ANTOINETTE RAST-EICHER

FIBRES

Microscopy of Archaeological Textiles and Furs

ARCHAEOLINGUA

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Antoinette Rast-Eicher

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Microscopy of Archaeological Textiles and Furs

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SWISSLOS Lotteriefonds Kanton Bern

ERNST GÖHNER STIFTUNG

Unterstützt vom Kanton Zug

Front Cover
Reindeer fibres, modern. SEM-photo

Back Cover
Very fine textile mineralized by lead – it is made of flax or hemp in the warp and fine wool in the weft, Jaunay-Clan, France, SEM-Photo

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Preface

The three most important developments to consider when looking at the early textile history of Europe are all linked to individual fibres. These would be: the domestication of flax, sheep with a white fleece and the importation of silk. Flax was produced by the earliest farmers around 6000 BC, white wool came up in the Bronze Age and Chinese silks were imported by the Romans. Although cotton was eventually to become one of the most significant textile fibres in the later Modern Period, flax, white wool and silk held their own as the most important fibres in textile history before that time. In addition to these it must also be mentioned that there existed a large variety of fibres before industrial manufacture took over the production of both textiles and furs.

One fibre atlas in particular was compiled in more recent times, it being the culmination of about 20 years of work from this author. Initially, it was thought of as a tool for the laboratory and especially for research in the fields of archaeology and conservation. It utilized microscopy as a most important instrument for fibre analysis. Images derived from both the SEM (scanning electron microscope) and the light microscope became the basis from which these fibres were studied and identified. This atlas was at first conceived as a descriptive listing of individual fibres, however, it evolved into a study of the historical aspects of fibre development. Numerous archaeological finds became the compelling evidence for such work and it has continued to develop into a study that links the artifacts with an historical background of the fibres. Photographic documentation has helped to reinforce the physical evidence coming out of the lab.

The basic aim of the atlas was to report on the kinds of fibres employed in Europe for the manufacture of textiles and furs, fibres native to Europe as well as those that were imported. Animals that are today extinct have been identified in archaeological material and added to the atlas as well. Some special fibres were included because of their importance to the analysis of archaeological material. Wood, as one such material, was included as the presence of its fibres can interfere with an accurate identification of textile fibres. A section on microscopic methodology and its limitations is also an important part of the atlas.

It is the belief of this author that costume and textile studies begin first and foremost with the individual fibres and that without an understanding of how they are processed it is not possible to proceed fully with the study of a particular textile, garment or fur.

A fibre atlas of one group of ancient textiles would not be possible to compile without the possibility of comparison to similar material from another and separate collection. Of the first accessible materials that became available for this purpose was a collection held by the EMPA (Eidgenössische Materialprüfungsanstalt) in St. Gallen (CH), a large reference assemblage of natural fibres. Any missing fibre representatives were then collected from stuffed animals from various museums, including the Naturhistorisches Museum of Vienna (A), the Naturhistorisches Museum of Bern (CH) and the Landesmuseum of Liechtenstein (FL). Samples awarded to this author have been much appreciated. The author also thanks the University of Bern's Centre for Microscopy for the use of their instruments, to Martin Grosjean of the Institut of Geography for the use of the SEM and to Michael Stoffel of the Institut of Veterinary Anatomy, for the sputter machine. Before, from 1996 to 2001, the SEM at the Institute of Botany, University of Zurich was available, with much photographic data deriving from this time period.

Thanks are forthcoming as well to the colleagues and friends who have contributed to this work with ideas, hints, photos or fibre samples. An early advocate who, many years ago, drew my attention to the subject of fibres and wool qualities was Klaus Tidow (Neumünster, D). Special thanks are due to Lise Bender Jørgensen who has reviewed a large part of the manuscript and to Kim Travis for the English language corrections. I would also like to thank Carmen Alfaro (Valencia, E), Judith Cameron

(Australian National University), Corinne Debaine-Francfort (Université Nanterre – Paris, F), Sophie Desrosiers (EHESS/Paris, F), Marcel Halbeisen (formerly of EMPA St. Gallen, CH), Lena Hammarlund (Gotheburg, S), Felicitas Maeder (Basel, CH), Ulla Mannering (National Museum of Denmark, Copenhagen), Ina Schneebauer-Meissner (D), Sylvain Olivier (Université de Nîmes, F), Nicole Reifarth (Trier, D), Hans Reschreiter and Karina Grömer (NHM Wien, A), Anna Silberschmidt and Nicolà Sanso (Studio Aphrodisma, I), Mattias Seifert (Kantonsarchäologie Graubünden, CH), Werner Schoch (Labor für Quartäre Hölzer, CH), Jacques Sinz (SwissFur), Krista Vajanto (Helsinki, FI) and Marianne Vedeler (Museum of Cultural History Oslo, N), Elizabeth Wincott Heckett (Cork, EI).

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Photos and drawings: by Antoinette Rast-Eicher, except where noted in the captions.

1. Introduction

1.1 Fibre & microscopy

Fibre microscopy is a large field and encompasses an array of disciplines. Research in the fields of botany and zoology, something taken up by the textile industry, has provided a foundation for the in-depth study of fibre anatomy. Forensic science, veterinary anatomy, archaeology and conservation are disciplines to be included as necessary to fibre investigations.

Fibre anatomy and its chronicling began with the use of light microscopy (e.g. Hausmann 1920; see also chapter 4.), taking on significant advances with the introduction of scanning electron microscopy (SEM). Fibre identification and analysis of individual textile and fur objects has been greatly enabled with the use of these instruments (e.g. Meyer *et al.* 2002; Chernova – Teslikova 2004).

Microscopy continues to be the first most important step for fibre analysis when it comes to forensic science (Farag *et al.* 2015). In the context of archaeological study, the analysis of individual fibres has been essential to the study of the textile as a whole. M.L. Ryder, a specialist of the wool industry in Scotland, introduced a wool analysis method in the 1960's which allowed for in-depth study of the history of sheep and wool production (Ryder 1964; Ryder 1969); it continues to be used both in the industry and for archaeological material. Klaus Tidow, former director of the Textile Museum in Neumünster/D and a textile engineer, undertook wool analyses of Medieval and Early Modern textiles from German towns (e.g. Tidow 1992). With an "industrial eye" he worked with material, which was rich, not only in the regional history of the textile industry but also in Prehistoric and Early Historic textiles. The historian Dominique Cardon, in her book on drapery from Medieval times, discusses the wool quality of textiles from that time (Cardon 1999). Penelope Walton Rogers (Anglo Saxon Laboratory, York/GB) combines research on textiles with an analysis of dyes (e.g. Walton Rogers 1991). Aspects of study have moved beyond simple fibre determination. The ability to figure out different processing procedures, for example, has been greatly enabled with the significant magnification and resolution capabilities of the scanning electron microscope over the regular light microscope. The SEM allows for the finest of details to be viewed, including those which are not linked to the natural state of the fibre.

1.2 Anatomy of animal fibres

The hair follicle consists of an outer keratinized cylinder, a dense inner layer of spindle-shaped cortical cells and a central medulla (which is not always present) (Meyer *et al.* 2002; Chernova 2002) (*Fig. 1*).

The following main criteria are important for the determination of animal hairs in archaeological material – and the more of these that are visible, the higher the possibility of making an accurate determination:

- diameter of fibres
- pigmentation
- scale design
- scale surface
- medulla structure
- scale measurements
- other measurements: distance between scale margins, scale perimeter, the width:height of the scales (X/Y-Feret), scale index

Taking a look at the diameter of a fibre would be the initial step in identifying it. With wool, it would be considered the main criterion for quality (see ch. 2.5.2). Pigmentation is often not visible and is usually dependent upon its state of preservation. Scale design is also quite important as it can determine the family or the species (*Fig. 2*). Preliminary observation may not clearly show whether the fibres are primary hairs or secondary fibres (underwool) – a secondary and closer look is almost always advisable. Most of the published atlases are based upon the primary hairs (see *Table 1*). As examples of the beaver and the otter show, the fine fibres (secondary fibres) have been found because there are so many per cm^2, and their morphology is most important for the determination of the species (see ch. 4.3.6 and 4.5.22). Computer based analysis of the scale pattern is problematic as measuring larger quantities is often difficult. The kinds of measurements proposed by Meyer *et al.* – the distance between scale margins, the scale area, the scale perimeter, the width:height (X/Y-Feret), and scale index which is the amount of scales per mm^2 – should be calculated if possible and all taken into consideration if the preservation is good (Meyer *et al.* 2002). The distance of the scale margins and the X/Y-Feret are especially helpful (see e.g. ch. 4.5.22.3). Changes in size due to shrinkage, however, must be kept in mind and it is often difficult to obtain a sufficient amount of scale measurements with archaeological material.

Some scale surfaces are smooth while others show a distinct pattern; scales can be flat or nearly three-dimensional.

The study of the medulla is the second main criterion for identification. Size and design are the key factors but are not always visible in archaeological material (*Fig. 3*). With metal-replaced textiles or furs it is important to observe where in the medulla the fibres are broken. If what is left of the fibre is a negative imprint, there may be enough to see what main type it is. In well preserved material the fibres may be dark (from pigmentation or preservation) and in these cases only the longitudinal sections as seen using the SEM will aid in identification.

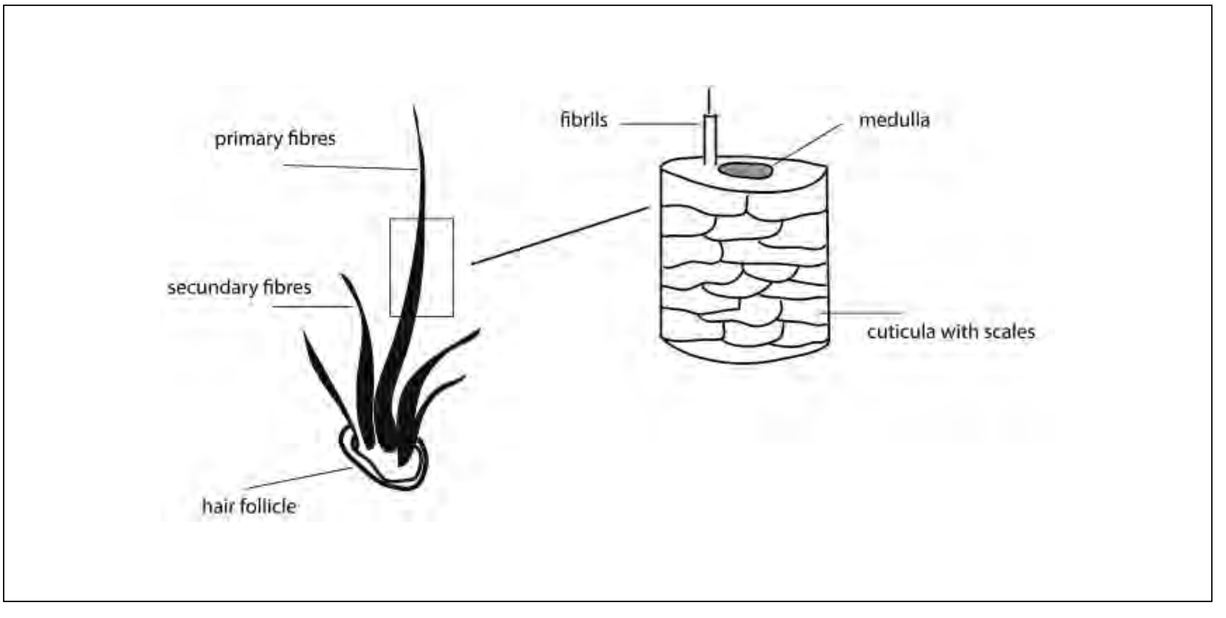

Fig. 1. Hair

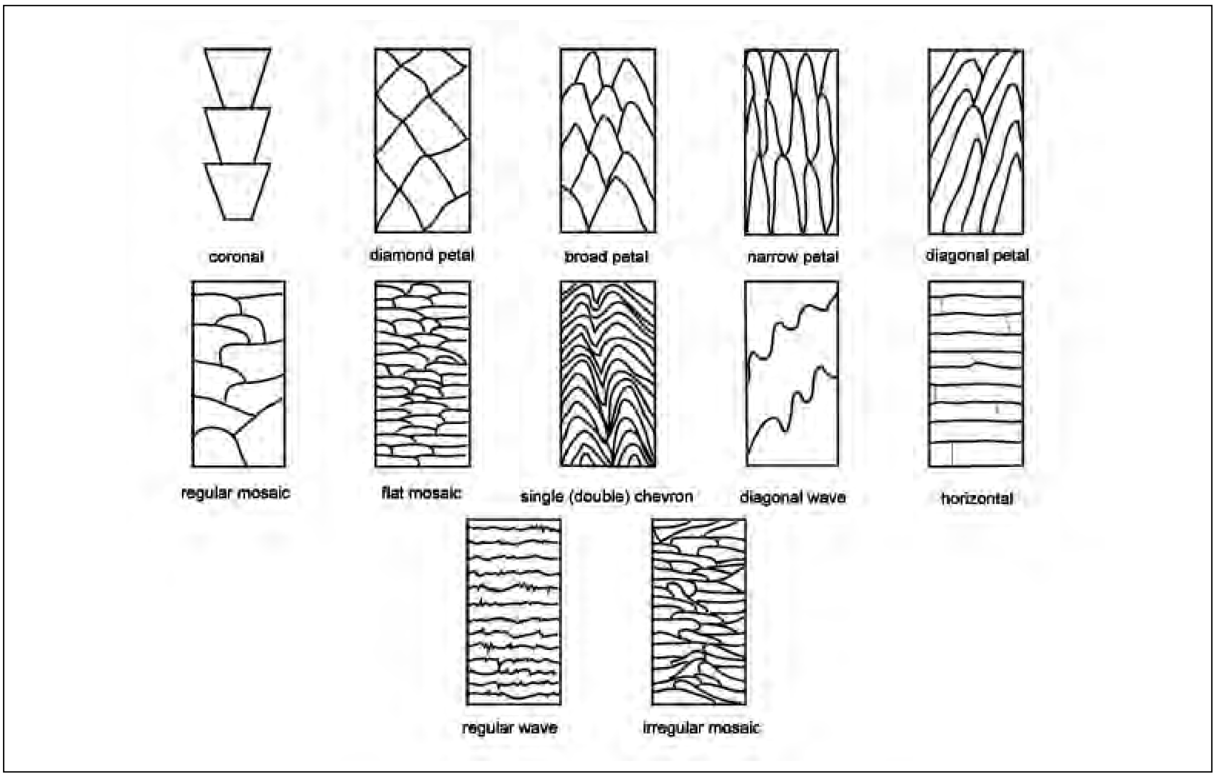

Fig. 2. Scale structure, following the terminology after Meyer et al. 2002

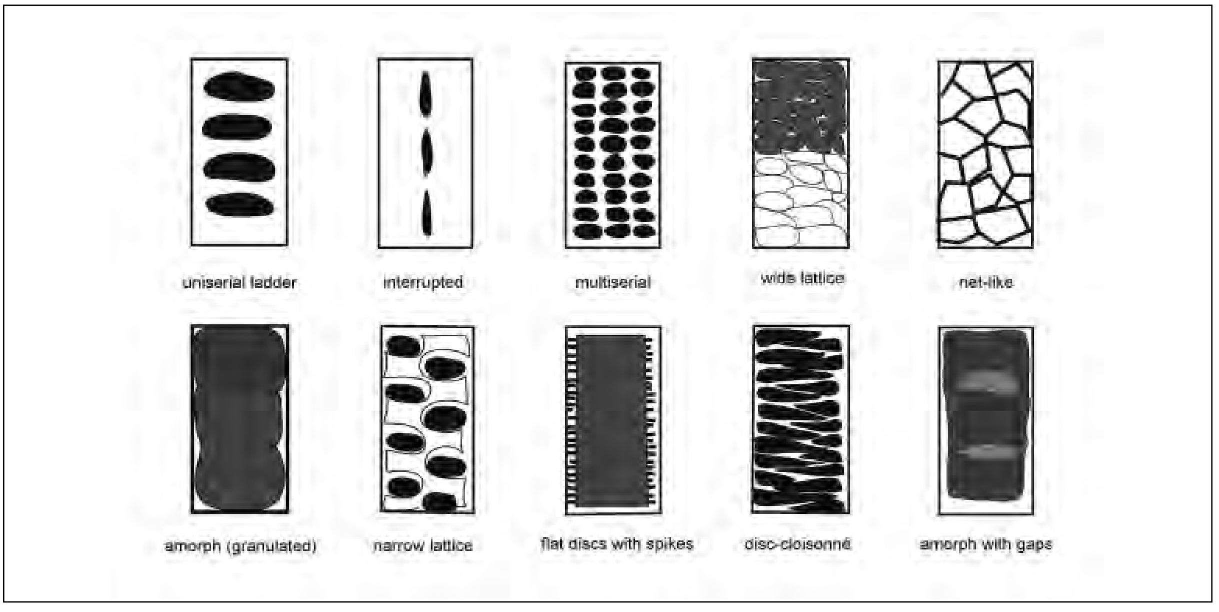

Fig. 3. Medulla structure, following the terminology after Meyer et al. 2002

1.3 Anatomy of plants

Cotton as seed fibre is pure cellulose and grows in a capsule around the seeds of the the plant.

Bast fibres are harvested from certain plants (dicotyledonous) such as flax or hemp. They bear a fibre layer underneath the epidermis in the phloem with conducting cells which strengthens the stem (*Fig. 4*). Similarly in trees, the bast layer is in the phloem, found between the bark and the wood (xylem).

Of taxonomic importance for other plant fibres such as grasses, sedges, rushes or palm fibres, is the shape of the cells of the epidermis, hairs and stomata as well as the form of the silica cells (grasses) and crystals.

a) *Bast layer*

b) *Stomata*

Stomata are openings in the epidermis of both leaves and stems and are built up with bean-like cells. They control gas exchange between carbon dioxide and oxygen as used by the plant for respiration and photosynthesis. If visible, their form and arrangement is important for the determination.

c) *Epidermis hair cells*

The hairs can have different forms such as straight unicellular, multicellular or branched.

d) *Calciumoxalat crystals in the epidermis*

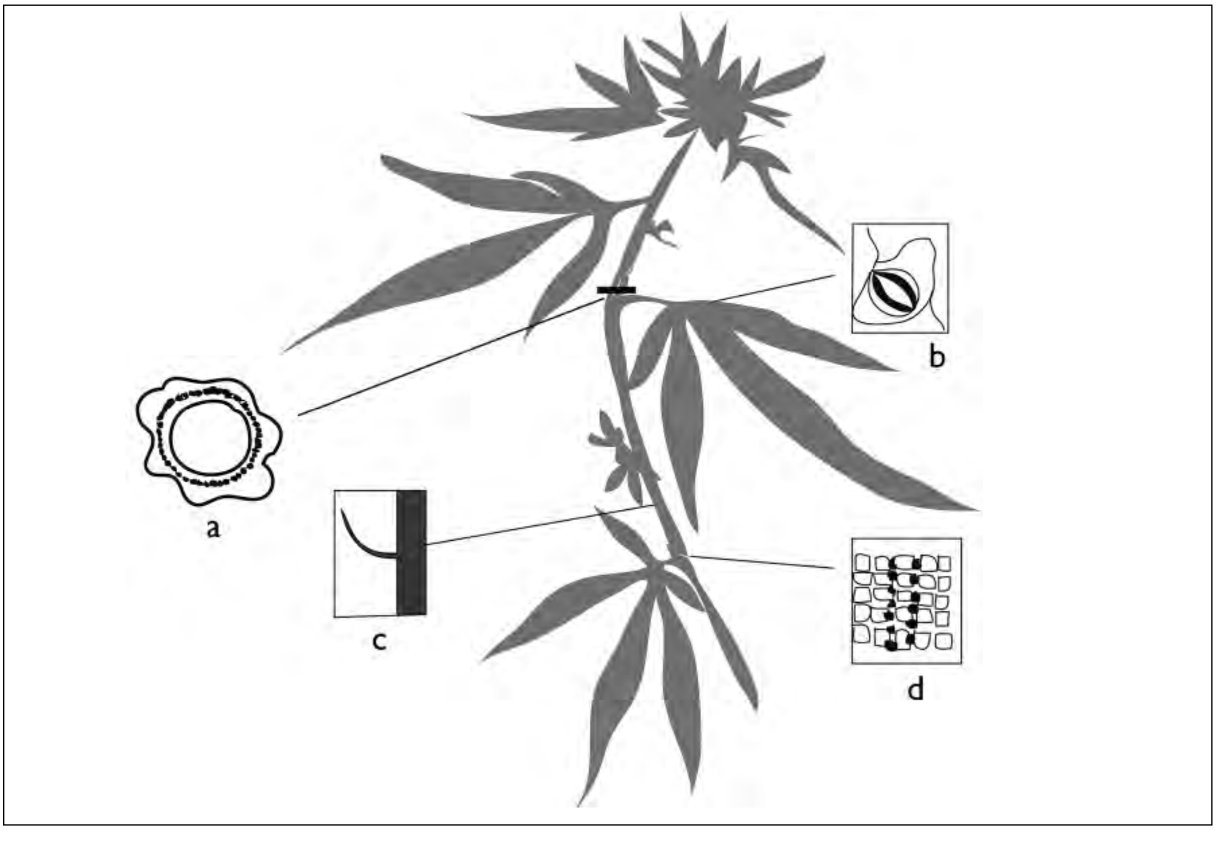

Fig. 4. Hemp (Cannabis sativa) with cross-section of stem, stomata, epidermis hairs and crystals

2. Methods

The analysis of archaeological material is quite complex. Fibres coming from archaeological excavations are very often not fully comparable to modern material. Sometimes, identification is not definitive because the fibre is not determinable. In other cases an animal or plant fibre is discernible but more detailed information is not forthcoming. In still other cases there are enough criteria for a full identification. Some fibres are more tricky to identify than others, with even the modern textile industry struggling with the likes of fine sheep wool versus cashmere. The specific decay of a fibre becomes part of the identification and archaeological material has the further problem of the preservation treatment it may have been given; depending upon conservation treatment measures that have been applied, some or even several identification indicators may not be clearly visible. Determination of archaeological material does not only mean clarification of the plant or animal fibres used. While the specific decay of a fibre becomes part of the criteria for identification so too does information concerning the processing of the fibres: sorting, combing, splicing, glue for weaving and colors are to be detected. Information determining the difference between fibre and processed yarn is also to be taken into consideration.

2.1 Preservation

2.1.1 Dry

2.1.1.1 Desert finds

Fibres of both plant and animal nature that have been kept in dry conditions are usually quite well preserved (*Fig. 5*).

The scales of the wool fibres, for example, are clearly visible even if covered by a superficial layer of dirt. Other animal fibres may lose nearly the entire cuticle of the fibre, turn into a mineralized state and leave only an imprint of the scales. This can happen, for instance, if textiles are deposited onto ceramic (*Figs 6* and *7*). The linen fibres of ancient mummy shrouds, such as those brought from Egypt to Europe in the 19th century, are usually in a good state of preservation. With the enveloping shroud around the mummified bodies and their undisturbed preservation under the constant dry conditions of the Egyptian desert for millennia, the fibres of these textiles have survived well (*Fig. 8* and *9*).

2.1.1.2 Church/Grave finds

Medieval graves deposited in the nave or crypt of a church can often be found in a dry state even after having once been humid during the original decomposition of the body. Early Medieval and Medieval graves are those most frequently found in this state. If the organic material has not been re-exposed to humid or wet conditions – that is, it has been kept consistently dry – it will remain in a quite stable state of preservation. Under conditions of secondary humidity, however, organic material will at first expand, then subsequently dry out and shrink which will cause inevitable and irreversible fibre distortion and destruction. Original thread and fibre shapes will be lost. (*Figs 10* to *12*; see also *Fig. 38*). Especially fine material such as silk seems to suffer most (*Fig. 13*). Environmental exposure of this sort will depend upon where in the church a sarcophagus stands, of course. Being in the basement or crypt, for example, might give more exposure to such secondary humidity.

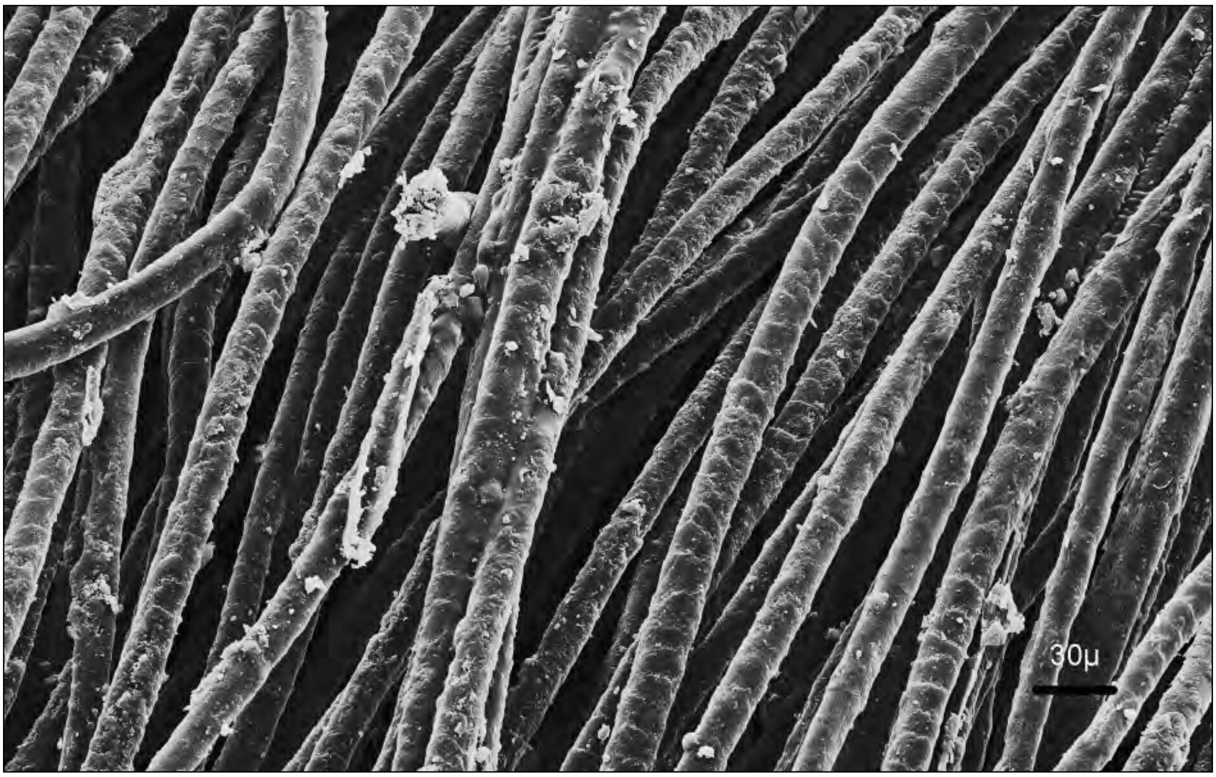

Fig. 5. Wool from a desert context, well preserved. Egypt, probably Roman

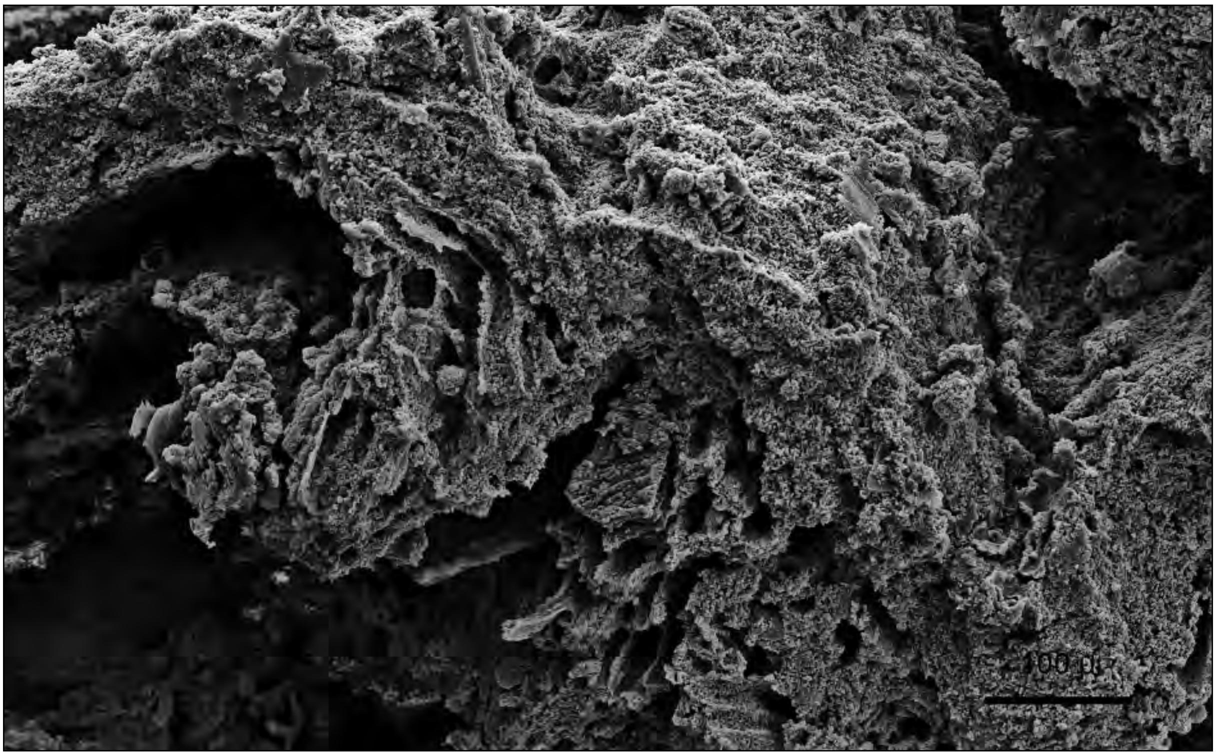

Fig. 6. Wool fibres in a conglomerate of mineralized material (textile is white), Chagar Bazar (Syria), Bronze Age

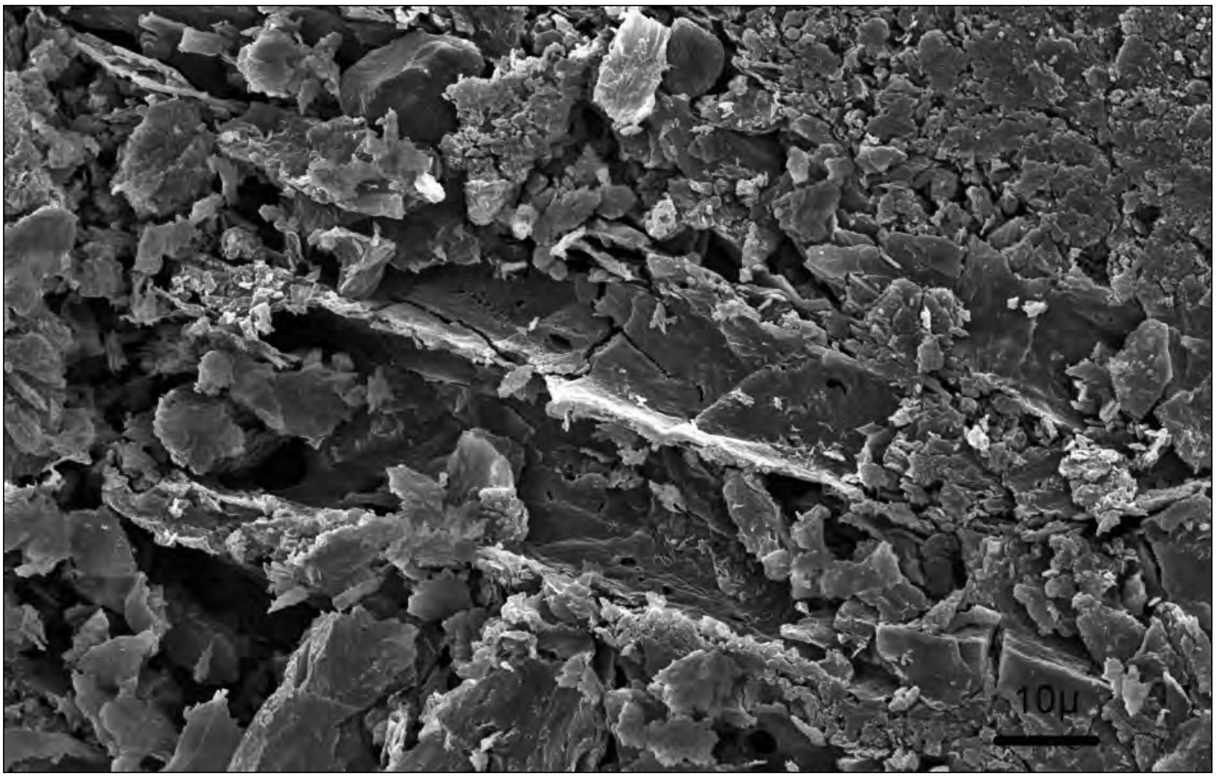

Fig. 7. Sheep wool, mineralized fibres with negative imprint of scales, Chagar Bazar (Syria), Bronze Age

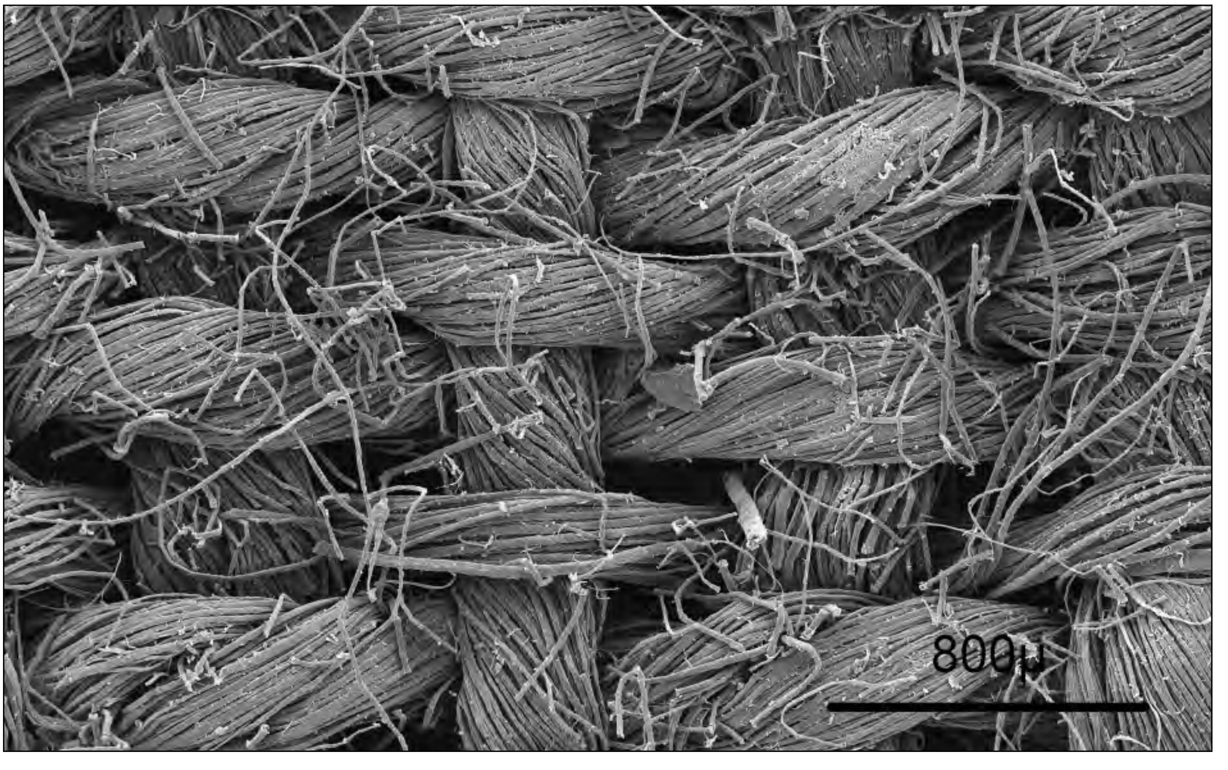

Fig. 8. Linen shroud around Egyptian mummy, Rätisches Museum Chur (CH)

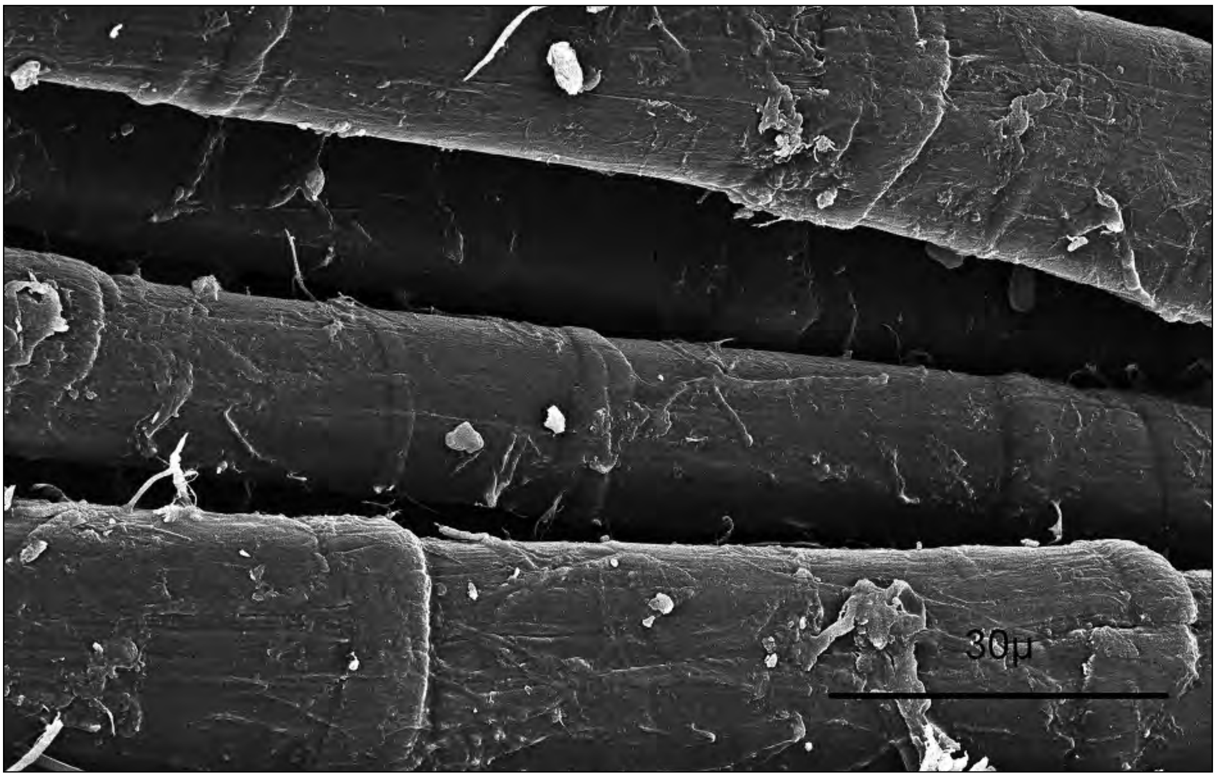

Fig. 9. Linen shroud around Egyptian mummy, Rätisches Museum Chur (CH). Flax fibres, detail

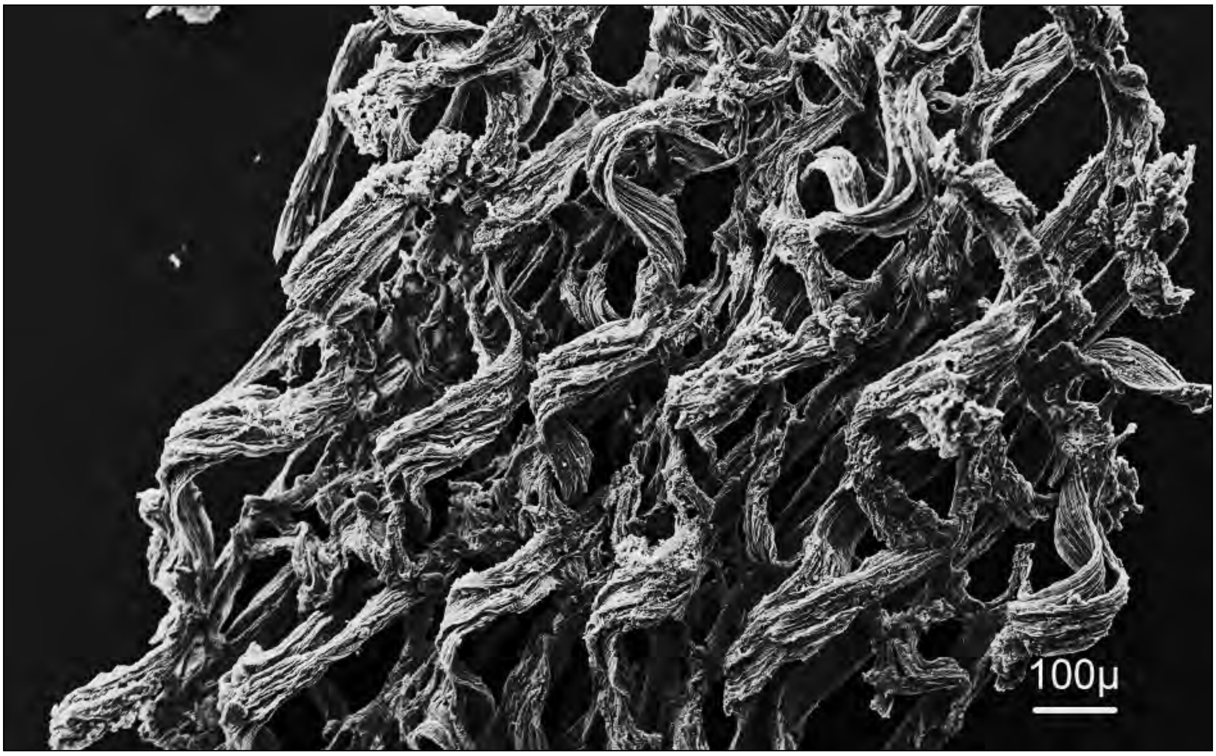

Fig. 10. Shrunk textile, Saint Denis/Paris (F)

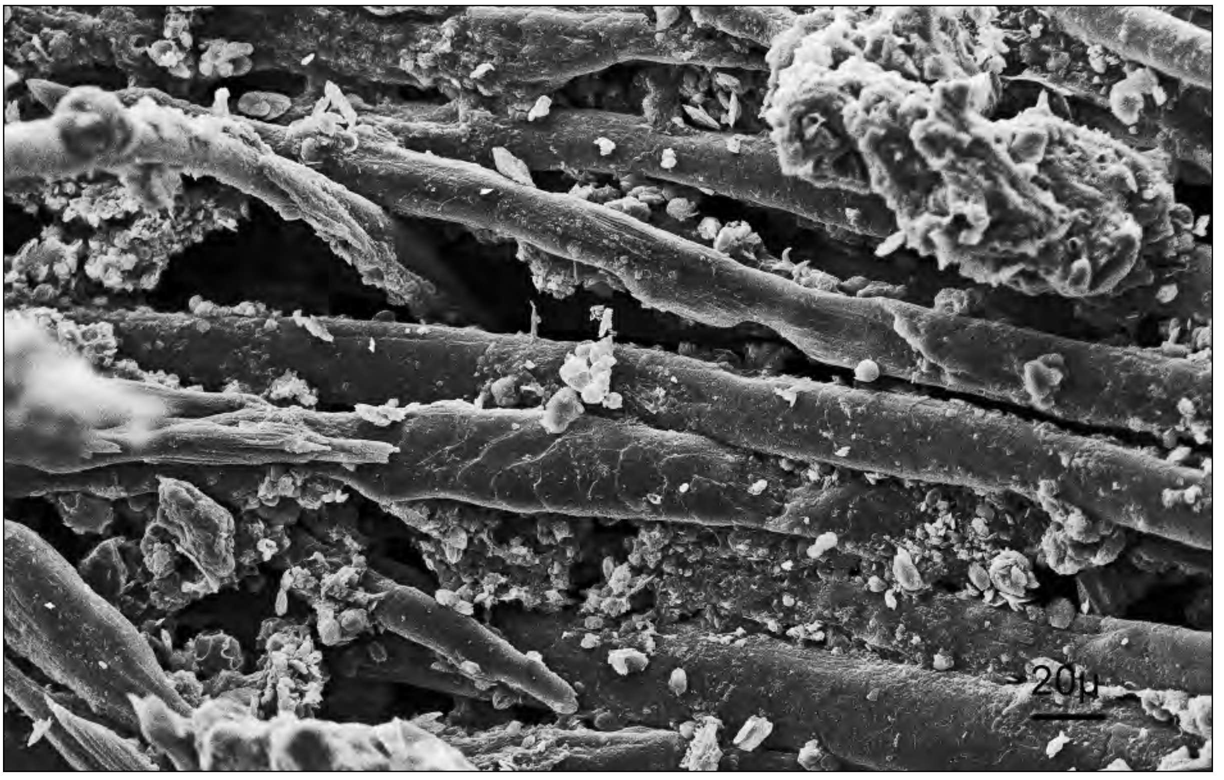

Fig. 11. Animal fibre (wool) in different state of preservation. In the center fragment with scales, otherwise the scales are not preserved, Saint Denis/Paris (F)

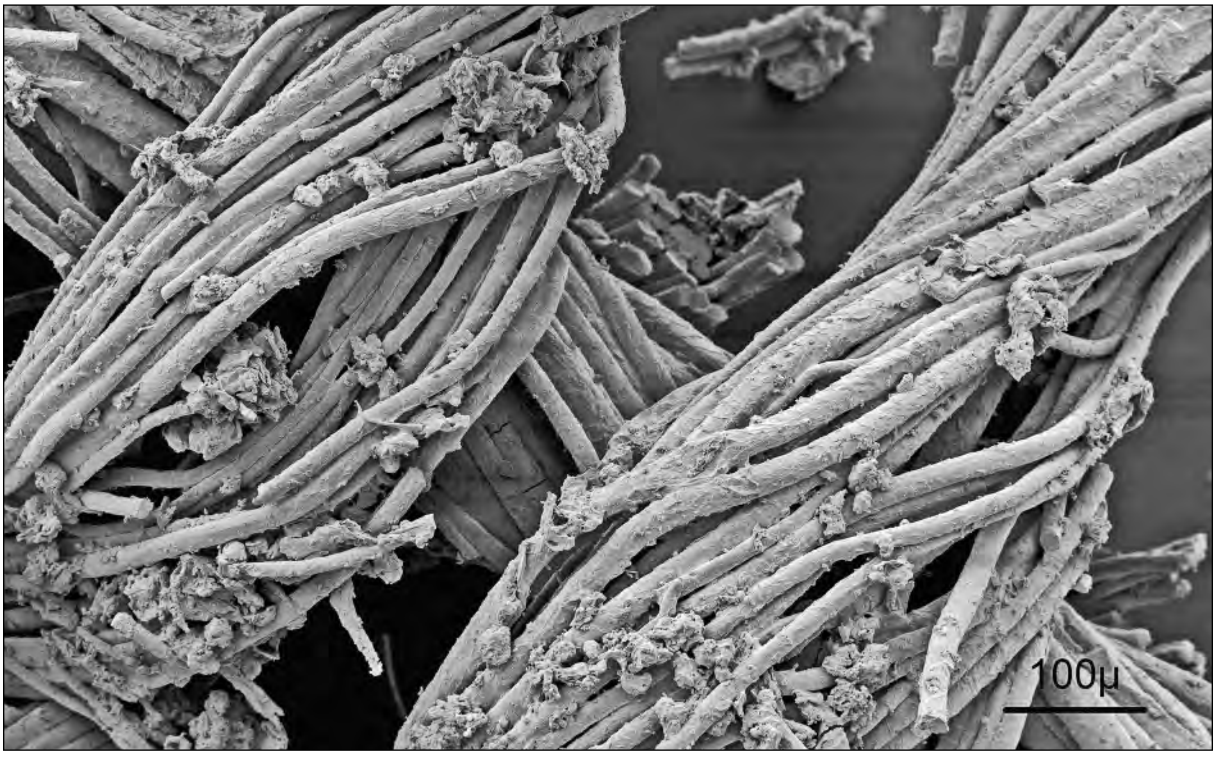

Fig. 12. Well preserved wool textile, Saint Denis/Paris (F)

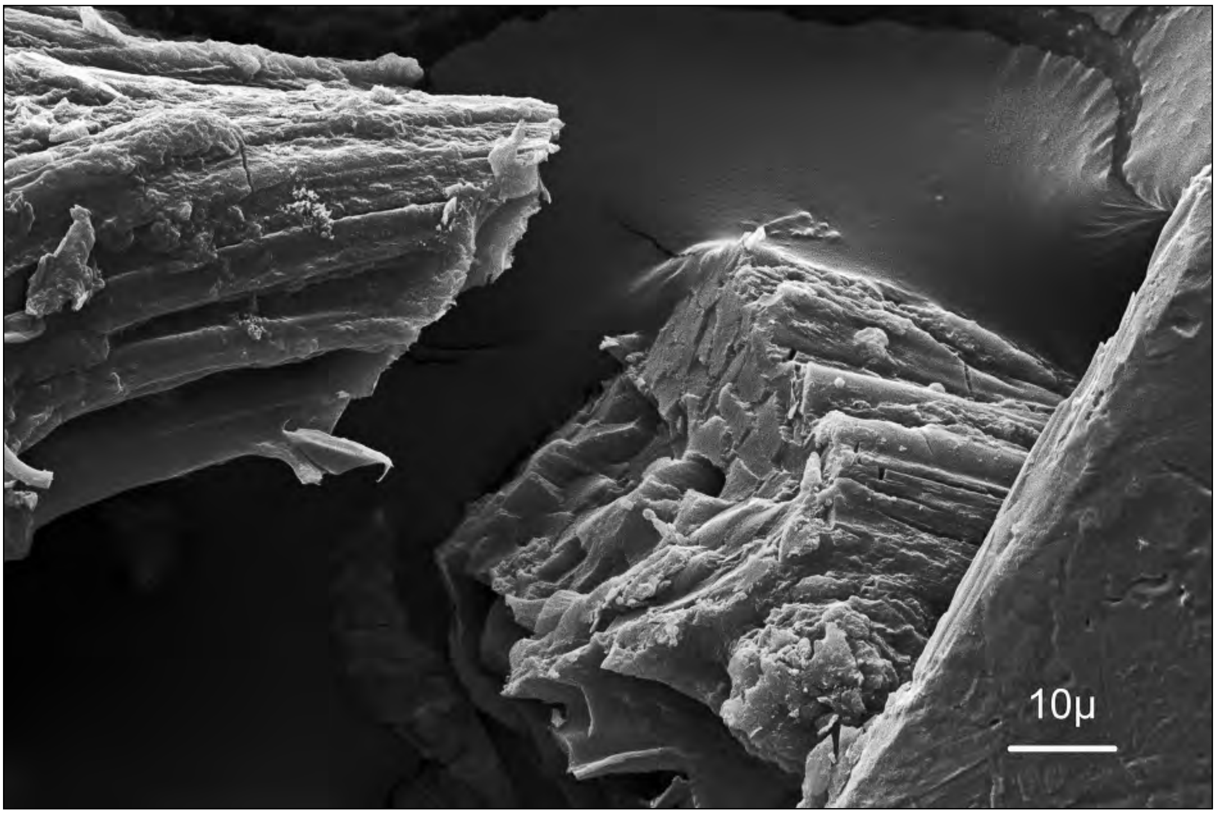

Fig. 13. Silk thread. From the outer side the fibre has shrunk and is not well visible, but the cross-section of the thread shows the triangular section of Chinese silk (see also chapter 4.10), Saint Denis/Paris (F)

An exceptional case of preservation was discovered in a grave found in the Augustinerkirche of Konstanz (D) (*Figs 14* and *15*). The grave found under the central floor and covered only with stone plates (Röber *et al.* 2008) held a body which had been completely covered with chalk before deposition in the nave. The chalk had created a full envelope around the body and held imprints of the textiles used in the garments. Tiny bits of original fibres had been preserved with remains found even in the imprints.

