from different quires were sampled, resulting in a total of 317 folios over 67 manuscripts. The list of folios analysed within each manuscript can be seen in supplementary material Tables S2 and S3.

3.2. Proteomic analyses

The enzymatic digestion is performed based mainly on the procedure described by Kirby [11]. Ultrapure water (Milli-Q®) was used throughout. 60 µL of Ammonium bicarbonate (AMBI) 50 mM is added to the Eppendorf tubes containing the samples and heated at 80 °C for 1 hour. After cooling at room temperature, samples are placed in an ultrasound bath for 10 min and then heated again at 80 °C for 30 min. Samples are cooled to room temperature (RT) and 3 µL of 20 mM Tris(2-carboxyethyl)phosphine hydrochloride (TCEP) in 50 mM AMBI is added. Incubation at 37 °C is performed for 20 min. Samples are cooled to RT and 3 µL of 40 mM Iodoacetamide (IAA) in 50 mM AMBI and followed by incubation in the dark for 30 min. 8 µL of trypsin (0.02 µg.L⁻¹ in 50 mM AMBI) is added, and incubation at 37 °C overnight in the dark is carried out. 1 µL of 10% (v/v) Trifluoroacetic acid (TFA) is added to end the digestion. If not used directly, samples are stored at -20 °C prior to ZipTip fractionation. Digest samples are loaded onto a C18 ZipTip® pipette tips which has been conditioned with 50:50 Acetonitrile (ACN)/0.1% TFA (v/v) followed by 0.1% TFA. Loaded samples are washed with 0.1% TFA and eluted with 50:50 ACN/0.1% TFA (v/v). Sample solution from each ZipTip® fraction (0.3 µL) is spotted onto a target plate, mixed with 0.6 µL of αCHCA matrix solution (30% ACN in H₂O) and dried at room temperature for crystallization. The fraction of each digest is analysed in duplicate by MALDI-MS using an AB Sciex MALDI TOF/TOF 5800 Applied mass spectrometer equipped with a pulsed Nd:YLF (Neodymium-dopedyttriumlithiumfluoride) laser at 345 nm, in positive and reflector mode. Mass spectra are acquired over the *m/z* range 700–4000 Da with an accumulation of 2000 shots. Each sample spectra are manually calibrated against an adjacent external calibrant spot containing a peptide mix 4 (Laser Bio labs, Sophia-Antipolis, France). Peptides markers from sample spectra are compared with an internal mass spectra database. Mass spectra are visualized with mMass software. Table S1 in the supplementary materials shows the *m/z* values of markers peptides used to identify animal species. Those peptides markers of known type I collagen (α1 and α2 chains) sequence are sufficient sequence variation to distinguish the three major mammal species used in the production of parchment for French medieval manuscript: calf, sheep and goat.

3.3. Parchment thickness measurement

The thickness of the parchment folios is measured using a digimatic micrometer Mytutoyo CLM-QMX with a force of 2.5 N. Measurements were taken in the middle of each folio edge (top, side and bottom) up to 25 mm within the parchment folio. The measurements were carried out on folios that has been analysed by proteomic analysis in a selection of 27 manuscripts across each group. For each folio, the measurements were repeated three times in each location and the nine values were averaged and the standard deviation calculated. The list of manuscripts and folios analysed is provided in supplementary material Tables S2 and S3.