2.1.1.3 Finds in houses (Secular Grounds)

Finds in houses are mostly dated to the Medieval or (Early) Modern Periods. The textiles are mostly well preserved if they were deposited between floors or in walls for insulation. Colors are often still visible. Some have been found as part of construction materials, such as in ovens where textiles were used for reinforcement of the structure (*Fig. 16*). There is no difference, in terms of preservation quality, between plant and animal fibres. Problems do occur sometimes from rodent damage – mice will collect textiles for a nest tearing them into little pieces which makes dating by the layer impossible.

2.1.1.4 Paper finds

Prior to 1850, paper was prepared in mills using old textiles and water. It was processed by using long cellulosic fibres and sizing (Ilvessalo-Pfäffli 1995). Today, short fibres can be used with lignin and other substances to enhance the quality of the product. With the older methods, each paper was constructed of individual components and this enables modern methods of research – such as FTIR (see below) – to be carried out in identifying chemical fingerprints (Manso – Carvalho 2009). At the beginning of the 18th century, René-Antoine Ferchault de Réaumur came up with the notion that much could be learned from observing the wasp and its use of wood fibres for making a sort of paper product (Thiel 1932). A close look at Early Modern art work has shown distinct animal and vegetable fibres being used. Their quite damaged state may well be due to the fact that they were pressed and processed in a mill (*Figs 17* and *18*).

2.1.2 Humid

2.1.2.1 Lake Dwellings

In humid conditions, as found between the alkaline layers of fine sand, an abundance of organic finds may be very well preserved. Due to the alkalinity (basic soils) of the Circum-Alpine lakes (and in the absence of acidity), no animal fibres or leather/skins have been found. Rather, plant fibres such as tree bast (willow, oak or lime) or flax have been preserved. Very often, plant fibres will have been charred, becoming chemically changed but thereby reinforced in their state of preservation (Peacock 1996). In the case of houses that had burnt down completely, organic material could remain in a certain state of preservation through charring. Uncharred/uncarbonized material is less abundant except in areas favorable to it having become waterlogged. Such finds have to be treated at the cellular level by replacing captive water with other solutions that will better support the walls of the hollowed out cell. With these solutions in place, a drying procedure is carried out through sublimation or freeze-drying. The end result is a strong cellular structure and an object that will retain its form upon exposure to air and the regular atmosphere. The textiles from Swiss lake dwellings are dated between 4300 BC–2400 BC (Neolithic) and 1050–850 BC (Late Bronze Age). Most have been found in Neolithic layering. They are made of tree bast (lime, willow, oak) or flax (Rast-Eicher – Dietrich 2015). When charred they are quite brittle to the touch but chemically more stable than when uncharred (*Fig. 19*). In the charred or charcoaled state even the characteristics of very fine threads can quite easily be detected (see *Fig. 19*), although the rays shrink with carbonization (*Fig. 20*). In some of these cases carbonized fungus has been documented, meaning that the object had once been in a humid condition before it was burnt (*Fig. 21*). Without this carbonization, plant fibres are preserved in anaerobic layers only. This means that as soon as they are excavated they must be kept humid, avoiding all contact with air, until conservation with replacement solutions followed by freeze-drying can take place. Determining features, such as typical calcium-oxalate crystals, are enabled if the fibres are well preserved (*Fig. 22*). If allowed to air dry without special treatment, however, the plant cells will collapse and all characteristic thread identification and structure will be reduced to dust or undistinguishable string fragments.

2.1.2.2 Bogs and graves in mounds

Human bodies found in bog burials – many cases having been due to sacrifice or punishment – have provided a host of information. Bronze Age oak log coffins, have been preserved under special conditions in which micro-bogs have been created in mounds. Unlike the conditions found in lake dwelling sites, bogs are found with acidic soils (see chapter 2.1.2.1). Plant fibres, therefore, are rarely found to exist whereas animal fibres and skin (as well as human skin) can be well preserved (Broholm and Hald 1940; Dieck 1965; Hald 1980; Gleba – Mannering 2012; Schlabow 1976; Van der Sanden 1996). Bronze and Iron Age graves found in Northern Europe have contained many garments in an extraordinary state of preservation (Hald 1980; Schlabow 1976; Bender Jørgensen 1992; Mannering *et al.* 2012). Wool was found to have remained in a very good state with visible scales (*Fig. 23*) and pigmentation still visible, albeit with the color turned mostly brown because of the bog water. Chemical analysis can reveal dyed fibres.

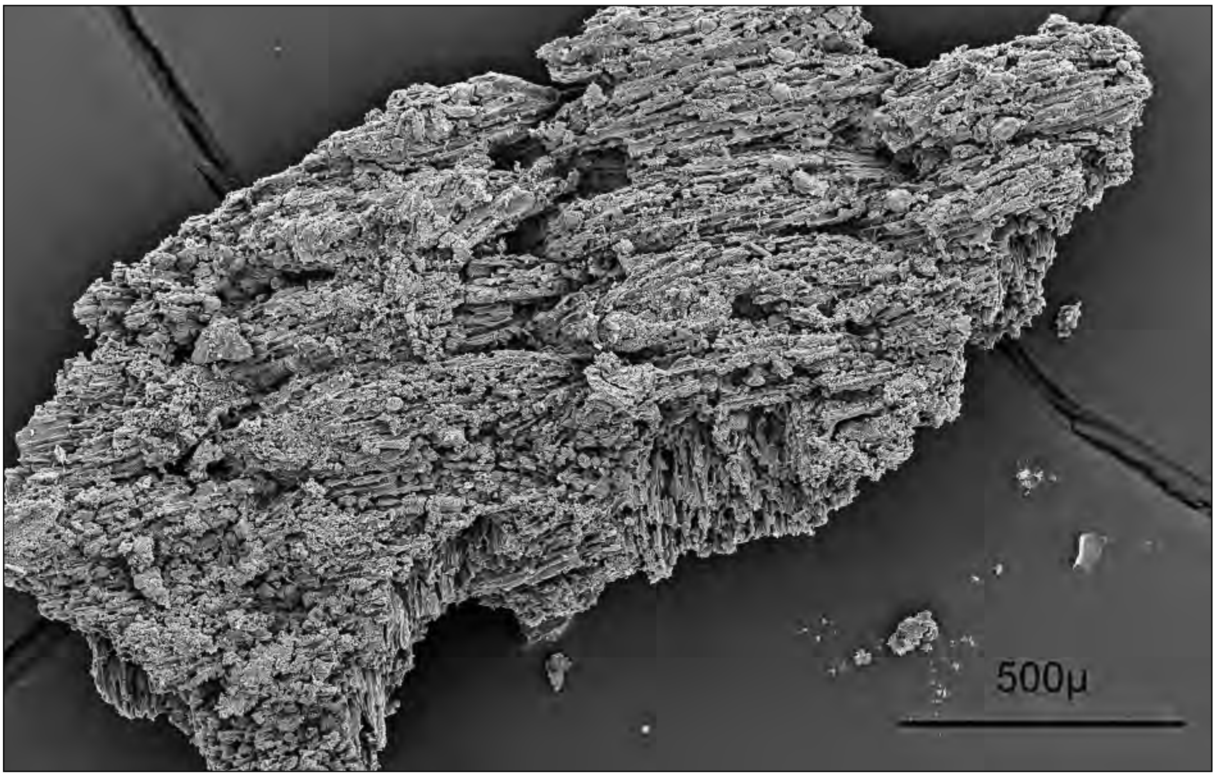

Fig. 14. Textile preserved by chalk, Konstanz, Augustinerkirche (D)

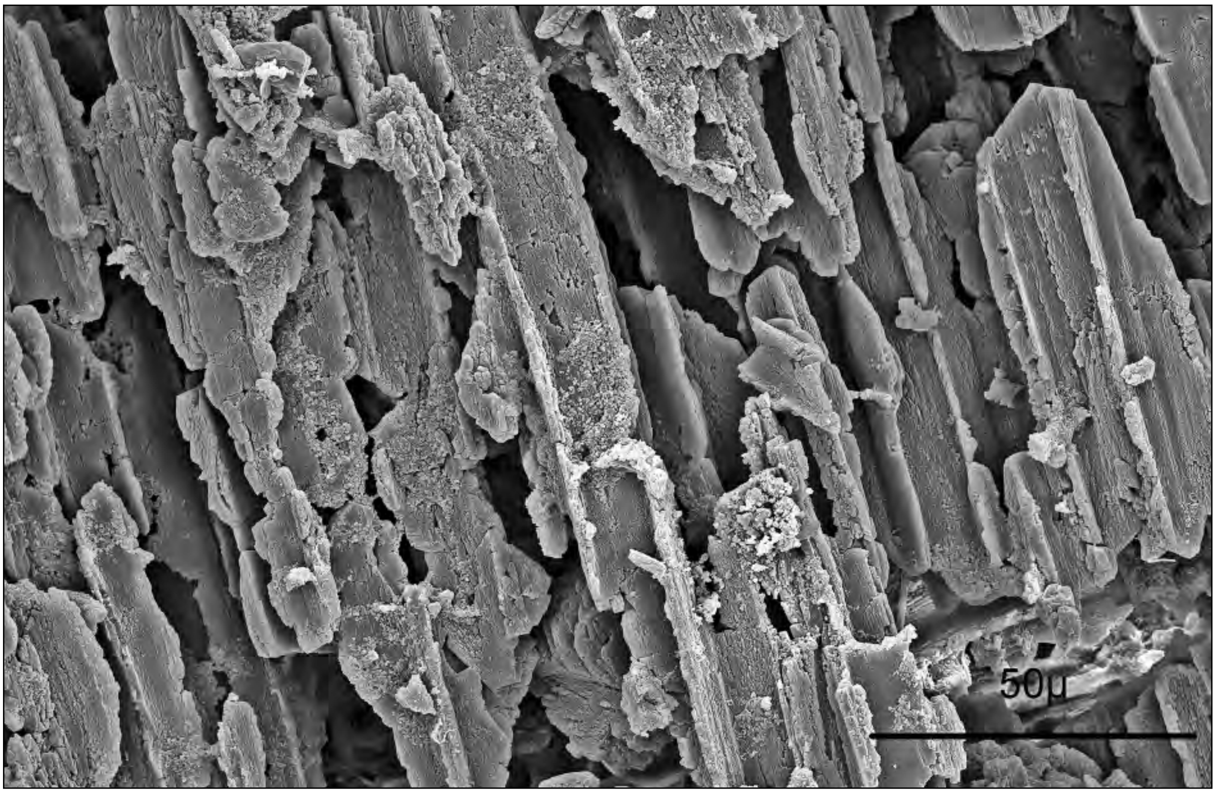

Fig. 15. Silk fibre as negative imprint. Edge of triangular fibre well visible, Konstanz, Augustinerkirche (D)

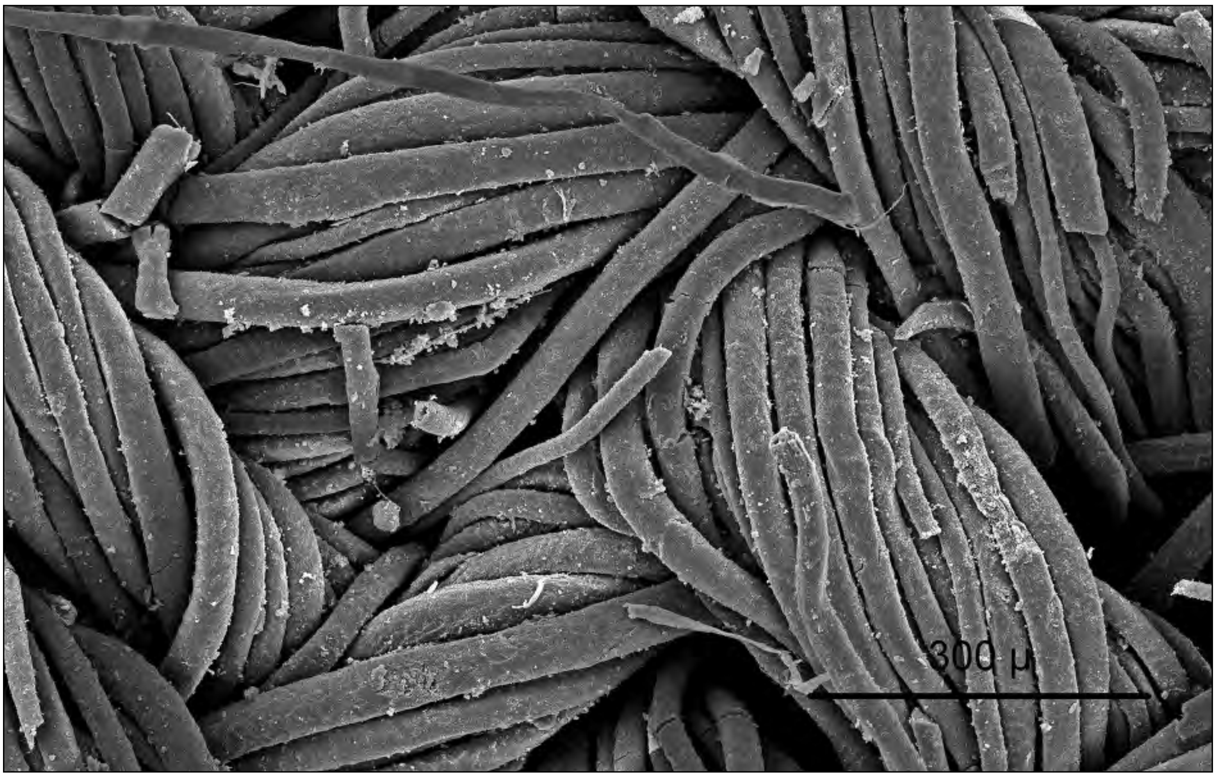

Fig. 16. Wool textiles found in a floor, beginning of 15th c., Kempten-Mühlbergensemble (D)

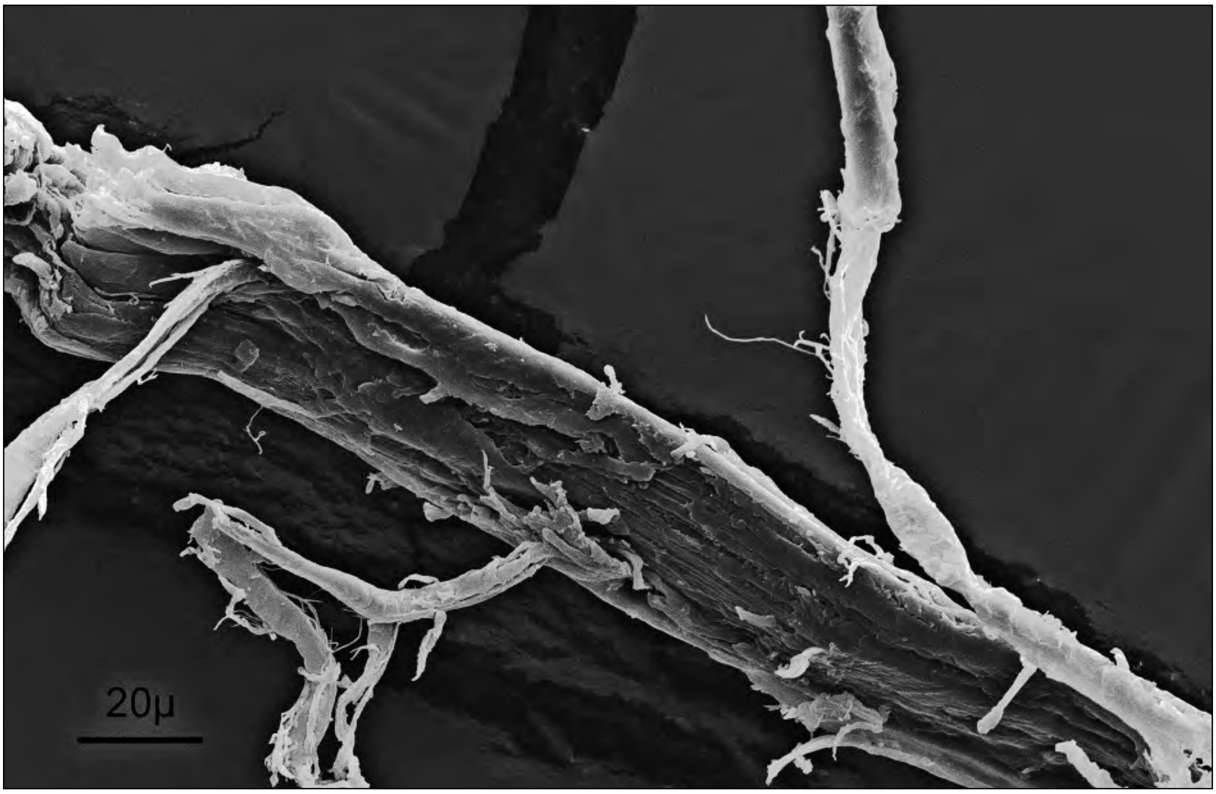

Fig. 17. 16th century paper showing a plant fibre

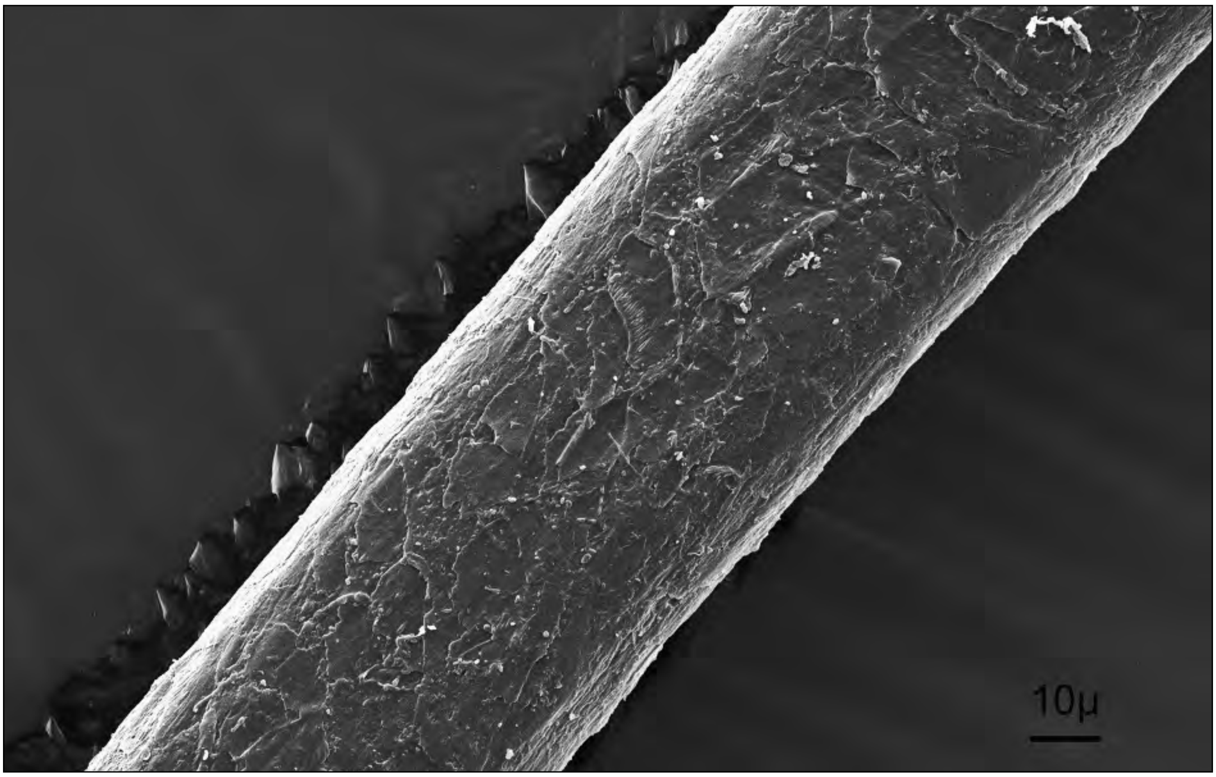

Fig. 18. 16th century paper showing a wool fibre. The scales are mostly erased

Fig. 19. Carbonized thread of flax, Zürich-Breitingerstrasse (CH)

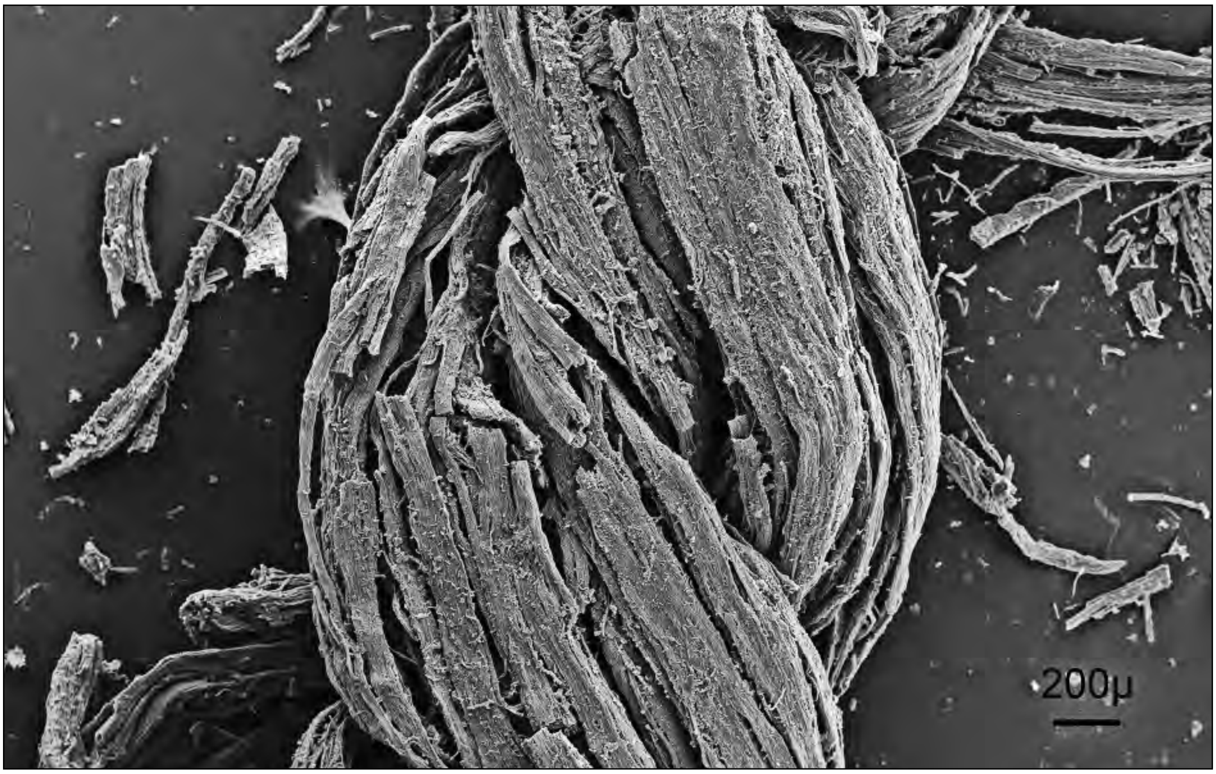

Fig. 20. Neolithic thread made of tree bast (lime bast), Zug-Riedmatt (CH)

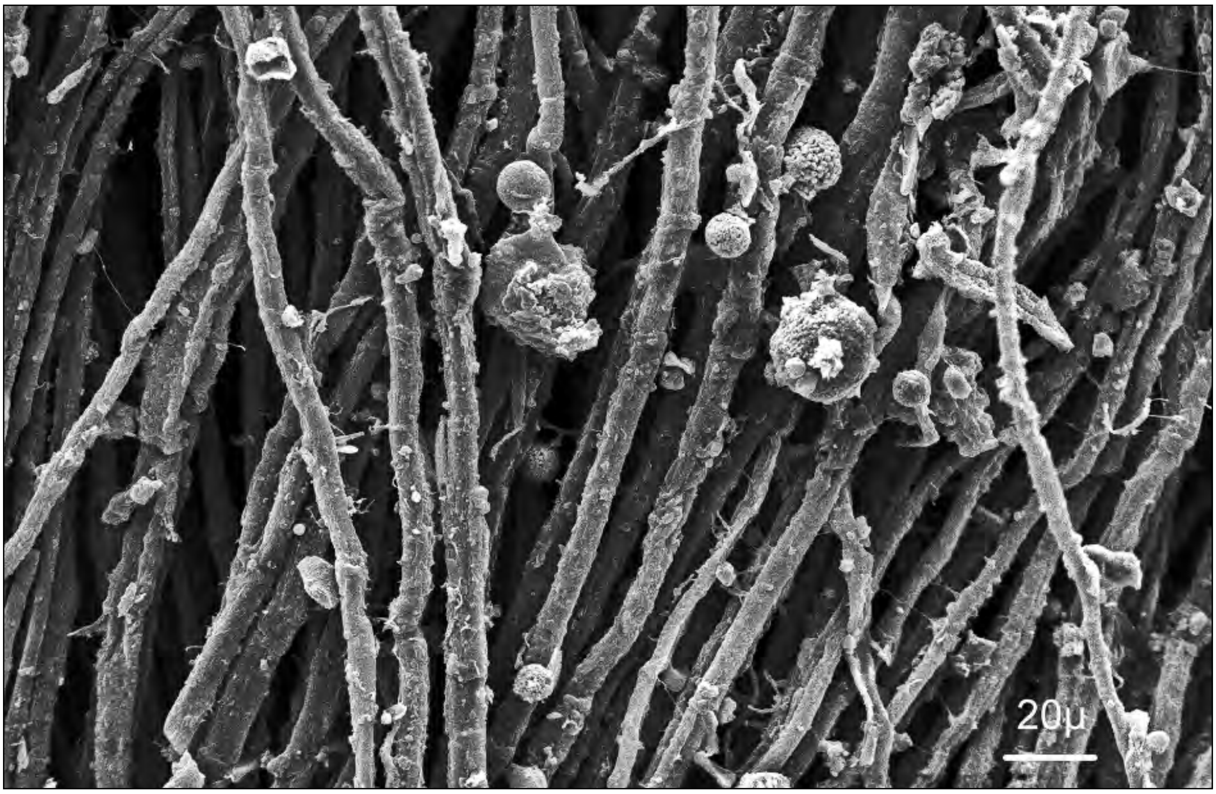

Fig. 21. Carbonized fungus, Sutz-Lattrigen (CH)

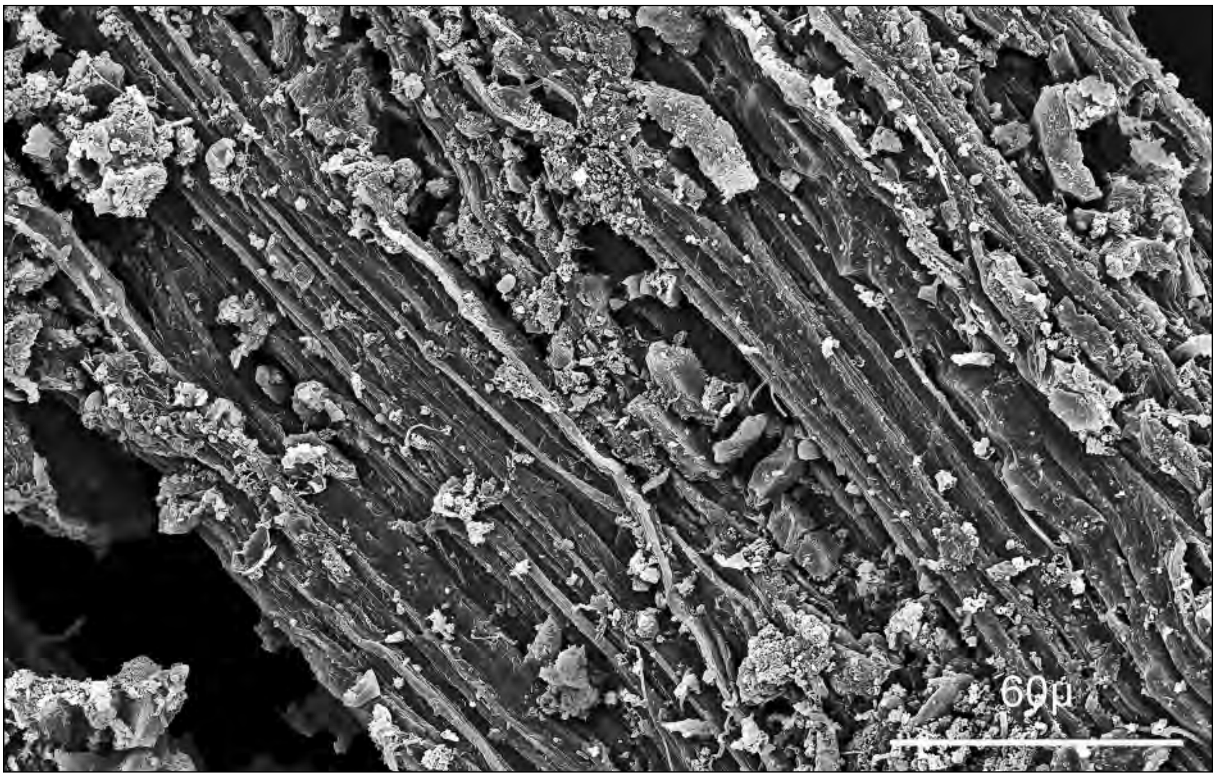

Fig. 22. Calcium-oxalate crystals visible in rays, Steckborn (CH)

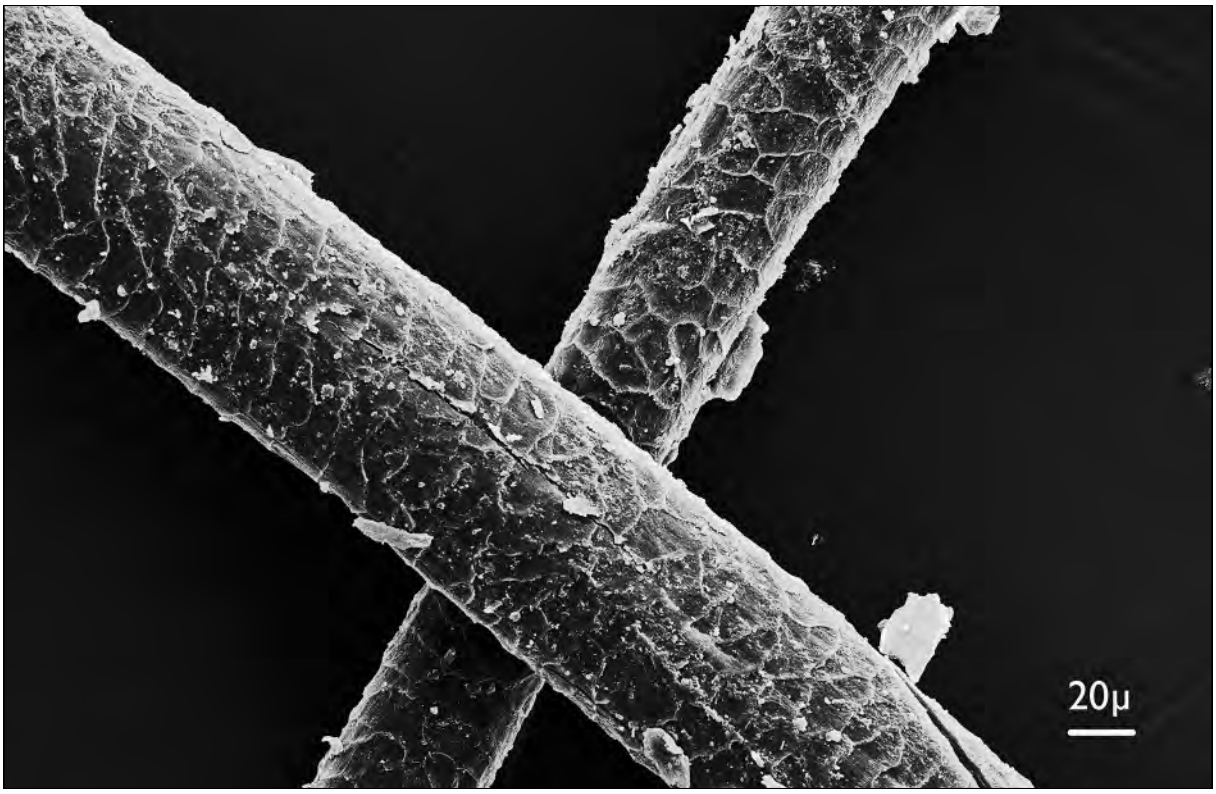

Fig. 23. Wool fibres, Iron Age, Huldremose (DK)

2.1.2.3 Sea Water

Sunken objects, found mostly from the cargo of ships, can be preserved in the salt water of the sea. Not all oceans allow for optimum conditions, however. The North Sea is one where conditions and water components do not favor conservation but the Baltic and Mediterranean Seas do favor them. Dating from prehistory (Iron Age ships) to Medieval or even Modern times, there are two categories of organic material found: ship construction parts (cords, caulking material) and shipping goods (e.g. baskets made of plant fibres) (*Figs 24* and *25*). Objects in both categories are usually uncharred, but also very fragile with poorly preserved fibres (see also *Figs 118–119*).

2.1.2.4 Other Humid Conditions

Sites or graves can be critically affected by humidity. If organic materials are kept under consistently humid conditions which disallow a drying out of the cellular structure, the object will remain in a tentative state of preservation. Such a case is the grave of a small baby in the Roman site of Eschenz (CH) which was found in ground water (Rast-Eicher 2005b). The little body was wrapped in a woolen cloth and buried in a box made of wooden shingles (*Fig. 26*). The fibres are quite well preserved as the wet conditions in the ground had been constant. Wool in a chamber grave from Pustopolje (Bosnia-Herzegovina) was found with fungus on its fibres leading to a conclusion that it had been in contact with air. Evidently it had not been kept in a strictly humid environment. As a result, the fibres of the shrouding textile were in a severe state of deterioration (see *Fig. 40*).

In the marshy lands of the North Sea coast in Northern Germany, humid conditions have been known to preserve organic materials. An especially well known site is the settlement of Feddersen Wierde (D) which dates from the 1st c. BC to the 5th c. AD with its many textiles (Ullemeyer – Tidow 1981).

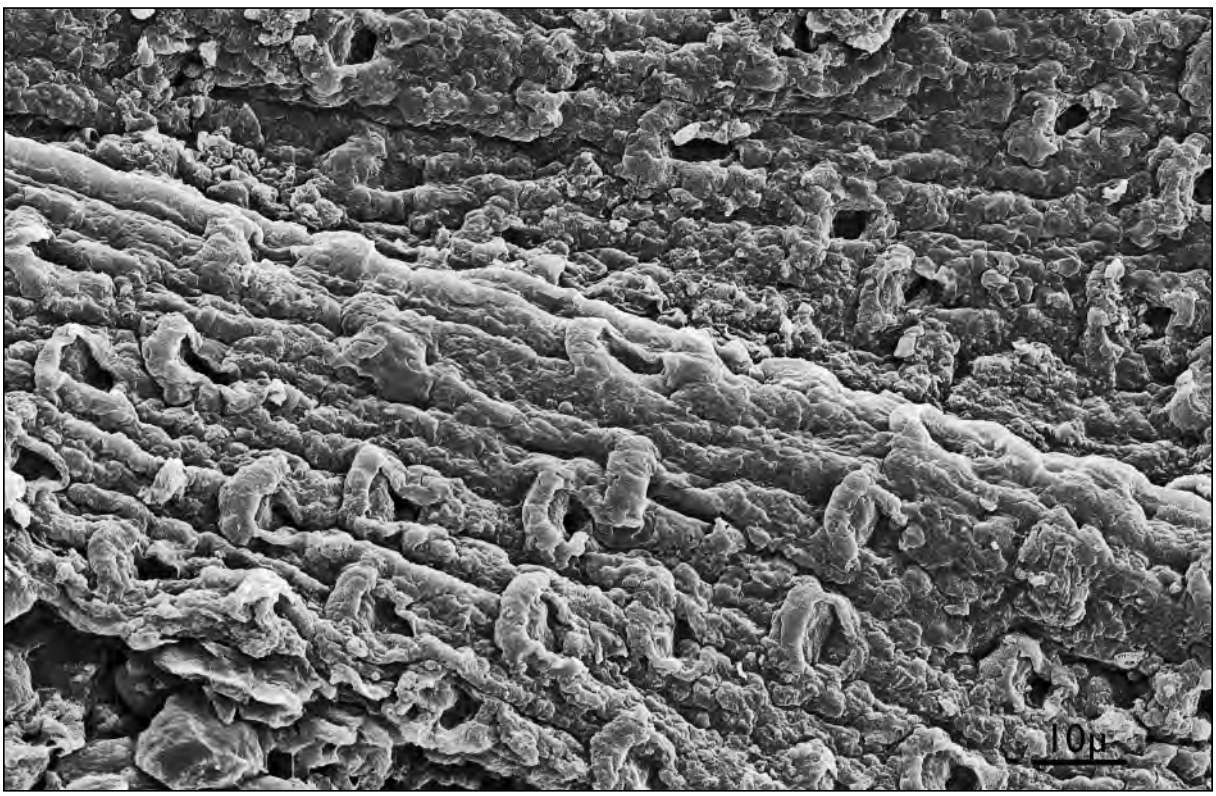

Fig. 24. Plant fibres (Esparto grass) from a basket (Roman period), Zaton (HRV)

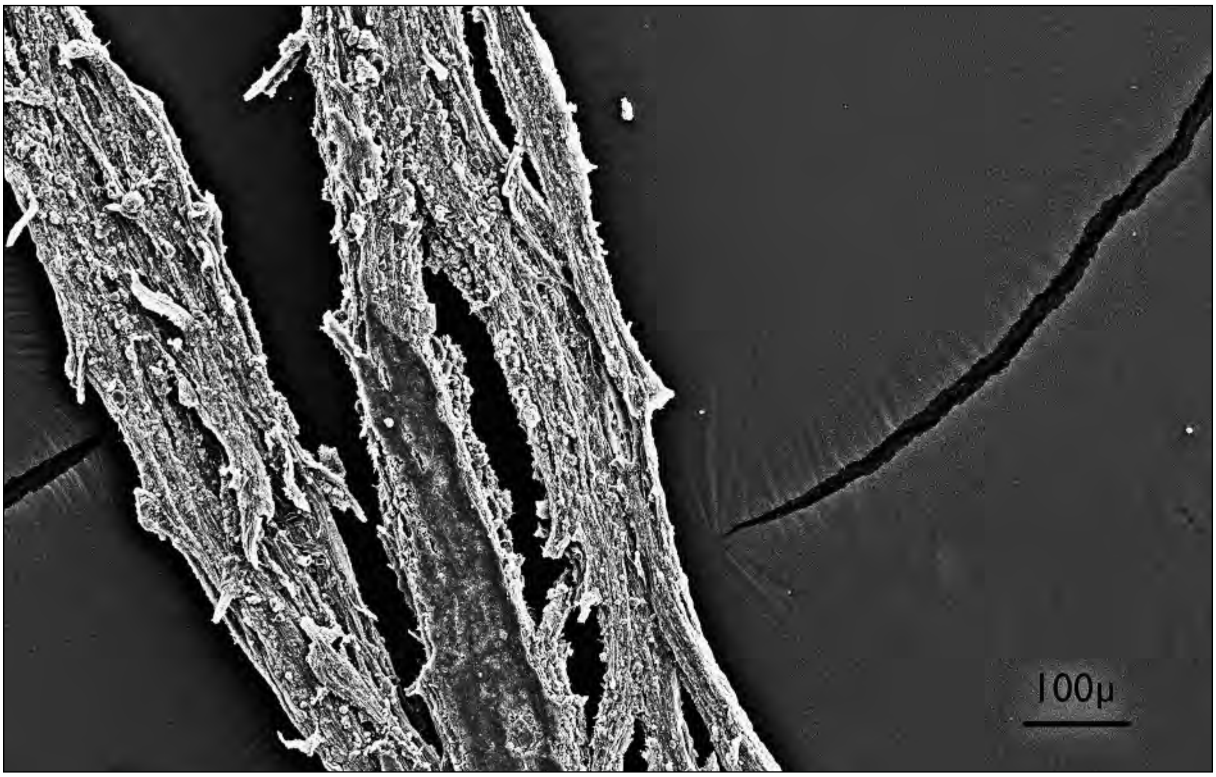

Fig. 25. Tree bast from a mat. Rays are visible, but crystals which could make the determination possible are missing, Dor 2006 (Israel)

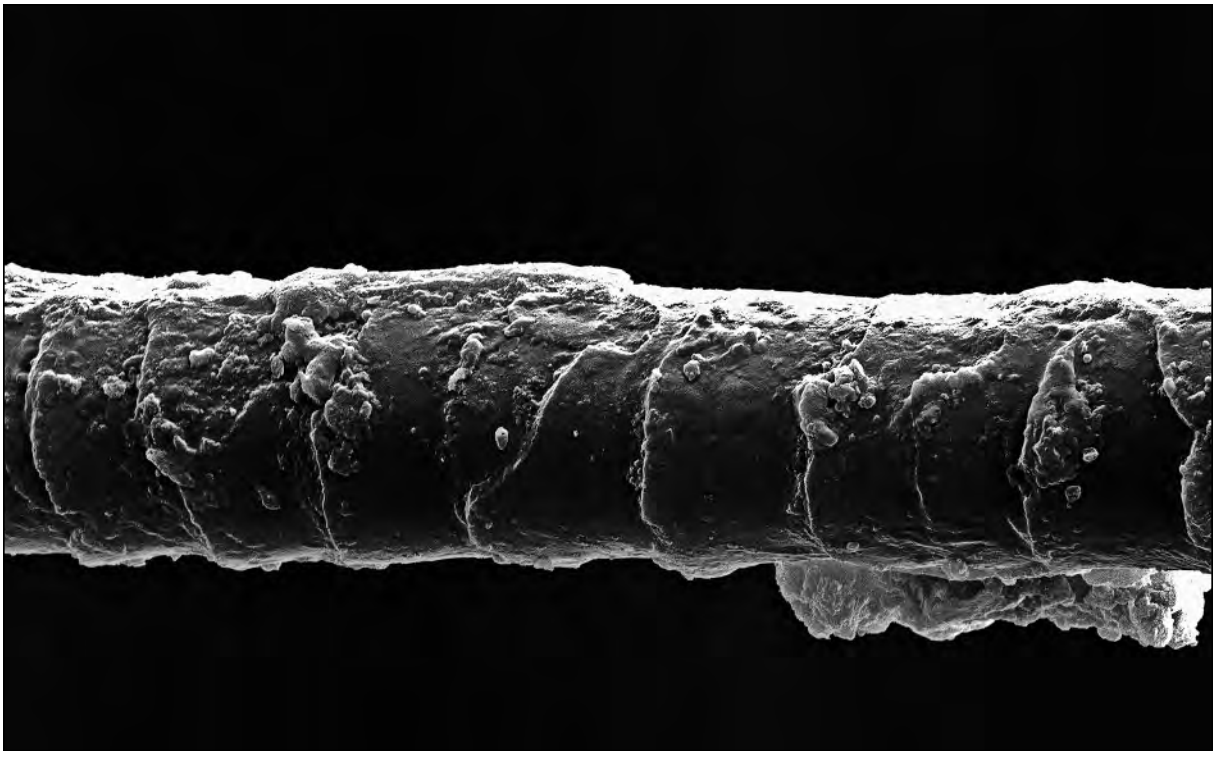

Fig. 26. Wool fibre from the shroud wrapping the baby, Roman Period, Eschenz (CH)

2.1.2.5 Ice/Frozen ground

Archaeological finds such as “Ötzi”, the Iceman from the Similaun Glacier discovered 1991, have become internationally renowned (Egg – Spindler 2008). With him, a new chapter and category in archaeology has been opened, that is, discoveries made due to melting ice. Finds coming out of glaciers or frozen ground are becoming more frequent due to climate change. Scientists are well aware of the incredible value of frozen material, not least in cases of extinct animals (Kirillova *et al.* 2015). Adding to the evidence of these changing temperatures are the textile finds from Lenk-Schnidejoch (CH) at a 2700m altitude. A warm period from the Late Neolithic (around 3000 BC) is reachable now that the glaciers have melted to the extent they have. If there had been warmer temperatures prior to the present, these Neolithic organic materials would not have been preserved at all (Hafner 2015). Prospection projects have been initiated in Scandinavia and in various areas of the Alps. Remains of reindeer hunting on ice patches have been found in Scandinavia, as well as complete garments (Vedeler – Bender Jørgensen 2013).

Freezing is a superior means of preservation, including the fact that fungus cannot grow to cause damage to fibres. Coming out of the ice, organic remains very often appear to be fresh. However, as soon as they are exposed to the regular atmosphere microbiological processes and therefore decay begins (*Fig. 27*). As far as wool fibres are concerned, any pigmentation may be destroyed quickly by the sun. Sheep wool from a Bronze Age textile found on the Schnidejoch appears to be in remarkable shape, the scales being still thick (*Fig. 28*). A Neolithic bast object from the same site, such as this coat made of willow, came out of the ice as if it had just been constructed with the fibres seemingly very stable (*Fig. 29*) (Rast-Eicher 2015). Conservation was carried out using pre-treatment solutions followed by freeze-drying (as with the objects from the lake dwelling sites) to prevent the plant cells from collapsing when drying out. Flax has not yet been found in a glacier context; at a high altitude, this fibre was probably not very functional.

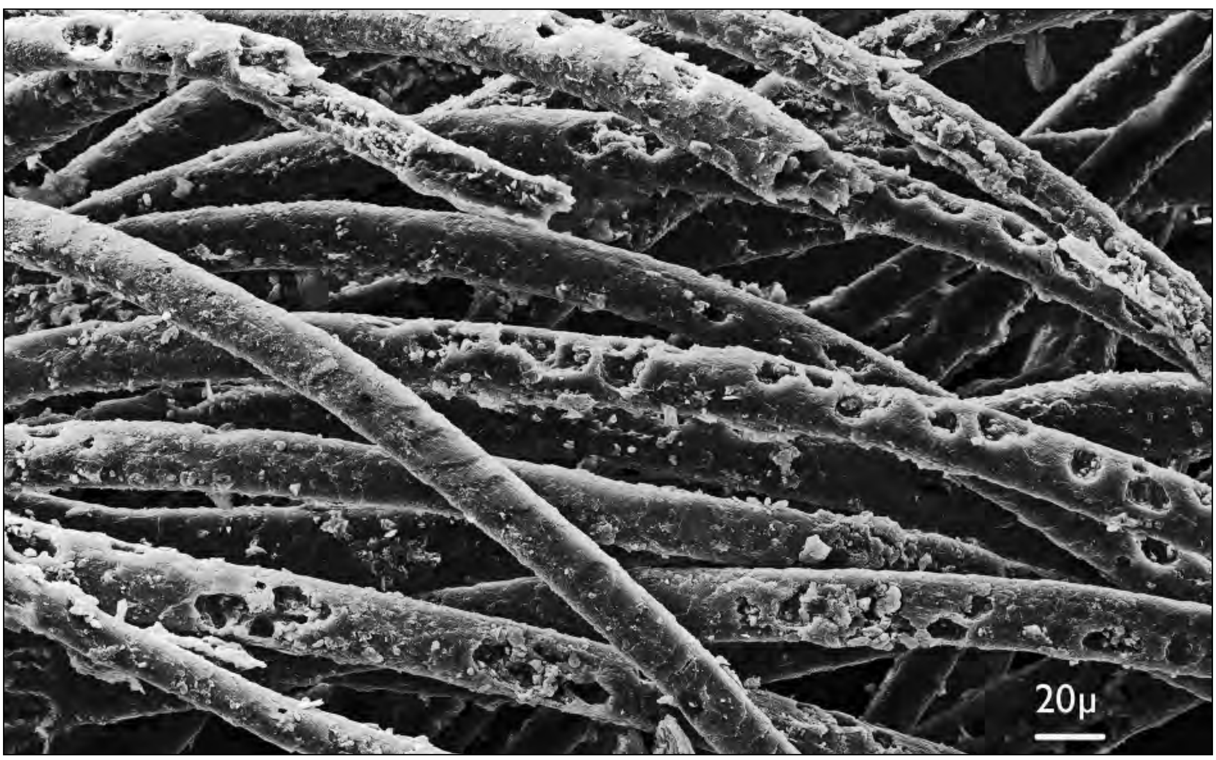

Fig. 27. Roman wool with heavily damaged fibres, Lenk-Schnidejoch (CH)

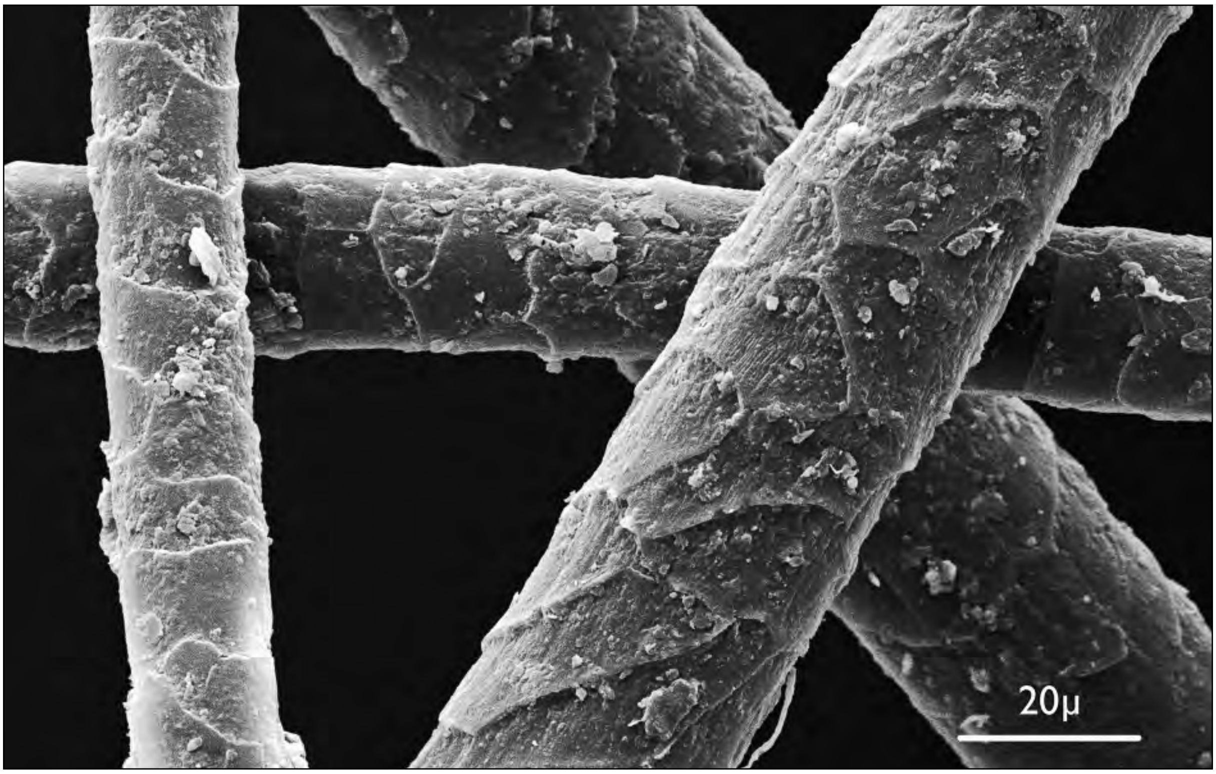

Fig. 28. Bronze Age wool with well preserved fibres, Lenk-Schnidejoch (CH)

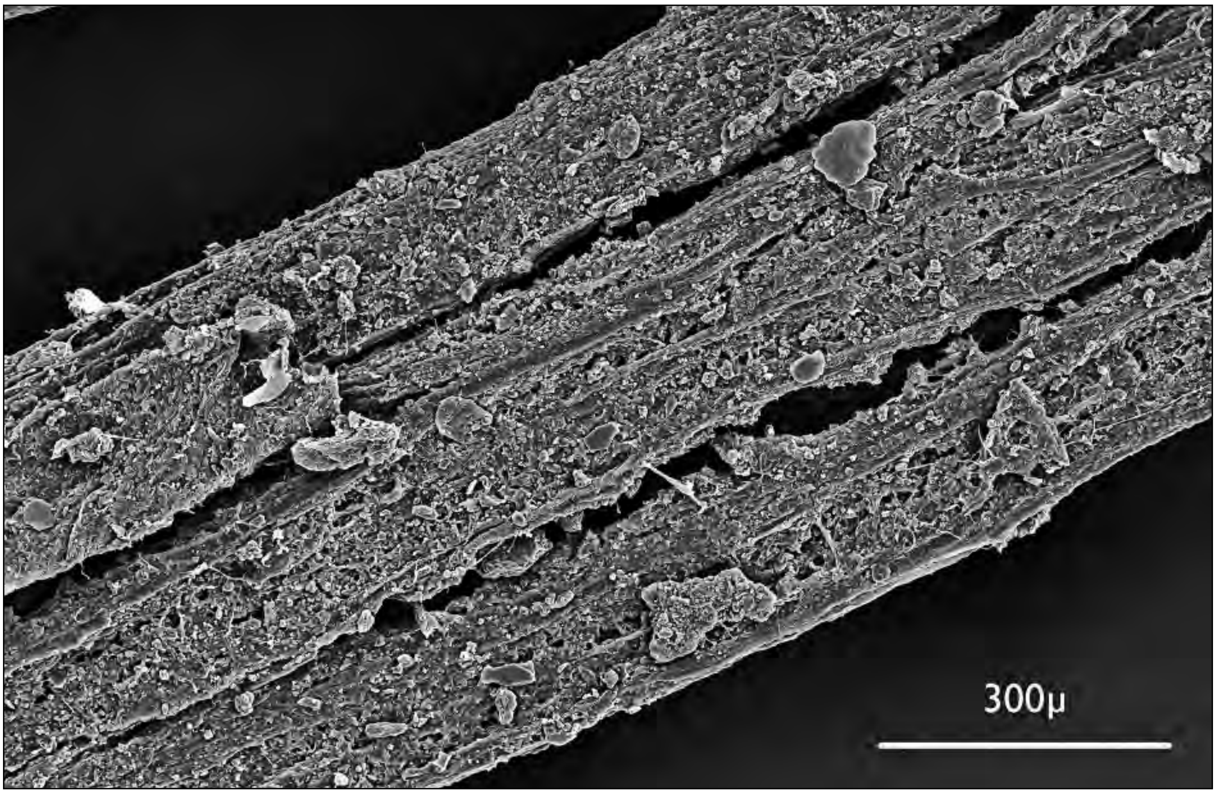

Fig. 29. Neolithic willow bast from a twined textile, Lenk-Schnidejoch (CH)

2.1.3 Salt

Textiles preserved by salt are rare but do make up an important group of prehistoric textiles in Europe (Grömer *et al.* 2013). Generally they are well preserved. Still flexible and looking fresh, not shrunken, even colors are well preserved. As much salt as possible must be removed through repeated rinsing in order for the fibres to remain stable. Even after thorough washing, however, salt crystals will sometimes still be visible under SEM or even under light microscopy. Some fibres may well have lost their scales or have breaks (*Fig. 30*; see *Fig. 41*). Flax, like wool, is usually well preserved in salt layers (*Fig. 31*).

2.1.4 Metal

Organic materials preserved by metal salts make up an important part of the preserved textiles in our soils. There are numerous materials in this group including textiles, but also feathers, grasses, wood and even minute animals such as fleas. (Janaway 1987; 1989; Anheuser – Roumeliotou 2003). The more precious the metal chemically, the lower the speed of oxidation. Organic remains, textiles, skins and other materials are preserved by the exchange of metal ions. The structure of the organic material, such as the scales, is conserved and can be viewed even at microscopic levels. In many cases, however, the material has become hardened and remains as only an imprint in the metal remains. Oxidation is an ongoing process. With bronze or even silver, where oxidation is slower than with iron, there may still be flexible textiles. With gold, textiles are a rarity due to the fact that in the absence of oxidation fibre deterioration will proceed more rapidly than in the presence of oxidation. Because metal is not translucent, light microscopy is not helpful in viewing the state of these mineralized textiles. Scanning electron microscopy (SEM) was introduced in the 1990's and has enabled visibility at extreme magnifications. In this way, discerning and thus identifying fibres has been greatly enhanced.

Preservation of a fibre depends very much on the speed and state of oxidation, ranging from one extreme (stable) to the other (barely visible) (*Figs 32–34*). A special characteristic of lead is that this metal sustains organic material (see *Fig. 38*). Lead coffins have been used in both Antiquity and Early Medieval graves. Textiles within a tightly closed coffin will deteriorate in a unique way.

Even metal-replaced silk can be spottet – similarily as wool, the cross-section of the fibre is visible with the form of the "hole", here as triangle (*Fig. 35*).

2.2 Fibre damage

2.2.1 Animal fibres (without silk)

Under varying conditions of preservation, fibres degrade and show damage in different ways. There can be mechanical breaks or there can be secondary influences such as fungus or chemical effects. Damages that show typical images under microscopy are those that occur by abrasion of the cortex (animal fibres) or epidermis (plant fibres) or by tearing. What is seen are the fibrils sticking out like the ends of a brush (*Figs 36* and *37*). These brush ends create the well-known "pilling" effects of pullovers and other wool items which is a sign of wear or other types of stress on the fibre (such as chemical damage) (Hearle *et al.* 1998). If the fibres lose their scales and the cortex, the fibrils will remain and the sample looks like fine "spaghetti" (*Fig. 38*). Primitive wool consists of fine underwool and kemp. These kemp fibres tend to collapse quickly as soon as the medulla structure (which is usually very large and brittle) is gone (*Fig. 39*). Damage in the longitudinal direction of the fibre is sometimes difficult to spot by light microscopy, making wool measurements difficult. SEM will usually clarify the details greatly.

If humidity has compromised the material, wool fibres will collapse and may be consumed by fungus. The cortex will become very thin and the fibrils will disappear beneath the cortex (*Fig. 40*).

In salt mines, as another example, where fibres take up salt, a possibility of crystal formation and damage to the fibres is greater when the textiles are neither washed nor kept in dry conditions (*Fig. 41*).

Animal fibres can sometimes show breaks which have the look of the broken nodes of plant fibres. It is always important to get an overview of the sample and to look at the fibre diameter (*Fig. 42*). In cross-sections needed for the identification of the fibres, the medulla structure – often an important criterion – has sometimes disappeared. However, some remains may still be visible under the SEM, these being on the inner walls of the cortex and giving some aspects of the medulla and its width (*Fig. 43*). In a mineralized context, fibres can have a different sort of degradation. If the mineralization is slow, wool fibres can lose the scales (*Fig. 44*). Without SEM such a sample could not be determined by means of microscopy. This is the reason why this textile had previously been thought to be made of silk but was in fact wool (discussion in Bender Jørgensen 2013, no 1).

Fibre damage can be related to the use of textiles or skins. In the salt mines of Hallstatt some cattle fibres showed interesting breaks, and had been visibly squeezed (*Fig. 45*).

Fig. 30. Wool thread, scales of fibres partly abraded otherwise well preserved, Hallstatt (A)

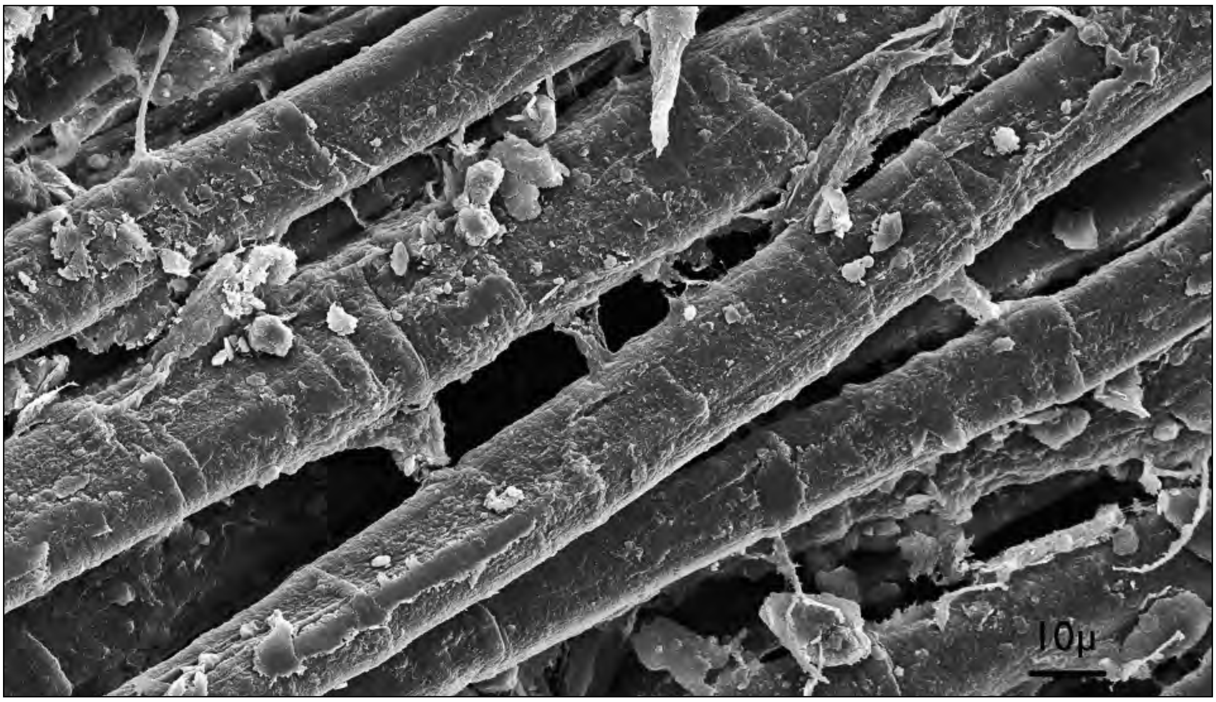

Fig. 31. Flax fibres, Hallstatt (A)

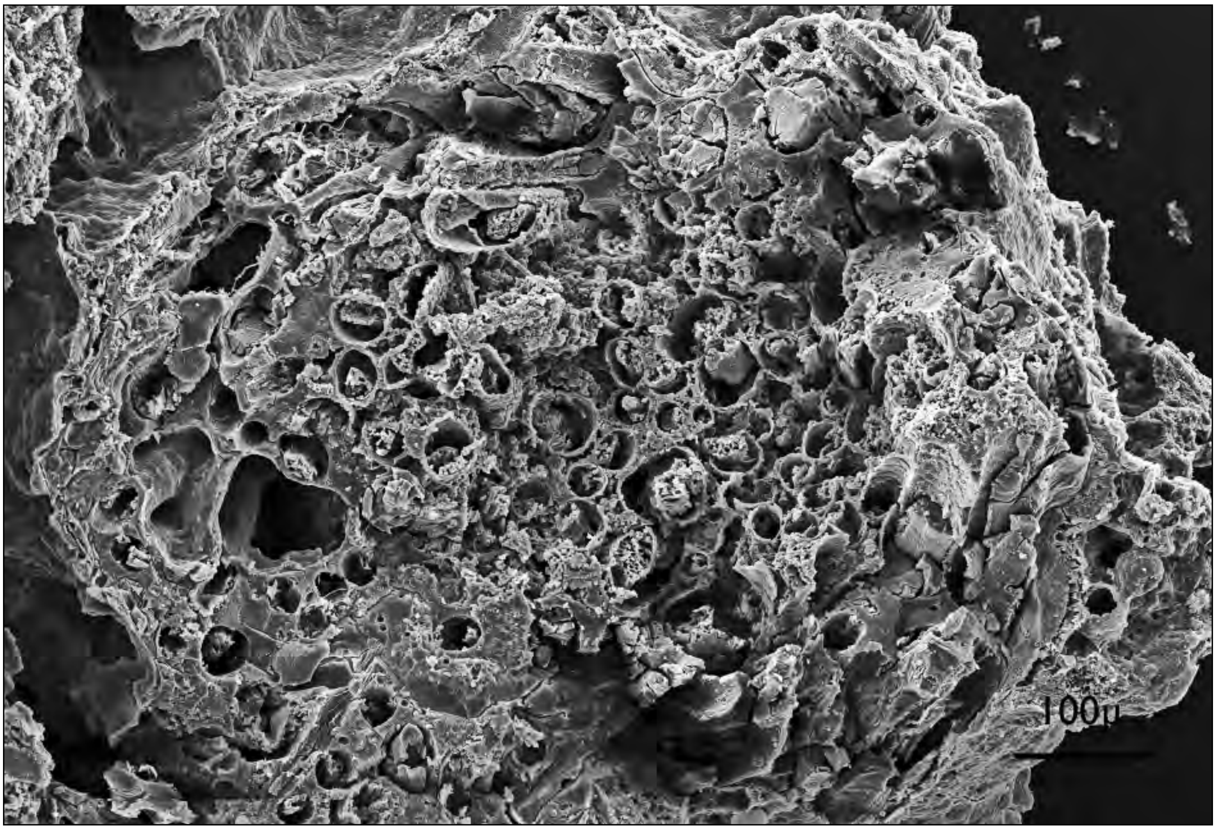

Fig. 32. Mineralized wool thread seen in the cross-section. The cortex is clearly visible as a ring. Inside the „tube“, scales are visible as a negative imprint in the metal oxide. Remains of the former organic fibre are in the casts, Estagel (F)

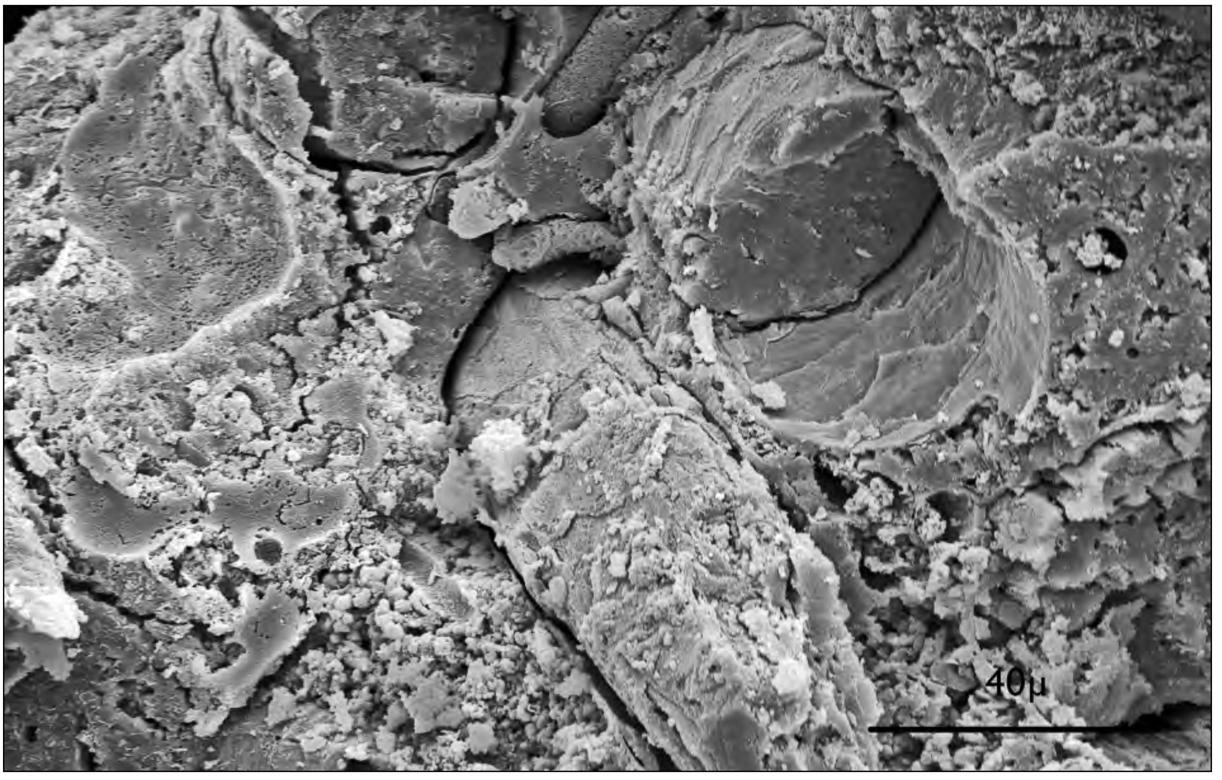

Fig. 33. Wool fibres squeezed in the metal oxide. The former organic fibres are still full size, Langenthal-Unterhard (CH)

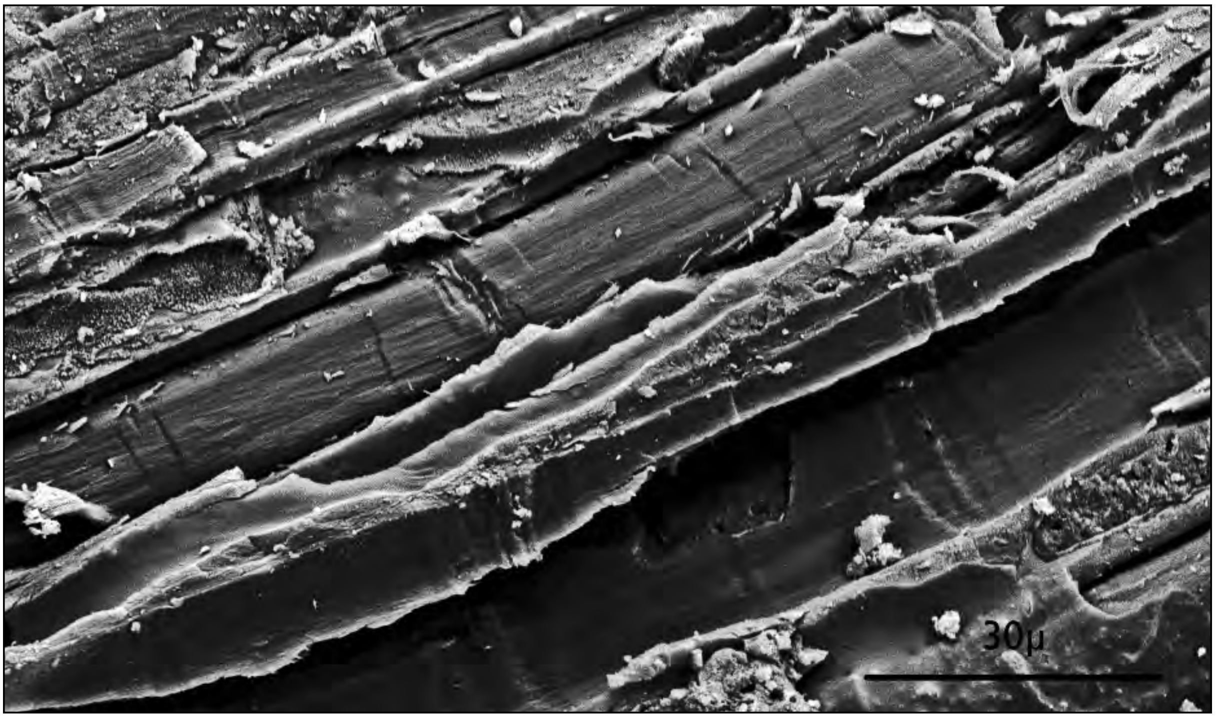

Fig. 34. Plant fibre (probably flax) in a fibre cast with one fibre still visible, the others gone and the cast of metal preserved, Baar-Früebergstrasse (CH)

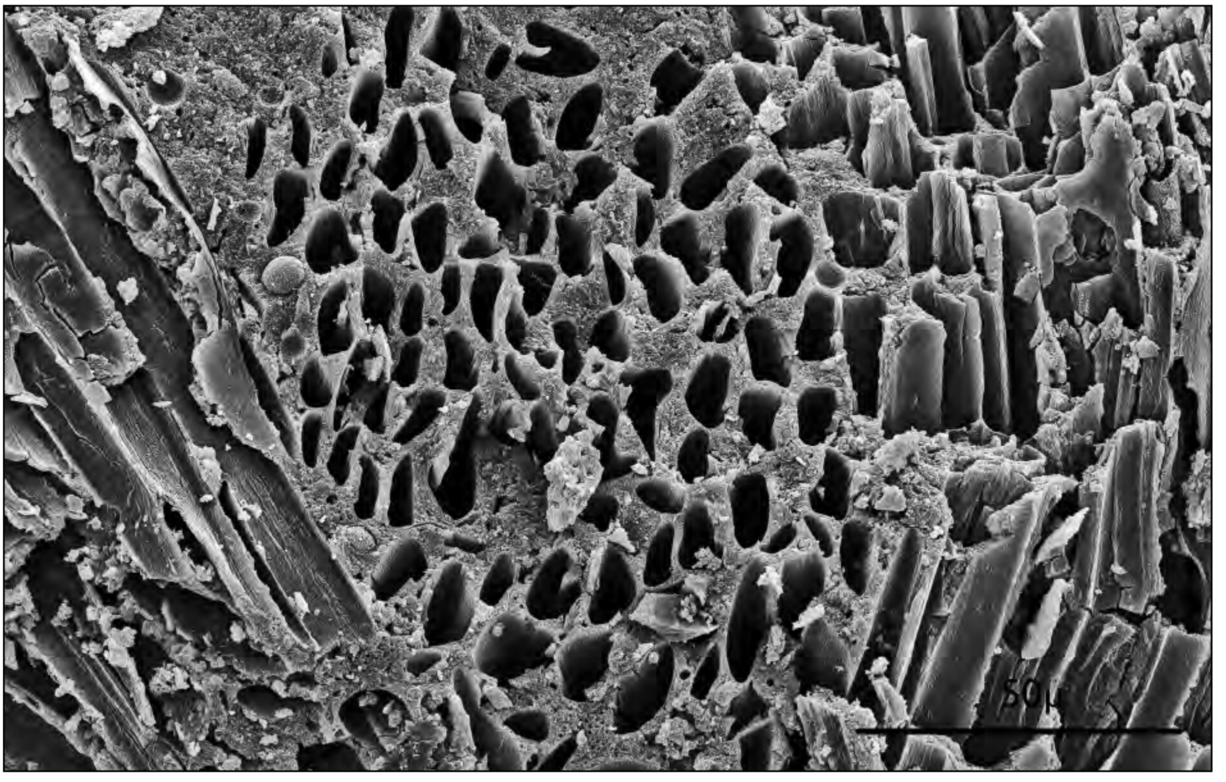

Fig. 35. Cross-section of a metal-replaced silk thread, the longitudinal view is visible as well, Louviers (F)

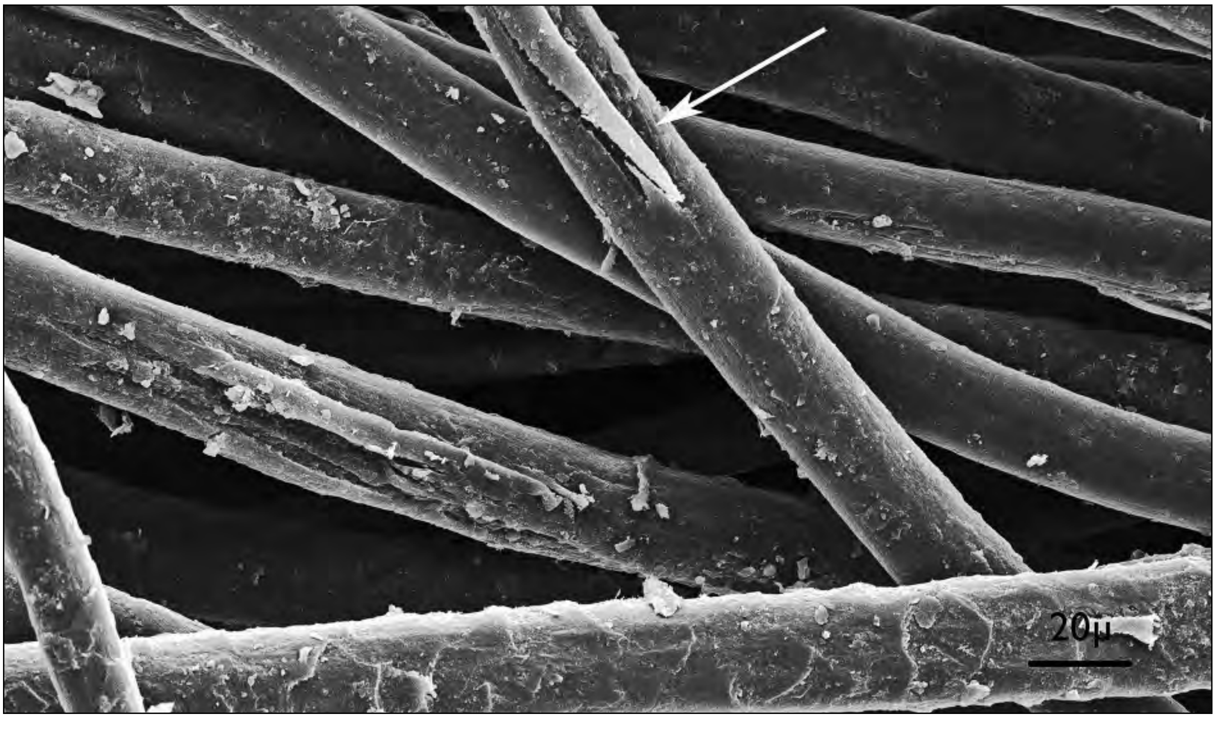

Fig. 36. First stage of breakage, the scales of the wool fibre are off, then the cortex is damaged, Hallstatt (A)

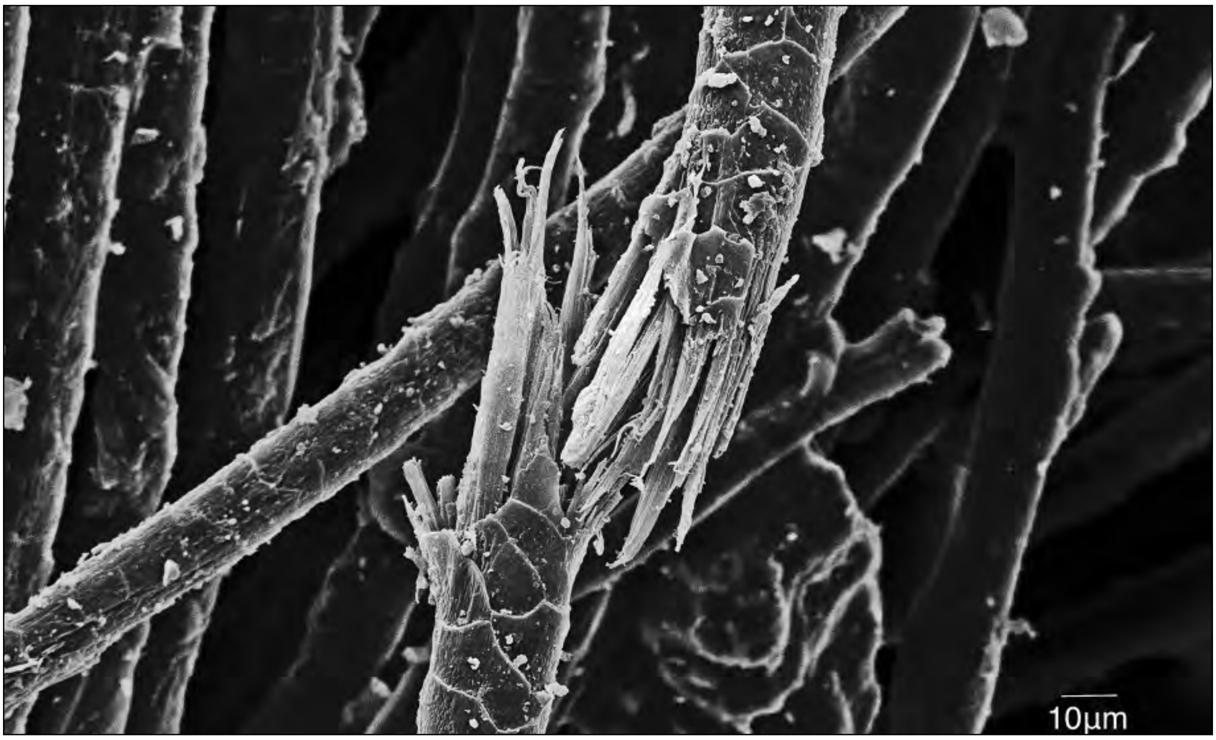

Fig. 37. Second stage: as soon as the fibre cortex is stripped off, the fibrils break and create brush ends, Lendbreen (N)

Fig. 38. When scales and cortex have gone, only fibrils remain. A small bit of cortex remains on the fibrils. 18th c. grave of a child, Daillens (CH)

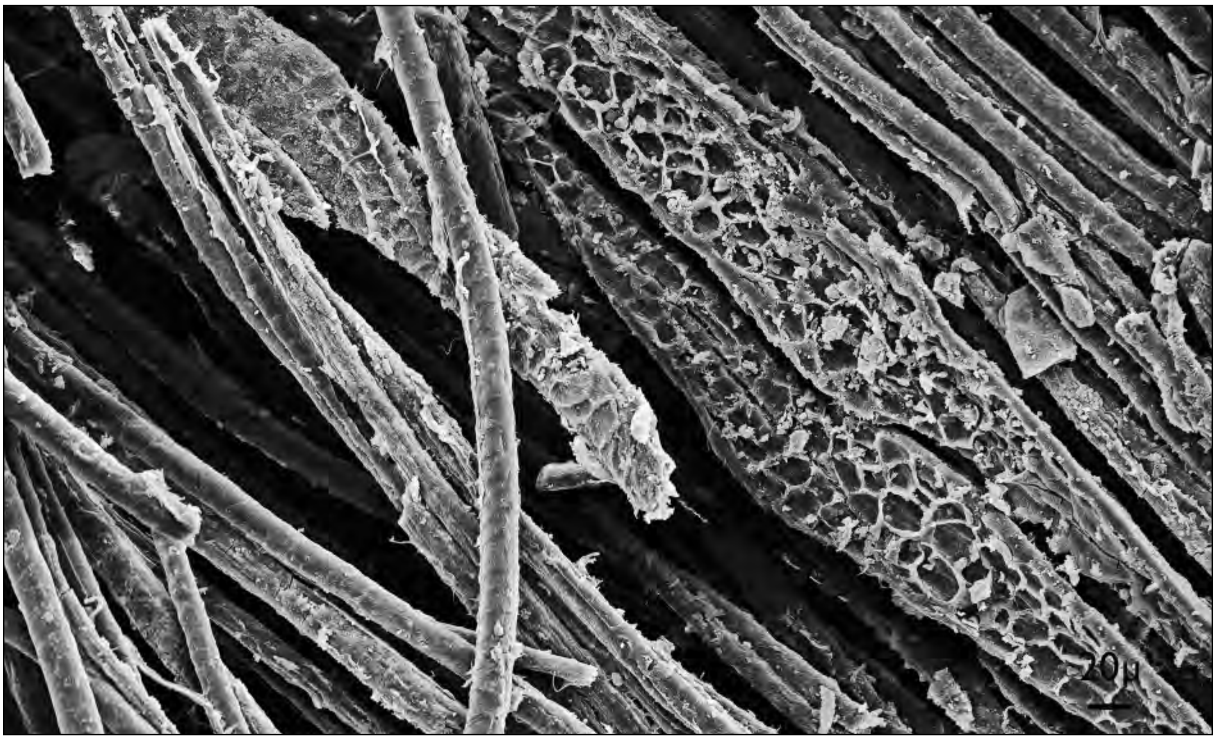

Fig. 39. Collapsed and broken kemp fibre. Only small pieces remain showing the inner side of the fibre with the net-like medulla structure of sheep kemp fibres, Jåsund (N), Bronze Age

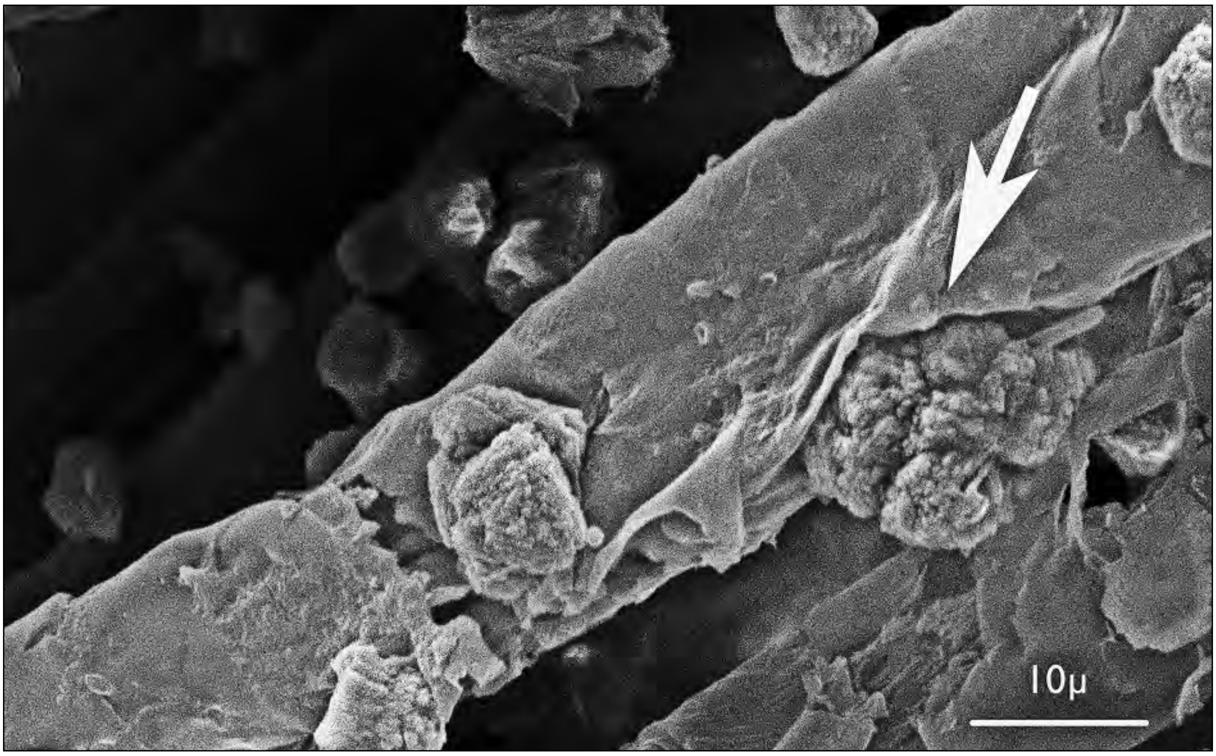

Fig. 40. Wool fibre with destruction by fungus, Bronze Age inhumation, Pustopolje (BIH)

Fig. 41. Damaged wool fibres, salt mines of Hallstatt (A), Iron Age

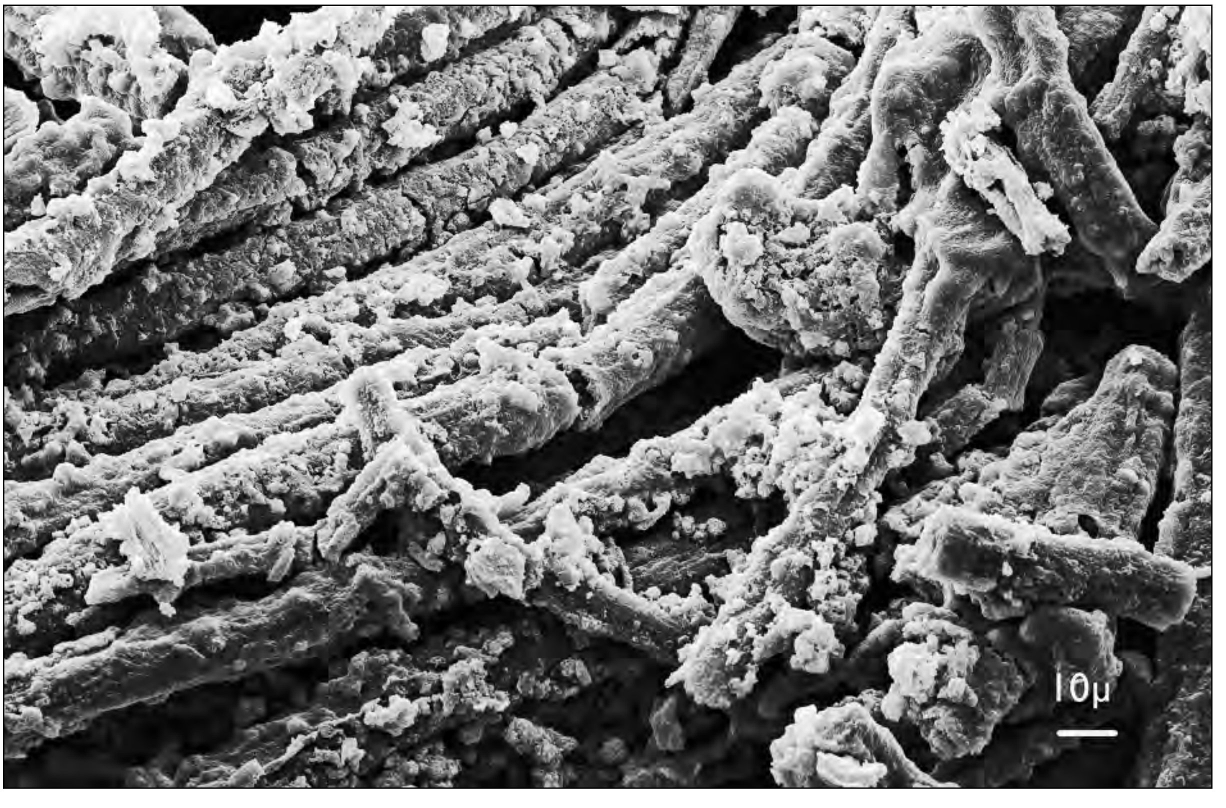

Fig. 42. Fibres with horizontal breaks looking like broken nodes of plant fibres, Bleckmar (D)

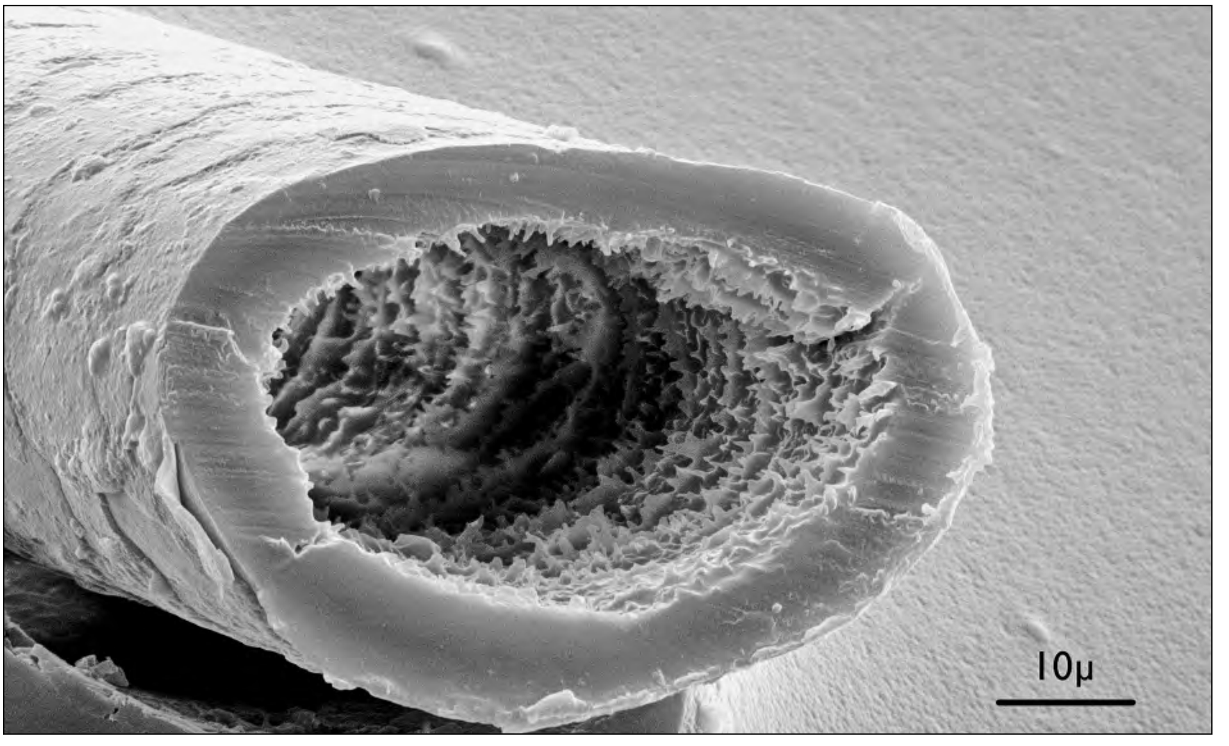

Fig. 43. Cattle fibre cross-section, granulated medulla structure visible on cortex walls, Møgelmose (DK), Iron Age skin

Fig. 44. Scales are nearly gone, and appear in some parts of the thread as a very faint structure, Altrier (LUX)

Fig. 45. Damaged cattle fibre, squeezed on the stairs in the mine, Hallstatt (A)

2.2.2. Plant fibres

While animal fibres possess several criteria that are important for fibre analysis, plant fibres present more difficulties especially when badly preserved. The degradation of cellulosic fibres has been studied in experiments (Peacock 1996 with references). The nodes (see *Fig. 34*) are typical in determining bast fibres in general. If deterioration has occurred they mostly flatten and the structure is much finer, as it is for animal fibres (fibrils) (*Fig. 46*). When bast fibres degrade slowly in a humid, non-mineralizing context, they shrink and look like cotton (*Fig. 47*). It is to be noted that even deteriorated wool can break and give the appearance of plant fibre breakage at the nodes (see *Fig. 42*)! Heavily processed flax shows signs of treatment, such as vertical breaks or bumps in the fibre (Rast-Eicher – Thijsse 2001).

2.2.3 Silk

Silk fibres deteriorate differently and more rapidly than hair fibres and identifying damaged silk is much more difficult than for any other fibre type. Silk fibres have a smooth surface and do not show distinctive characteristics as with other animal or plant fibres; the triangular cross-section, however, is very typical (see. ch. 4.10.3, mulberry silk). Silk will shrink greatly even in a mineralized state, making analysis difficult. This is especially so if types other than mulberry silk are present (*Fig. 48*). Even then, a cross-section can show the typical form (see chapter 4.10). Silk will show clear breaks – like glass – and never fibrous breaks as is often seen with animal or bast fibres (*Fig. 49*). It can also shrink (*Fig. 50*).