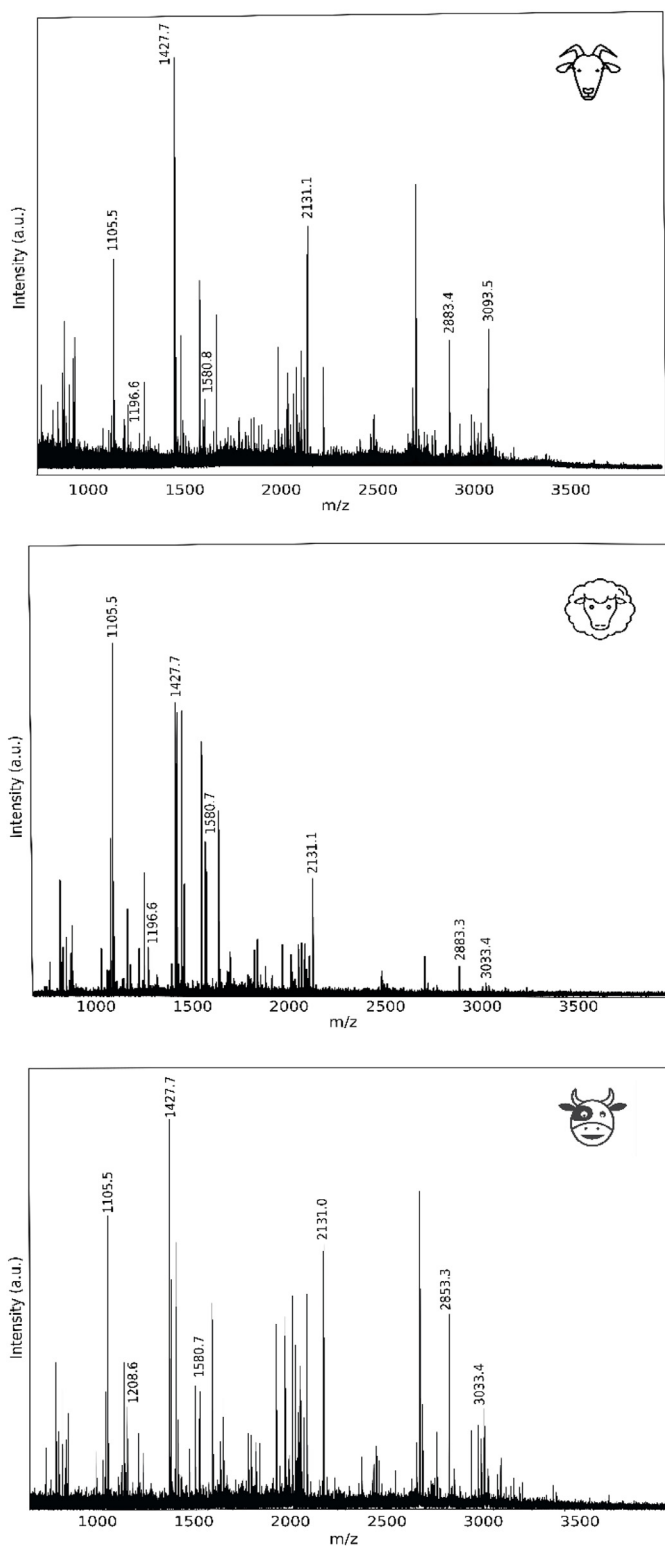


Fig. 2. MALDI spectra of goat parchment from M.641f61, sheep parchment from Ms70f109 and a calf parchment from Ms59f1.

4. Results and discussions

Amongst the 67 manuscripts analysed, the mass spectra obtained by proteomic analyses revealed the presence of ovine or bovine markers and occasionally caprine markers in the case of one manuscript (Fig. 2). Therefore, the animal species used for the