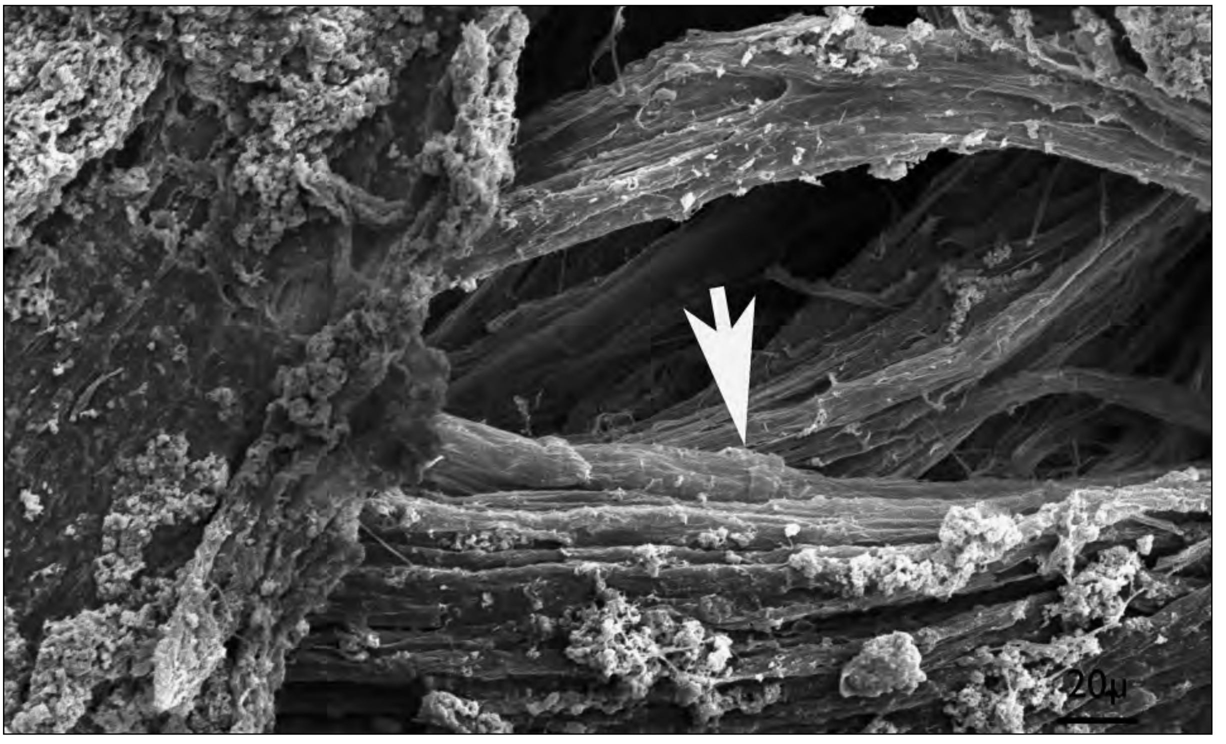

Fig. 46. Badly preserved flax. In the center, one fibre with nodes is still visible (see arrow), Roman, Jaunay-Clan (F)

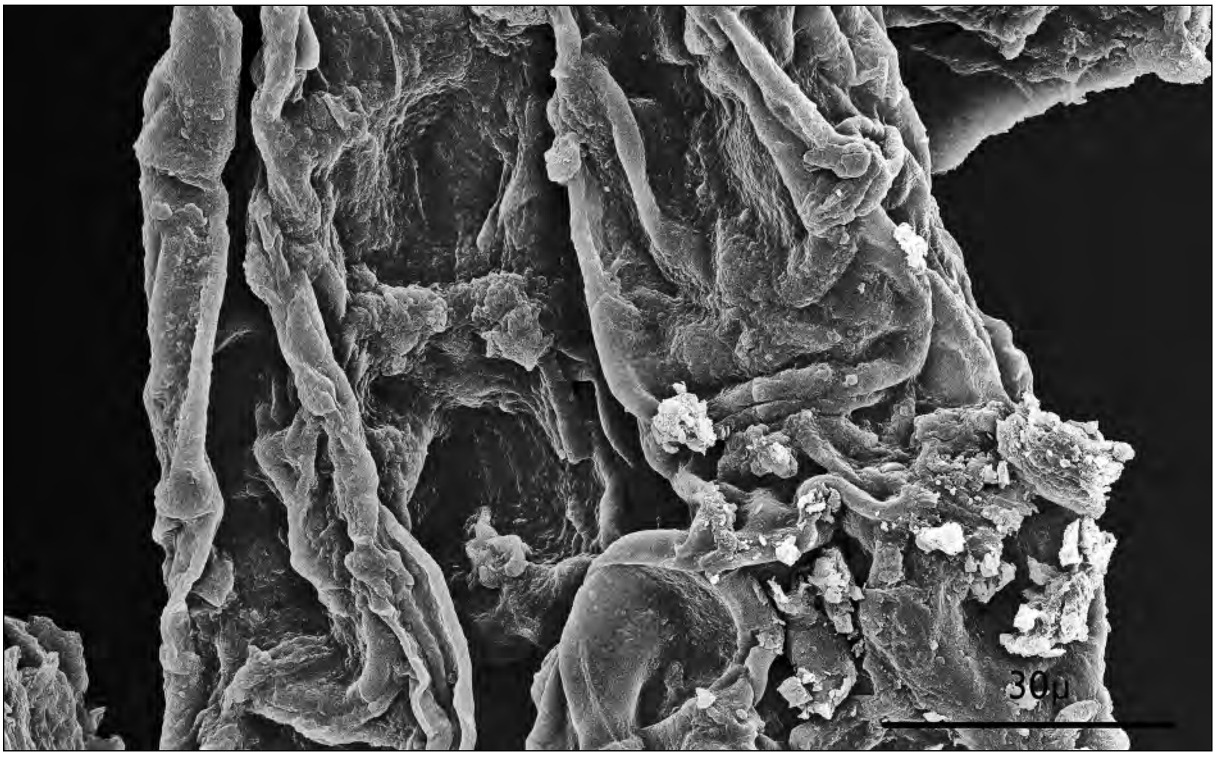

Fig. 47. Badly preserved and shrunken hemp or flax fibres. According to other spots in the thread, it is not cotton, Bourges (F), Medieval

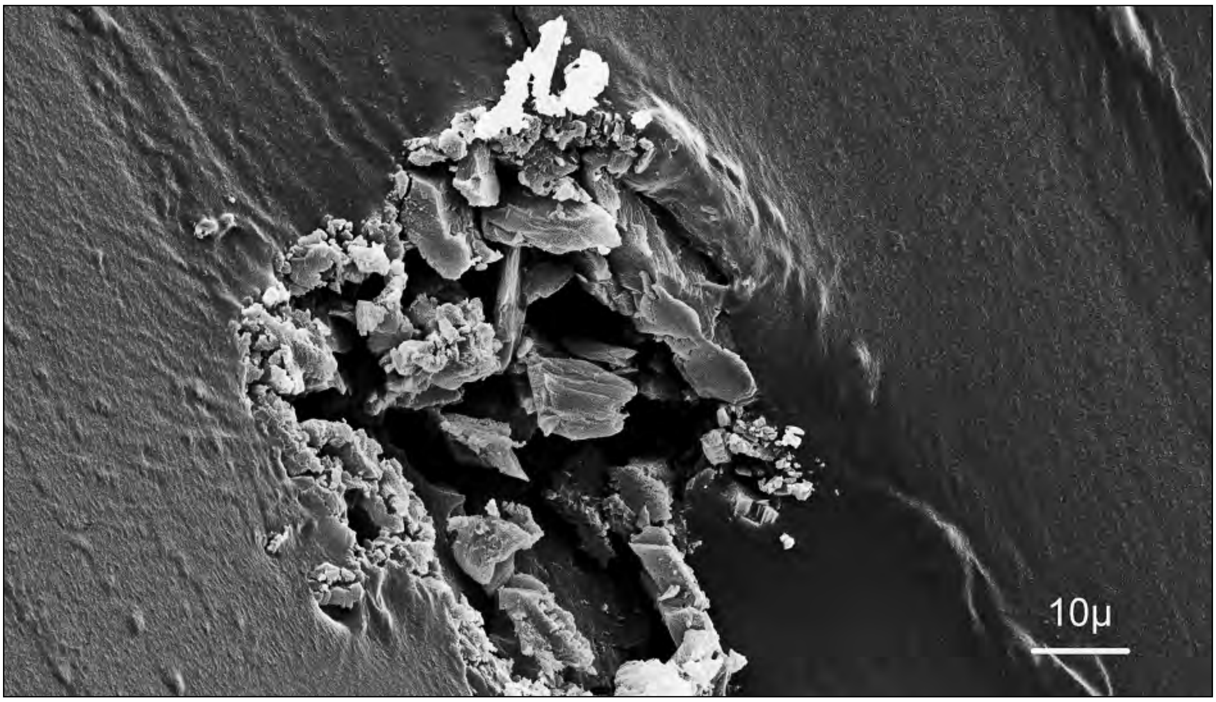

Fig. 48. Cross-section of shrunken silk fibres in a thread, Saint Denis/Paris (F), Early Medieval

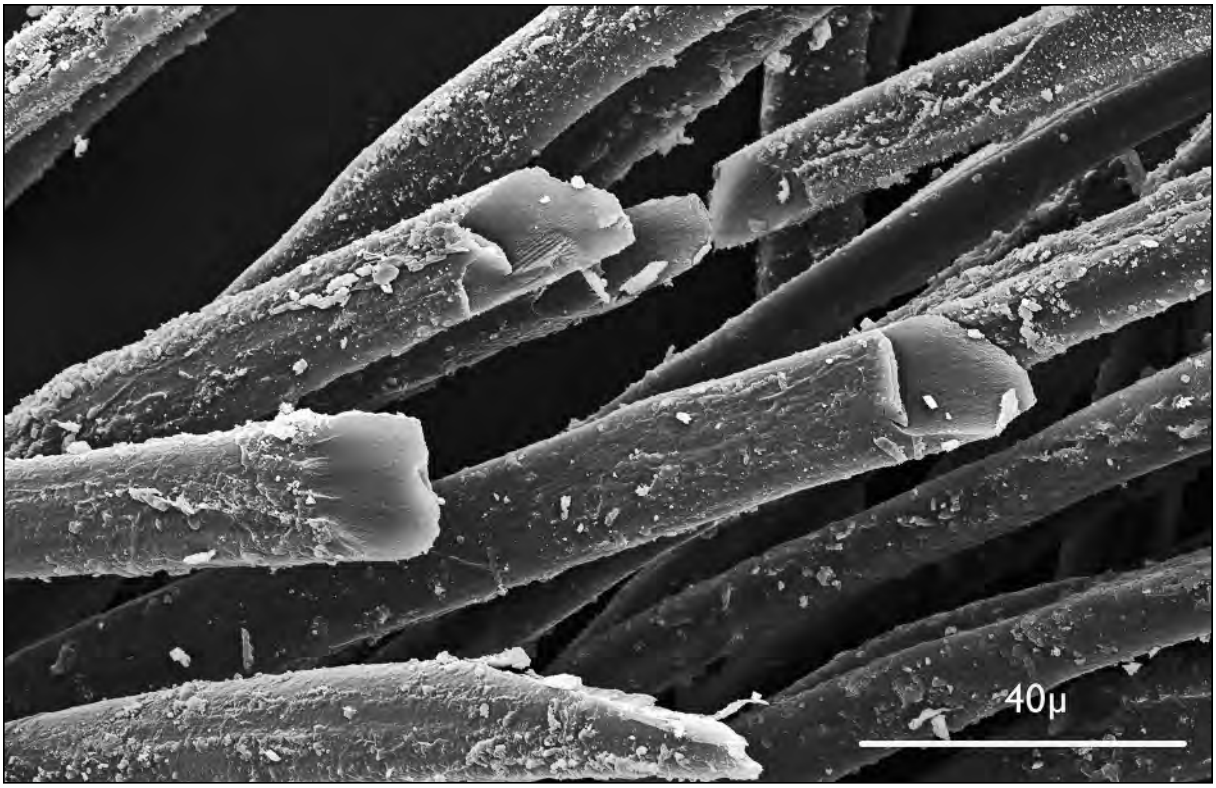

Fig. 49. Break of silk fibres, Chelles (F), Early Medieval

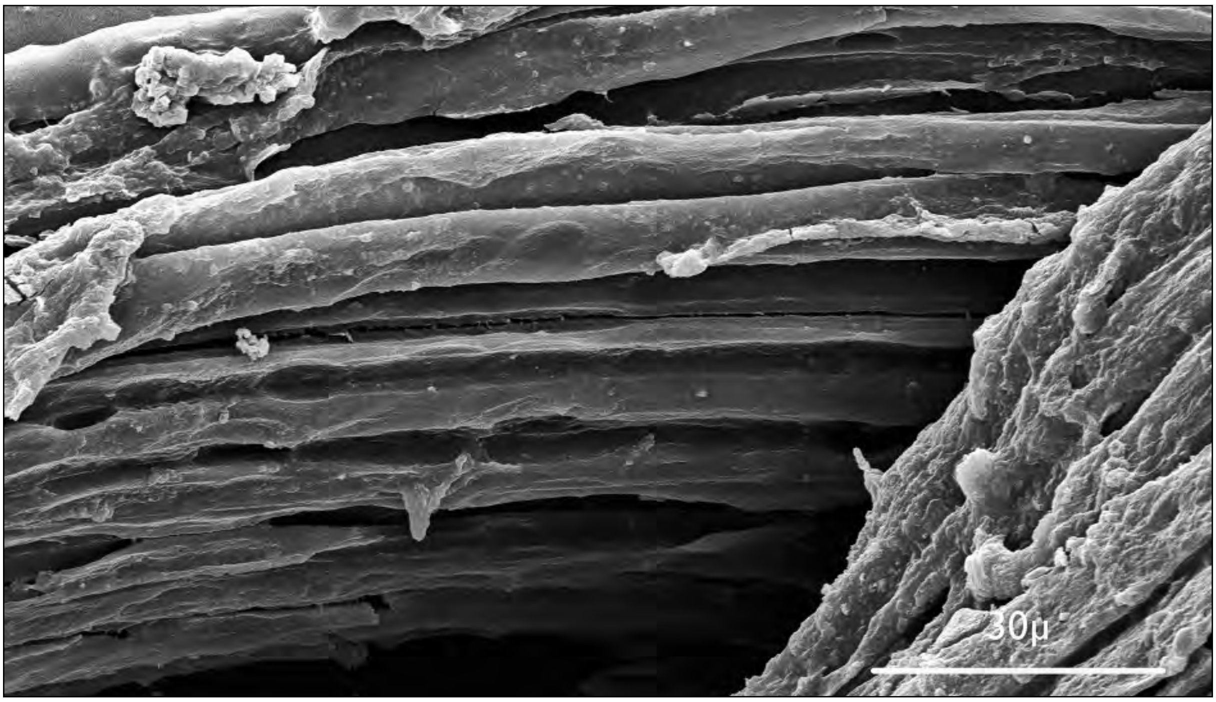

Fig. 50. Badly preserved silk fibres, Basel-Petersplatz (CH), Medieval

2.3 Processing

2.3.1 Animal fibres

Sheep wool is the main animal hair used for textiles and the process of preparing the fibre is a major source of study. The fibres of sheep wool have undergone numerous changes over the course of domestication (see chapter 4.1.2). Chronological changes, therefore, are a very important and complicated consideration in the analysis of fibre preparation (Rast-Eicher 2008c, 120).

Photographic images of processed fibres can show distinct characteristics. For example, sheep wool which can be either plucked or shorn. Plucking would show a tearing of the fleece and something that might have been carried out during the molting season of the sheep in late spring. Shearing came up during the Iron Age when fine sheep wool was developed through special breeding and by allowing a continuously growing fleece. In terms of microscopic fibre characteristics, plucking will leave roots and tips (*Figs 51* to *53*). Tips appear in lambswool and in plucked sheep wool. As well, wool gained from dead sheep (*"Gerberwolle"*) can contain roots. In another instance, fibres spun without further processing after plucking or shearing will all keep the same scale direction. If wool has been combed (with unheated combs), however, the scales in a thread will point in different directions (*Fig. 54*). The simple act of combing may cause the fibres to be turned in different directions (at the root-tip). With warm metal combs – used since the Roman Period – a straightening of the curled fibres is enabled. Worsted textiles made with such wool have been found of a very fine quality (*Fig. 55*). Even prehistoric wool threads have been found as straight fibres indicating combing as well. However, with the cold combing used at that time only separation from the short underwool and longer and straighter fibres was possible (*Fig. 56*). In this case, crimp may be visible as it doesn't disappear with cold combing (*Fig. 57*). It can also be said that crimp improves spinning performance and gives a bulkier yarn (Menkart – Detenbeck 1957).

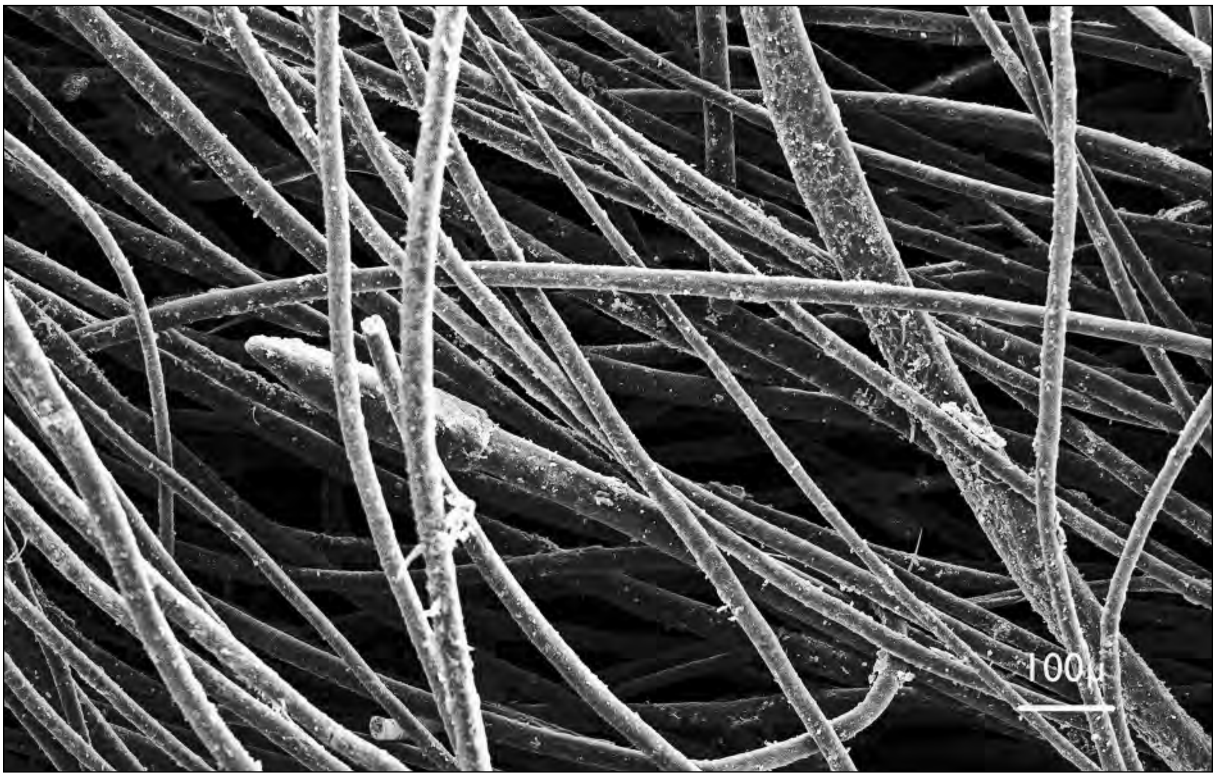

Fig. 51. Root visible in a textile of the Hallstatt Period, Hallstatt (A)

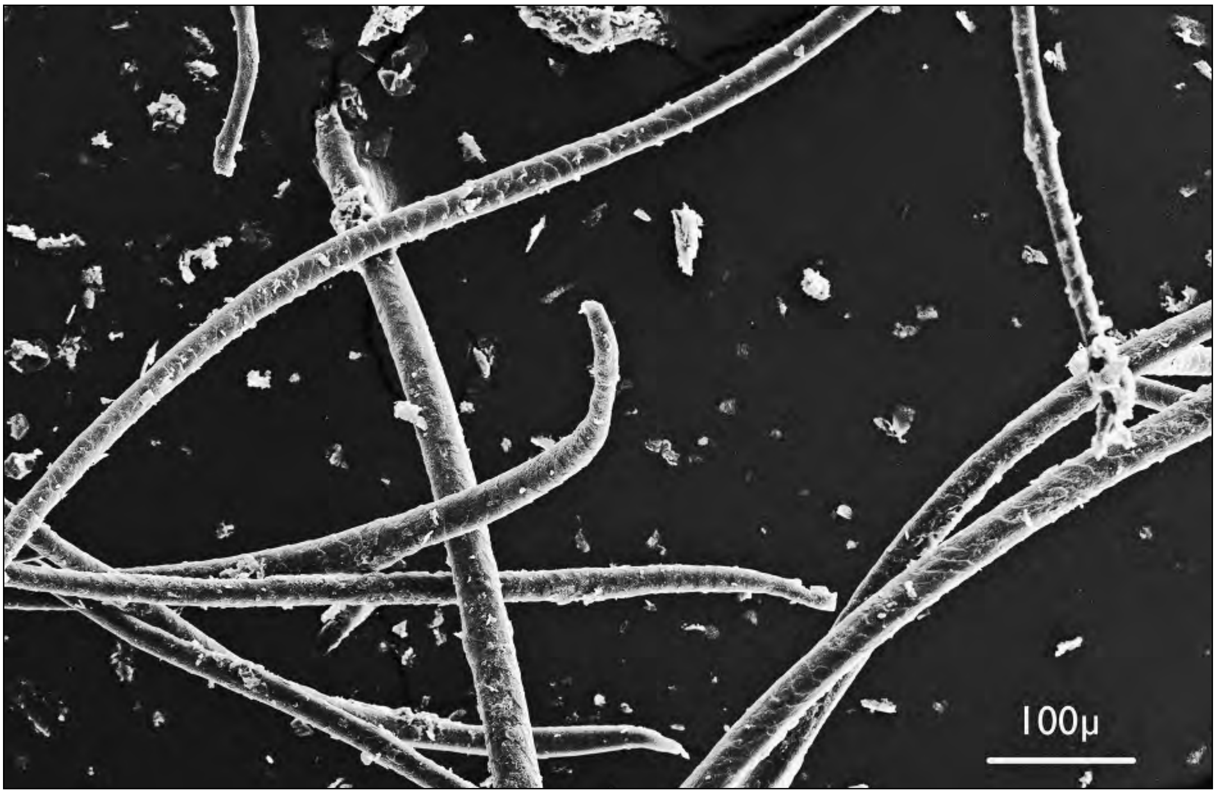

Fig. 52. Fibre tips, tunic from Lendbreen (N)

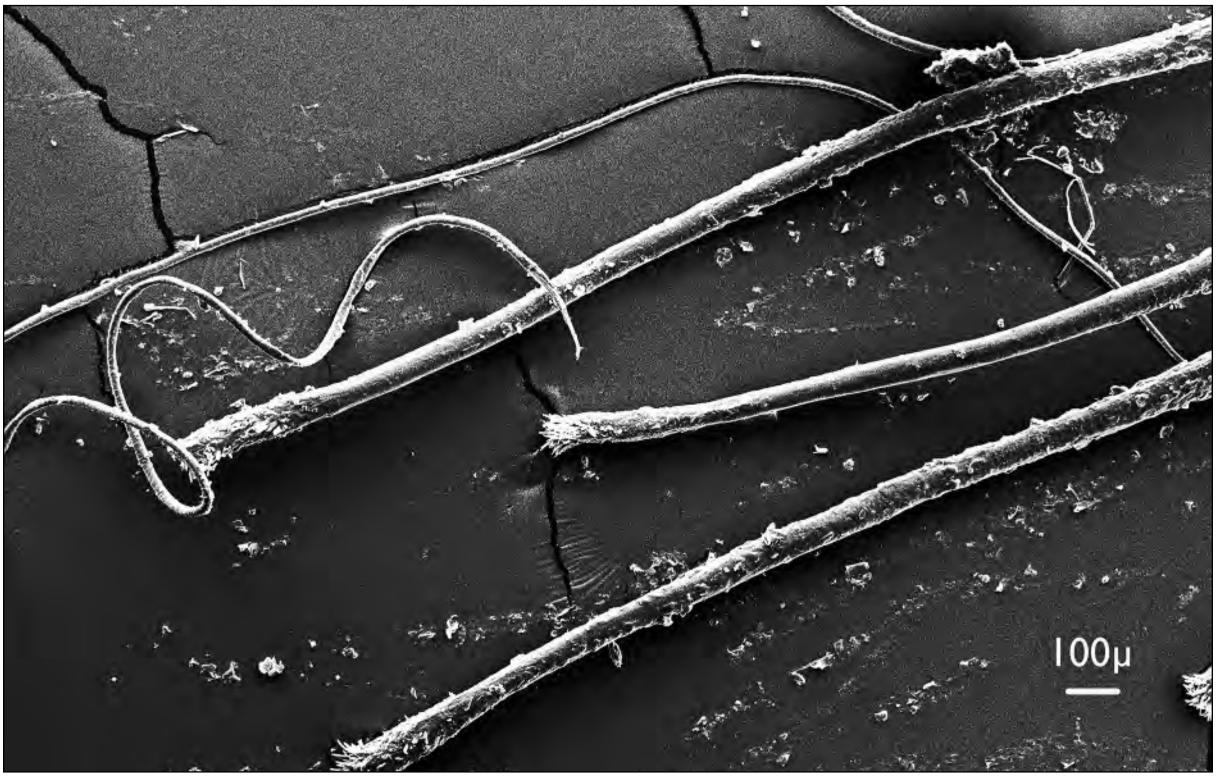

Fig. 53. Modern plucked Soay sheep wool with tips and roots

Fig. 54. Combed thread with changing scale direction, Hallstatt (A)

Fig. 55. Thread of worsted textile, Kempten (D), Early Modern

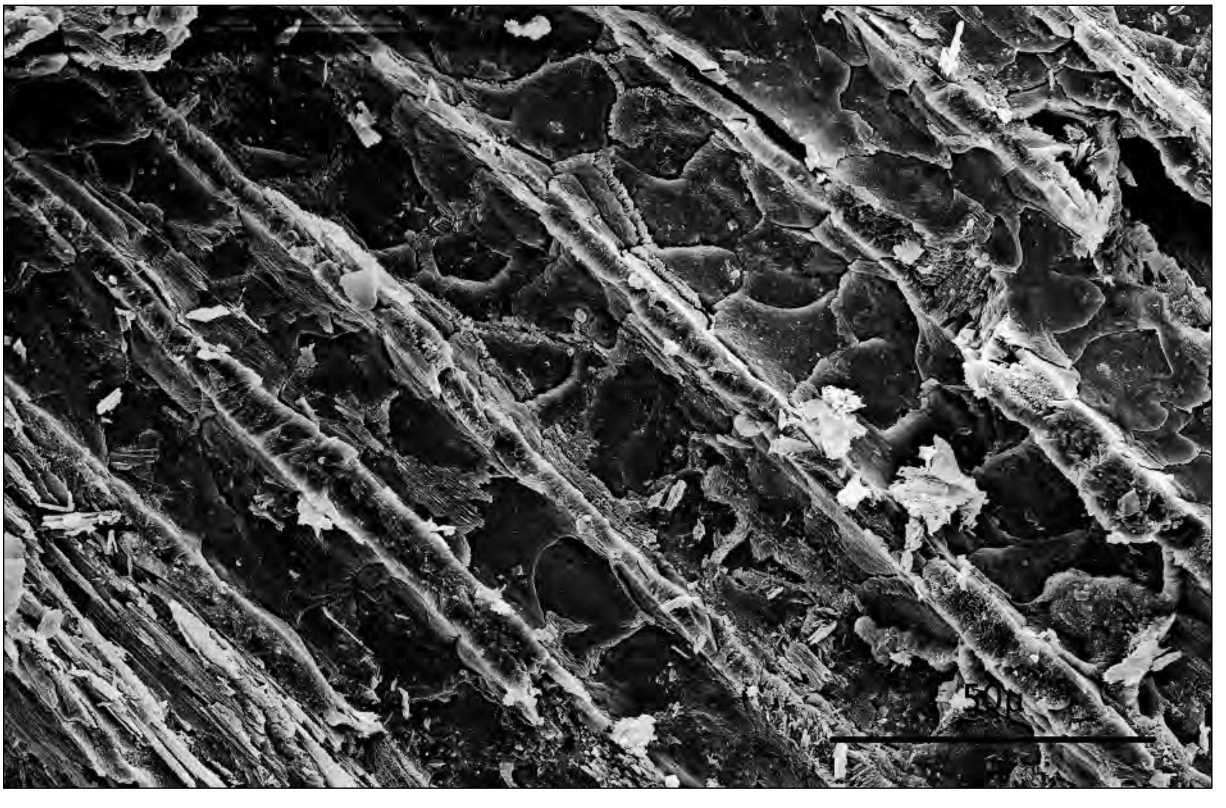

Fig. 56. Late Latène textile with very straight fibres, Bramois (CH)

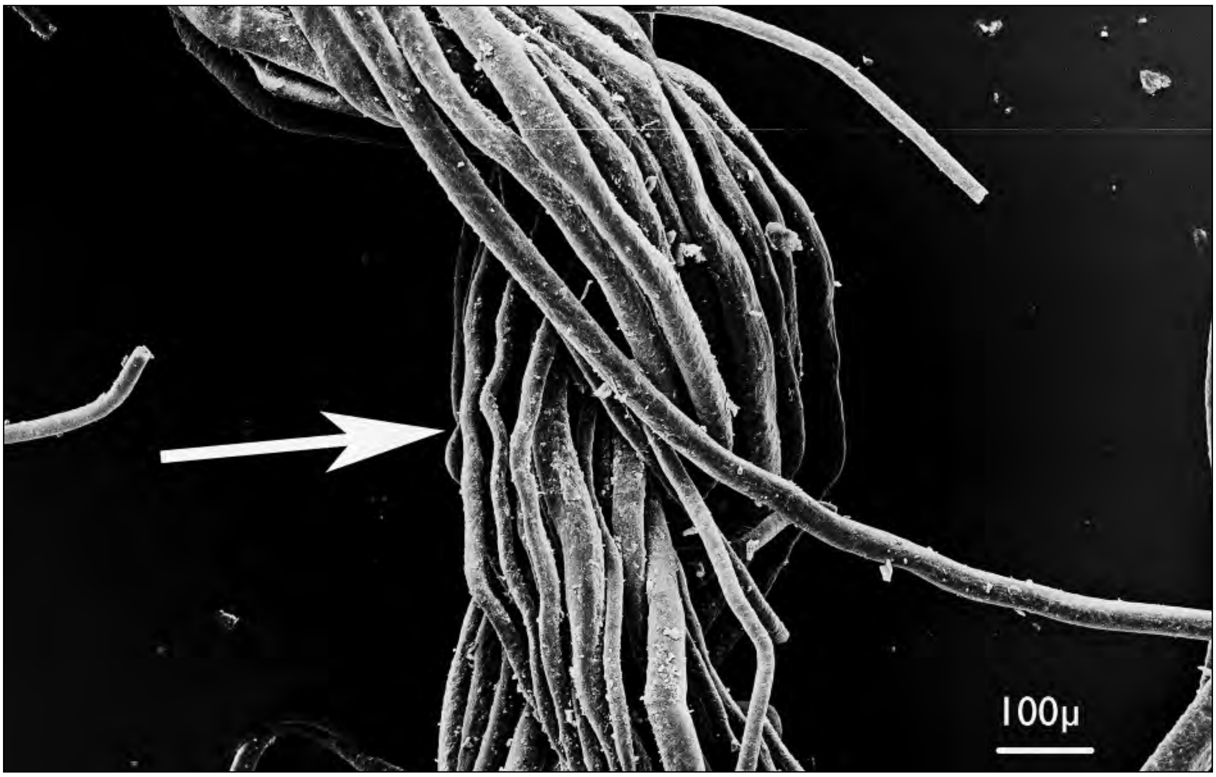

Fig. 57. Wool thread of the Hallstatt Period with crimp, Hallstatt (A)

Cashmere fibres must be dehaired during production if no coarse hair is to be left (see ch. 4.8.19). Mohair goat fibres are shorn and combed as the hairs don't molt and all hair types are used (see ch. 4.8.18). Other fibres such as beaver (see ch. 4.3.6), marten (see ch. 4.5.15–4.5.21) or cattle (see ch. 4.8.11) employed for blended yarns have to be shorn. In cases of beaver, coarse hairs were removed with only the underwool being used for yarns (see ch. 4.3.6).

The next stage is the spinning. Examples have been found of very fine plied prehistoric wool yarns with parallel fibres stuck together. SEM imaging of such yarns can indicate whether a glue or a starch has been used (*Fig. 58*). Without glue, fibres remain loose with spaces in between them. When glues were used they were made from lanolin (wool fat), fish or bone. *Fig. 58* shows the remains of such sizing, visible on the fibres. An experimental thread produced during the project "Textiles of Seafaring" was greased with fish oil until it became waterproofed (pers. comment Bender Jørgensen; Bender Jørgensen 2005). The remains on the surface resemble the ones from the Eberdingen-Hochdorf (D) find (s. *Fig. 58*; *Fig. 59*). The industrial glues of today create a smooth surface very different from those in which natural components were used. Modern industrial chemicals such as chlorines change surface structures. The surface of threads is therefore important to the interpretation of processing (*Fig. 60*) (Rippon – Evans 2012). In archaeological finds, surface damage can come from mordants or vat dyes (Grömer *et al.* 2013; Joosten *et al.* 2006) It is important, therefore to acquire a sample that has not been treated for conservation; each product introduced in the conservation process can change essential identifiying aspects of the fibre (see chapter 2.4).

The spinning of fibres can hold important clues in the identification of a textile. Important factors will be visible under stereo-microscopy. A warp thread, for example, has to be tight in order to hold and can be identified as such as hard spun. The warp thread may also be glued which becomes visible as tight and parallel fibres. A weft thread is often loose yet sometimes very hard spun for special textiles, as with pleated woolens.

2.3.2 Plant fibres

Bast fibres (those taken from a stem or stalk such as with tree basts, flax or hemp) are processed in a similar way to those from animals. Fibres will stick together if not combed. Depending upon the function of the finished product, strips of fibres instead of single threads may be used. Tree basts are then recognizable as having rays, and with good preservation it is even possible to spot crystals in them (see chapter 3.2.1) (*Fig. 61*). Flax goes through the same process through retting which will separate the fibres. Fibre strips of flax from Neolithic times have been found that were very probably lightly retted and not completely separated by a combing of the fibre (Leuzinger – Rast-Eicher 2011). Typical are the nodes in a line (*Fig. 62*). Experiments have reproduced such threads. Middle Bronze Age threads from the salt mines of Hallstatt (A) still show parallel nodes even if separation was caused by humid conditions in the archaeological layering (*Fig. 63*). Late Bronze Age material from Greifensee-Böschen (CH) is different, with the fibres being separated and the nodes not in a line (*Fig. 64*). It could be deduced that the processing technique had changed and combing of the fibres introduced. (Rast-Eicher – Dietrich 2015, 34 ff.)

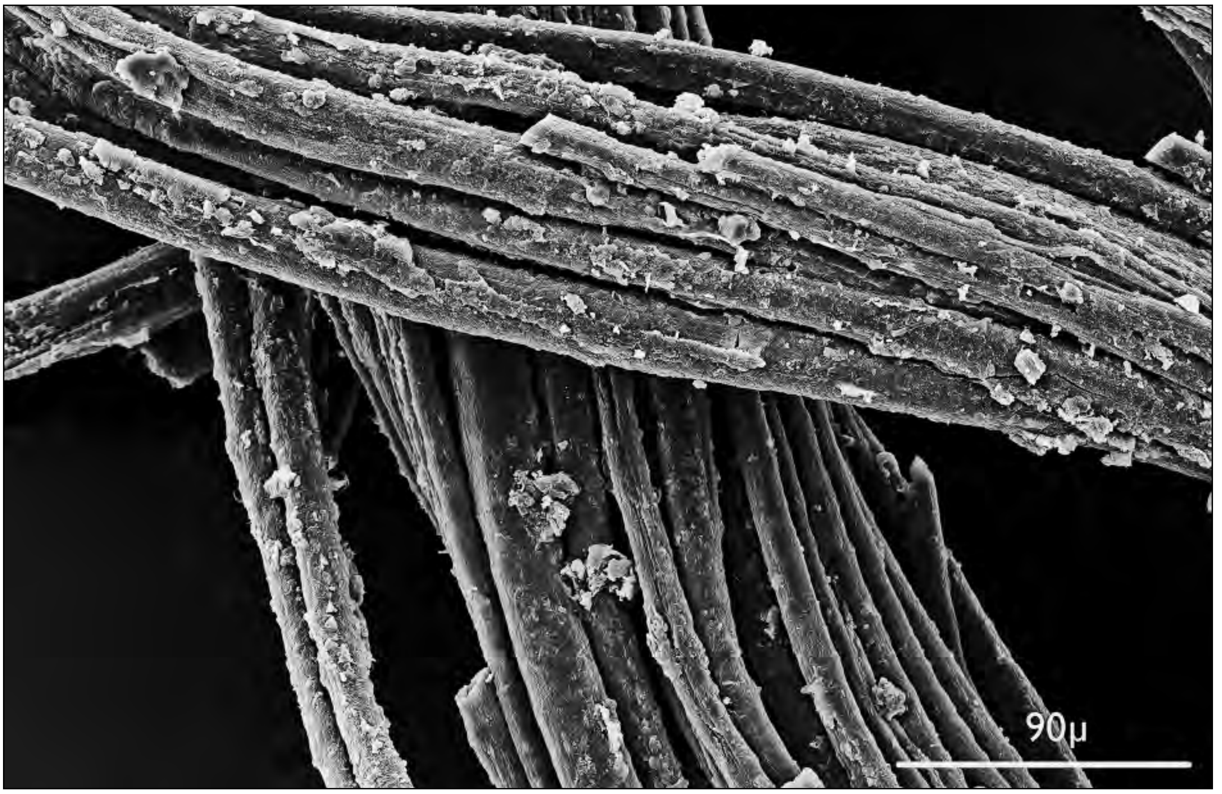

Fig. 58. Fibres of the main violet textile with probably glued warp threads, Eberdingen-Hochdorf (D)

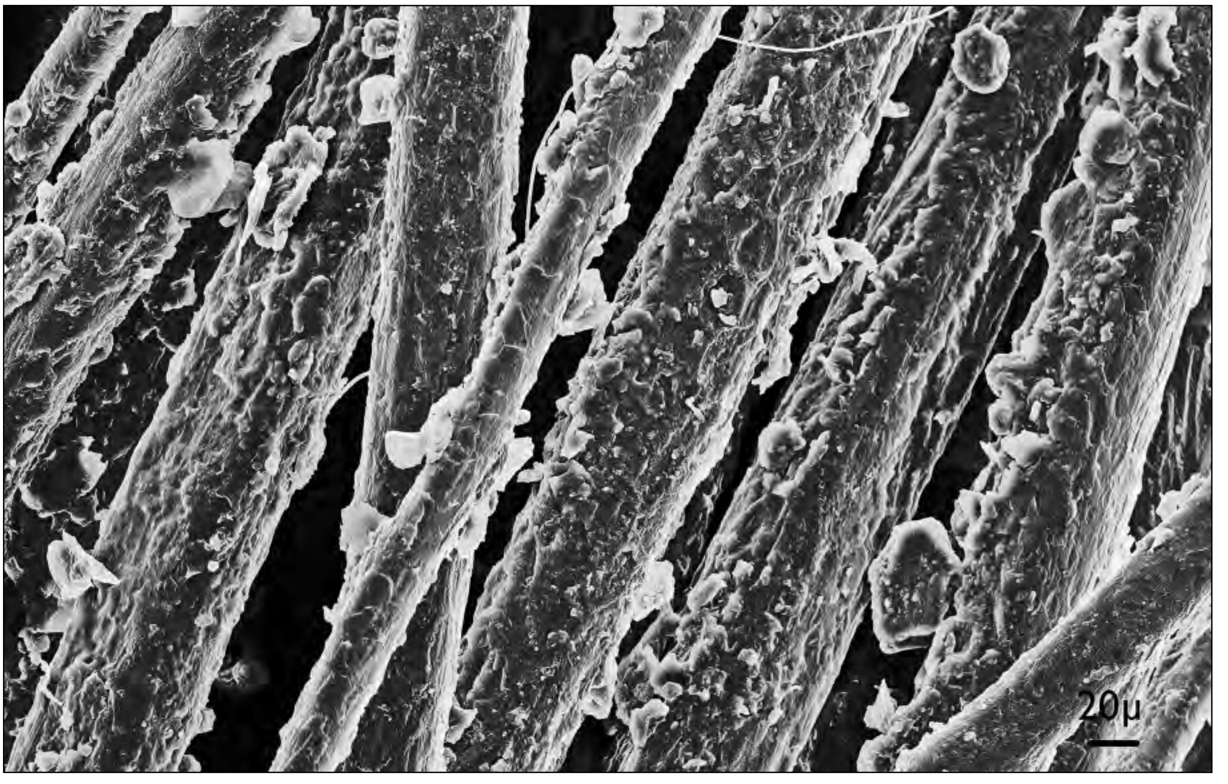

Fig. 59. Yarn prepared for the reconstruction of a Viking sail and well greased with fish oil

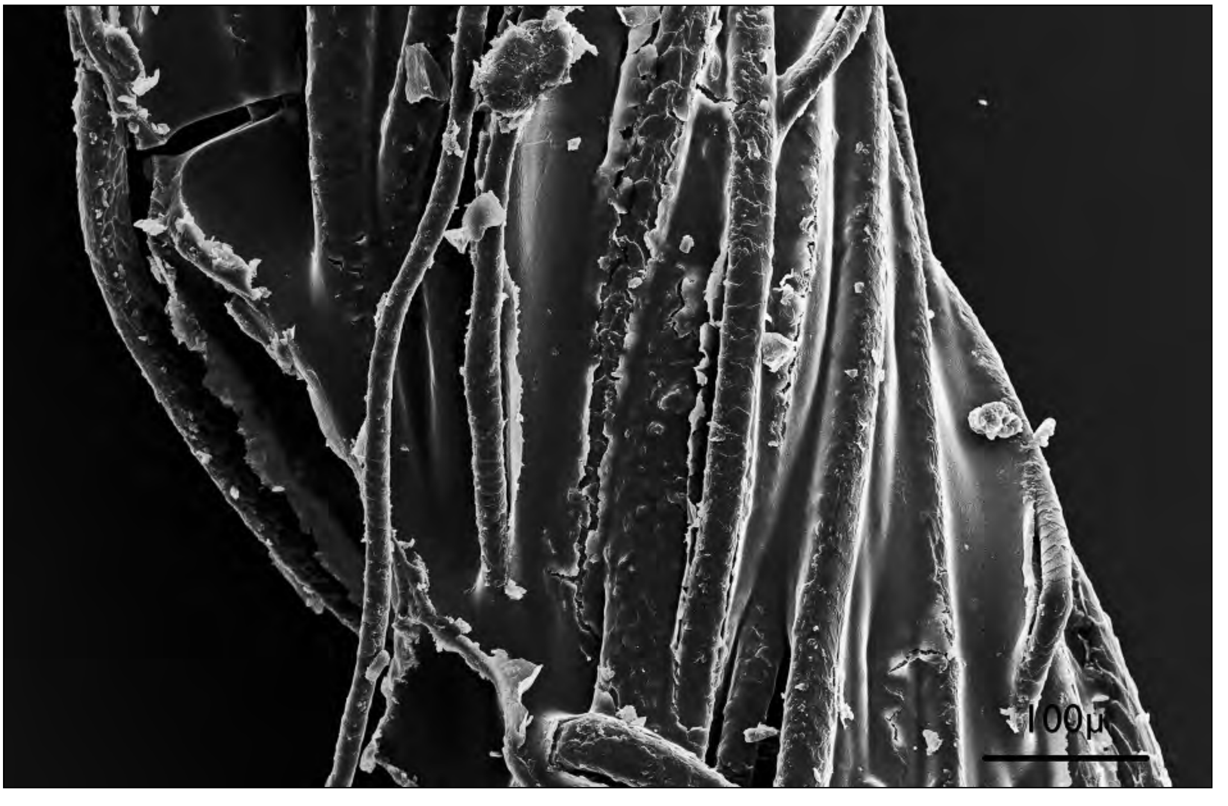

Fig. 60. Modern sample with industrial glue

Fig. 61. Neolithic thread made of strips of tree bast (lime bast) fibres, strips, Zürich-Mythenschloss (CH)

Fig. 62. Neolithic thread made of flax fibre strips (spliced), Risch (CH)

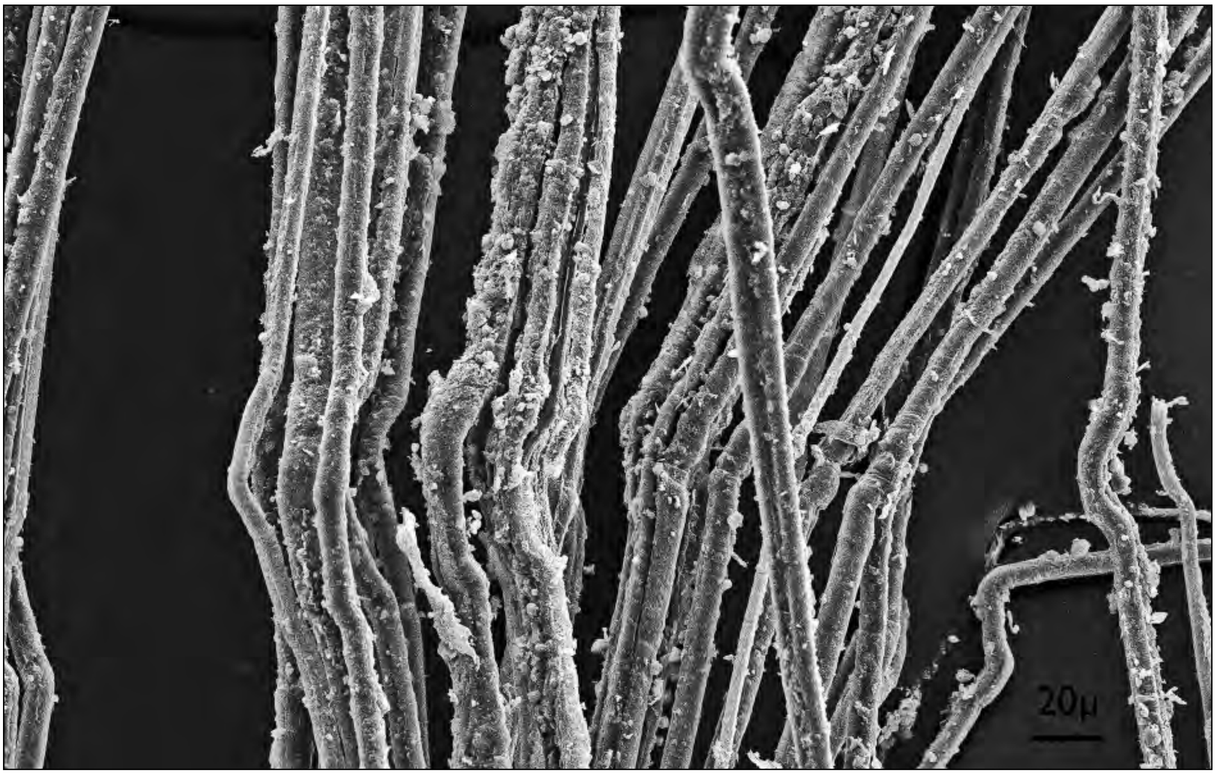

Fig. 63. Flax thread with parallel nodes found in the salt mine, Hallstatt (A)

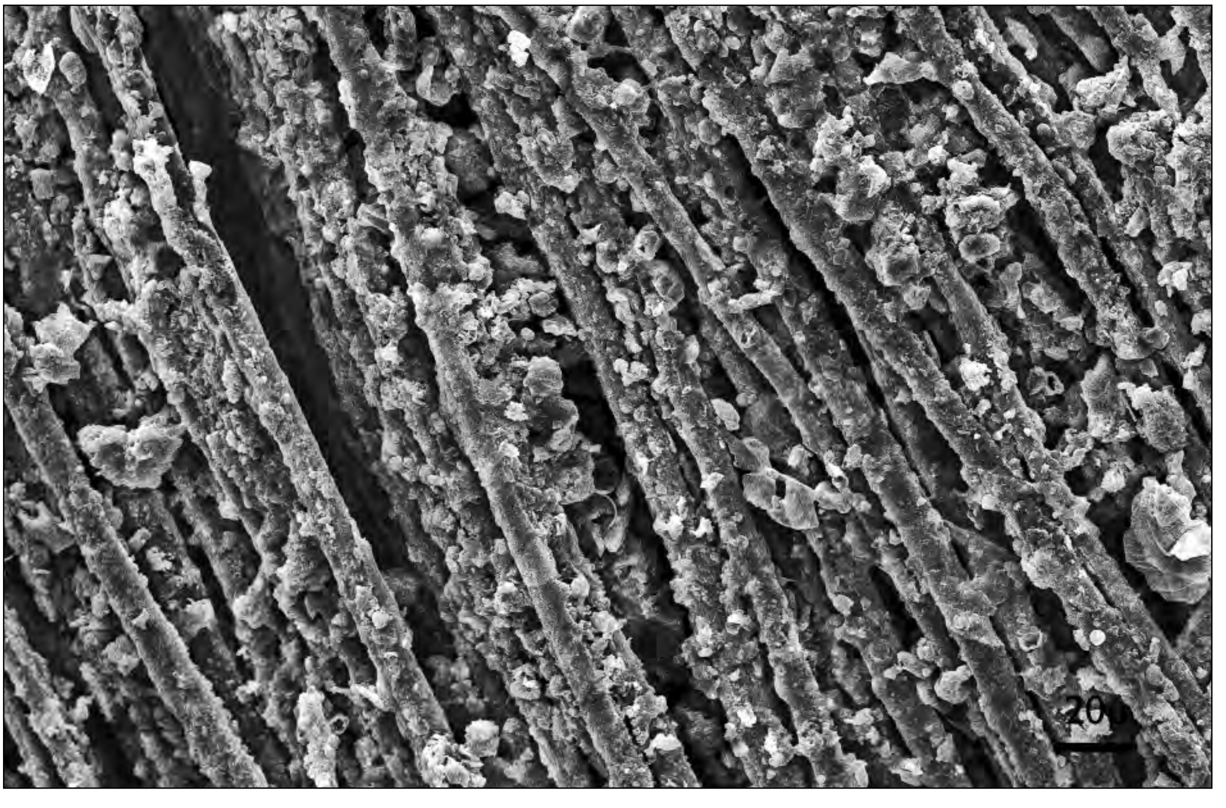

Fig. 64. Linen thread with separated fibres, Greifensee-Böschen (CH)

Tree basts and flax have longer fibres than wool so that glue is mostly not needed for spinning. An exception may be the ultrafine yarns of Ancient Egypt. These have been spun with the yarn/spliced yarn going through a bowl, probably filled with glue (Cooke *et al.* 1991). Spun threads were treated with starch (e.g. flower and water or boiled rice-water) to make them stronger (Clarke 2010). Fibres from 7th c. linen textiles found in both Southern Germany and Switzerland show in some cases a thin layer covering the fibres. This can be said to be very specific to this textile type. Because of mineralization no chemical tests are possible although this layer has been interpreted as starch (Rast-Eicher in prep, Dielsdorf) (*Fig. 65*). Clear surfaces with glue appear on fine linen textiles from Medieval times when starch was applied to the warp threads mounted on a horizontal treadle loom (*Fig. 66*). Linen or hemp textiles may be treated with wax after weaving to make them rainproof. This type of treatment is noted in written sources from the 16th century and has been found among the textiles in a floor dated to the beginning of the 16th c. in Kempten (D; Rast-Eicher – Tidow 2011) (*Fig. 67*).

Strings made of plant fibres look very different if they have been fixed very tightly to an object. *Fig. 68* shows fibres from a string around the handle of a sword. These were covered by leather so that the handle would be comfortable to hold. Strong pressure from the handle squeezes the fibres. The bow string, another important aspect of the find, shows clearly the wax treated multiple-plied linen cord even in a mineralized inhumation context (Bader *et al.* 2002, Fig. 38; Rast-Eicher 2010, Figs 138 and 139) (*Fig. 69*).

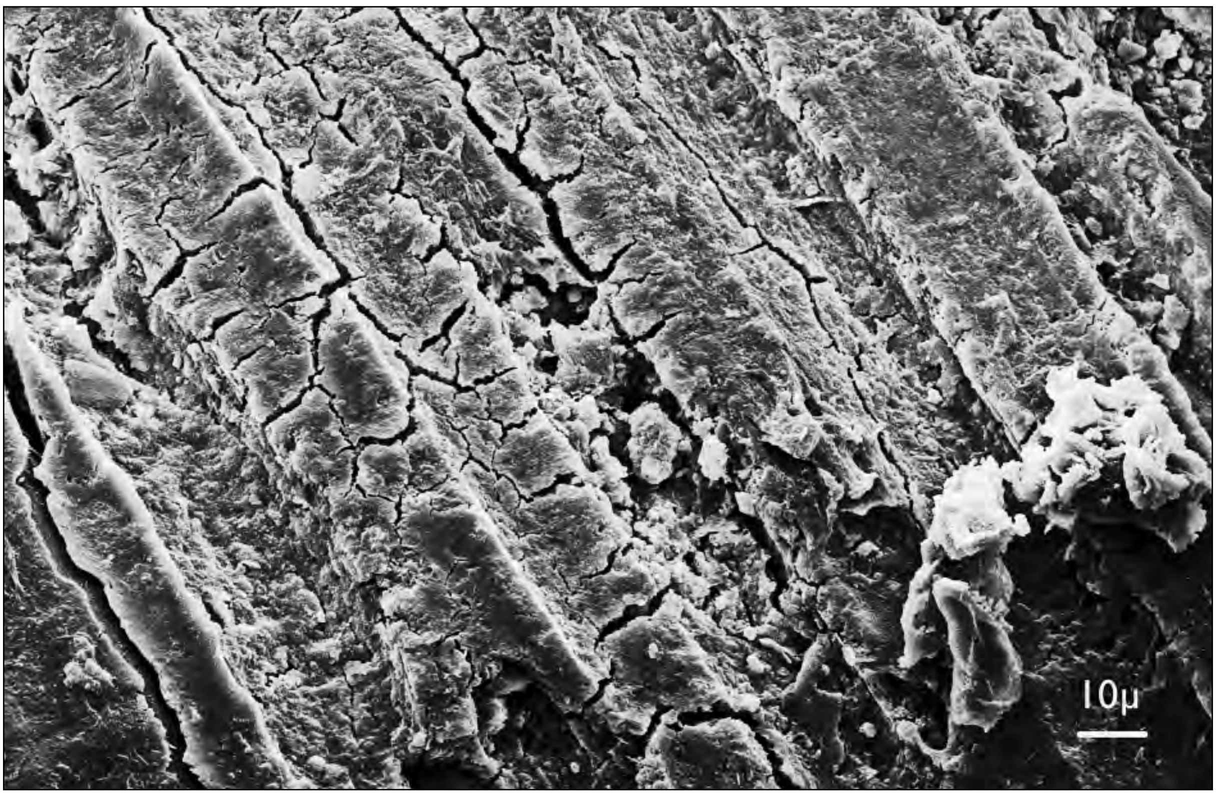

Fig. 65. Linen thread with probable starch, Dielsdorf (CH)

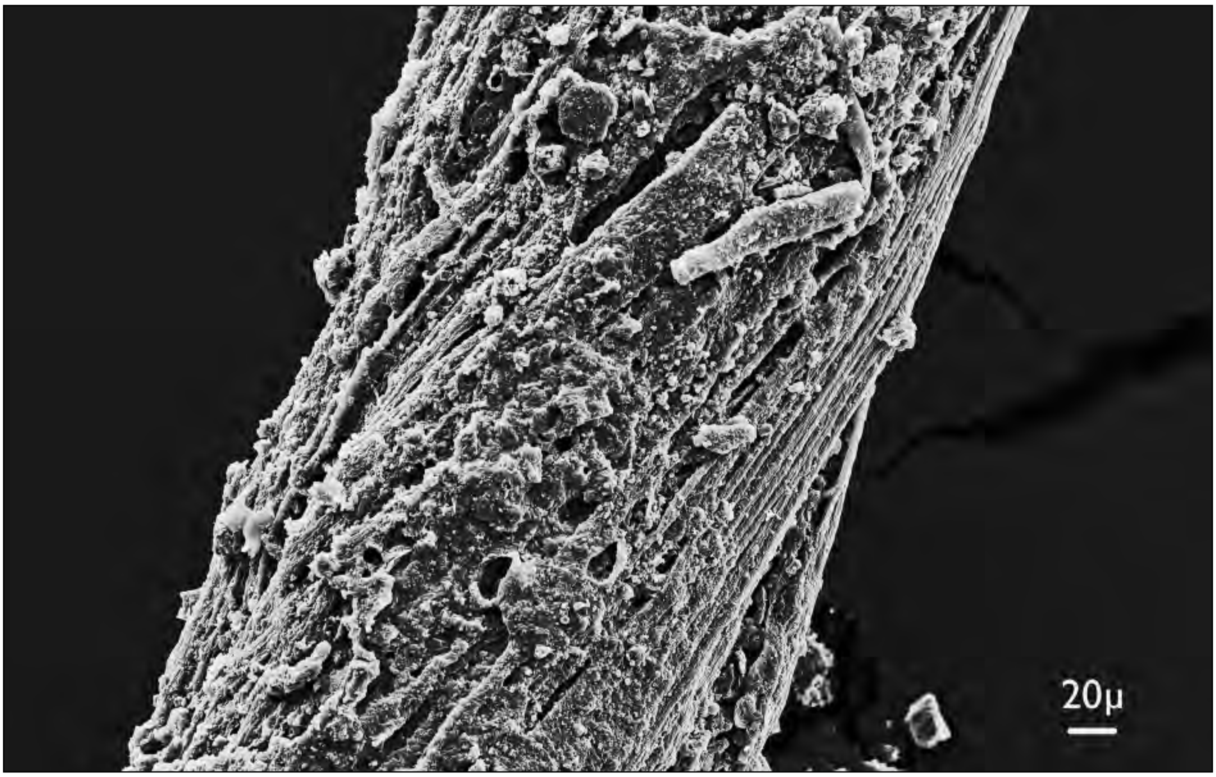

Fig. 66. Medieval linen thread with starch, Winterthur (CH)

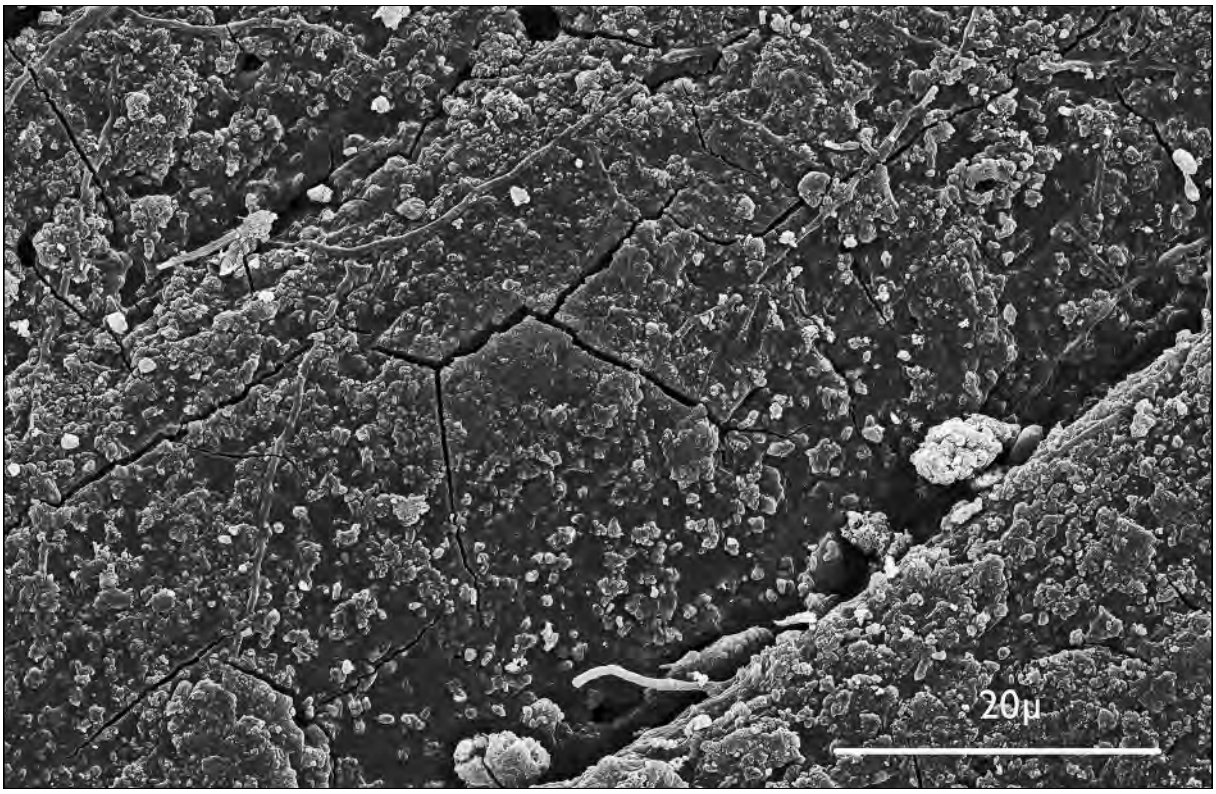

Fig. 67. Early Modern linen textile with wax surface, Kempten (D)

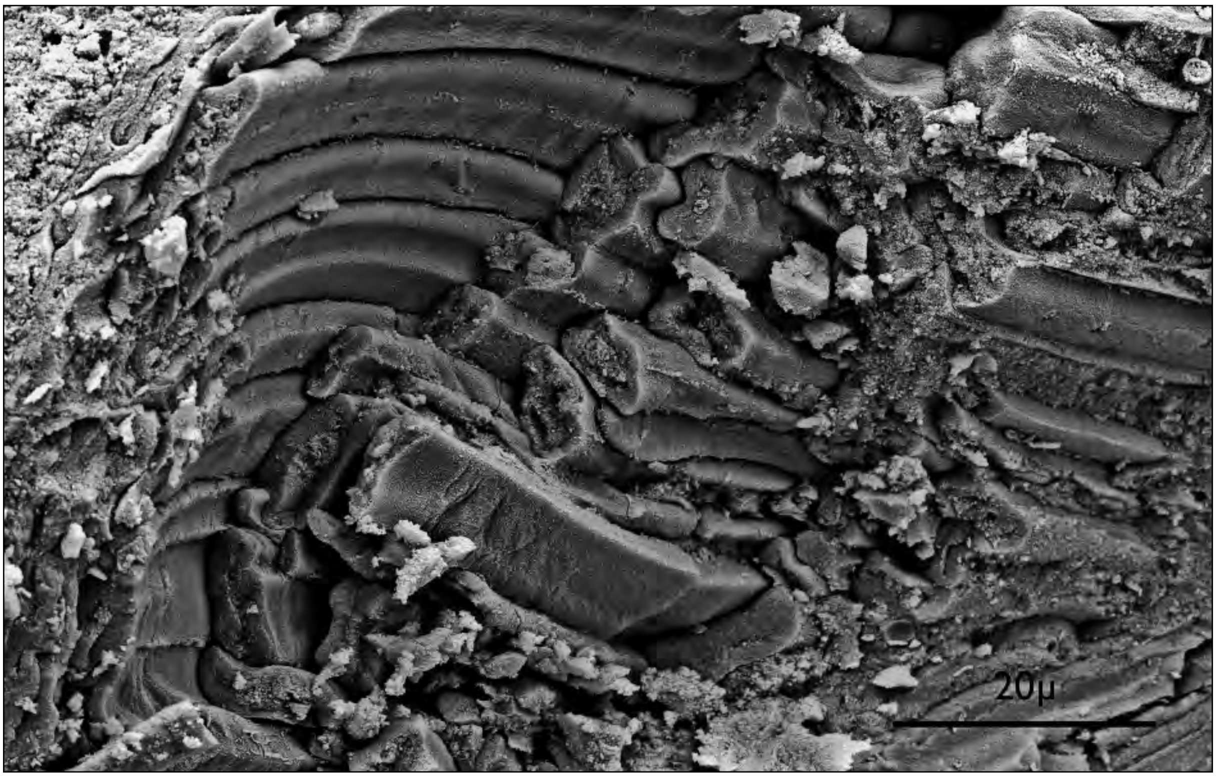

Fig. 68. Squeezed fibres from a handle of a sword, Baar-Früebergstrasse (CH)

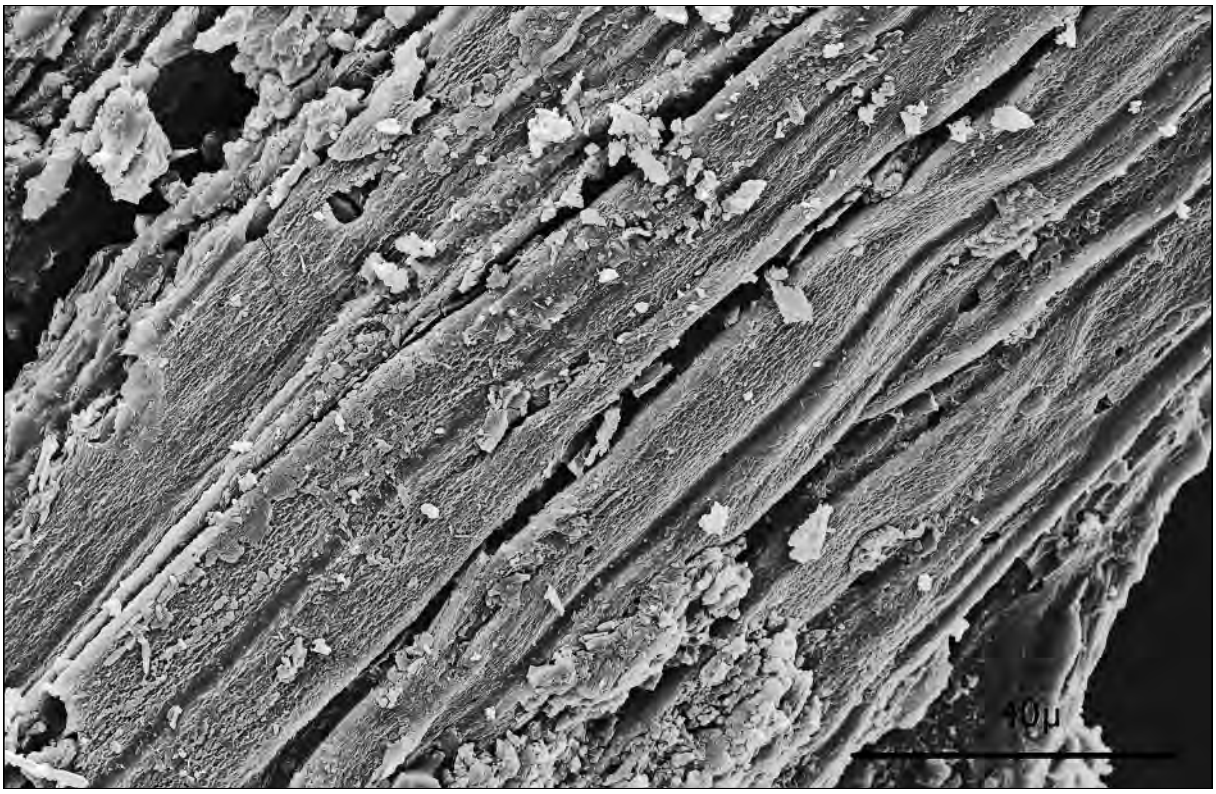

Fig. 69. Wax on bow string, Baar-Früebergstrasse (CH)

2.3.3 Silk

Silk is obtained from the cocoons of the larvae of the *Bombyx mori*, (or silkworm of the mulberry tree) (see ch. 4.10.3). Extracting the silk includes the light melting of the gum that coats the fibres (sericin) in order to be able to draw it from the cocoon (reeling). Immersing the cocoons in hot water was a way to achieve this (see chapter 4.10). Filaments containing two fibres will separate from other filaments. The sericin during this initial process will not be completely removed and it is possible under magnification for a typical fibre pair to be seen in the cross-section (*Fig. 70*). This may be seen with the cross-section in the light microscope as well. As silk of the *Bombyx mori* caterpillar is an endless filament, it does not necessarily need to be spun and it is the only silk which can be reeled. Other silks do not have the endless fibre (see chapter 4.10.2). Degumming is also necessary to obtain a full and shiny fibre. Textile fibres tend to spear in this case (*Figs 71* and *72*). The warp on figure 71 is tight as it is very slightly spun (z), and parallel fibres still held together by sericin are visible; the weft has only been reeled with the threads that have lost the sericin, being spread out and gaining in size. Mulberry silk needs very few turns per meter to keep the compact form of the thread. If the caterpillar escapes from the cocoon, as in the wild, the silk will not provide an endless filament; shorter bits will then have to be spun and those threads ("bourrette silk") will have a clear spin direction (visible in Nowak-Böck – v. Looz 2013, Fig. 34) (*Fig. 73*). Silk that is not an endless thread may hint towards production methods other than Chinese weaving. In the Buddhist religion, for instance, the killing of the caterpillar was forbidden; the cocoon was simply pierced and the silk fibre was not an endless filament (Liu 1998, 57; Desrosiers 2015b). The less spun the silk fibres are, the shinier they will be when degummed. In archaeological material such differences in processing are clearly visible. Several of the Early Medieval silks from Saint Denis and Chelles (France) still showed some double filaments which means that the silk has not been completely degummed (*Fig. 74*). In the warp this gives more stability but in the weft, as in a samite weave, fibres are certainly less shiny and there are inferior dyeing properties if not degummed. Silk that is not degummed may appear under light microscopy as very flat cotton-like fibres. Cross-sections of these samples proved, indeed, that all the fibres were not degummed, with the turning fibres being just a bit flatter than the others (Desrosiers 2015b) (*Fig. 75*).

2.4 Conservation *(Products)*

Conservation products can be utilized for archaeological material at all stages of artifact retrieval and stabilization. The relatively modern idea of using reversible materials for the preservation of objects (i.e. substances that may be removed at any time from the object without causing undo harm), in addition to the adage "less is more" is the approach towards conservation treatment today. Modern conservation products are more transferable and have vastly improved from many of those that had been employed in previous decades. However, all foreign applications will interfere with analyses to some extent.

At the excavation site various block lifting techniques may be employed to secure artefacts, the approach to this varying according to soil conditions and environment. The first step in protecting an object, whether it be large or small, is often to let it lie within its surrounding block of soil. This is then covered with a barrier layer, this possibly carried out simply by placing a polyvinylidene chloride film (basic plastic kitchen wrap) over it, followed by encapsulating this and the soil block with a sturdy support of a material appropriate to the environment of the site and the size, weight and fragility of the artefact. Materials for this encapsulation can range from basic plaster bandages (for use in a dry environment), to bandages of paraffin wax or expandable polyurethane foam (for wet surroundings), to dry ice for use in extreme conditions.

Stabilization requirements from the archaeological site to the conservation lab have hopefully been reached using a block method that is able to avoid, at least temporarily, the use of consolidants on the object.

A basic principle to follow is that samples from an artefact for analysis should be taken BEFORE ANY conservation products are applied. While cleaning and/or consolidating an object is often necessary for it to be preserved, each application of solvents, adhesives or any other outside material will interfere with later analyses. Observation under simple microscopy, for example, is based upon optical differentiation and no secondary change of the surface is welcome. Accurate C14 dating, as a quite sophisticated technique for analyzing the date of an object, will absolutely be compromised with the presence of foreign materials.

Conservation products used in former times were often less, or not at all, reversible. “Araldite” (a 2-part epoxy adhesive), for example, was a product in common use for a time employed to hold artefacts in a hard and permanent encapsulation. During 19th century excavations, textiles from the lake dwelling sites of Pre-Alp Central Europe were treated with linseed oil, a permanent application which hardens and discolors the fibres after a time (Travis 2007).

While many of the natural resins from the turn of the 20th century may still be found to have successfully completed the job of stabilization and may continue to be somewhat reversible, some of the more notorious synthetic resins experimented with and employed during much of the 1960’s and 70’s have created problems for both researcher and conservator. Applications of such substances over a great many objects have resulted in many textile artefacts being covered with compact, smooth surfaces that are not removable and which in themselves have caused serious irreversible damage to the fibres (*Fig. 76*). It can be noted that objects that have been treated in this way will produce electrical charges, making analysis at the SEM, for example, impossible.

In the opposite direction, a product that has a wide range of uses – from industrial to medical applications – has also been employed successfully in the conservation treatment of archaeological organic materials. Polyethylene glycol (PEG) is a polyether compound and is used as a bulk material to structurally support the weakened cell walls of organic artefacts that have been waterlogged. Archaeological textiles can undergo PEG treatment and their fibres will remain visible for later analysis (*Fig. 77*).

While many consolidation products are impossible to remove completely, others can be reduced substantially with solvents. One such conservation product that has been used for at least a century is wax (both natural and synthetic). It is something that will tend to permeate an archaeological find and while it may be sufficiently withdrawn through heat extraction, it can never be completely removed. Mineralized materials, for example, have often been coated with a “protective” layer of wax and while protecting the objects to an extent from environmental changes, it will also permanently interfere with the visibility of a cross-section (*Figs 78* and *79*).

An even more important product, its use beginning in the 1950’s and still of valid and important use today, is Paraloid, a thermoplastic resin. Its use as a stabilizing superficial glue or deep penetrating consolidant has been successfully applied to many an object. It may be reduced to varying degrees with a variety of solvents, making it a very versatile conservation product.

Fig. 70. Modern silk (Bombyx mori) not degummed, fibre pair held together by sericin layer

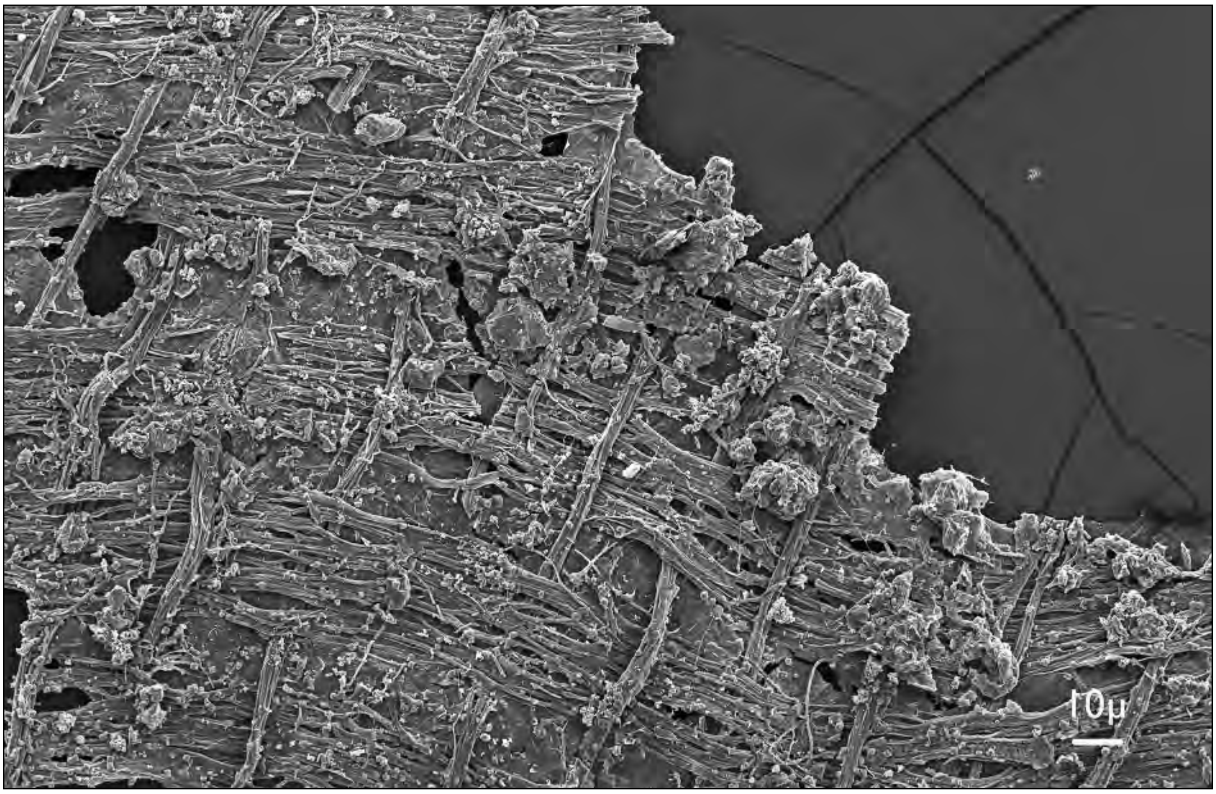

Fig. 71. Early Medieval silk, Saint Denis/Paris (F)

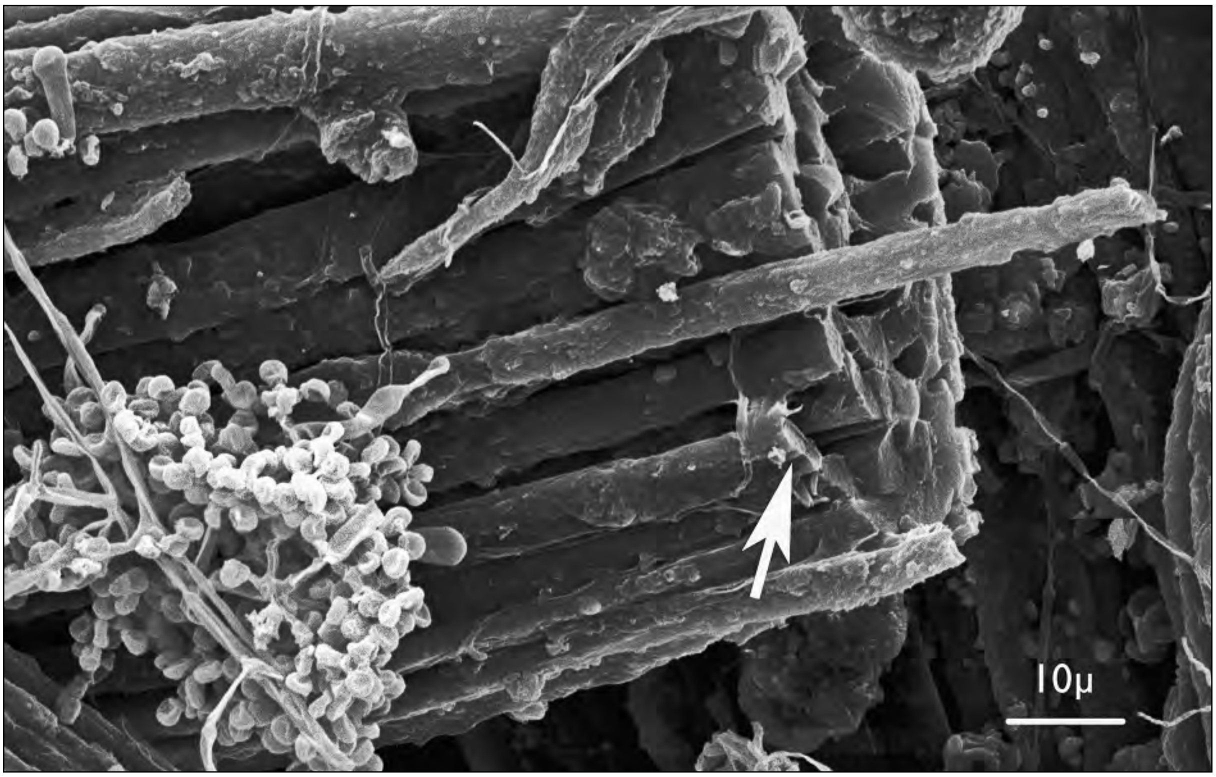

Fig. 72. Saint Denis/Paris (F), Early Medieval Chinese silk (grave 13), warp thread with filament containing the two fibres and on top a thin layer of sericine, Saint Denis/Paris (F)

Fig. 73. Modern “bourette silk”

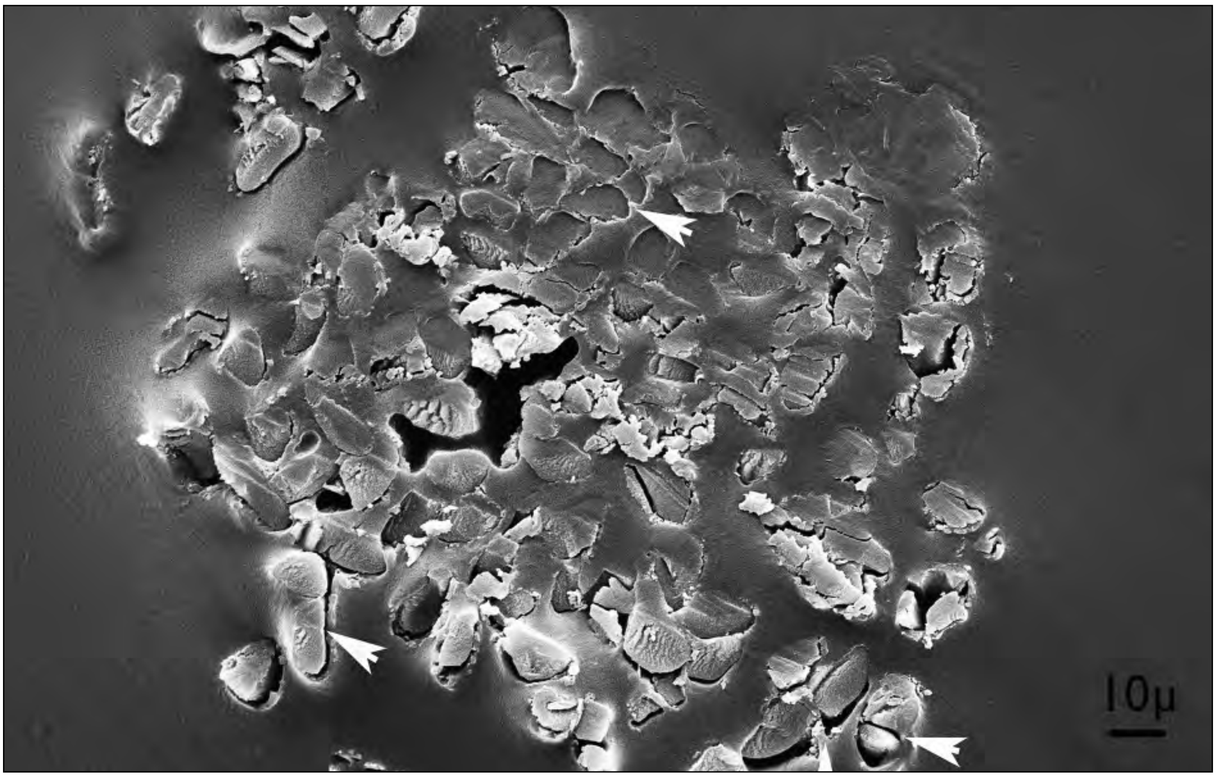

Fig. 74. Fibre pairs typical for not completely degummed silk visible in the cross-section, Saint Denis/Paris (F)

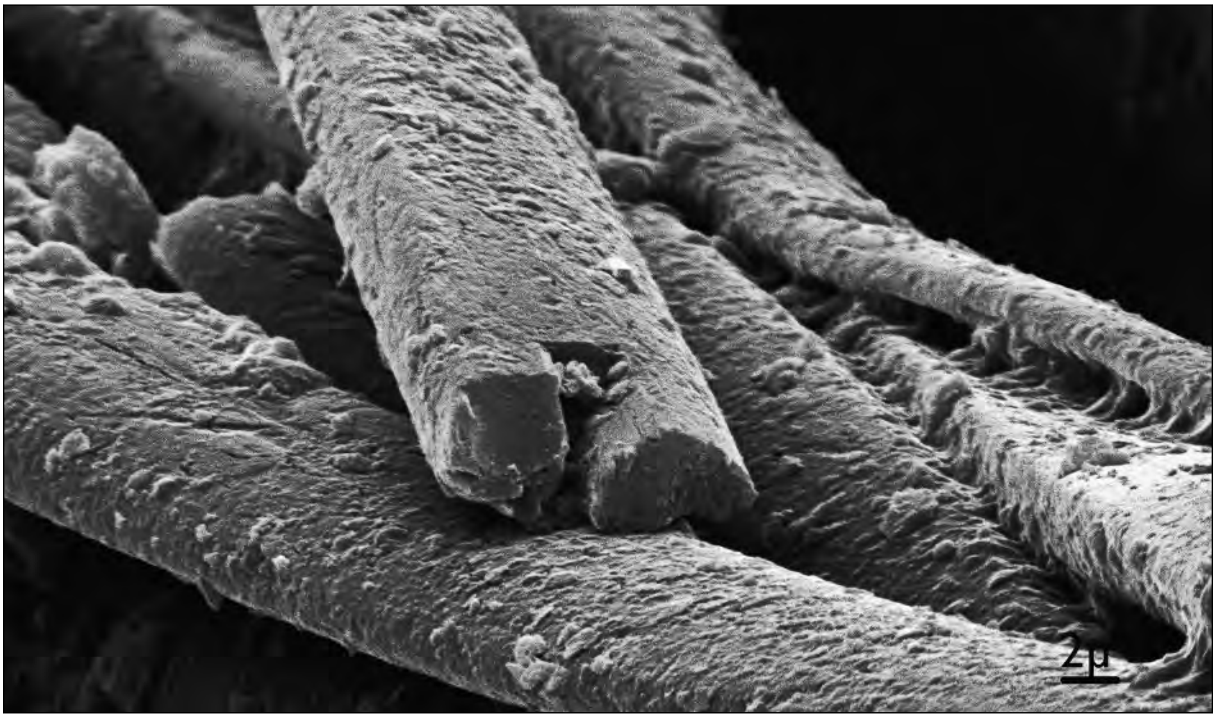

Fig. 75. Cross-section of flat silk filaments showing two fibres per filament still hold by some sericin, Karadong (Xinjiang, China)

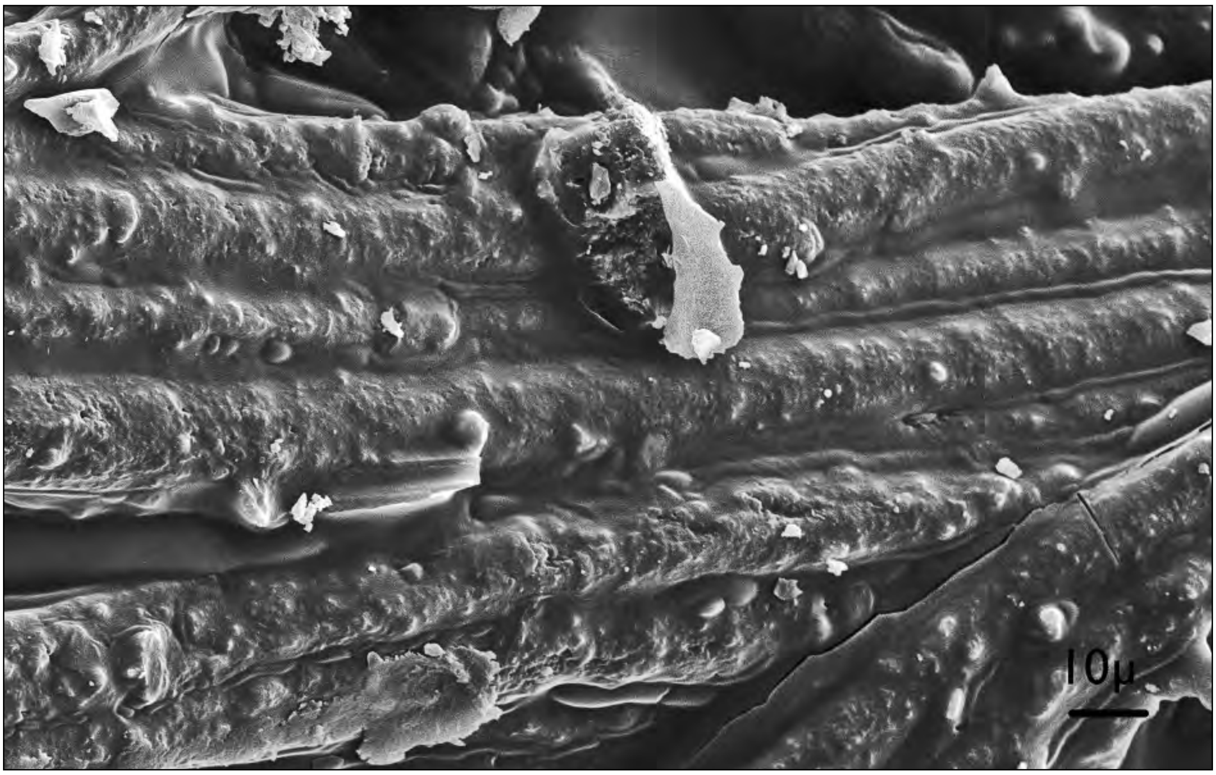

Fig. 76. Resin on fibres

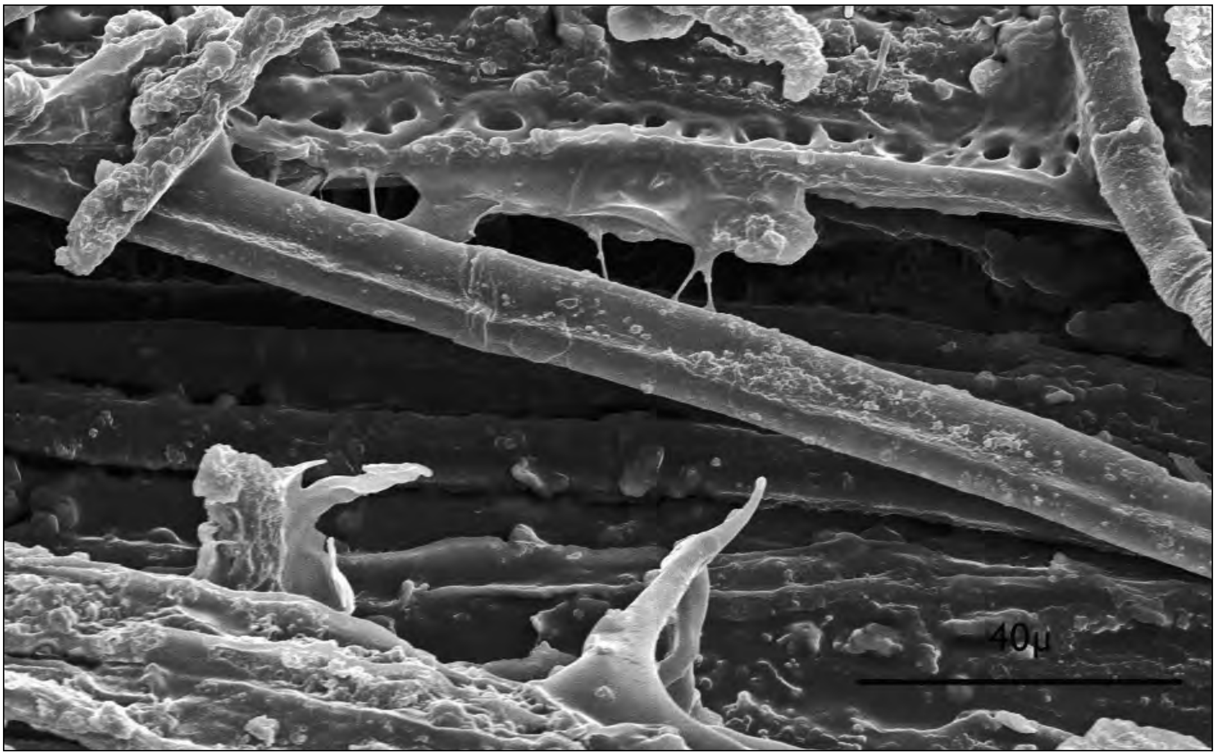

Fig. 77. PEG on vegetable fibre (Neolithic Period)

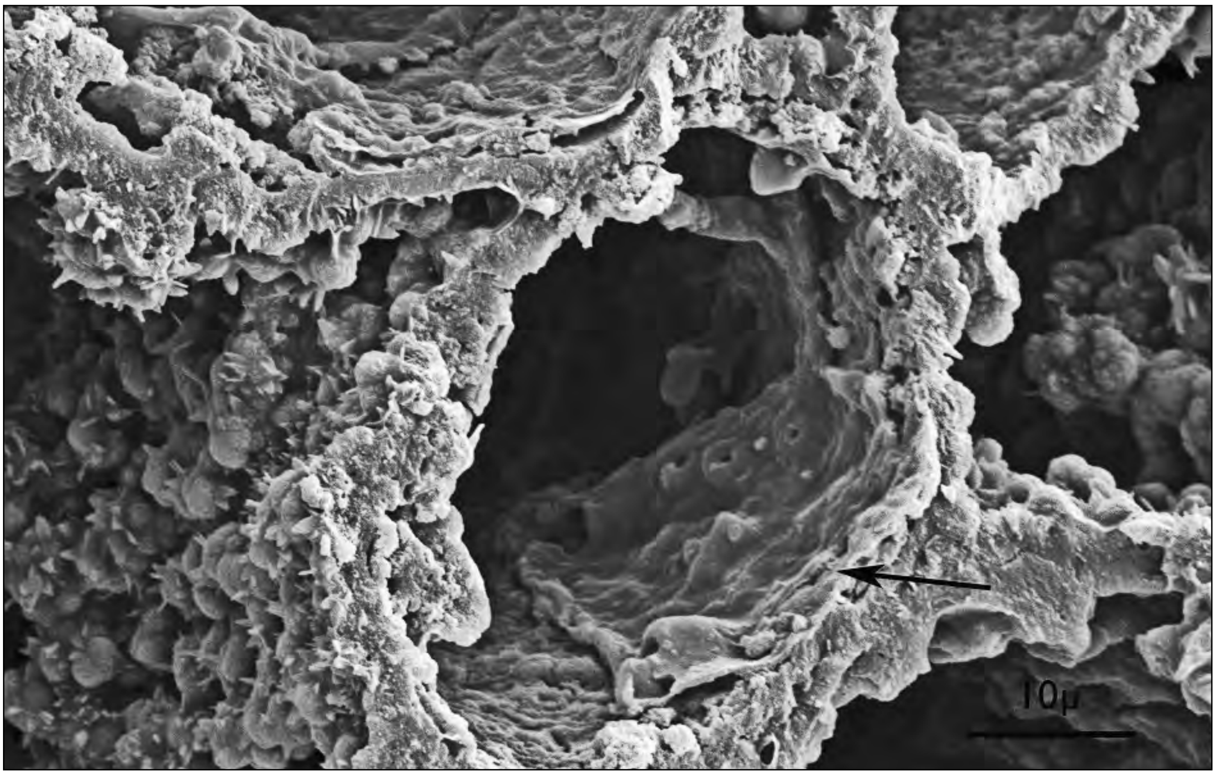

Fig. 78. Cyclododecan in fibre casts of metal-replaced fibres seen in the cross-section, after three month under warm lamp

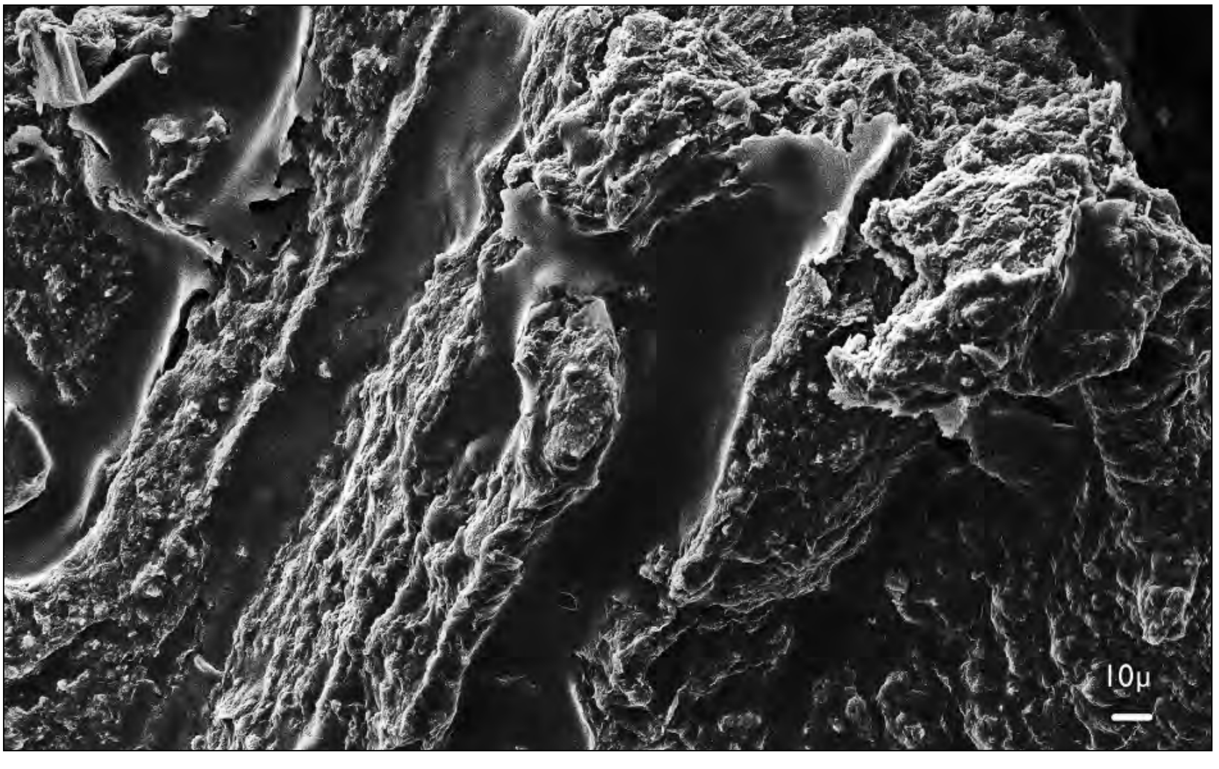

Fig. 79. Cyclododecan in fibre casts

2.5 Analysis

2.5.1 Introduction

The methods presented here are based on microscopy. All other methods, such as protein or DNA analyses, will not be discussed except for a short description in chapter 2.5.10.4.

The combined use of light microscopy (LM) and scanning electron microscopy (SEM) is ideal in many cases for the analysis of animal fibres; certain scale patterns may be similar from one animal to another (e.g. cattle-goat) but can also be well differentiated by the medulla structure. Some questions, as in the pigmentation of wool fibres, can only be answered by LM. Depending upon their preserved state, however, archaeological fibres will not always allow for all the types of analyses. SEM is the best optical alternative that will give results when LM is too difficult or fails.

2.5.2 History of fibre analysis and wool measurement

The development of microscopes made possible the ability to differentiate and identify fibres for fabrics. At the beginning of the 20th century, fibre atlases came into being and systematic descriptions of fibres became important (Hausmann 1920; Frölich *et al.* 1929; Herzog 1930-1933; Lochte 1938). Research done with the light microscope during these early years and the many detailed observations made at this time are still valuable today. Th. Lochte mentioned numerous details in his book which are still very useful, including the many possible pitfalls in the determination of animal species. Epidermal scales are transparent but with light microscopy the description of scale patterns can be made. Leon Hausmann was the first to propose that analysis for animal fibres using the morphology of the scale pattern and medulla type could be used (*Fig. 80*). This basic system was more precisely defined by Wildmann in 1954, and in the 1970s by means of the SEM (Short 1978), improved later by Meyer *et al.* in 2002 and Chernova and Tselikova 2004. The SEM allows direct observation, has a very high resolution and high magnification. Today, optical fibre analysis, as used for industrial purposes but with added quantitative methods in image analysis, has many advantages. New methods such as DNA or protein analysis can provide almost certain identification, that is, if the preservation of the material is good enough. These procedures are very expensive, however, and the cultural importance of an artefact is a determining factor when deciding to engage in any or any combination of these methods. There is the choice today between destructive or non-destructive sampling and this, of course, will depend upon the value of the object to be analyzed.