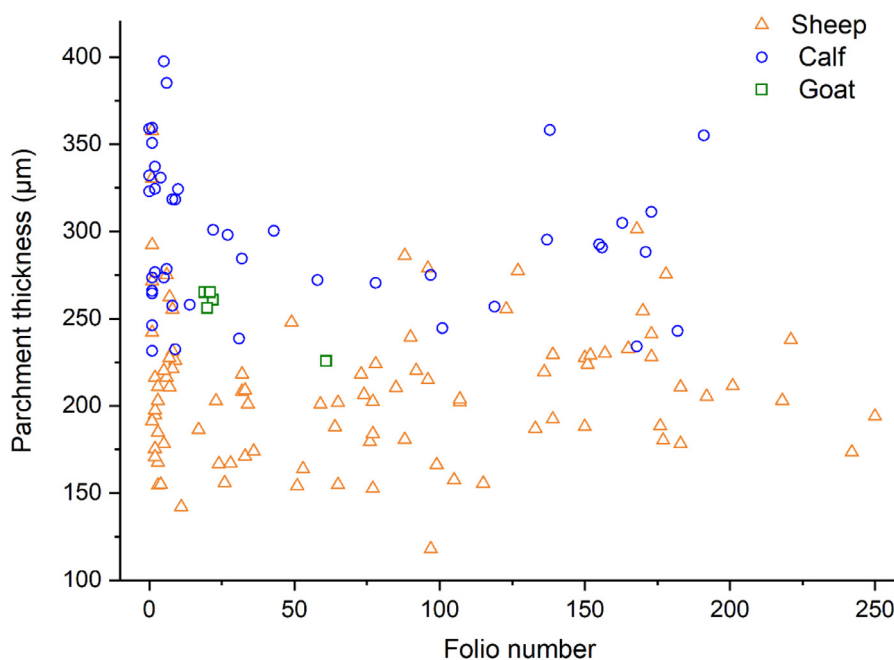


Fig. 3. Parchment thickness as a function of the folio number (position in the volume) and animal species in the manuscripts.

production of parchment in the corpus are sheepskin in the majority of the folios, minor calfskin and punctually goatskin. Over time, while flipping through a manuscript, it became possible to spot isolated calf folios from the touch and observation, since calfskin was always more uniform with sometimes a velvety surface on the flesh side and appeared thicker. As a result, we occasionally increased the number of folios sampled per manuscript to confirm our empirical identification, which was always confirmed by proteomic analyses. Therefore, although all the folios in the manuscript corpus could not be analysed, we are pretty confident that all the calfskin folios have been identified.

The difference in parchment thickness felt was confirmed from the measurements carried out on selected manuscripts, with greater thickness for calfskin, ranging from 250 to 350 μm in average, compared to 150 to 250 μm in average in sheepskin parchments (Fig. 3). For the few goat skin folios measured, the parchment thickness is intermediate varying between 230 and 265 μm . For calf and sheep parchments, thicker parchments are generally encountered for the first folio of the manuscript, or parchments with full page illumination that used to be the first folio (Fig. 3). Additionally, thicker sheep parchments with values over 250 μm is also observed further in the Mont Saint-Michel Bible BM1. This manuscript being the largest in size for this corpus with 530 \times 360 mm, it is likely that older animals have been used to make the parchment, resulting in thicker folios. The results of the animal species identified and the average thickness measured for all the parchment folios analysed are given in Table S2 in supplementary materials.

The results also reveal an evolution in the scriptorium practice in the use of the type of parchment over the 120 years period considered, and evidence a strategy in the selection of the parchment animal species depending on the content or type of manuscript (Table 2). This change in practice is directly linked to the evolution of the illuminating practice in the scriptorium. However, several exceptions are observed over the period that could be related to the manuscript status.

The period between approximately 980 and 1040, covering the *Early* and *Transitional group*, is characterised by a great constancy with the use of almost exclusively sheepskin. Within the twenty

manuscripts from this period, four exceptions are noticed. In the case of Ms 240, only a single calfskin bifolio (f39 and f44) is found among the whole sheepskin parchment manuscript. Its presence appears accidental, since no element in the content of the text nor particularities in the layout or the decoration helped to understand this rupture. In the case of Ms 105 part.2, we observe an insert of three parchment folios (f100–102), which is a practice carried out around 1060–1080 to introduce a table of chapters. The folio in the middle is in calfskin (f101) while the surrounding bifolio is in sheepskin (f100 and f102). No motivation explains this choice except possibly the parchment availability. The situation is very different for the other two exceptions, both corresponding to prestigious manuscripts. The Ms 211 part 2, copied between 990 and 1015, was made only with calfskin with a single sheepskin bifolio likely present accidentally (f176 and f177). This is a very special manuscript, remarkably calligraphed by the well-known copyist of Mont Saint-Michel Hervardus. It contains essential hagiographic texts on the Archangel Saint Michael, namely the account of his appearance on Mount Gargan in Italy at the end of the 5th century (*Apparitio*), followed by the account of his appearance on Mount Tombe, which led to the foundation of Mont Saint-Michel at the beginning of the 8th century (*Revelatio*). Given the recent reattribution of the provenance of Ms 50 to an abbey in the Loire Valley [14], the Ms 211 thus becomes the oldest manuscript conserved to be produced in the Mont Saint-Michel scriptorium. Moreover, the enhancement of the decor on the folio f156 of this manuscript with gold, lapis lazuli and lead white between the middle and the third quarter of the 11th century (Fig. 4), confirms the great value of this manuscript for the surrounding community. The second unusual case is Ms 128 part. 1, dated between 1015 and 1035, which is a collection of homilies by the Fathers of the Church and great exegetes. Used almost daily for liturgical activities, this manuscript had a special function and was of particular importance to the Mont Saint-Michel community. It is made up ofquires that are sometimes made of calfskin (especially for the oldest parts, but also for certain more recent additions), and sometimes of sheepskin. Codicological analysis reveals that we are dealing with a collection made up of several generations of copyists active between the years 1020/1030 and 1070/1080; the changes