Very early on the microscope was engaged for measuring the diameter of wool. Already in 1777 a scientist by the name of Louis Jean Marie Daubenton had compiled a manual about sheep breeding and in doing so attempted to find a system of classification for the fineness of fibres by measuring them (Burns 1930; de Wit 1993, 107). Microscopy (the “lana-meter”) was for a long time the basis for any measurement, that is until the invention of the airflow instrument in the 20th century (Anderson 1954). The *International Wool Textile Organisation* (ITWO), founded in 1930, created standards which have been generally accepted decades on for wool and vegetable matter. Only in the early 1980’s was a standard system for determining staple length and strength set up. A standard for the position of break based on sub-samples taken from grave samples was also initiated at this time. The objective sample measurement method enabled the selling of tested material at auctions (by computer) (Cottle 2010, 581ff.).

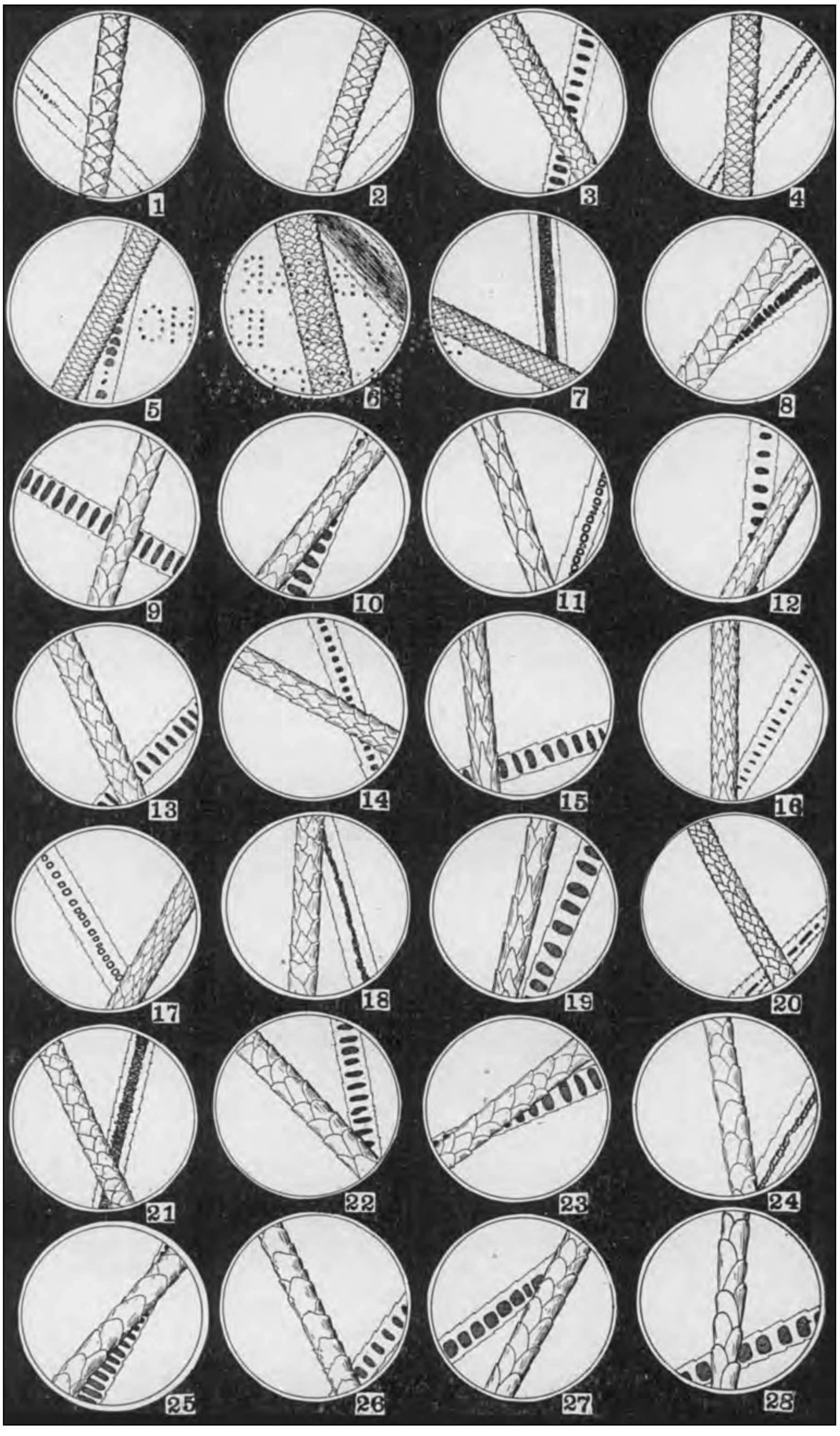

Fig. 80. First systematic approach of the fibre morphology by scale pattern and medulla type (from: Hausmann 1920, p. 498)

Archaeology followed these developments and employed the new methods. Fibre analysis was a basic necessity for textile archaeologists. In the 1940's, the Voltofte textile (DK) was published as being made of nettle fibre (Hald 1980, 125; see all ref. in chapter 3.2.8) and has since been confirmed as such through modern analysis (Bergfjord *et al.* 2012). In the 1960's, M.L. Ryder began using industrial methods for wool measurements of archaeological textiles (Ryder 1964; 1969; 1983).

The method has been revised and different categories proposed as archaeological textiles do not necessarily contain a fleece, but possibly selected wool (Rast-Eicher 2008; Rast-Eicher – Bender Jørgensen 2013). The SEM took hold in the late 1970's, first for use by forensic scientists but followed shortly thereafter by conservators and archaeologists (Janaway 1983). The SEM was fully incorporated for all research purposes in the 1980's. Today FTIR (see ch. 2.5.9), DNA, protein analysis and isotope analyses are sophisticated methods which give highly precise answers to fibre type, fibre origin or the development of the animal species. Needless to say, these methods are quite expensive, with some requiring quite large samples. Essentially, these advanced methods do not really replace basic microscopic fibre analysis, which in itself will also show the important criteria of fibre preservation, processing and quality.

2.5.3 Sampling

The taking of samples is the starting point of any research to be done on an archaeological textile. It is of utmost importance to retrieve samples from the freshly excavated object, before the applications of any conservation materials. Ironically, a well preserved textile will present the dilemma of extracting sample material from it without altering or compromising it in any way. It is sometimes possible to tease out a sample where pieces are torn. For cross and longitudinal sections, half a centimeter is enough. Analysis of metal-replaced remains has the best chance of success if the structure has first been verified under the stereo microscope. A sample of 2–3 millimeters in this case would be sufficient. Carefully chosen samples makes the work easier. Large pieces may be difficult to mount on a stub for the SEM. Wet samples will have to be dried for the SEM under vacuum, although use without vacuum is also a possibility. Sampling for wool measurement will require, if possible, at least 100 measurements, meaning 100 fibres. In dealing with textiles, it is best to have at least one sample from the warp and one from the weft. Well preserved wool fibres of textiles can also be measured using a digital reflected light microscope (lens 500x). But while this method does not harm the textile, it also does not qualify for fibre determination (Rast-Eicher – Bender Jørgensen 2013). An advantage is that many different threads can be measured against each other so that statistically the measurements are much better.

2.5.4 Questions to ask

The practical first step to observe a fibre is under the stereo microscope. How do they appear? Straight? Curled? Are different dimensions visible? Are there different fibre types in warp and weft? For skins, what are the dimensions for both the coarse and fine fibres? General impressions? Are roots or tips visible?

The next step would be the light microscope if preservation is good and the object is neither carbonized nor mineralized. Are the fibres pigmented? Are there nodes? Is there a medulla visible? What type? How does it appear?

Then it would be on to the SEM. Is it possible to differentiate between plant and animal? Are there nodes? Is there any direction of the epidermis visible? If there are scales, what type? Is the medulla visible in cross-section?

2.5.5 Light microscopy

Light microscopy (LM) is a classical and essential technique used in fibre identification (Lochte 1938; Wildman 1954). First version atlases and fibre descriptions have been made on the basis of LM (Hausman 1920). It works only if the fibres are transparent, meaning not completely dark with pigmentation. The LM provides little depth of field and – compared to the SEM – low magnification. It is especially important for information about the medulla structure, pigmentation (animal fibres), longitudinal shape, cell structure and nodes (plant fibres). Plant fibres, such as strings or caulking material coming from wet conditions, will shrink massively and change appearance if dried.

The samples have to be mounted with liquid but it is, of course, important to know that fibres may swell with water. Wool, for example, will take up 10% within half an hour. Liquid paraffin is a good alternative to water to prevent changes in size, as well as to show the medulla structure more clearly. If not eventually removed, however, the paraffin will remain on the surface and create problems for any observation under the SEM. If the fibres are dark (not completely black), turpentine oil or liquid paraffin may help to lighten them up.

Polarization combined with the light microscope shows different refractive indices of a fibre at right angles. The application has been important for cellulose fibres to make a differentiation between flax and hemp (see chapter 3.2.6.4).

Certain plant fibres contain calcium acetate crystals which can be important for determination (Prychid – Rudall 1999). It is quite rare to spot the crystals in archaeological samples, the best chances being found with tree basts that have not been heavily processed (see ch. 3.2.3-3.2.5). It is possible to burn the sample and analyze the ashes by light microscopy or SEM; crystals will remain in this case and can be detected. It is quite unusual to burn samples from archaeological finds, especially as samples are either very small, overly processed or preserved by metals. This method was successfully tried, however, with samples from Pompeii (I), which enabled the identification of Kapok fibres (D'Orazio *et al.* 2000).

2.5.6 Cross-sections

2.5.5.1 Embedded section

The fibres are embedded in a resin, being very carefully placed so as to lie at a correct angle to the fibre axis. The resin hardens around the sample and then the resin block is cut into very fine slices and colored. Without this coloring, the organic parts are barely visible. The slices can be fixed with a glue, which will remain stable and serviceable for years. The main disadvantage to this process is getting the fibres cut to the correct angle. Cross-sections will appear oval if fibres are not correctly cut. Spun fibres, which will never lay in a straight manner, must be sliced diagonally! And then it is not possible to use such cross-sections to calculate measurements. For identification purposes this method has proven to be favorable for fibres which have a very distinct and determining shape of the cross-section. Otherwise, very fine slices are not very helpful. The best examples are the silks, where differences in the shape of the cross-section will show whether it is Chinese silk (domesticated silk), tussah silk or sea silk (see chapter 4.10.2 and 4.10.4). When the medulla is important for the determination, such slices are not always helpful as they can collapse and distinct features of the medulla will not show up. One example may illustrate the problem: *Fig. 81* shows the embedded cross-section of a dark fibre. As the scales were completely erased, the structure of the medulla remained an important criterion. One of the fine slice shows the medulla shape well enough. The same sample seen as a cross-section at the SEM is much better (*Fig. 82*).

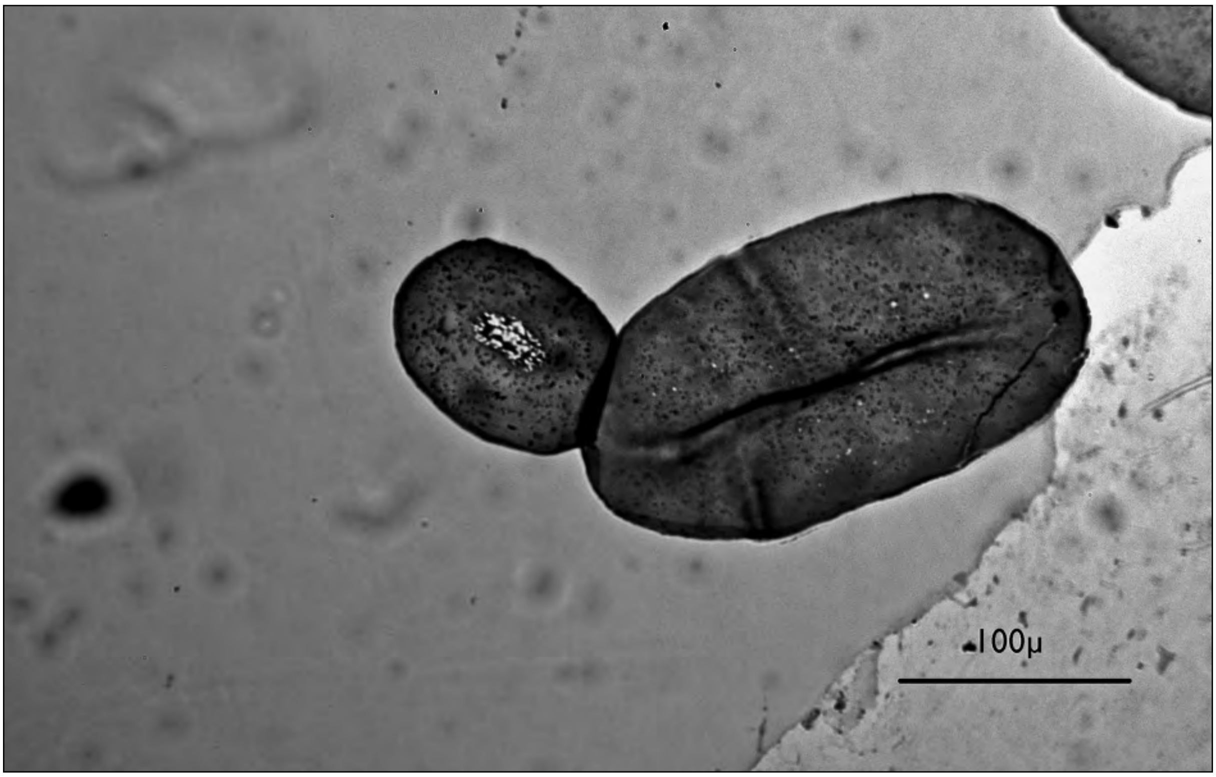

Fig. 81. Cross-section of a dark fibre, the medulla is visible as dark dots and not determining, Hallstatt (A)

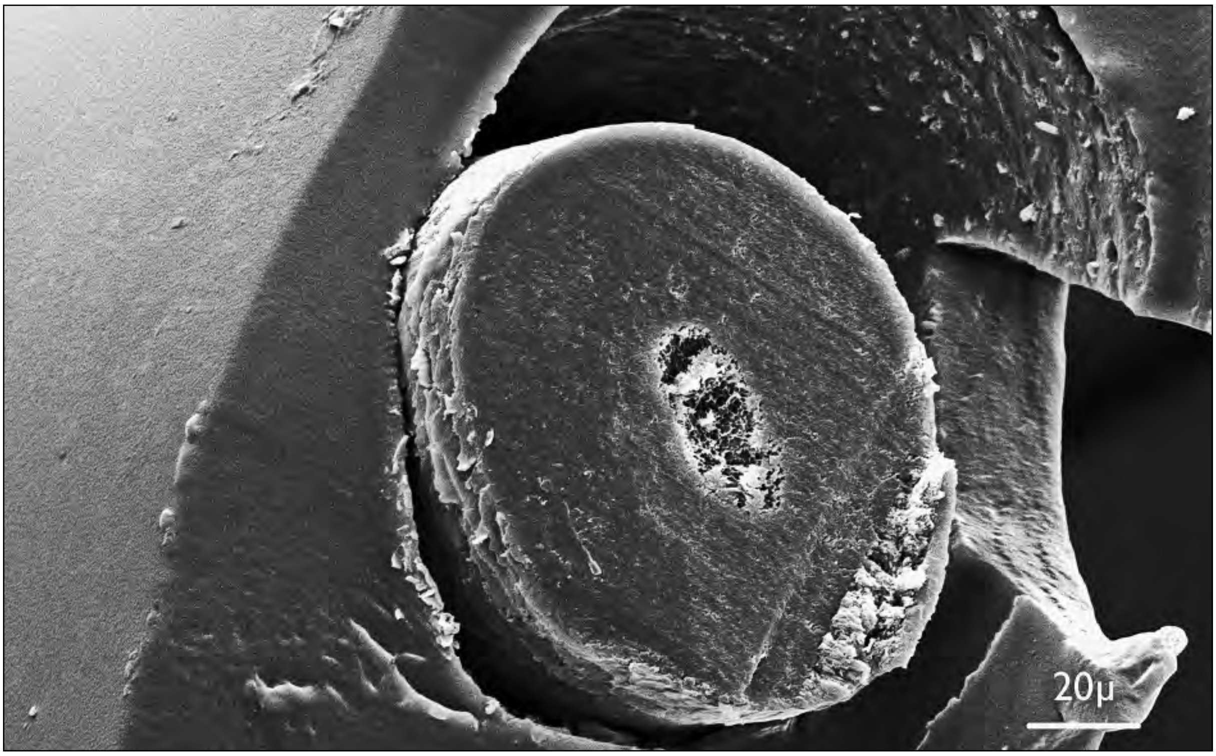

Fig. 82. HallTex 113870, Cross-section of the same fibre as fig. 81 seen with the SEM, the cross-section is typical for bovine, Hallstatt (A)

2.5.5.2 Plate section

Plate sections are quickly made and can‘t be saved. Polyester (no cotton!) threads are pulled through a very small hole in a metal plate. The fibres in the polyester form a “flower” and are pulled back through the hole so that they are fitted in a good position. With a new razor blade, remains of the polyester can be cut on each side of the plate. By adding a drop of liquid paraffin onto the cut fibres, the plate is ready for the light microscope (*Fig. 83*). Polyester is well differentiated from the other fibres, especially if a colored thread is used. Cross-sections such as these are good only for comparisons or on material which is not rare and quite well preserved. The sample can, of course, be documented with photos but will afterwards be lost (*Fig. 84*). Fig. 83.

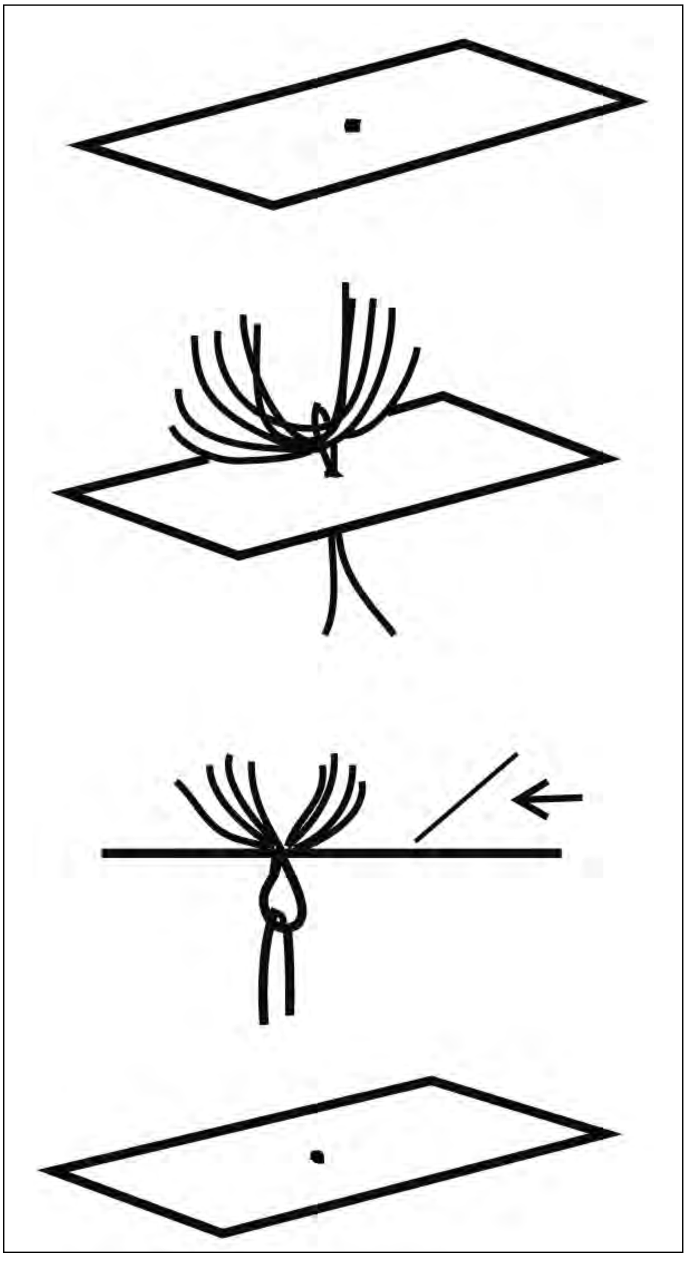

Fig. 83. The making of a plate section

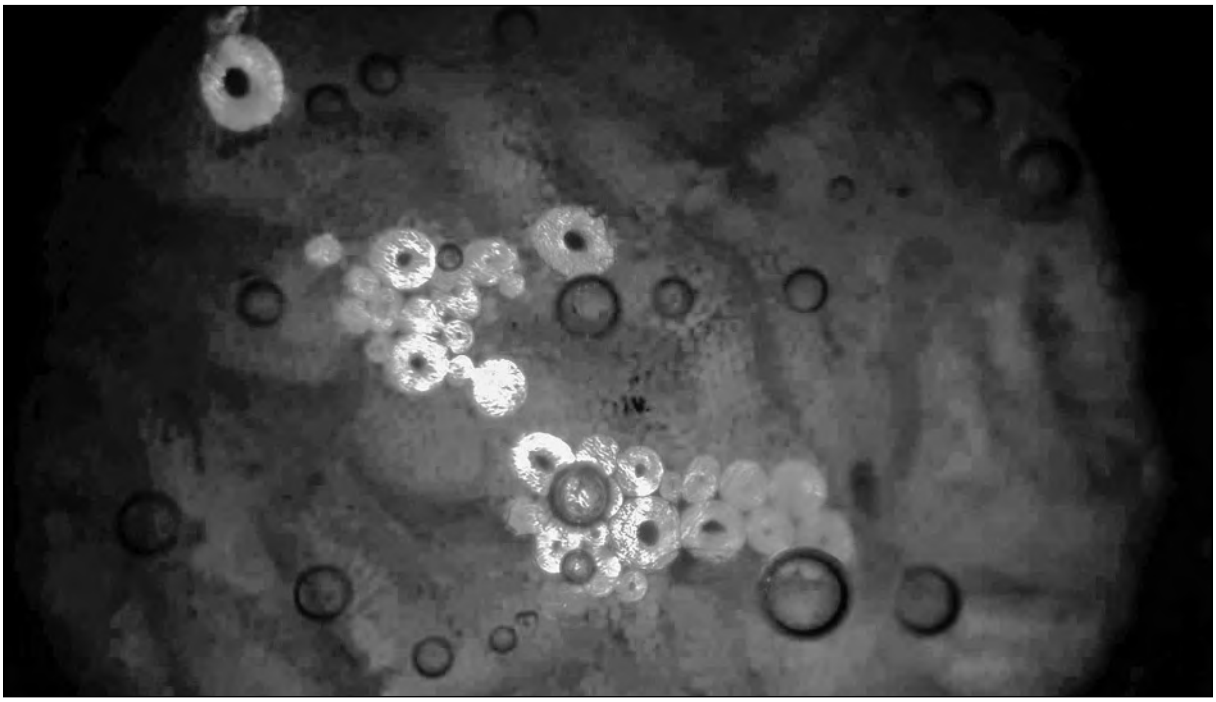

Fig. 84. Cross-section of dog fibres as plate section.
The width of the medulla is important to differentiate dog from wolf or fox

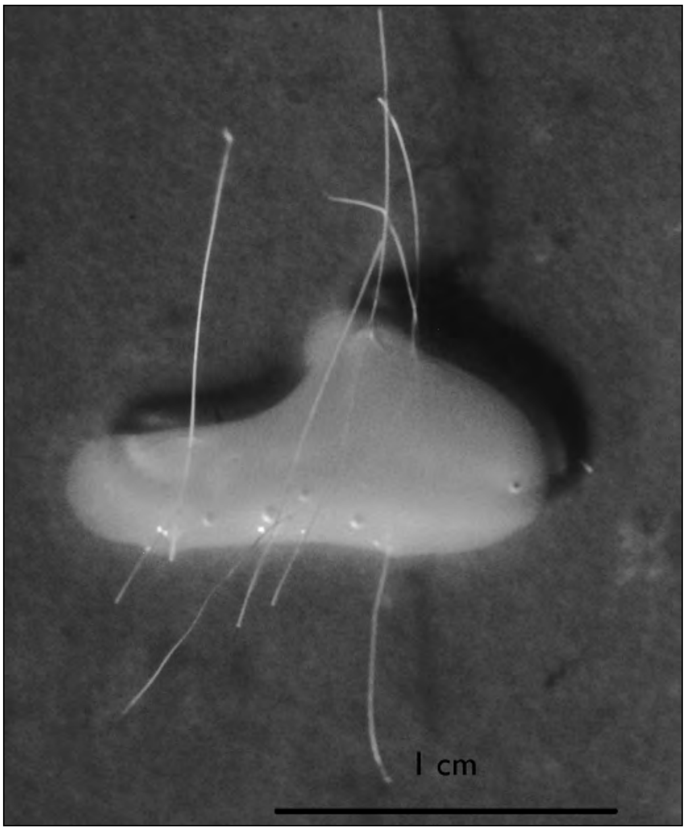

Fig. 85. Glue method: application of glue and mounting of fibres

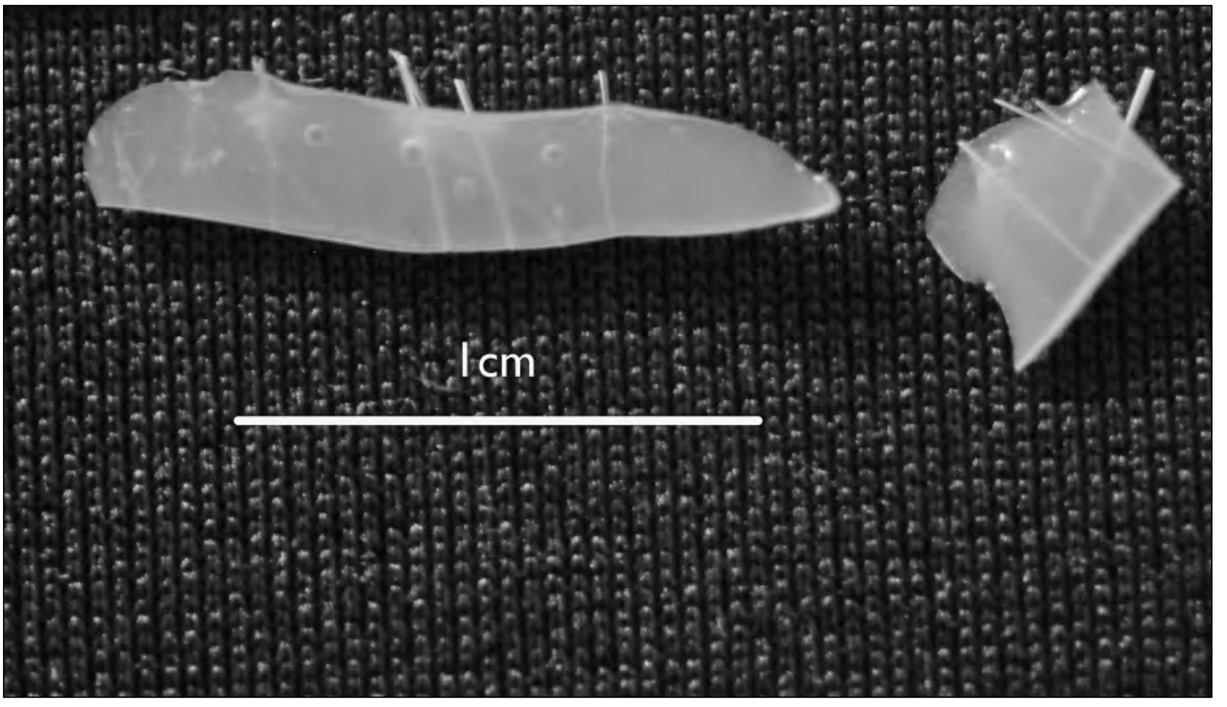

Fig. 86. Glue method: cutting of the strips after drying

Fig. 87. Glue method: mounting of the glue & fibre-strips on a stub

2.5.5.3 Glue section

There is another method that will produce cross-sections for the SEM quickly and well. As a kind of extension of embedded sections (which need quite a lot of time to prepare or are costly to hire out), glue sections can be cut. Instead of using hard embedding material, a normal white paper glue can be employed in its place. It works for samples where plenty of material is available. (Preparation of very precious material, on the other hand, must entail embedding in resin or mounted as a flat sample on the SEM and tilted in the machine). A small strip of white paper glue is first applied onto a microscope glass. The fibres are laid down in this glue at a 90° angle to the glue strip (*Fig. 85*). It is dried overnight then cut on both sides of the fibres close to the glue. The sample can be doubled by cutting the glue strip in half (lengthwise) (*Fig. 86*). The glue strip is then removed from the glass and mounted on the tape of the SEM stub. Working with the SEM, the analysis is less time consuming if the stub hasn‘t to be tilted. Therefore, the cross-section is placed facing the top and is as flat as possible (*Fig. 87*). If the glue strip is very fine, some red nail color applied first on the stub will help to fix the fine slice with the fibres.

2.5.5.4 Tape section

The fibres are fixed between two strips of tape and cut with a razor blade or scalpel (Meyer *et al.* 2002, 34). This should be done with conducting tape, otherwise there will be charging at the SEM.

2.5.7 SEM

The scanning electron microscope or SEM has become the most effective machine for fibre analysis and especially for poorly preserved fibres. It was first used in criminology (Verhoeven 1972), but later employed in conservation work (Janaway 1987). It is ideal in the study of fibres when in combination with light microscopy if the fibres are translucent. If not, the SEM is the only way to make fibre analysis possible. The machine provides high magnification, a very good depth of field and a much better resolution than the light microscope. Details, especially surface topography, are highly visible which is exactly what is needed for fibre analysis. Very small samples are sufficient – 2-3 mm are enough – but it is very important to choose these carefully under the binocular microscope where even single fibres are clearly visible. The poorer the preservation of the sample, the smaller the chance to see determining criteria with the SEM. It is important to carry over as little dirt as possible to prevent loading in the vacuum. Samples can be cleaned prior to mounting if the material is not mineralized or carbonized. It should first be determined if the material is stable enough to be cleaned and then only with distilled water.

Cross-sections and longitudinal views can be mounted on the same stub.

Samples are mounted on aluminum stubs, small single stubs or larger ones, with a double-sided sticking paper. In a conventional SEM, samples should be sputtered. Newer SEM models (environmental SEMs) can be used without sputtering but with less KV and therefore less depth of field. The author achieved best results by sputtering with 20nm gold or platinum for 360 seconds. The SEM brings out the best depth of field with 20KV, but if loading is too high the KV can be taken down to 15KV or 10 KV. Fresh samples (unburnt, non-mineralized) might obtain burn spots when there is high magnification which would be caused by electrons ejected onto the sample. If the sample is not in good contact with the stub it may be charged with electrons. In this case a reduction of the KV from 10 to 15KV may help. Charging may also happen if the sample has too much dirt that will charge as loose particles in the vacuum column. Charging is also a problem if there are many fibres on the stub, especially curled fibres, which can‘t all be tightly fixed onto the stub.

Pictures for wool fibre measurements should be taken with at least 200x magnification. Metal replaced samples can be mounted so that the fibres are seen as cross-sections (see *Fig. 32*). Ideal is a mounting of half of the sample in the longitudinal view with the other half in a cross-sectional view. Well preserved material can be mounted for a cross-sectional view by adhering fine and short material to a small drop of nail color. If the fibres are long, it is better to produce a cross-section with the glue (see *Figs 85–87*). While this "glue-method" is good for samples with enough material, for very small and very costly ones it is preferable to produce an embedded cross-section, which can be viewed under the light microscope (see *Fig. 81*).

Today, the SEM is the method of choice for the determination of specialty fibres, as in the differentiation of wool and cashmere (Langley – Kennedy 1981; Wortmann – Arns 1988) and in computer picture-based analysis (Wortmann *et al.* 2003; Moyo *et al.* 2006; Zhang *et al.* 2010; Li – Shang 2012). Image pattern analysis is difficult with archaeological material, as scale patterns are often not reflecting the best state of preservation. With archaeological material, scale height measurements can be important to differentiate sheep and goat, even if one has to be aware that the quality of preservation influences the analysis. Badly preserved scales will be thinner! Methods are explained in Varley 2006. Use of the SEM will magnify the edge of the scales enough so that the height can be photographed and/or measured (see ch. 4.8.13).

2.5.8 TEM

The transmission electron microscope (TEM) has, like the SEM, the advantage of high magnification and resolution. It has been used for the analysis of the internal structure of a fibre. Specimens need special preparation as thin slices of an embedded sample (less than 100nm thick) (Greaves – Saville 1995). This method was applied to distinguish between the fibres of cashmere and fine sheep wool. In samples prepared with staining techniques, there were differences observed in the arrangement of the orthocortical and paracortical cells between fine wool and cashmere (Tester 1987). TEM-samples need a quite long preparation compared to LM or SEM with embedding them into resin and then cutting the slices. It needs per sample about half a day.

2.5.9 Infrared microscope

With an infrared microscope the frequencies of infrared (IR) radiation in organic molecules can be recorded. The IR spectrum reflects the chemical bonds of the material and is characteristic of a specific plant or animal. This method has been combined with FTIR (*Fourier Transform Infrared Spectroscopy)* allowing for very small samples. The problem with archaeological material is that it is not always clean enough and that there is usually only one material. The curves need to be interpreted in these cases which means comparison material and experience are necessary. Another combination is with the Raman microscope, which is capable of spotting the chemical bonds of a material, whereas the FTIR defines the polar nature of molecules (Greaves – Saville 1995, 46). The FTIR method needs reference points to compare the wavelengths of the material. This seems very useful for different silk types or bast fibres (Garside – Wyeth 2003). In fact, a recent study by Chinese researchers using these different methods shows the potential of FTIR (Liu *et al.* 2011). The silk textile samples analyzed with FTIR came up with especially interesting results, as with the *Bombyx mori*, *Tussah silks* and the wild *Xinjiang silk* fibres that did not have the same wave length. The archaeological object turned out to be *Bombyx mandarina*, the wild mulberry silk. This differentiation, especially between *Bombyx mori* and *Bombyx mandarina,* could not have been obtained by using the SEM or light microscope as the difference is not visible with optical microscopy. FTIR can also be used on silk to determine degradation, as well for non-destructive color determination (Sato – Sasaki 2005).

2.5.10 Other methods

2.5.10.1 Amino-Acid composition

Among the types of chemical analyses, amino acid analysis can be used for the presence, determination and/or degradation of protein fibres (hairs and silks). For discussion of the presence or absence of silks, amino acid analysis has been utilized in the case of very deteriorated fibres. In the case of the Hochdorf silks, I. Good and K. Mann got opposing results (Mann 1999; Vanden Berghe – Wouters 2005; Good 2011; Bender Jørgensen 2013).

2.5.10.2 Synchroton

The synchroton is a particle accelerator and will show a diffraction diagram of a single fibre (like a moleculer finger print) so that each plant (fibre) is given an individual picture (Müller *et al.* 2004). Only a tiny sample is needed and even poorly conserved materials can be determined. While instruments such as these are rare in Europe and the method is very expensive to use, it could well be engaged to study very important cultural materials to a high degree. In Müller *et al.* 2004, for example, it was imperative to determine whether or not cotton was present in the textiles found in the Qumran caves (Israel). The Voltofte (DK) textile (see chapter 3.2.8.4) was confirmed as being nettle (Bergfjord *et al.* 2012).

2.5.10.3 Protein

Protein analysis will determine an exact protein which will then relate to an exact species determination, that is, if the material is well enough preserved to find proteins. The method uses mass spectrometry to do protein sequencing. It has been applied to the collagen of skin garments (Hollemeyer 2008) and can be used on materials where no results were gained by DNA analysis (e.g. bog finds of Denmark, Ørsted Brandt *et al.* 2004). A disadvantage is certainly the high cost of the method, making it an unlikely approach for study on a large scale (e.g. skins).

2.5.10.4 DNA

DNA analysis provides information about plant, human and animal genetic evolution and species determination. DNA can be found in plants, skin or hair. Usually, the older the animal or plant, the less DNA can be found. An exception to this rule has been material found in ice which has preserved DNA very well (Schlumbaum 2010). One problem is modern contamination and concerns human DNA only. Forensic analysis of hair using DNA analysis has become an important part of archaeological study (Wilson 1995; Bonnichsen 2001). Genetic markers can define individuals, populations or species, and have become the main source in evaluation of the evolution of plants, animals and humans (see e.g. Rocha *et al.* 2011). It will help if similar fibres are used and differentiation is needed, such as cashmere-fine sheep wool or flax-hemp (Murphy *et al.* 2011). But depending on the preservation, DNA may no longer be available. In old finds, chances are minimal that positive results will be found, especially if the objects were stored in a warm environment.

3. Plant fibres

Customary classifications of plants – as based upon floral and seed characteristics – are difficult to apply when describing textile fibres. Discussion of textile fibres for the purposes of this study will therefore be presented by dividing the topic into three main categories: seed fibres, bast fibres and structural fibres. Each of these will be grouped according to their use in the making of woven textiles followed by a sampling of their structural fibres.

3.1 Seed fibres:

3.1.1 Cotton

3.1.1.1 Habitat

Cotton was a known commodity in Antiquity as coming from Africa, Egypt and East Asia. The plant grows in a warm climate (no frost) and needs abundant water during the growth of the plant.

Primary cottons:

Old World, diploid, 26 chromosomes (today about 5% of world production):

- *Gossypium herbaceum,* Africa (now grown in Asia), fibre length below 25mm
- *Gossypium arboreum,* Asia (now grown in Asia), fibre length 25-28mm

New World, tretraploid, 52 chromosomes

- *Gossypium barbadense* (Sea-Island cotton), fibre length over 28mm
- *Gossypium hirsutum* (Upland cotton), fibre length 26-28mm

3.1.1.2 History

Prehistory/Roman Period/Early History

The earliest cotton found in an archaeological context dates from the 6th c. BC and was discovered in Pakistan inside a copper bead. As some of the fibres show clearly concentric rings (Moulhérat *et al.* 2002, Fig. 8), this determination has to be questioned. Another prehistoric find from the 4th millennium BC in Pakistan (Shahi Trump) is proof of an early use of the plant (Tengberg – Moulhérat 2008, *Fig.* 5). Several prehistoric finds in India, including evidence of plant diversification beginning in the Bronze Age, show a continuous cultivation and probable domestication of cotton in this part of the world (Tengberg – Moulhérat 2008).

Prehistoric seed finds in Upper Egypt revealed both wild and cultivated cotton. Cultivated were *G. arboreum* and *G. herbaceum*. Wild were *G. anomalum*, *G. somalense* and *G. Stocksii*. These cotton species have a different number of chromosomes than the cotton of the New World (Chowdbury – Buth 1971). In the Old World, cotton was grown in tropical and subtropical regions. Early textiles from Arabia date to the 4th mill. BC and the Chalcolithic Period (Betts *et al.* 1994). Several finds from the 1st mill. BC in Mesopotamia and Arabia show a well established fibre plant. The finds in Bahrein (named Tylos; Theophr. Caus. Plant, IV, 7,5-7) are especially interesting as the Greek historian Theophrastus described cotton on this island (Tengberg – Moulhérat 2008). Recent investigations on the island could show the cultivation of cotton involving a specialized production technique combining it with date palms and something already being carried out in the 1st mill BC (Bouchaud *et al.* 2011). The authors were not able, unfortunately, to determine whether the remains could be attributed to *Gossypium* *herbaceum* or *Gossypium arboreum*. In the 5th c. BC, the Greek historian Herodotus mentions cotton and the cotton garments of the Indians (Hdt. 3,106; 7,65,1).

The Romans knew cotton well and finds in Egypt, especially from the Red Sea port of Berenike (Egypt), have revealed important historical clues as to the use of cotton during the era of the Roman Empire (Wild – Wild 2014; see ch. 3.1.1.4). Papyrus documents from the 2nd and 3rd c. AD contain remarks on cotton garments as well as the quality of cotton, proving that cotton was also grown and quite common in Upper Egypt at that time (Winter – Youtie 1944). Among the finds from Egypt (many now in European museums) are numerous samples of partially undated cotton textiles (e.g. Fluck 2001). Recent finds show that cotton spread to other regions and was grown in the first half of the 1st mill. in Uzbekistan (Baker Brite – Marston 2013). The "Silk Road" allowed for trade routes from east to west, but also from west to east. Cotton was not indigenous to China during the Tang-Dynasty but imported from India and Persia and from the 10th c. was brought in from Southeast Asia. The Chinese are known to have produced very fine and expensive textiles (Trombert 2000, 117), but printed cottons found in the Xinjiang (China) were probably imported from India. Similarly, resist-dyed textiles were also found in Berenike within the boundaries of Egypt at that time (Wild – Wild 2014).

Middle Ages

During the Middle Ages cotton was a growing market and imported from the Levant to Europe. During the Crusades the market was especially vibrant in Venice and Genova (Italy). By the 10th c. cotton plantations had become important in Mesopotamia, Syria, Palestine, Egypt (under the Fatimids) and then in Sicily by the end of the Middle Ages (Bearman *et al.* 2014). In the 12th c., processed cotton arrived from Antioch, Armenia, Damascus, Acco (Acre), Cyprus and Laodicea (Syria) and in the 14th/15th c. from Egypt as well (Oppel 1902, 22f.). By 1200 a guild for cotton beaters was controlling the work in Venice (Mazzaoui 1981). Constance (D) saw the first cotton spinners of Western Europe, later to be found in Ulm for mixed textiles ("fustian").

In Southern Germany such mixed linen/cotton textiles were made ("fustian" German: *"Barchent"*). The famous family Fugger, who originated from Augsburg (D), organized the export of these textiles to Italy and other places (Baur 2015).

Modern Period

Initially, cotton was imported from the New World in the second half of the 16th c. It became a serious concurrence to Egyptian cotton only in the 18th c. (Bearman *et al.* 2014). By the end of the 18th c., England had become the dominant supplier in the cotton market, no less as a result of legislation in the first half of that century that allowed the mechanized cotton industry to transform the production of fustian weave (O'Brien *et al.* 1991). By the end of the 18th c./beginning of the 19th c., the mechanization of spinning and weaving in combination with a growth in demand for Calico prints – a new 18th c. fashion which also appeared in part on coarser Indian cotton – caused an incredible increase in the use of cotton. The 18th–19th centuries saw cotton printing rise to become a major industry in England (Manchester), France (Rouen, Mulhouse), Switzerland (canton of Glarus), and Poland (Lodz). The 19th c. saw the exportation of printed cottons to such countries as India, Indonesia and Africa, introducing products that began to replace cloths made by traditional methods of design on wool (cashmere shawls), ikat and batik (Sykas 2005; Rast-Eicher 2009). In 1818-19, the Frenchman Luis Alexis Jumel discovered in Egypt a special variety of cotton with very long fibres. This cotton would come to fetch higher prices and eventually was cultivated for the European market. By the 1860's, and especially during the American Civil War, large quantities were being produced albeit with the cotton trade becoming ever more complicated in tandem with the politics of the day (Bearman *et al.* 2014). After the Civil War in America, new cotton exchanges were opened in Liverpool, New York and New Orleans. The cotton industry (especially in America) introduced regular quality control measures and by 1907 a vast reduction in product varieties – from 600 to just 31 – were officially allocated (Bally 1951b, 3671). After World War I, the cotton industry (again, especially in America but also in England) relocated manufacturing to less expensive areas such as India and Japan (Bally 1951a). This, in turn, helped to create monocultures of cotton production which in themselves are ecologically problematic because of extensive water and pesticide use. Modern but positive derivatives of this situation are organically grown products; the purchasing of such "BIO-cotton" brands not only promotes the production of good quality, ecologically grown cotton but raises advantages for the small farmer (Hofer 2000, 73f.).

3.1.1.3 Fibre properties

As seed fibre, cotton has no lignin, something that would have to be dissolved by retting as with flax. Cotton fibre is tubelike, with a large lumen and without nodes as bast fibres have. Due to changing directions of the cellulose layers that serve as building blocks, the fibres are twisted (Fraenkel 1928, 207ff.; Hofer 2000, 69). They have diameters of 15–30μ, depending upon the variety (Fraenkel 1928, 214). Very ripe cotton appears flat with large bands (*Fig. 88*), something that is an unwanted attribute to the industry as the spin and dye properties present difficulties. Cross-sections usually appear kidney-shaped (see *Fig. 91*), with the cell wall making up 1/3 to 2/3 of its diameter. Cotton doesn't show up in the cross-sectional view of its concentric rings as it does with the bast fibres of flax or hemp (see *Fig. 102*).

Cotton quality is differentiated by the length of the staple (length of fibres), its resistance (break point), evenness, shine and silkiness; it can also differ in color from white to brown. In 1844, J. Mercer developed a chemical treatment using caustic soda to straighten cotton fibres, a process known as "mercerizing". The chemicals destroy the epidermis, causing the fibre to swell and lose its twist (*Fig. 89*). Straight cotton fibres are more stable, more shiny and better to dye (Hofer 2000, 94). Such modern layering will be evident when dating a piece although finds found in houses are sometimes difficult to date even so.

3.1.1.4 Archaeology

Textiles found on the Arabian island of Bahrain are interesting as they are z-spun and therefore different from the traditional s-spinning of Egyptian cottons (Bouchaud *et al.* 2011; Wild – Wild 2014). In the Graeco-Roman Red Sea port of Berenike (modern day Egypt), nearly half of the textiles found from the 1st c. AD layers are made of cotton. One group was found to have been produced in the same manner as other Egyptian plant fibre textiles, that is, with s-spun yarns. Another group was made up of z-spun yarns and interpreted to have been made in India (Wild – Wild 2014). As research has supported the fact that there was cotton cultivation in the 1st mill BC in Bahrein (Bouchaud *et al.* 2011), the provenance of the z-spun cottons found in Berenike has to be discussed. Among the textiles found with the famous scrolls at Qumran cave (Israel), cotton dated before AD 68 has been identified (Müller *et al.* 2004). In the Roman tradition, cotton has been found also among Abbassid textiles in Egypt, including its use as filling material (e.g. Desrosiers 2004, 69).