Table 2

Animal species identified for the parchments of the corpus of 11th century Mont Saint-Michel manuscripts according to the type of decor. () correspond to the occurrence of a single bifolio. * parchment tab likely from a folio with an illumination that has been cut out.

	Date	Location	Illumination	Ornate letter	Text
Early group					
MS 78	980–1000	Avranches		Sheep	Sheep
MS 35 part. 2 (f. 194–316)	990–1015	Avranches			Sheep
MS 69 part. 2 (f. 119–302)	990–1015	Avranches			Sheep
MS 95	990–1015	Avranches			Sheep
MS 97 part. 1 (f. 1–257)	990–1015	Avranches		Sheep	Sheep
MS 109 part. 2 (f. 37–73)	990–1015	Avranches			Sheep
MS 211 part. 2 (f. 156–210)	990–1015	Avranches		Calf	Calf (Sheep)
MS 229 part. 2 and 4	990–1015	Avranches			Sheep
MS 240	990–1015	Avranches			Sheep (Calf)
Latin 8055 part. 2 (p 141–178)	990–1015	Bnf		Sheep	Sheep
MS 6G/56	1000–1020	Caen		Sheep	Sheep
Latin 5920	1000–1025	Bnf		Sheep	Sheep
Transitional group					
MS 105 part. 2 (f.6–177)	1000–1035	Avranches		Sheep	Sheep (Calf)
MS 68 part. 1 (f. 1–112)	1015–1035	Avranches			Sheep
MS 70	1015–1035	Avranches		Sheep	Sheep
MS 99	1015–1035	Avranches		Sheep	Sheep
MS 115	1015–1035	Avranches	Sheep	Sheep	
MS 128 part. 1 (f. 1–270, 280–284)	1015–1035	Avranches		Calf	Calf/Sheep
MS 91	1015–1040	Avranches		Sheep	Sheep
MS 38	1015–1040	Avranches		Sheep	Sheep
Middle group					
MS 61 part. 3 (f.317–343)	1030–1045	Avranches			Sheep
MS 101	1030–1045	Avranches		Sheep	Sheep
MS 59	1030–1045	Avranches	Calf	Calf/Sheep	Sheep
MS 61 part. 2 (f. 111–316)	1040–1055	Avranches	Calf*	Sheep	Sheep
MS 72 part. 1, 2, 3 and 4	1040–1055	Avranches	Calf	Calf/Sheep	Sheep
MS 75	1040–1055	Avranches	Calf	Calf	Sheep
MS 76	1040–1055	Avranches	Calf	Calf	Sheep
MS 107	1040–1055	Avranches			Sheep
A. 143	1058–1061	Rouen		Sheep	Sheep
MS 90	1050–1065	Avranches	Calf	Calf/Sheep	Sheep
Latin 2639	1050–1065	Bnf	Calf	Calf	Sheep
mm 15	1050–1065	Rouen		Calf (goat)	Calf
M. 641	1050–1065	NYC	Calf (goat)	Calf	Calf
MS 51	1055–1060	Avranches		Sheep	Sheep
MS 77	1055–1080	Avranches		Calf	Sheep
MS 86 part. 1 (f. 3–57)	1055–1080	Avranches		Calf/Sheep	Sheep
MS 86 part. 2 (f. 58–135)	1055–1080	Avranches		Calf	Sheep
Latin 2055	1055–1080	Bnf		Calf	Sheep
Latin 2088	1055–1080	Bnf	Calf	Calf	Calf
Ms 97 part. 2 (f. 257–264)	1060–1080	Avranches			Sheep
BM 1	1050–1100	Bordeaux	Calf/Sheep	Calf/Sheep	sheep
Late group					
BM 1	1050–1100	Bordeaux	Calf/Sheep	Calf/Sheep	sheep
MS 103	1065–1072	Avranches	Calf	Calf	Calf/Sheep
MS 86 part. 3 (f. 136–173)	1065–1080	Avranches		Calf	Sheep
MS 163	1065–1080	Avranches	Sheep	Calf	Sheep
Latin 5290 part. 1 (f 1–21)	1065–1080	Bnf		Calf	Sheep
MS 128 part. 2 (f. 271–279)	1065–1080	Avranches			Calf
MS 61 part. 1 (f. 1–110)	1065–1080	Avranches		Calf	Sheep
A. 178	1065–1085	Rouen		Calf/Sheep	Sheep
MS 58	1065–1090	Avranches		Calf	Sheep
MS 73	1070–1085	Avranches			Sheep
Latin 8055 part. 1 (p 1–140)	1070–1095	Bnf			Sheep
MS 89	1070–1095	Avranches		Sheep	Sheep
MS 82	1070–1095	Avranches			Sheep
MS 146	1070–1095	Avranches			Sheep
MS 35 part.1 (f. 74–193)	1070–1095	Avranches		Sheep	Sheep
MS 9	1080–1100	Avranches			Sheep
MS 47	1080–1100	Avranches		Sheep	Sheep
MS 57 (f 49–110)	1080–1100	Avranches		Sheep	Sheep
MS 102	1080–1100	Avranches		Sheep	Sheep

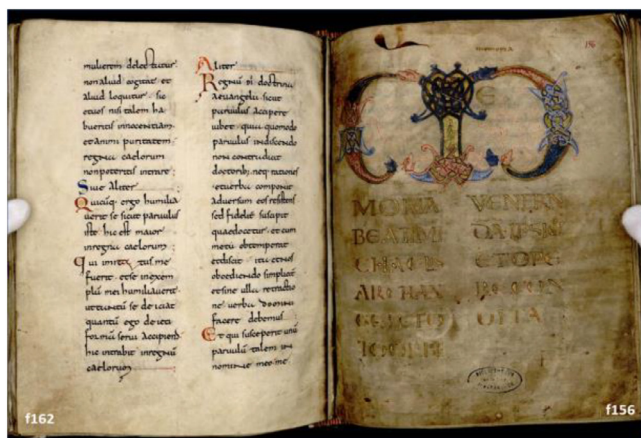


Fig. 4. Folios f162 and f156 in Manuscript 211 (990–1015) made of calfskin parchment. The manuscript contains hagiographic texts written by the copyist of Mont Saint-Michel Hervardus.

in animal species coincide with these different writing phases. Despite being produced over several decades, the copyists endeavoured in this manuscript to give the whole a homogeneous form, both in the layout and in the writing and decoration (the latter, which is very sober, is limited to simple coloured initials, even for the parts added in the period 1040–1080, corresponding to the golden age of Montois decoration).