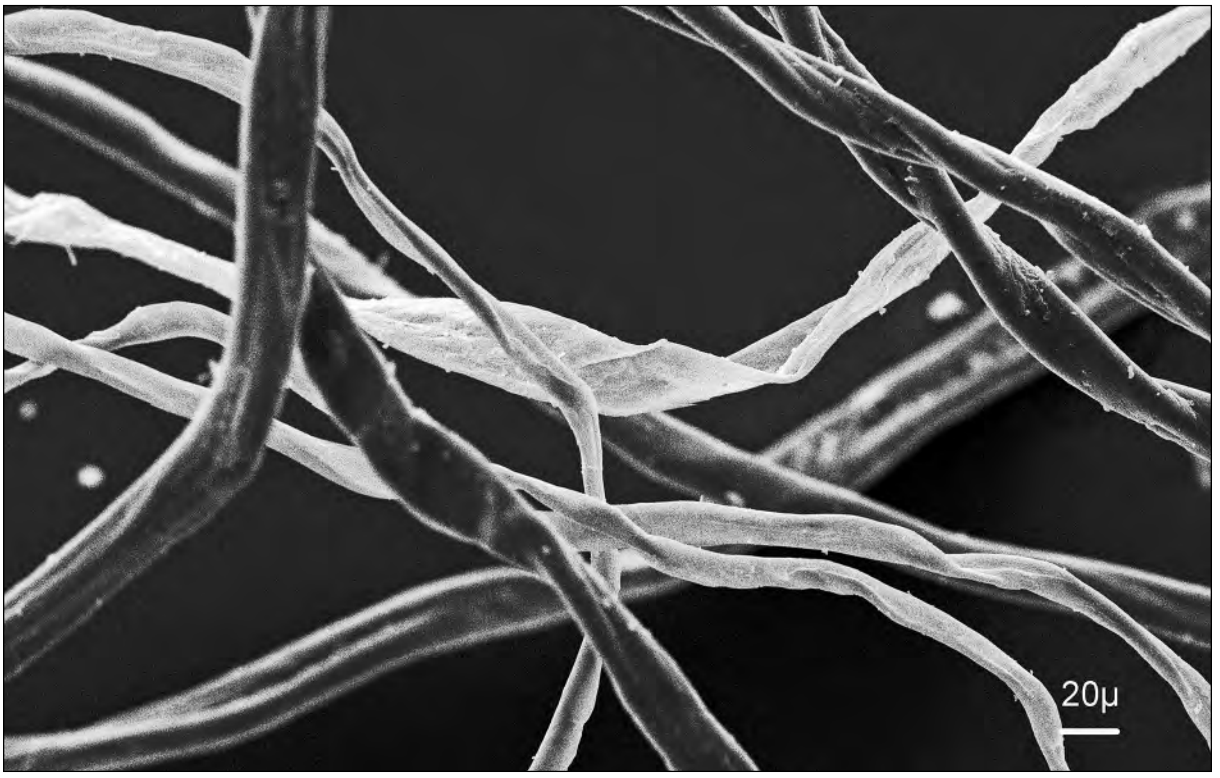

Fig. 88. 19th century cotton from Egypt, archive of the firm Barth. Jenny&Cie, Ennenda (CH)

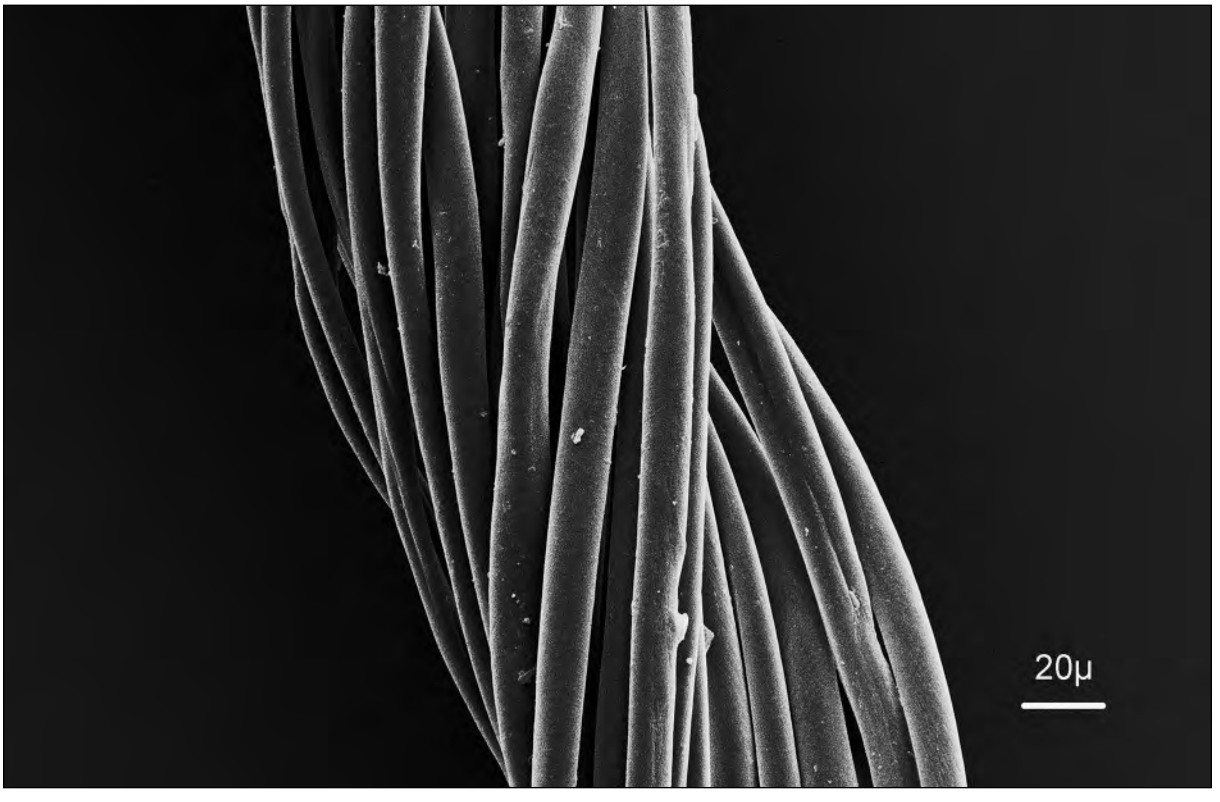

Fig. 89. Mercerized cotton, modern

Early cottons in the area of Europe have been found in Greece in the Iron Age cemetery of Kerameikos (5th c. BC). Recent study of a textile, previously thought to have been of silk has proven it to be made of cotton and not of a proteinous fibre (Margariti *et al.* 2011, textile Y2). Two other finds, older by date, are cited by Maragriti et al., one from Attica (5th c. BC), the other from Vergina (4th c. BC). Roman cottons in Western Europe are rare but one has been documented from a cold bath in a Roman villa in France (Dept. Vosges, Schluck *et al.* 2012). A textile from Pompeii (I) has been identified as made from cotton (D'Orazio *et al.* 2000, 747, Fig. 1).

Early Medieval cottons can be difficult to spot (see below), but a sample from the 6th c. grave of Lauchheim (D) has been reported to be cotton (Walton Rogers 1998). In metal-replaced preservation, cotton can be especially difficult to recognize clearly. Flax may be so badly preserved that it becomes extremely flat and thin-looking, with turning fibres appearing to be those of cotton. In such cases it is important to be able to detect whether there are nodes or not. Early Medieval finds in such cases are therefore not so clear. An example that illustrates a problem such as this is a metal-replaced textile from a 6th c. grave from Langenthal, Switzerland. The fibres are hollow (and therefore certainly not wild silk) and nodes are not visible; the width of the fibres is greater than with flax (*Fig. 90*).

Archaeological material from the Medieval Period contains much more cotton than has been unearthed from sites of earlier eras. Fustian mixed cotton and linen textiles have been found in castles dating from the 10th–11th centuries (Degen *et al.* 1988, 149), as well as in towns from the Late Medieval to Early Modern times (Windler – Rast-Eicher 1999/2000; Rast-Eicher 1999; Rast-Eicher – Tidow 2011). In these cases it has been possible to differentiate cotton from flax and hemp by its having no concentric rings in the cross-sectional view (*Fig. 91*). A recently found Medieval textile from the Zürich-Fraumünster (CH) is a high quality woven piece with a linen warp and cotton weft (a so-called "fustian"). Preserved under wet conditions, it has become very dark (Rast-Eicher, unpublished report 2015). Nevertheless, both fibres of cotton and linen are quite well preserved and differentiation between the two is well visible (*Fig. 92*). Cotton was not only woven but lower qualities were used as stuffing material for textile braids. Articles such as these were worn at the beginning of the 16th c. as a type of wig, depicted as such in many 16th c. portraits (Rast-Eicher – Tidow 2011, 338). Depending upon the object, it is sometimes possible to open a thread (sample) and check the length of the staple.

Something that could interfere with analysis and identification of fibres are the modern-day tissues and tissue paper often used to wrap objects during excavations; they tend to leave modern cotton fibres on the surface! Under the SEM it is possible, however, to differentiate the ancient fibres that are within a thread from those recently attached to the top of the thread or textile.

3.1.2 Others

3.1.2.1 Kapok (Ceiba pentandra)

Kapok is a seed fibre from the tropical tree *Ceiba pentandra* which grows in Central America, West Africa and Java (*Fig. 93*). The fibres (length 15–40 mm) are fine and hollow. They are not able to be spun as the fibre is too brittle but are used as special filling material (Hofer 2000, 132). This has been reported from finds in Pompeii through morphological analysis (D'Orazio 2000, Fig. 9).

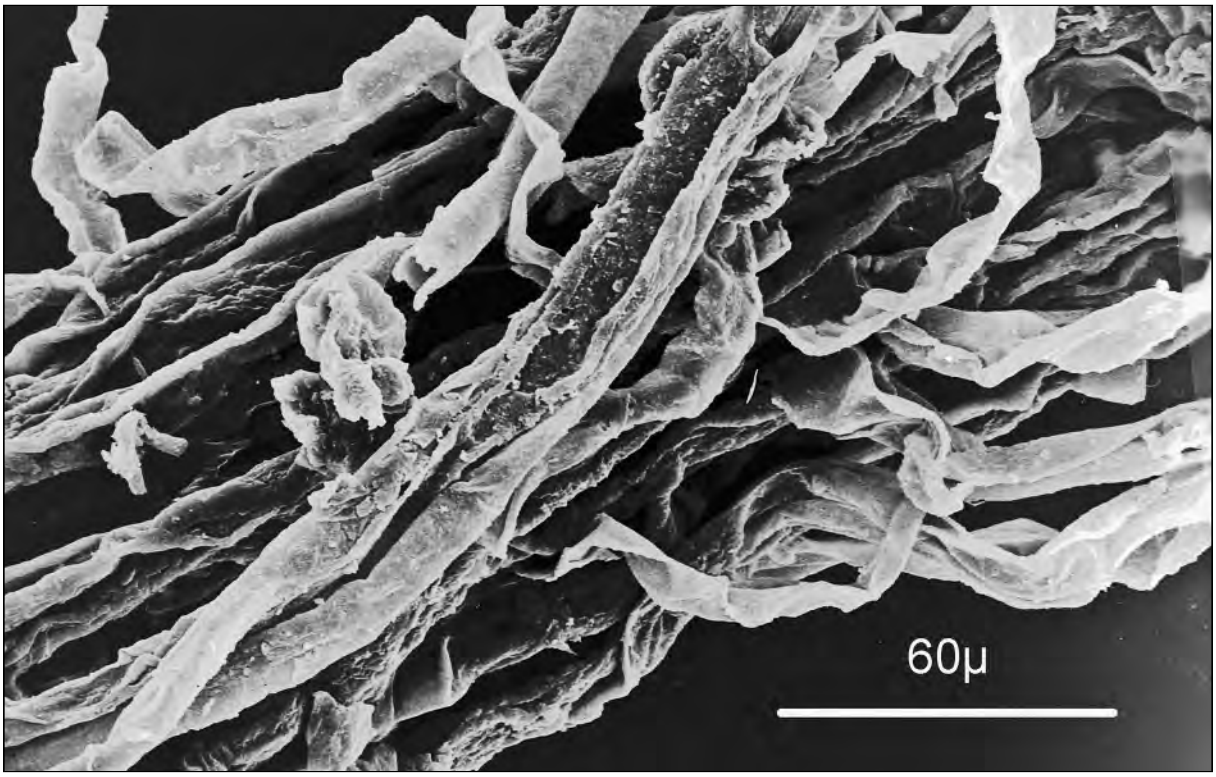

Fig. 90. Early Medieval find, cotton? Langenthal-Unterhard (CH)

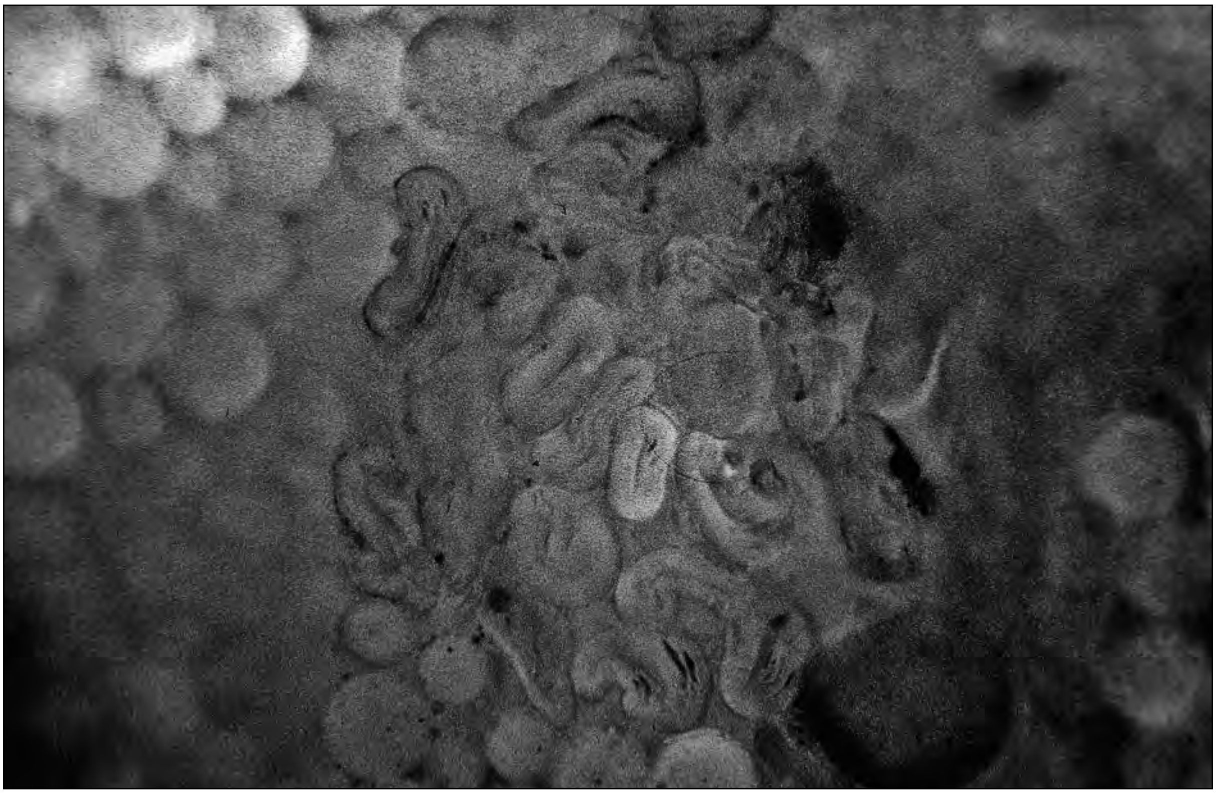

Fig. 91. Cross-section of Early Modern cotton thread, Zug (CH)

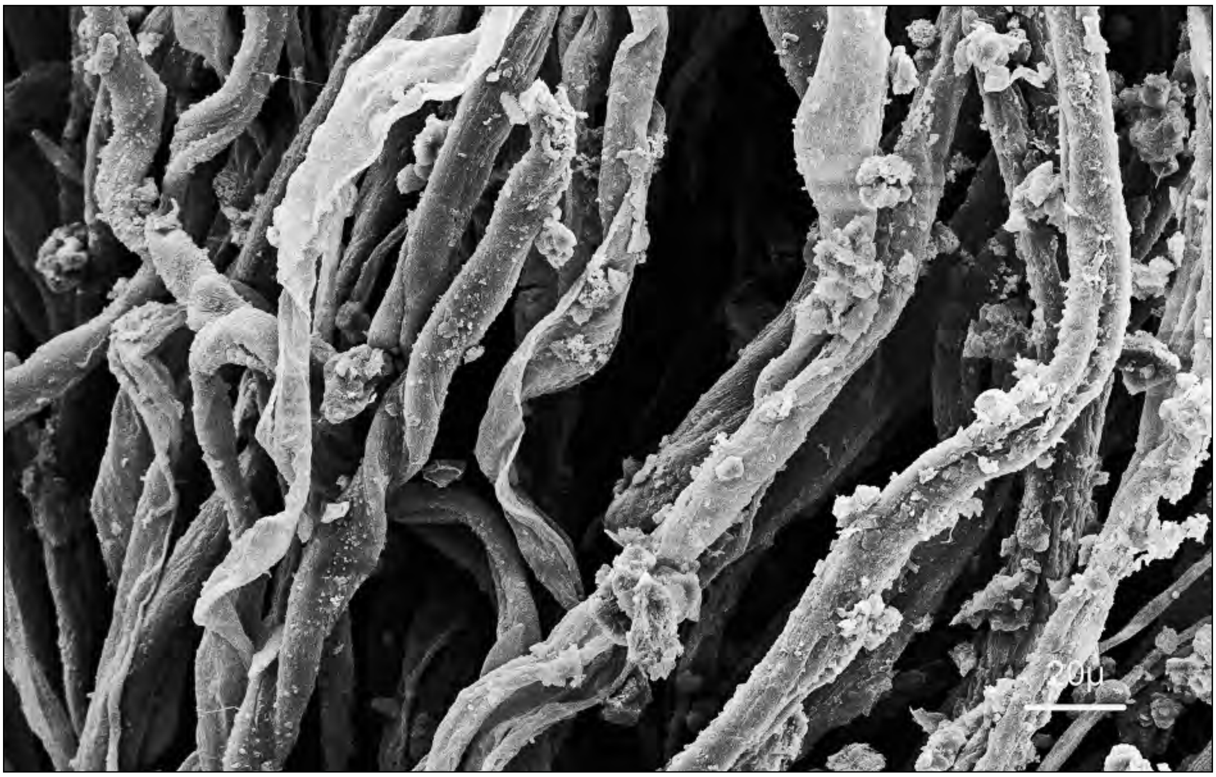

Fig. 92. Medieval fustian, cotton thread, Zürich-Fraumünster (CH)

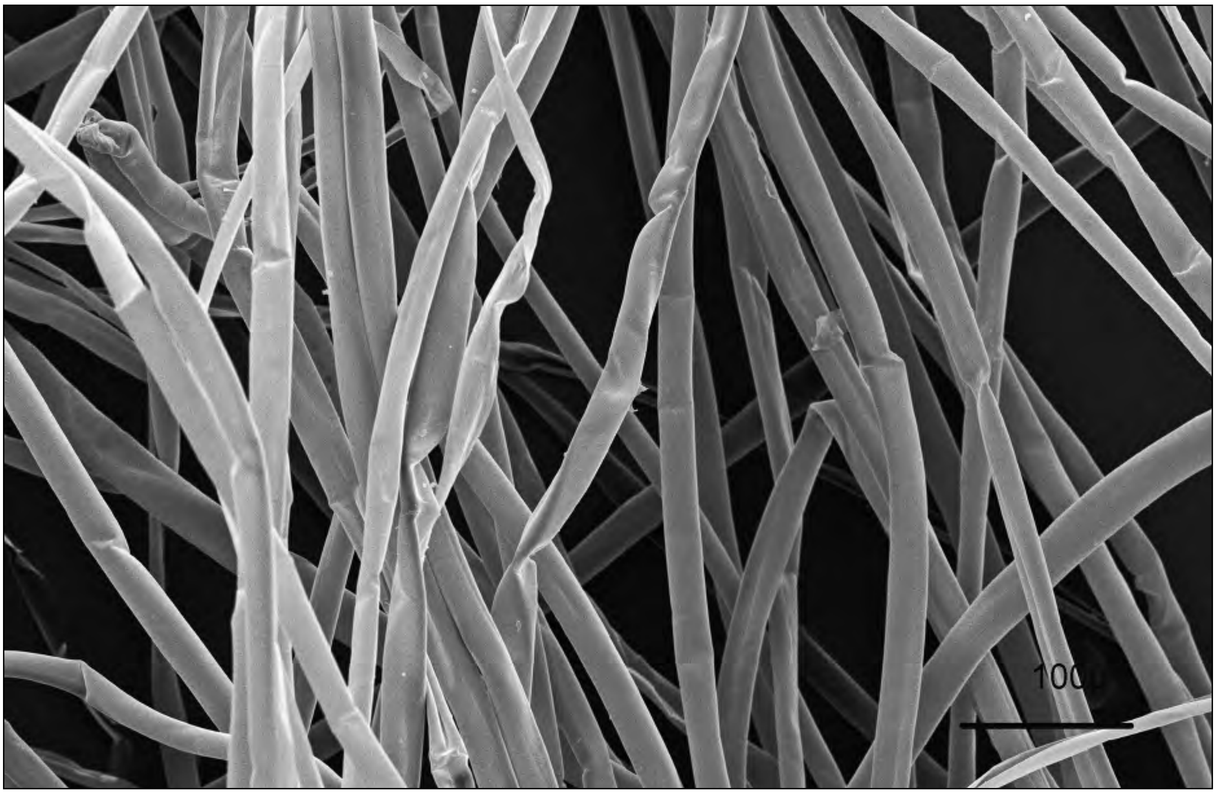

Fig. 93. Kapok fibres, modern

3.1.2.2 Milkweed (Calotropis procera)

The plant is common in India and the Near East. Its fruits bear fibres, as well as stems, that are suitable for spinning (Friedman – Amar 1997; Shakyawar *et al.* 1999; Reddy – Yang 2009). Milkweed seed fibres have been used in modern 18th c. Europe, especial in the paper industry but also as filling material and knitwear (Shakyawar *et al.* 1999). In the search for eco-fibres, milkweed seems to have been (re?) discovered, this not only as a fibre plant but also for the oil its seeds produce and its use as fuel (Holser – Harry-O'Kuru 2006).

3.2 Bast fibres

3.2.1 General introduction

Bast fibres are all those within a stem and that which lie between an epidermis layer and a woody core. This would include tree basts, flax, hemp and other stem fibres. The chemical and physical properties of bast fibres are different depending upon the plant (summary in: Summerscales *et al.* 2010). Fibres will show "nodes" or dislocations – horizontal lines which are more or less thick – perpendicular to the fibre axis. They are the weak part of the fibre and influence moisture and dye penetration (Akin 2010, 91) (see *Fig. 34* and *105*).

During the earliest times of the Paleolithic, tree basts were the most important textile fibres used. This was true until the end of the Neolithic Period (Rast-Eicher 2005). In Northern Europe bast was employed up until Modern Times (Bielenstein 1995). From about 4000 BC every sort of object was produced using tree bast, from threads and strings to coiled baskets and twining basketry to woven textiles (Rast-Eicher 2005a; Rast-Eicher – Dietrich 2015). Until the introduction of wool during the Eneolithic Period, coats and hats made of tree basts were important to the ensemble of garments worn, including skin garments. Similarly, garments worn in mountain areas or in the arctic regions were twofold, with skins for warmth and bast as an outer layer to keep the person dry (Fienup-Riordan 2005; Feldtkeller 2004, 61). Flax followed in Central Europe by the Early Neolithic with the first farmers coming from the Near East. Hemp was introduced during the Iron Age. High qualities were used for the finer threads, as for fishing nets and fine woven textiles; coarse qualities were for use in the construction of strings, cords, sacks or caulking.

The determination of bast fibres is not always straightforward. With (tree) basts that were used unprocessed, determination is possible by looking at the rays and crystals. Finely processed basts, however, will show single fibres with nodes and in this state differentiation is difficult. As mentioned, many plants contain calcium oxalate crystals in the fibres (Prychid Rudall 1999; Schoch 2015). In fibres that have not been heavily processed, such as the bast fibres used in basketry techniques from the Neolithic, these may be spotted in the rays. As soon as such fibres are thoroughly processed for the production of finer threads, the ability to see crystals becomes much harder. Carbonizing the sample so that dirt has been eliminated and the calcium oxalate can be seen by microscopy, will better enable visibility.

Ancient texts have named unspecific tree bast fibres, as with the story told by Mela describing the Germans as being "…clothed only with a sagum of tree bark" (*Viri sagis velantur aut libris arborum…*), even in the depth of winter (Mela, 3, 20,21).

3.2.2 Processing

Bast fibres can be used unprocessed (fresh) or processed. Tree basts, for example, are taken most often as bands or twisted bands and in order to obtain a single fibre from them they must be either retted or separated by another process, such as boiling with ashes. Tree basts are taken in spring when the bark and the bast layer is wet. The strips can then be easily torn from a branch or trunk. The thicker the wood, the thicker and more numerous will be the bast layers. Fresh and flexible bast strips can be taken directly by pulling them apart at the needed width. Harvesting flax and hemp fibres will follow the same procedure when they are to be used as green bast fibre (Clarke 2010; ch. 3.2.6). In Europe, retting the fibres can be accomplished by putting bundles (tree bast) or stalks (flax, hemp etc.) into water or by spreading them on top of grass. Retting is a microbiological separation of the cellulosic fibres from the epidermis and woody shive (Akin 2010, 94ff.). When done in either of these ways, flax and hemp will show the nodes in the same line (see *Fig. 62*). The time needed for these retting processes depends upon the actual fibres as well as water and air temperature. According to ancient finds, early flax threads were produced in the same way as tree bast threads, by splicing together fine strips. Even green flax was used in this way (s. ch. 2.3.2; Leuzinger – Rast-Eicher 2011). Evidence of splicing has been recorded in Egypt and the Near East and seems to have remained the main system for thread production until about 600 BC (Vogelsang-Eastwood 1992; Kemp – Vogelsang-Eastwood 2001). It was present as well in classical Greece – Stella Spantidaki's article on a figure from this time having flax threads with only partially retted fibres is proof of this (Spantidaki 2013, Fig. 1). The processing of flax and hemp by retting, hackling, combing and spinning appears initially in the Iron Age and continues in this way by hand until the 19th c., or even up until the 20th c. in some regional areas. While green decorticated flax is mentioned in modern industry articles (for its bad quality) (Muzyczek 2012, 315), it seemed to have served as an option even in the 19th century in Europe and traditionally in Asia (Clarke 2010).

3.2.3 Lime bast *(Tilia sp.)*

3.2.3.1 Habitat

Common tree, growing in Europe in temperate climates, different species.

3.2.3.2 History

Tilia sp is known as a native tree of varying species that grow in the temperate areas of the northen hemisphere, e.g. Europe, North America and Asia. Lime-bast is certainly one of the most common types used in prehistory, especially in Northern Europe and up to Modern Times. In the Neolithic lake dwellings it was an important part of string, cord and basketry construction, with even a single woven textile having been recorded as being made of tree bast (Rast-Eicher 2005; Rast-Eicher – Dietrich 2015). Technically, from large strips used for cords to spliced and fine threads used for the woven textiles, everything was possible. Herodotus reports that the Scythians made an oracle with lime bast (Hdt. 4,67). In Northern Europe, many objects were made of lime bast up through the Modern Period, this including even the coarse clothing for workers (Bielenstein 1995, 19ff.). Martha Bielenstein describes the processing as follows: the bast is harvested from young trees from May to mid-June (called in Finnish "peel-time"); the green upper bark is to be scratched away from the fresh bast or, if dried, must be moistened or boiled in order to remove it. The bast can now be used as strips to make shoes or strings, or it could be processed by retting and beating it until the fibres loosen. Textiles were woven only with basts with a linen warp and the textiles were used for clothing or bed linens.

Remains of bast strips from Neolithic dwellings confirm the description Martha Bielenstein has given (Rast-Eicher – Dietrich 2015). It is also very probable that the bast of small trees or branches were harvested. It is rare to see the visible remains of bark bast (thread) (*Fig. 94*).

3.2.3.3 Fibre properties

Lime bast has the longest fibres of the commonly used tree basts (willow, oak, lime) and as such can be processed into fine threads. As long as its single bast fibres are not separated, lime bast shows a characteristic ray with a ladder-type structure that sometimes reveals polygonal crystals (*Fig. 95*). Fibre diameter depends upon where it is found in the bast layer; the smaller the branch or tree and the closer to the wood, the smaller the diameter and the finer the thread. Lime bast is 47% stronger when wet, yet has a low water absorption rate; it dries quickly, is resistant to decay,and is soft when retted (Harris 2010).

3.2.3.4 Archaeology

There are many finds, especially from ancient lake dwellings. During the Neolithic Period strings, ropes and basketry of lime bast were made in abundance (*Fig. 96*; see *Fig. 61*). In one case, a string sample made of both lime and willow was found, the mix having the effect of two colors with reddish for willow and a lighter hue for lime (Rast-Eicher – Dietrich 2015, Abb. 46). A woven textile from Zürich-Mythenschloss (CH) has been reported to be made with spliced yarns in which die rays are still visible (Rast-Eicher 2005; Rast-Eicher – Dietrich 2015, Taf. 106f.). Good fibre properties (see ch. 3.2.3.3) make lime bast ideal for the construction of upper garments, such as rain capes. The object from Zürich-Mythenschloss was probably just such a cape. Bast ropes have been found in the salt mines of Dürrnberg (Stöllner 1999, 144) and one found in the salt mines of Hallstatt in Austria has been dated to the Bronze Age (Reschreiter – Kowarik 2008, 64). The latter was a thick cord (dm. 4 cm) seemingly having been used to pull sacks filled with salt to the surface. Strings found in the Viking Age Oseberg ship burial were used most probably for ropes (N; Vedeler 2014, 289).

3.2.4 Willow bast *(Salix sp.)*

3.2.4.1 Habitat

Common tree, growing in Europe in temperate climates, different species, some in Alpine regions.

3.2.4.2 History

As with lime bast, willow bast has been, until recent times, one the most commonly used tree basts. It is reddish in appearance.

3.2.4.3 Fibre properties

As with all bast fibres *Salix sp.* (Dm. 15–20µ), nodes are evident. The best criteria for determining salix are the crystals in the rays, which are small squares and are added like a chain (*Fig. 97*). They are more often visible in archaeological material than in the larger crystals of lime bast as the rays are smaller and often keep the form.

3.2.4.4 Archaeology

Especially among the material of the ancient lake dwellings, willow is well accounted for in many sites. Willow is one of the three tree basts most commonly found (*Fig. 98*).

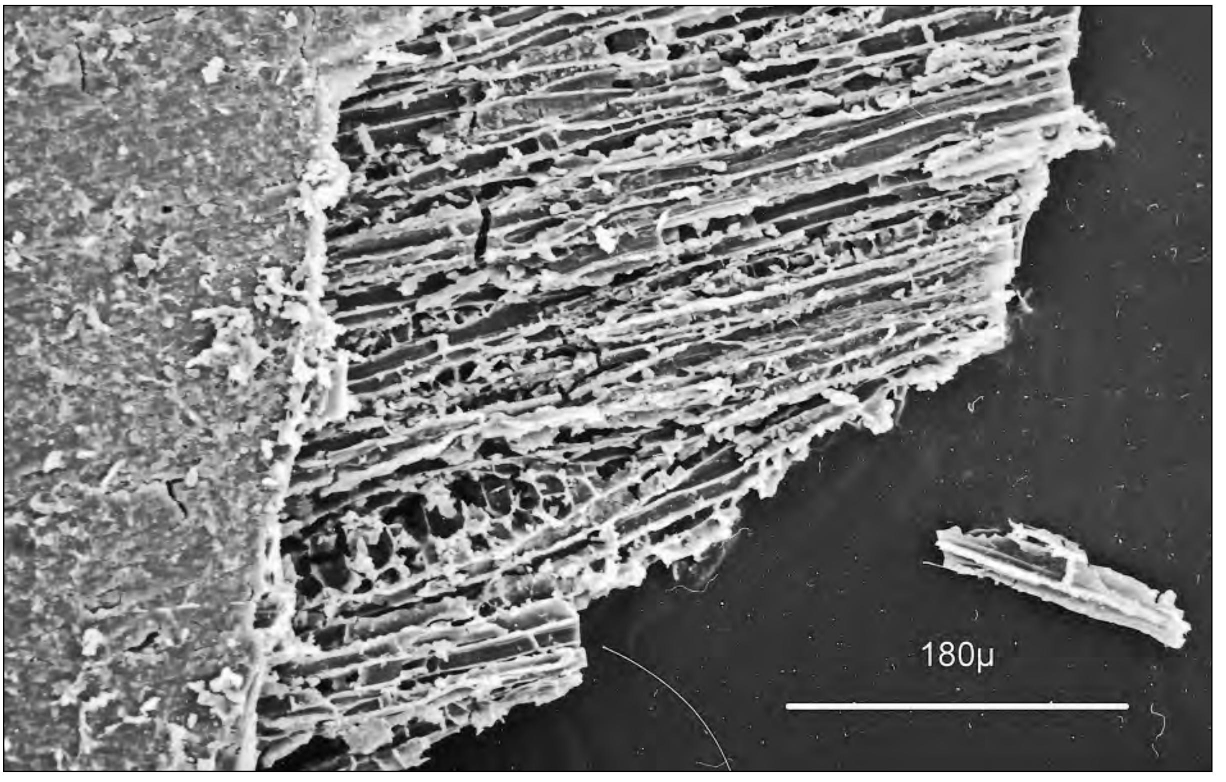

Fig. 94. Lime bast with remains of bark, Risch (CH)

Fig. 95. Lime bast with crystal, Modern. Photo W. Schoch

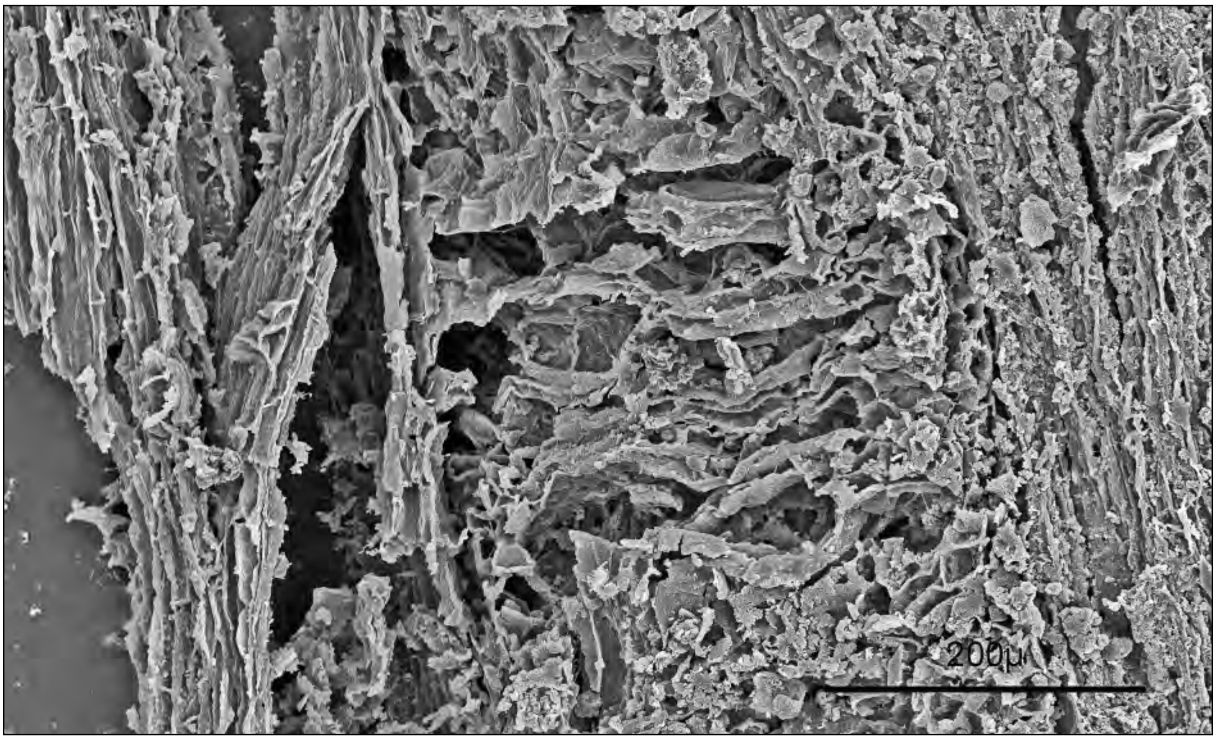

Fig. 96. Lime bast, Neolithic Period, Meilen-Schellen (CH)

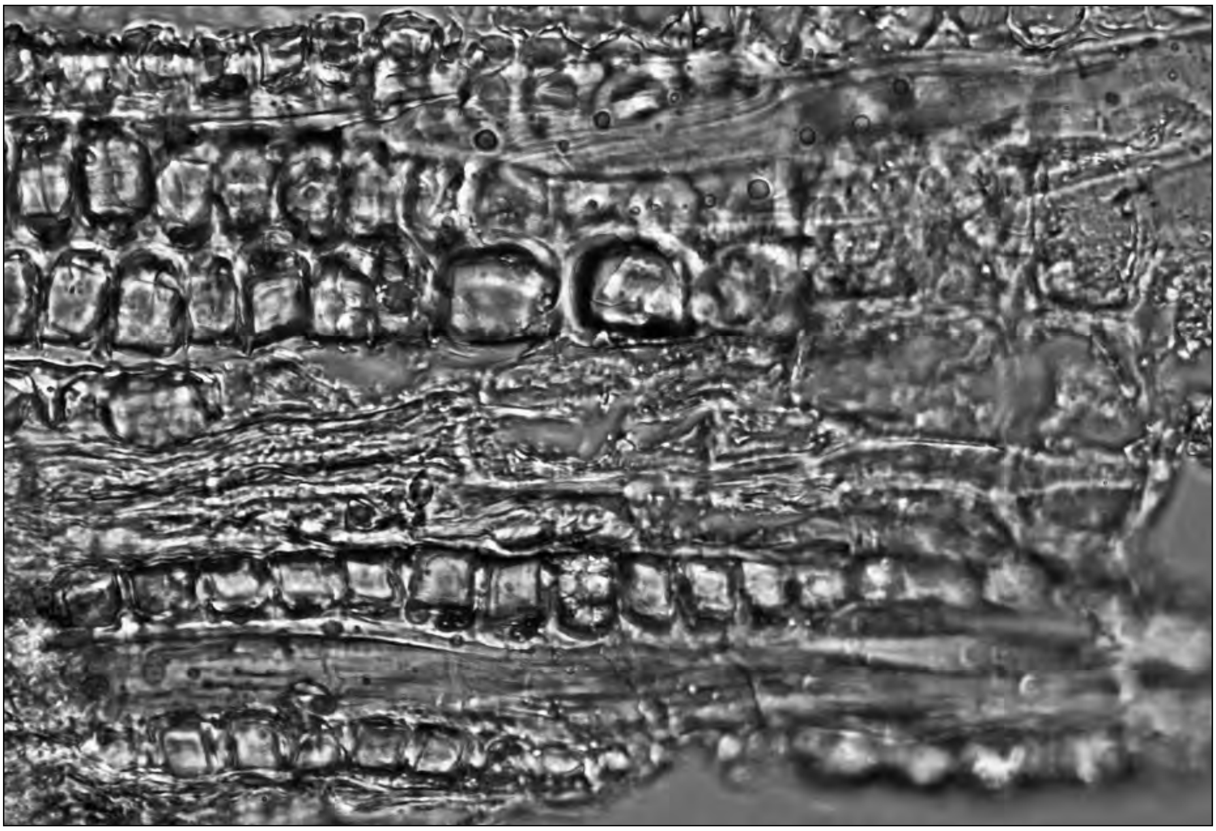

Fig. 97. Crystals of willow bast. Photo W. Schoch

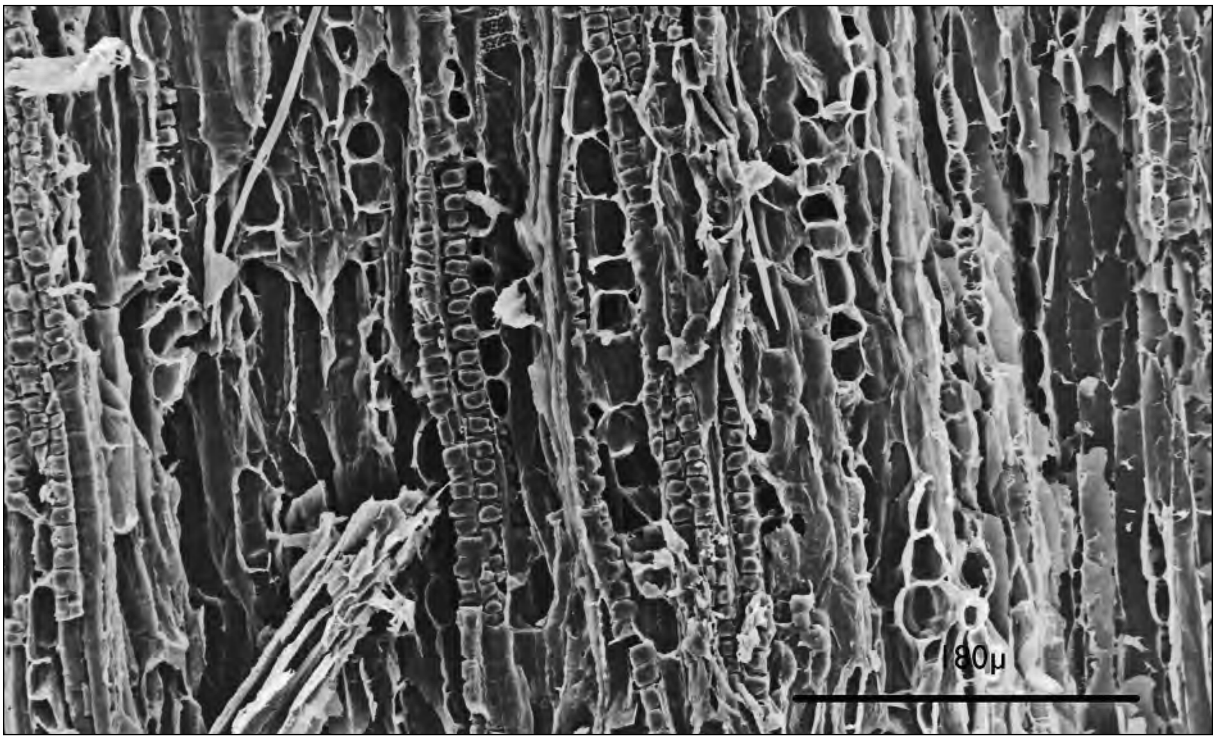

Fig. 98. Willow bast, charred

3.2.5 Oak bast *(Quercus sp.)*

3.2.5.1 Habitat

Common tree, growing in Europe in temperate climates, different species.

3.2.5.2 History

Quercus sp. is a widely used bast fibre and the one with the most tannin. It was for this reason that oak bark was important for both tanning and as mordant in the dye process.

3.2.5.3 Fibre properties

Oak fibres, dm. 10–20µ, show nodes and are mostly seen as round in a cross-section. The fine fibres can resemble flax fibres, which makes differentiation difficult if the fibres are completely loose. When it comes to identification, large rays often collapse making determinations problematic if not impossible. It is important therefore, to check the object carefully under the stereo microscope to see if any rays are present. With tree basts, however, the remains of small crystals (similar to the ones in willow!!) within the large rays make identification efforts more plausible (*Figs 99* and *100*). As a note, oak bast contains more tannin than lime or willow bast.

3.2.5.4 Archaeology

Oak bast is a common fibre among the finds in ancient lake dwellings (Neolithic/Bronze Age). Oak bast, both retted and unretted, has been used for basketry. Having a lot of tannins, it is used especially for cords and shoes (Rast-Eicher – Dietrich, 2015, 62 and 80).

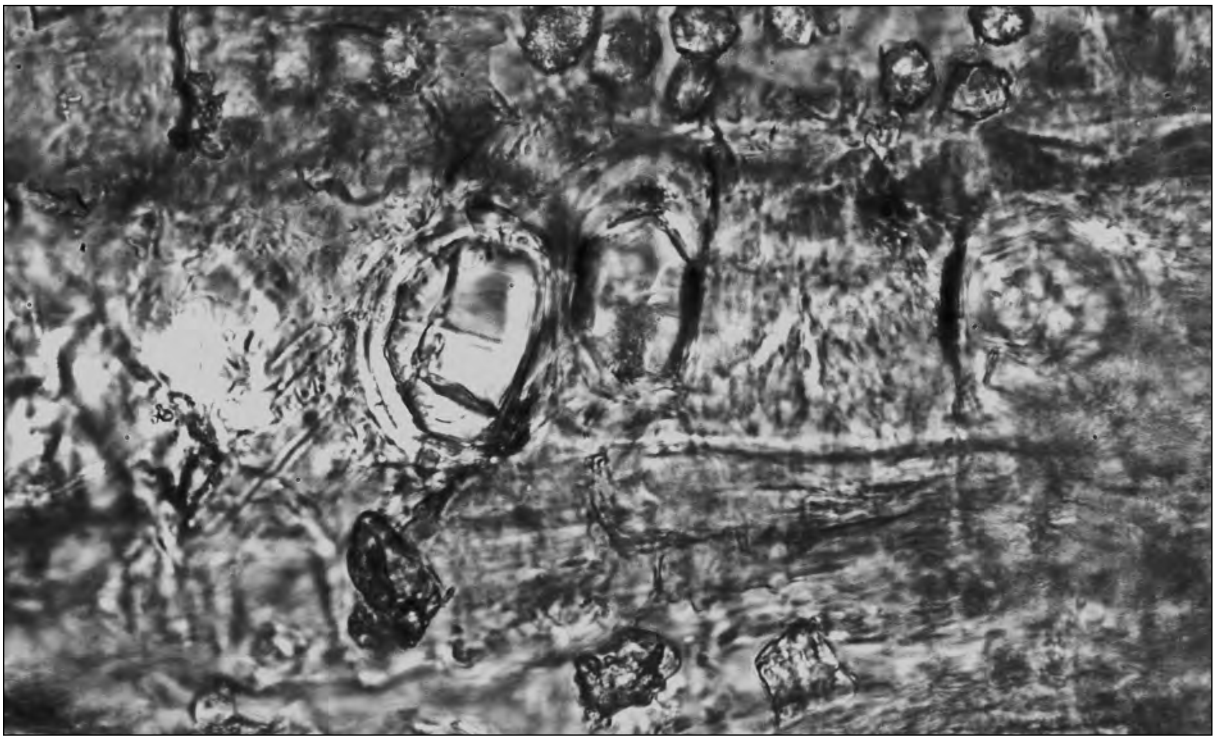

Fig. 99. Oak bast with crystals. Photo W. Schoch

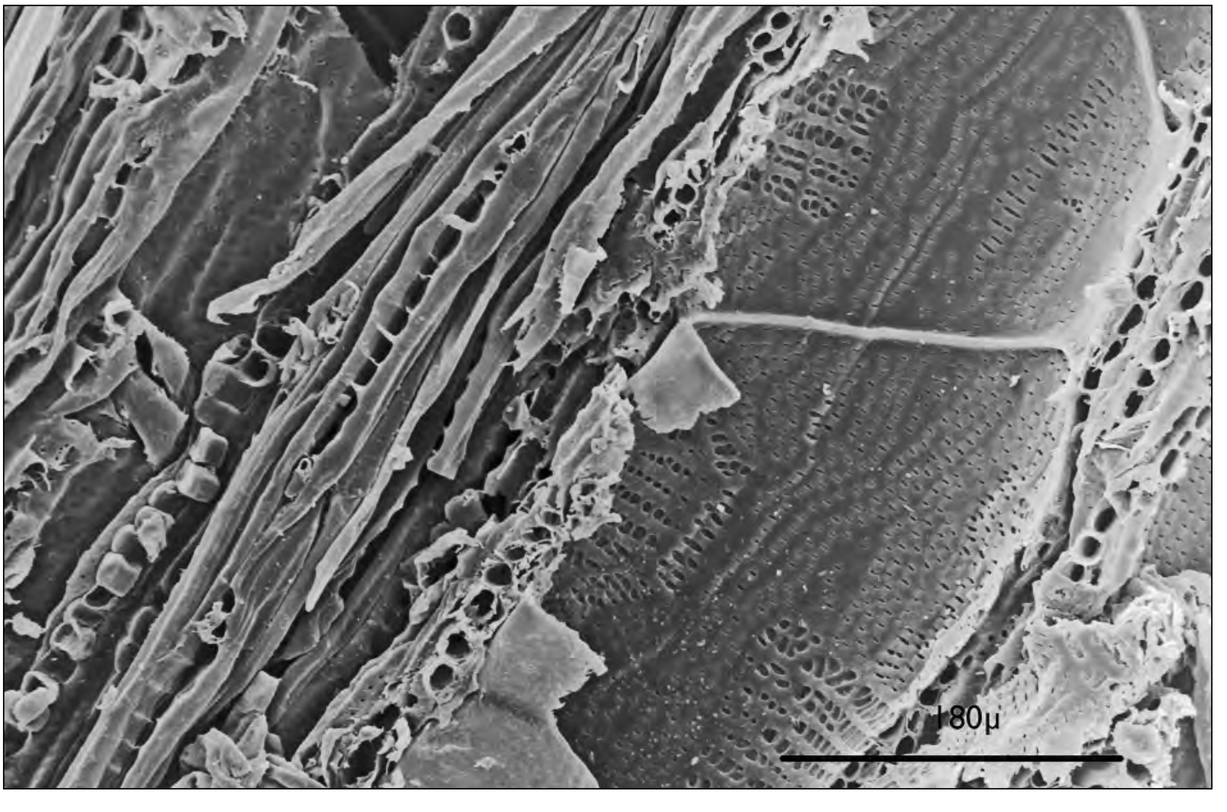

Fig. 100. With oak bast, it is not uncommon for the large ray to have disappeared; in such cases it can easily be confused with willow

3.2.6 Flax (*Linum sp.*)

3.2.6.1 Habitat

Plant is growing best in a temperate climate; however in warmer climate (Mediterranean) a winter annual flax was used (Körber-Grohne 1987, 368f.).

3.2.6.2 History

Neolithic

Hardly any other plant among the textile fibres – besides hemp – has been more used or referred to than flax. Botanically, pale flax (*Linum bienne sp.)* has been considered a wild progenitor of cultivated flax (*Linum usitatissimum).* Identification is given by a presence of pale flowers, narrow leaves and, in archaeological finds, by the size of the seeds and by the opening of the capsules (domesticated flax has closed capsules). *Linum bienne sp.* is a winter annual or perennial. Recent genetic studies have shown spatial patterns in pale flax and that genetically it was more closely related to dehiscent flax than to the winter type (Uysal *et al.* 2010).

Flax belongs to the earliest of domesticated plants. During the 9th millennium BC, it began to be cultivated in the Near East. Earlier uses of flax mentioned for the Palaeolithic Period seem problematic (Kvavadze *et al.* 2009; Bergfjord *et al.* 2010). Genetic analyses have put forward the idea of a first cultivation as a means of extracting its oil and not for fibres (Allaby *et al.* 2005). Differentiating between cultivated flax (*Linum usitatissimum*) and wild flax (*Linum bienne, syn. angustifolium*) can be made by observing the size of the seeds. *Linum usitatissimum* appears in Europe throughout Italy (7th mill. BC), and via the Danube towards regions north of the Alps. Researchers have also discussed the possible processing and use of the wild *Linum pubescens* growing in the Near East. Processing with retting, hackling and spinning has been carried out experimentally (Abbo *et al.* 2014).