At the start of the *Middle group* around 1030, the scriptorium started to produce rich illuminated manuscripts. During this golden age of the Mont Saint-Michel, copyists and artists started to use selectively calf parchments for illuminated folios with full page illumination, large ornate letters, decorated frames or titles, generally located in the first quire or even first two folios. This practice continued up to the beginning of the *Late group* when illuminations are present in the manuscript. It reflects a deliberate choice in the scriptorium, in the use of high-quality parchment for the most valuable part of the manuscript, possibly because of its value or for technical reason. Thus, all the parchment folios with full page illumination are made of calfskin (ten manuscripts concerned) and for folios with ornate letters, either calf or sheep skin

is used (Tables 2 and S2 supplementary). Only two exceptions are observed: for Ms 163, which contains an unfinished full-page decorated frame drawn on sheepskin parchment, and the monumental Mont Saint-Michel Bible BM1 (dimension 530 × 360 mm), where both calf and sheep skins are used. Two examples are given to illustrate the general practice for the first quire of Ms 59 and Ms 90 (Figs. 5 and 6). In medieval manuscripts, parchment sheets are folded to form bifolia which are assembled to make quire, with often four bifolia per quire (called *in quarto* assembly). Therefore, each folio has usually an associated folio made of the same animal skin. In these examples, we observe sometimes a peculiar practice, although it is not applied to all manuscripts, with the presence of bifolia created by gluing together parchments from two different animal skins, as in Ms 59 f2-f7 (Fig. 5), Ms 61 f1-f9, Ms 76 p1/2-11/12, Ms 77 f2-f7, Ms 86 part1 f4-f9 and Ms86 part2 f58-f65. Thus, the illumination was drawn on a folio made with calf skin, and the associated folio, that would receive text, was then replaced by a sheep skin parchment. Only in the case of Ms 90, no parchment folio is attached to f1 made of calfskin (Fig. 6). Both techniques are here used to preserve the highest quality calf parchment for illuminated or decorated folios.

For some manuscripts, only a parchment tab made of calfskin remains as in Ms 61 between f111 and f112, Ms 72 between f1 and f2, Ms A.178 between f6 and f7, and latin 2088 for f1 and f11. The identification of calf parchment from the analysis of this parchment tab or the associated folio, suggests that a full-page illumination was once present and had been cut out to be stolen, as in latin 2088 for f1 and f11 where a small part of the illumination border remains [1]. In some case, the illumination was selectively cut out leaving the parchment folio with a hole as in latin 2055 f1. Finally, the palaeographic study of the Ms 107 reveals that the manuscript is incomplete with the foreword, the chapter table, as well as the texts opening (incipit) and closing the manuscript missing. Our hypothesis is that an illuminated page was originally present in the first quire, possibly made of calfskin, and had been lost together with the rest of the folios. The same kind of lacuna can be observed at the beginning of Ms 89, so we can put forward the same hypothesis for the first quire of this book. Even in manuscript M.641, several folios are missing (six in the first quire, after f60 and after f160), some of which were illuminated, since we recover the ghost of a gold frame on the adjacent folio f61.

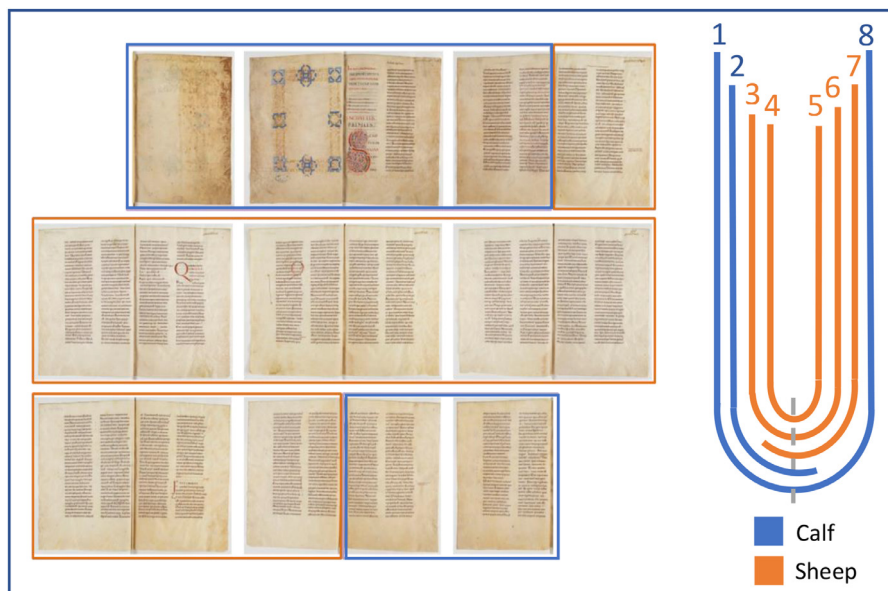


Fig. 5. Repartition of the calf and sheep parchment folios in the first quire of manuscript 59.



Fig. 6. Repartition of the calf and sheep parchment folios in the first quire of manuscript 90, and photographs for folios 1v and f2r.

Over this period, three exceptions also associated with a prestigious status of the manuscripts were encountered amongst the corpus. That includes the second part of the homiliary Ms 128, dated between 1065 and 1080, which importance was detailed previously for the part 1, that is made this time exclusively of calf skin. Similarly, the manuscript Latin 2088 that is a Treatise on the Holy Trinity dated between 1055 and 1080, is also exclusively made of calf skin. This manuscript was copied by Antonius and decorated by artists in the Mont Saint-Michel for the Abbey of Fécamp, which is under the patronage of the Holy Trinity. The most peculiar is the Sacramentary of the Mont Saint-Michel, split between manuscripts mm15 (Rouen) and M.641 (New York) and dated between 1050 and 1065. In this case, the parchment is made mostly of calf skin but goat skin is also found for the first and unique time in isolated locations in both parts of the manuscript. In the manuscript mm15 in Rouen, the goat parchment was identified in folio 22 as well as all the bifolia in this quire, however no difference in appearance or thickness could be observed between the goat and calf parchments in this manuscript. In the highly illuminated part of the manuscript M.641, the goat parchment was identified in folio 61, which has a different appearance to the rest of the folios, as it is the only folio retaining its pricking holes on the border and the parchment was thinner and more worn out (Figure S1 supplementary). Unfortunately, the presence of goat skin for the entire quire could not be verified. No motivation explains the choice to use goat instead of calf skin in this manuscript, nevertheless goat skin was also considered good quality parchment with equivalent thickness, therefore its use in these manuscripts may simply rely on parchment availability at the time.

Then, at the end of the *Late group*, between 1070/1080 and 1100, full page illumination and decorated frame disappear, and the decoration is only limited to ornate letters and titles. The color palette is reduced to two to four colours, always green and red eventually combined with blue and yellow colours. Amongst the six manuscripts from this period, whatever the type of decor, only sheepskin parchment is encountered.

Finally, based on the overall physico-chemical and codicological study (not presented here), four manuscripts were excluded from the initial corpus defined by Alexander and reattributed to another provenance: Ms 50, Ms 79, Ms 98 and Ms 129, (manuscripts marked with * in Table 1). Although these manuscripts are finally not included in the final corpus, their parchments were analysed during the campaign, and the results (see table S3 in supplementary materials) showed that all manuscripts are made of sheepskin

parchment. In Ms 98, the production of ornate letters was reattributed to Saint Julien of Tours or of Le Mans, because of information given by Martin, one of the two copyists, at the end of the manuscript (colophon, f227v). Ms 129 was produced in Saint-Malo because of two diplomatic documents of this place added at the end of the volume (f113). Ms 79 was not produced in the Mont Saint-Michel from palaeographical and material evidence, but its provenance remains uncertain. Finally, the production of the Ms 50, which was thought initially to be the oldest manuscript produced in the Mont Saint-Michel scriptorium, was reattributed to Saint Laumer de Blois in the Loire Valley thanks to X-ray fluorescence imaging that allowed to read the hidden donator name on the first illuminated folio [11]. Ms 50 is the only manuscript that contains a full-page illumination and large ornate letters in purple and metallic green, which was thought initially to be unusual for the Early group period. It is interesting to note that the full-page illumination on the first folio, is made on a very thick sheepskin parchment of around 400 μm , contrasting with 160 to 190 μm thickness in the rest of the manuscript. As mentioned above, thicker parchments are also encountered for the first folio of manuscript produced in the Mont Saint-Michel, where full-page illumination is encountered. This suggests that beyond the quality of the skin, the thickness of the parchment may be an important factor in the choice of a parchment in particular to paint the large illumination.

5. Conclusion

This study investigated the parchment used in the production of the manuscripts in the Mont Saint-Michel Abbey in the 11th century. The research was carried out on a coherent corpus of 63 manuscripts (plus four that were reattributed to another provenance), well attributed from previous codicological studies, which represents most of the still preserved manuscripts produced in the Mont Saint-Michel scriptorium in that period. By combining the information gained from the codicological studies and proteomic analyses, the research reveals the scriptorium practice in the use of parchment skins over that 120 years period. Indeed, copyists and/or artists deliberately select the type of skin depending on the content of the folio or the status of the manuscript. Thus, only sheep parchment is used for folios with text or only lightly illuminated manuscripts as can be encountered during the *Early and Transitional groups* (980 - 1040) and at the end of the *Late group* (1070/1080 - 1100). Instead calf parchment is selectively

used due to its higher quality for the most valued part in the manuscript, such as full-page illuminations and often large ornate letters opening the manuscripts, which are widespread in the *Middle group* and *early Late group* (1040 – 1080) during the Apogee of the scriptorium. Due to its expensive cost, calfskin parchments were generally used sparingly, leading sometimes to the replacement of the second half of a bifolio, receiving only text, with sheepskin. For the most prestigious manuscripts, which concern four volumes in the corpus (Ms 211, Ms 128, mm15/M.641, latin 2088), calfskin is used in the entire manuscript, with the addition in manuscript mm15/M.641 of goatskin, confirming the special status of these manuscripts for liturgical practices. For the Bible of the Mont Saint-Michel (BM1), this important manuscript was made on both calf and sheep skin parchments which dimensions are much greater (530 × 360 mm) than any manuscript in the corpus. The measurement of the parchment thickness also revealed that artists or copyists selected thicker parchment for illuminated folio, especially in the first folio where full-page illumination are encountered. This was done either by using calf skin, which is naturally thicker, or thick sheep skin parchments. The same approach being found in the Ms 50 produced in the Loire Valley may suggest that this practice is not unique to the Mont Saint-Michel. Therefore, it would be interesting to extend this investigation on parchment to other scriptorium in Normandy and beyond to find out if this is a common practice.

The demonstration of these practices constitutes for historian's invaluable information on the parchment production at the time, the significance of a manuscript or a folio. For example, at Mont Saint-Michel in the Romanesque period (11th century), the liturgical works considered to be the most precious and sacred to the community were copied onto calfskin parchment: lectionaries, sacramentaries and works dedicated to the patron saints of the place. The rest, whether religious or secular texts, were primarily copied onto sheepskin (even in the case of Bibles). As for the dogmatic treatises of the Fathers of the Church (Augustine, Ambrose, Jerome and Gregory), the only works, along with the Bibles and Gospels, deemed worthy of illumination between 1040 and 1080, calf skin was used only to accommodate the sumptuous decorations (illuminations and large ornate letters) and placed at the beginning of the volume. This sometimes helps to identify codicological units when several manuscripts, initially independent, have been brought together in the same binding (cf. Avranches manuscripts 61, 72 and 86, each of which contains 3 to 4 codicological units). Considering the animal species used in the parchment – in particular the calfskin – should help historians to better assess the importance of a book or of an illumination for the monastic community. It remains to be seen whether the practices observed for the scriptorium of the Mont Saint-Michel are specific to this abbey or if they can also be observed elsewhere, at the local (diocese of Avranches), regional (Duchy of Normandy and ecclesiastical province of Rouen), or even in a larger space (Anglo-Norman, continental or occidental area). For that reason, similar material studies will be carried out on other contemporary scriptoria as well as for later periods, in order to undertake comparative studies.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.culher.2024.03.013](https://doi.org/10.1016/j.culher.2024.03.013). The raw proteomic data can be accessed from <https://doi.org/10.48579/PRO/ZEEJTH>.

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