In Europe, flax cultivation has been well documented for the Neolithic settlements, from the mid-6th millennium onwards. The flax stems found are shorter than modern flax, reaching about 1/3 of today's flax size. The first finds of flax seeds (*Linum usitatissimum)* coming from the 2nd half of the 6th millennium BC in Southern Germany/Switzerland have been found to be mostly connected to the Linear Pottery culture (Jacomet 2009; Karg 2015). During the 4th millennium B.C. the amount of objects increases in and around the lake dwellings, this even given the fact that flax is under-represented. Most plant remains have been found preserved in layers of carbonized materials (Jacomet 2009, 53). New seeds seem to have been imported during the 4th millennium from the Mediterranean regions to regions north of the Alps. The evidence of weeds (*Selene cretica)* being imported together with the seeds points to a winter annual plantation; during the Late Neolithic (Late Horgen culture) there seem to be changes to the summer annual flax and weeds from the Mediterranean are not present (Jacomet 2012; Karg 2015). Flax is not well documented in prehistoric Scandinavia, probably due to the preservation in the acid ground (Mannering *et al.* 2012, 97). And Bronze Age fibres of Northern Germany supposed to be flax have turned out to be tree basts (Bender Jørgensen – Rast-Eicher in press).

No specific tools have been found to process flax. Neolithic flax in Europe has been spliced from retted or green flax (Leuzinger – Rast-Eicher 2011; see ch. 3.2.6.4).

Bronze Age

Written sources from Bronze Age Greece give an insight into large linen production. In the Minoan palaces flax production is a part of the palace economy (2000 to 1450 BC); even female flax workers are known (Georgacas 1959). There is not much written about cultivation, the palace probably being a place of consumption rather than a place for the primary stages of production, or for that matter of management and distribution (Militello 2007). In the Mycenaean economy two different words are known for flax which may correspond to two different stages of processing. Linear B texts don't give precise information about the price per weight of raw flax, unlike the cloth types. Women working for specialized linen cloth production have been recorded in Pylos (Rougemont 2007).

Flax cultivation is also largely known from Pharaonic Egypt and was controlled by the emperor. Wall paintings show the different steps of linen production. Young flax has been used for fine yarns, ripe flax for seeds and the fibres to make ropes. The yarn is made with the splice-and-twist-technique (Vogelsang-Eastwood 1992). Garments are woven of fine linen yarns. In funerary tradition linen bands are important materials for the wrapping of the mummified bodies as well as flax being used for funerary offerings. The Egyptians managed to spin such fine yarns that they can hardly be reproduced by modern machinery of today (Cooke *et al.* 1991). Herodotus reported that the Egyptians wore garments of linen freshly washed, taking singular care to have them always clean, for they esteem cleanliness more than ornamentation (Hdt. 2,37,2).

Iron Age and Roman Period

Linen textiles are quite common, both in the Iron Age as well as in the Roman Period. The Latin *linum* means not only the plant, but also the products (Mayersson 1997). There was a large linen production in Egypt, but Pliny the Elder has stated that (although) the Egyptian flax was not very strong it was the most profitable. He enumerates four different varieties of flax (Plin. nat. 19, 13-14), describes the production (Plin. nat. 19,3) and the steps of processing as sowing in late autumn or spring (they obviously knew how to work with both winter and summer flax!), harvesting and retting in warm water, drying, beating, combing and spinning. There is evidence here that the Romans no longer spliced yarns. As Pliny the Elder must have often observed flax processing, it is very likely that his account is not copied from another author but, in fact, his original viewpoint. According to him, linen threads were also used in the construction of nets (fishing nets and bird nets; Plin. nat. 19,10-12). Following this, the Gauls and Germans are well documented as linen weavers (Plin. nat. 19, 8; Tac. Ger. 17). In the Diocletian tariffs of AD 300, several qualities of linen garments were listed with names from towns that they came from – Scythopolis, Tarsus, Laodicea, Alexandria – and according to quality of the cloth (Lauffer 1971).

(Early) Medieval Period

In Fatimid Egypt, the new rulers that came after the Romans aspired to controlling a monopoly over the linen trade. Due to the concentration of linen production, Egypt soon became the main importer of grain (Mayerson 1997).

In the late 8th c., Charlemagne advised his *Capitulare de villis vel curtis imperii* on what to plant and produce in the villages. Specified groups of textile workers in the *gynaeceae* were to produce *linum* (linen textiles) (Capitulare de villis *XLIII*). Linen was also used as payment. In the 12th c., for example, people on the island of Rügen (D) still paid with linen cloth, *panno lineo* (Schier 1950, 311). *Vestis linea* was the term for women's shirts, *camisia* for men's shirts (Georgacas 1959).

Flax production was so important that it has been depicted in church murals, one important example being the figures on one of the doors of the cathedral at Chartres (about 1200) showing flax combing. Iron combs which are different from wool combs were found in York (GB) and Rheinau (CH) (Roth 2008, 51f.).

By the Medieval Period linen was woven on horizontal treadle looms, something that was easier than on the vertical systems. Finds from Riga (LV) and Winterthur (CH) reveal early looms in medieval towns (see also textiles finds, ch. 3.2.6.4). Linen weavers were organized in guilds which prescribed cloth quality and control. The southern German quality of the *"tele Alamannie"* was an especially fine linen cloth, exported even to Italy (Windler – Rast-Eicher 1999/2000). Another important quality in southern Germany was the so-called *Barchent*, the fustian, a mixed textile woven with a linen warp and a cotton weft and processed with thistles on one side to create a fluffy surface. This was traded, for example, by the Fugger company. Merchants played an important role in the linen and fustian trade, bringing these products to London (Sutton 1999; Baur 2015).

Some famous medieval linen textiles have been preserved purely by chance. The tapestry of Bayeux (F), a 68m (!) long linen textile with embroidery narrating the battle of Hastings (1066) has miraculously survived all centuries (Rud 1999). Another is the Shroud of Turin (I), deposited in the cathedral of San Giovanni as a miraculous cloth depicting a human body, something that has been controversially interpreted as the outline of the body of Jesus. Three separate C14 datings have revealed it as a medieval production dating from between 1260 and 1390 AD (Damon *et al.* 1985). Printed linen textiles (reserve print) were used to bind books (Wilckens 1983).

Modern Times

The most important areas for linen production were The Netherlands, Flanders, Russia, Poland, Ireland and France. Lace production in France, for example, promoted flax growing during the 17th c. At the end of the 18th century -1st half of the 19th, the mechanization of the spinning process along with the upcoming cotton industry caused the flax cultures and flax as a fibre plant to decline. In 1875 Russia still delivered 75% of the flax production (Körber-Grohne 1987, 367ff.; Collins – Ollerenshaw 2003). Although retting was not a contested method at this time, the use of green flax was being discussed in the 19th century (Sprengel 1840). The term "green decortication" was still a subject at this time for modern flax production, but it was especially used for poor quality products. This would be the case, for example, with weeded plantations or oil flax with low fibre quality. Flax (and hemp) can be produced as fine yarns when they are spun wet, also when spliced (Cooke *et al.* 1991).

In addition to the production of flax for its fibres, it is also an important source of linseed oil. For both food and medicinal use, linseed oil is also an important ingredient for paints, varnish and linoleum (Körber-Grohne 1987, 371). Today, flax is an element in the construction of thermoplastic matrix composite panels for the car industry (Summerscales *et al.* 2010).

In etymology, linen is often found in our modern-day words of "lining", *"lingerie"*, and – last, but not least – the measurement *"ligne"* which is 1/12 of an inch.

3.2.6.3 Fibre properties

Flax can absorb moisture very well but its heat retention is low. This means that linen textiles are a cooling source, able to regulate temperature especially in hot climates and is of the best quality for bed comfort (Muzyczek 2012).

Flax is a bast fibre with small, oval to hexagonal fibrils, dm. 10–20µ. The nodes, which are typical for bast, can be quite thick (*Fig. 101*; see *Fig. 62*). Fibre quality depends upon the amount of plants per m^2 and there will be fine fibres if the flax stems and plants are narrowly placed from one another. Retting continues to be done in warm water (in ponds) which helps with fibre quality (Heubach 1995, 8ff.).

Linen is difficult to dye unless it has been bleached beforehand (Baines 1989). The easiest dye for flax is certainly indigo (also woad), something that has often been used throughout history (and from the Roman Period as a resist-dye e.g. Schrenk 2004, Kat. 19).

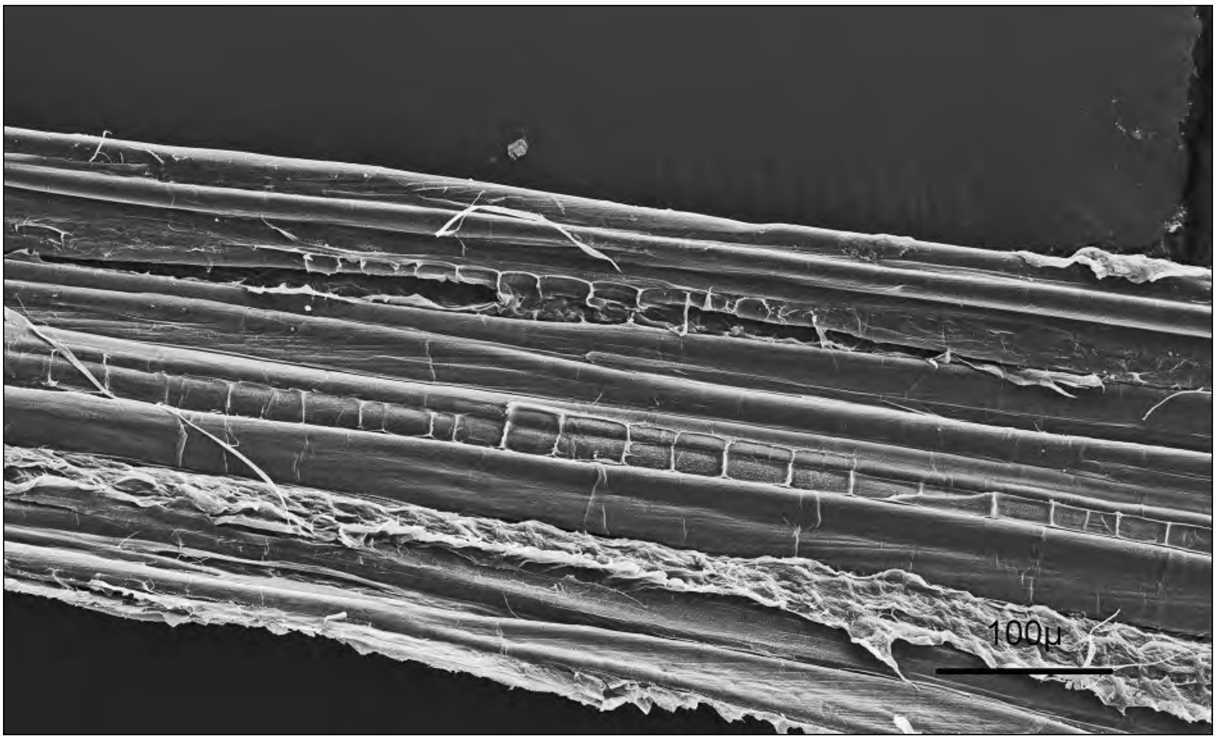

Fig. 101. Green flax, modern

One question which is asked frequently is how to make a determination between flax and hemp fibres. There are, in fact, several differences but determining them can be a problem in many cases:

- The cross-section of fine flax fibres (dm. 10–15µ) is often polygonal (*Fig. 102*), but can also be oval.
- Flax *cuticula* turns in an S-direction, while hemp turns in a Z-direction (see *Fig. 107*). Be careful: the negative imprint is "Z"!
- Flax fibre diameters are generally smaller than hemp and hemp has more variations in dimension.
- Flax fibres show thicker than hemp and crossing nodes (see *Fig. 105*).
- Hemp will often show fibre bundles (see *Fig. 111*), but in prehistoric processing bundles can also appear for flax.
- The lumen for fine flax fibres is mostly very small, like a dot in the center (see *Fig. 102*), while hemp lumen is usually broad and the fibres therefore often appear kidney-shaped. But both can have distinct concentric rings in the fibre, visible in the cross-section.
- If hemp is not processed well – especially in the case of cordage – the epidermis remains and fine hairs can be seen within it (see *Fig. 116*). Flax has no hairs.
- There are no crystals in flax bast, but small crystals in hemp.
- Seen with the polarized microscope, flax and hemp show inverse coloration (Koch 1972, 58ff.). However, in archaeological pieces this observation very often cannot be taken into account because of *degradation*.

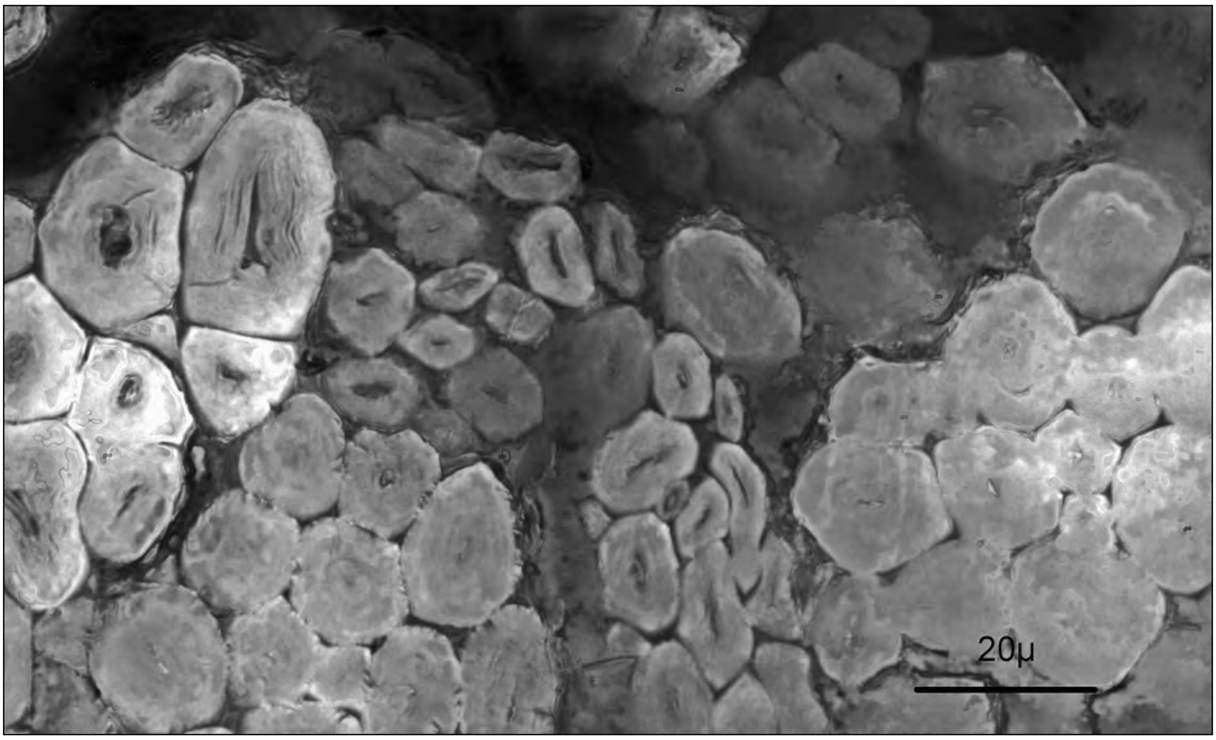

Fig. 102. Cross-section of flax fibres. Photo W. Schoch

3.2.6.4 Archaeology

A find of bast fibres dated to the Paleolithic Period from Georgia has been published as being of wild flax (Kavavadze *et al.* 2009). This determination is under discussion (Bergfjord *et al.* 2010) as methods used for differentiation between bast fibres are not always a sure thing. The fibre diameters given (on one photo about 60µ) are not typical for (wild) flax, furthermore, the blue color described is probably due to an optical phenomenon in microscopy. As there are many bast fibres with similar appearance, optical means are probably not enough to carry out a full study in these cases. Early flax may have been found in Çatal Höyük (Ryder – Gabra Sanders 1987; Fuller 2013, 121). In Ryder – Gabra Sanders a cross-section is depicted which shows fine fibres of about 12µ diameter and a quite large lumina, which this does not exclude flax (Ryder – Gabra Sanders 1987, Fig. 13).

In Europe, flax fibres have been found from Neolithic layers (about 5500 BC) and flax seeds from at least the mid 6^{th} mill. BC (see chapter 3.2.6.2; Rast-Eicher 2005; Karg 2015). Thanks to wet and airtight conditions, the Circum-Alpine lake dwellings in Germany, France, Switzerland and Italy provide numerous flax remains (seeds, stalks and textiles) which date from the mid 4^{th} mill. BC to the Late Bronze Age (*Fig. 103*). They are an extraordinary source for botanists and textile specialists. As the layers are chemically basic, animal fibres or leathers have not been preserved. The textile finds include finest threads (0.2mm), fishing nets, twined and woven textiles both fresh and charred. Charred plant fibres are chemically stable but can easily break (Rast-Eicher 2005; Médard 2010; Rast-Eicher – Dietrich 2015) (*Figs 104, 105*; see also *Figs 62* and *64*). Spliced linen threads dating to the Neolithic Period have been documented in Switzerland (Leuzinger – Rast-Eicher 2011; see *Fig.* 62) (*Fig. 106*). Among Bronze Age textiles found in the salt mines of Hallstatt (A), linen twills have been found; this is very exceptional as prehistoric linen textiles are usually tabby weaves (Grömer *et al.* 2013, HallTex 26).

Most of the Iron Age remains north of the Alps come from graves and are usually mineralized (*Fig. 107*). This is quite different from the dry soils of North Africa where linens are found in good condition. Greek finds of the Iron Age (Classical Period) reveal very fine linens, decorated with purple lines and deposited on the urns (SPANTIDAKI – MOULHÉRAT 2012, 195). Egyptian mummy shrouds are made from linen textiles (*Fig. 108 and see Fig. 9*).

In Western Europe, linen garments in close proximity to the body have been detected, such as La Tène C garments found under metal girdles or arm rings (RAST-EICHER 2008, 60; mineralized flax see *Fig.* 34). An important site for linen textiles is the salt-mine of the Dürrnberg (A; STÖLLNER 1999; STÖLLNER 2005). There, linen textiles seem to have been more frequently used than in the salt-mines of Hallstatt (A), which date earlier than Dürrnberg (A) (STÖLLNER 2005). In the Roman Period, archaeological finds in Central and Western Europe show mostly tabbies with z-spin in warp and weft (z/z); in Southern Europe and the Near East it is usually s/s spun (WILD – WILD 2014).

In an Iron Age or Early Medieval context, textiles have often been found in graves, preserved by metal oxidation (see *Fig. 34*; *Fig. 109*).

Due to acidic soils in Northern Europe, linen textiles are rarely found among the thousands of Early Modern textiles excavated in towns such as Lübeck (D), Lüneburg (D) etc. (e.g. TIDOW 1992). The excavation of the *"Mühlbergensemble"* in Kempten in South Germany (dated before 1528) revealed several qualities that are known from written sources but rarely seen among everyday textiles of that period: different qualities of tabbies and twills, some with blue colored stripes (also depicted as cushion or bed linens) were found as well as decorative early fine lace (RAST-EICHER – TIDOW 2011).

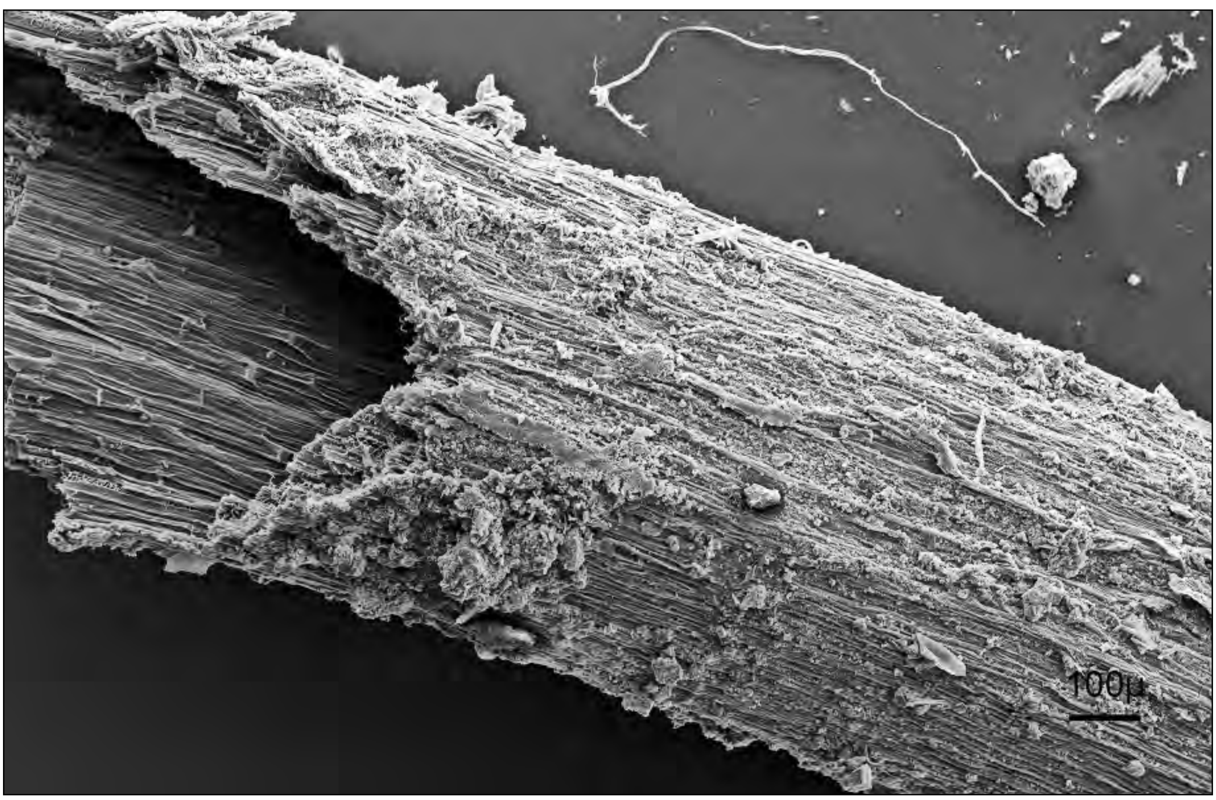

Fig. 103. Flax stalk, Neolithic, Zürich-Opéra (CH)

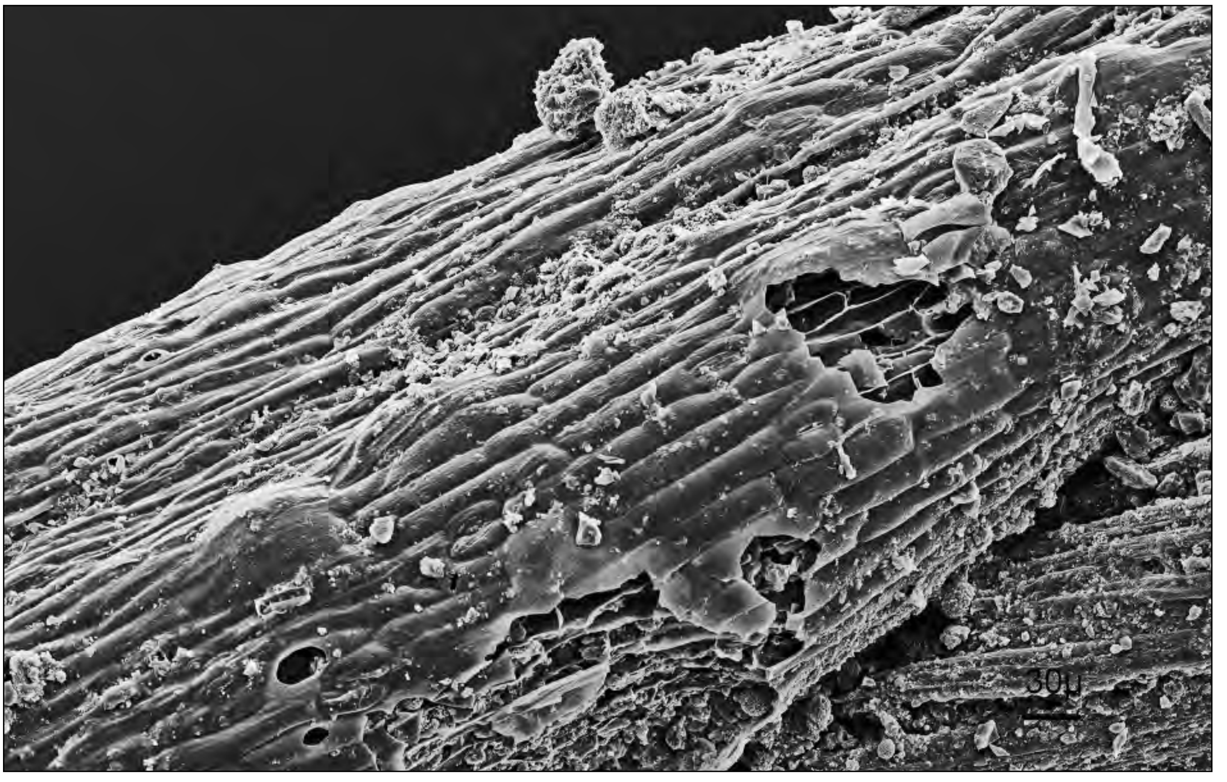

Fig. 104. Flax thread made of green flax with remains of the epidermis, Neolithic, Zürich-Opéra (CH)

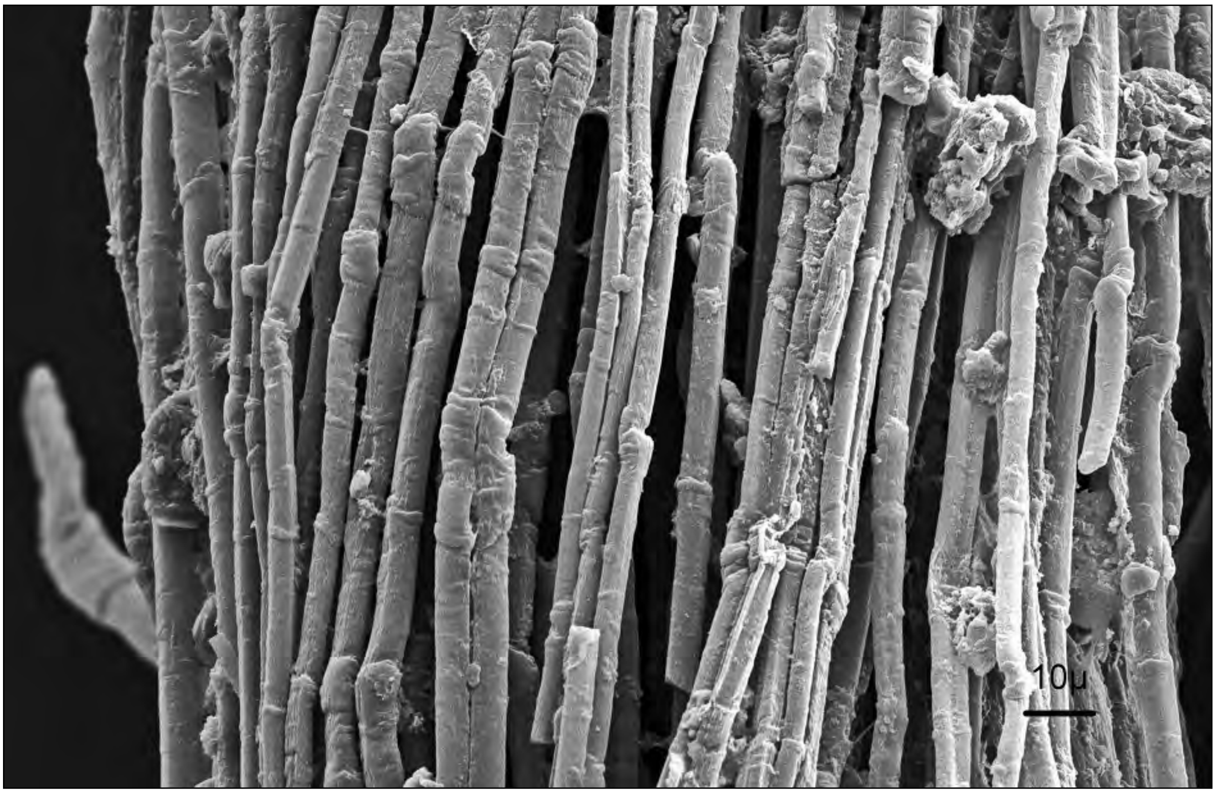

Fig. 105. Flax thread with typical polygonal shape of the fibres and thick nodes with crossings

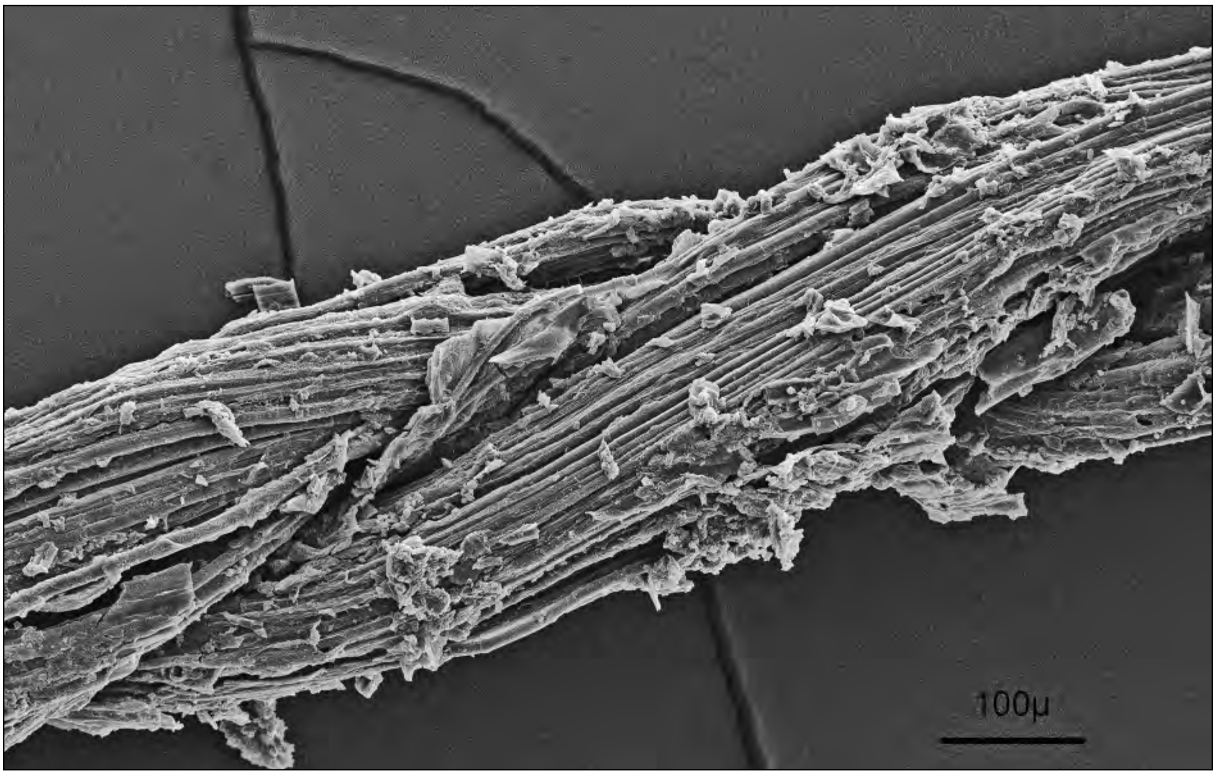

Fig. 106. Flax thread made with splicing, Zürich-Breitingerstrasse (CH)

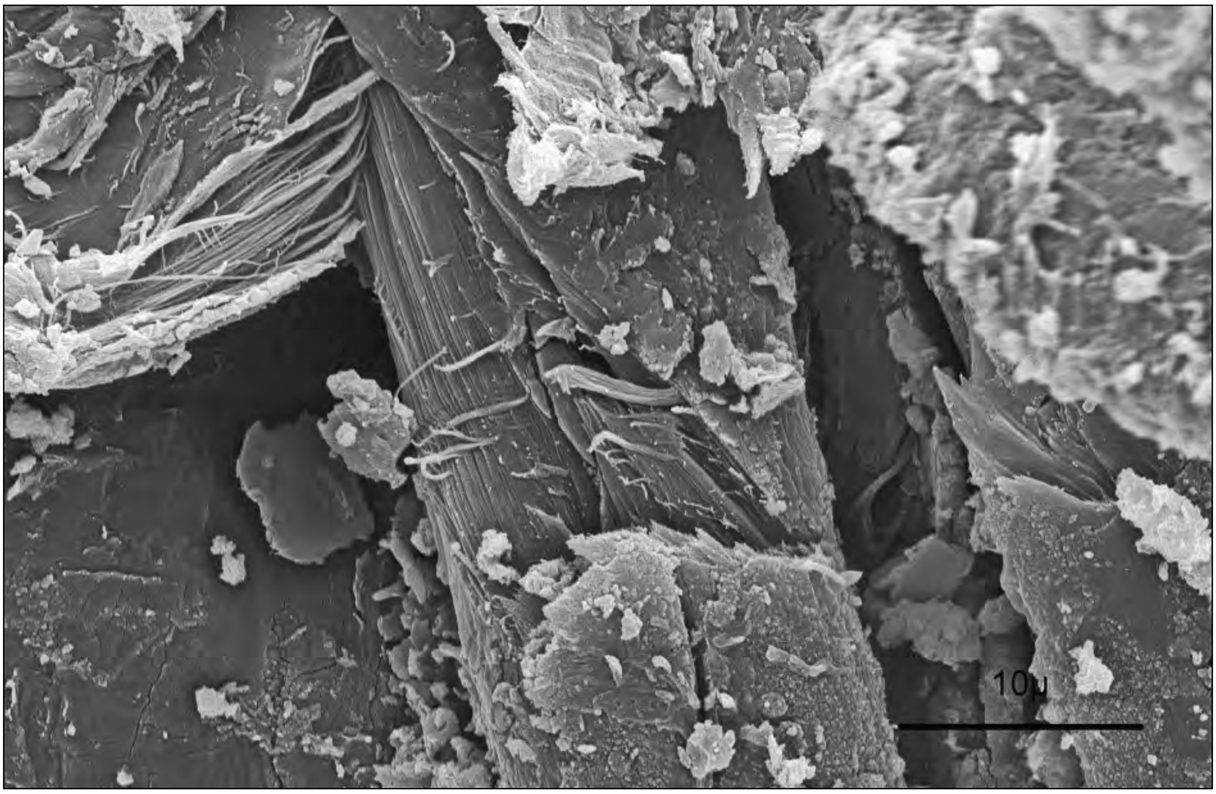

Fig. 107. Flax with very well visible S-direction of the fibre, Langenthal (CH)

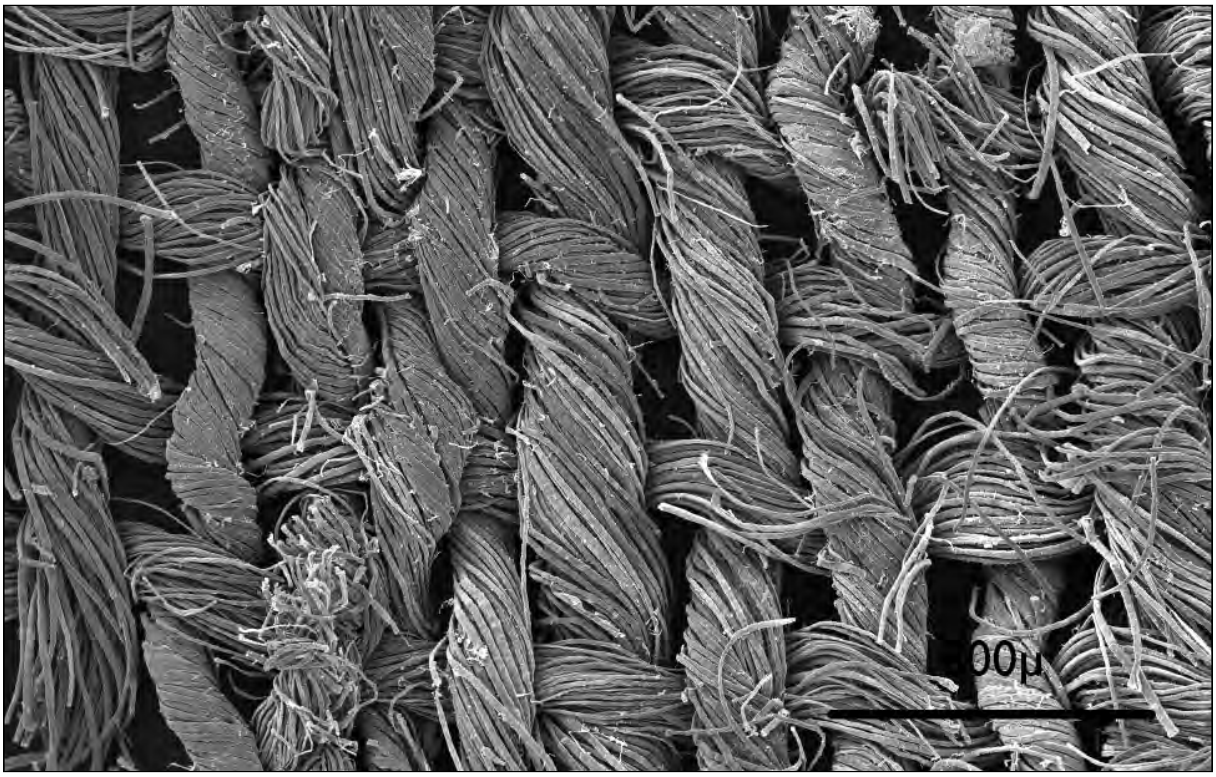

Fig. 108. Linen shroud of Egyptian mummy, Rätisches Museum Chur (CH)

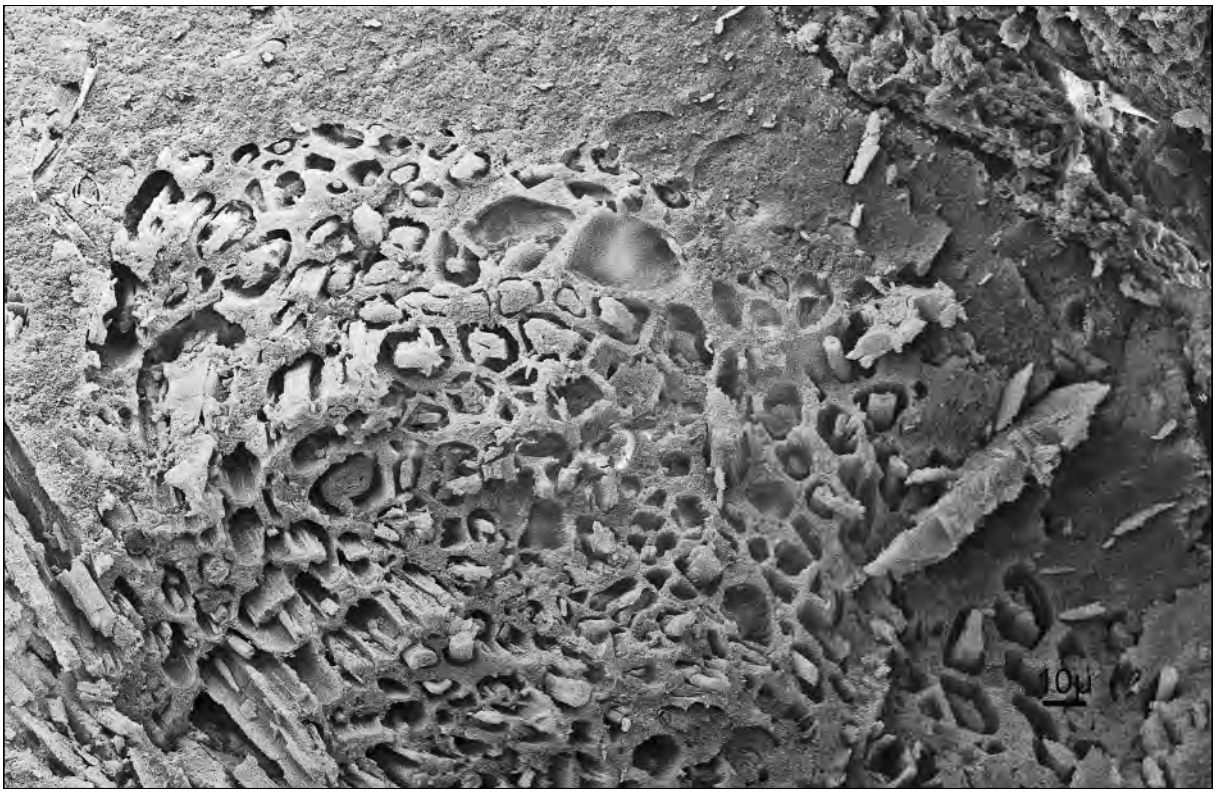

Fig. 109. Cross-section of a metal replaced thread with polygonal flax fibres, Early Medieval, Caudebec (F)

3.2.7 Hemp *(Cannabis sativa)*

3.2.7.1 Habitat

Originally from Central Asia, proliferates in warm climates and sensitive to late frost but was also grown in the dry climates of alpine valleys up to 1800 m/2000 m.

3.2.7.2 History

Hemp is a multifunctional plant and throughout history it has been used for textiles and cordage as well as for oil, paper and as both a medicinal and recreational drug. Today, industry has rediscovered the plant as a sustainable crop, well suited in semi-arid regions. It is more robust than flax and can be grown even at higher altitudes. (Other aspects of growing hemp are important as well, including the fact that it is a fast growing plant with no need for early herbicides, it removes heavy metal from the soil (bioremediation), and has a long top root which keeps the soil from eroding and which increases the yield of the next crop (Rinalli – Venturi 2004).

Hemp has been well known in China since the 5th mill. BC, including its use both as a medicinal plant (Wills 1998) and for the construction of paper (Schaefer 1944). Plantations for fibres have been recorded even though official texts of the state have given silk a priority. Both silk and hemp textiles were used as currency in China (Trombert 2000, 116).

In Egypt, hemp was mentioned on a 16th c. BC papyrus for its use as a fibre and a medicine. Egyptian mummies have revealed a high presence of cannabis (Wills 1998, 3). This plant seems to have been known quite early in Eastern Europe. Hemp seeds have been found in a Bronze Age grave in Romania. Hemp is mentioned by Herodotus in the 5th c. BC. where he states that the king Scythes used cannabis in a burial ritual, both smoking it in felt tents and using it in the fires of open vessels (Hdt. 4,74). In Scythian graves in the Altai (RU) smoking bowls have been found (Anthony 2007, 362; Godwin 1967, 42). Hemp was known in Greece by the Hellenistic Period, and Herodotus notes that in Thrace, garments were made of hemp although they have the appearance of linen (Hdt. 4,74, 1). In Western Europe, the first proof of the presence of hemp (seeds) has been found in the rich grave of Eberdingen-Hochdorf (D), which is dated to the mid 6thc. BC (see ch. 3.2.7.4).

In Roman texts hemp is mentioned from the 1st c. BC by Lucilius, then later by Cato and Pliny the Elder (Godwin 1967, 42). Interestingly enough, intoxication effects of cannabis was not mentioned. Hemp cultivation rises during the first century AD in Italy (Mercury *et al.* 2002). Pliny the Elder describes the plantation as follows:

"Hemp is sown when the spring west wind sets in; the closer it grows the thinner its stalks are. Its seed when ripe is stripped off after the autumn equinox and dried in the sun or wind or by the smoke of a fire. The hemp plant itself is plucked after the vintage, and peeling and cleaning it is a task done by candle light. The best is that of Arab-Hissar, which is specially used for making hunting-nets. Three classes of hemp are produced at that place: that nearest to the bark or the pith is considered of inferior value, while that from the middle, the Greek name for which is "middles", is most highly esteemed. The second best hemp comes from Mylasa. As regards height, the hemp of Rosea in the Sabine territory grows as tall as a fruit-tree." (Plin. nat. 19,56).

In Early Medieval Europe, hemp is known but is not well documented in all areas. Pollen profiles show there is an increase in usage in Anglo-Saxon England (Raman 1998, 38; Schofield – Waller 2005). But in archaeological contexts hemp is rare in villages north of the Alps at this time (Brombacher 2008, 118).

In his *Ethymology* of the 7th century AD, Isidor of Seville clearly finds differences between garments made of *cannabis* and those of *byssus*, or fine linen:

Cannabum a similitudine cannae vocatum, sive a Graeca etymologia; nam illi cannabum KANNABIN vocant. Byssum genus est quoddam lini nimium candidi et mollissimi, quod Graeci papaten vocant (Isid. Orig. 19,28,3-4).

Later, in the *Capitulare de villis*, Charlemagne gives instructions for the organization of weaving labor in the *gynaeceae* and flax and wool are listed among the raw materials required, but not hemp. The Arabs used cannabis *"hashish al kief"* (dried herb of pleasure) also as drug, as an "appetizer and to prolong life" as well (Fabre 2006).

Medieval texts such as the *Physica* of Hildegard von Bingen report the medicinal effects of cannabis. In eastern countries, cannabis was part of cultural folklore: e.g. seed soup for Christmas in Poland and Lithuania, or seeds thrown after the wedding ceremony in Slavic countries (Wills 1998, 8ff.).

In the Early Modern Period, cannabis was brought to America (Raman 1998, 38). The mariner was heavily dependent upon hemp fibres for ropes, rigging and caulking (Brown 1998, 115), and the frequency of pollen found in archaeological layers from this time rises in England, especially in the Tudor period (16th c.) (Schofield – Waller 2005).

Hemp has been used to manufacture paper of very good quality. At the end of the 19th c., the Prussians had hemp paper for their money (Heubach 1995, 38). The shorter core fibres were sometimes mixed with coniferous wood for paper production (Heuser *et al.* 1927).

In the 20th c., production was reduced, partially because of the introduction of other and new fibres, but also because of the prohibition or regulation of the drug (Raman 1998, 41). High costs were another factor for decline after World War II (Rinalli – Venturi 2004, 4). In spite of the controversy over its medicinal qualities, it has continued to be used as a pain reliever. It has been argued that powerful industries – from the cotton, petrol, chemistry consortiums – have managed to set prohibition laws against hemp, cutting it off for the production of paper (Brown 1998, 118ff). Seed oil, like flax oil, was used as a base for paints, resins and varnishes. And last, but not least, it can be said that the original Levi's jeans were made from recycled hemp sail cloth (Brown 1998, 115)!

Today, hemp is considered a plant for multiple uses as textile fibre, in fibre-reinforced composites, as a form of insulation and in the woody core as horse bedding or in the construction sector. The seeds are highly praised for skin care and in cosmetic applications. And the cannabinoids continue to be important in the pharmaceutical industry (Amaducci – Gusovius 2010).

The processing has been different in Asia and Europe. In Asia, the stalks are harvested before male and female can be differentiated and are then peeled wet. In Europe, on the other hand, male plants are stripped off after they have shed pollen and after being dried. In Asia – as in Nepal, Japan and Korea – the thread has traditionally been made by splitting the bast into fine strands and arranging them one by one in a base-to-tip direction. This processing is also called "splicing" and is used for tree basts and flax. A final twist is added after wetting the spliced yarn with a spindle (Clarke 2010, 230ff.). This resembles the linen thread production of Neolithic Europe (see ch. 2.3.2). To soften the spliced and spun yarns, they are and were boiled with wood ash (Clarke 2010, 236).

In the modern processing of fibres, the industry has tried to introduce mechanical means in the taking of the young hemp stalks ("baby canapa"). But even with modern methods hemp fibre production for the highest quality material takes 60-70 days of work per hectare. Regulated hemp breeding is an attempt to improve fibre quality and yield of seed and oil, this by increasing the amount of output per hectare in combination with reducing the amount of THC in the plants (Ranalli – Venturi 2004, 5).

3.2.7.3 Fibre properties

Female plants are larger than male plants. The earliest to ripen are the male plants, the female ones only after seeds are fully grown and ripe. Fibres from both are processed in the same way as all bast fibres (see ch. 3.2.2). The best quality plants tend to grow in conditions that are not too dry in order to avoid brittleness (Raman 1998, 41). The plants are grown close together in order to avoid branching (an approach already stated by Pliny the Elder). Fibre yield is twice or three times that of cotton or flax (Brown 1998, 116). Hemp fibre has excellent resistance to rotting and therefore has been very important in rope construction and for usage on ships. Hemp fibres have diameters with an average of 18–40µ (but can be quite larger), the lumen takes about 1/3 of the fibre width (*Figs 110, 111*). Generally, hemp is coarser than flax and more variable. The single fibre is built up of quite a few thick concentric rings, its outer fibrils are turned to the Z-direction and the inner part turned according to the fibre axis. In longitudinal view, the fibre ends are spatulated or bifurcated (Heuser *et al.* 1927, 33). In archaeological material fibre ends are not really of importance as they are difficult to spot. The epidermis is often still visible in ropes and is either full of "hairs", broken hairs (see *Fig. 116, 117*) or has the round remains of broken hairs (*Fig. 112*). Hemp appears often as a fibre bundle. If these compact bundles, held together by lignin, are loosened and each fibre separated, hemp fibres will then take on the appearance of cotton, the fibres becoming flat ribbons (the so-called "cottonizing of hemp", Heuser *et al.* 1927, 36; Muzyczek 2012). The fibre becomes softer and gains better spinning properties (*Fig. 113*). Modern usage is based upon the following advantages of the fibre: absorbs high heat, inhibits electrostatic charges, protects itself against UV radiation (due to a high lignin content) and absorbs to a high degree toxic gases. Disadvantages are thickness, stiffness and low elongation (Muzyczek 2012).

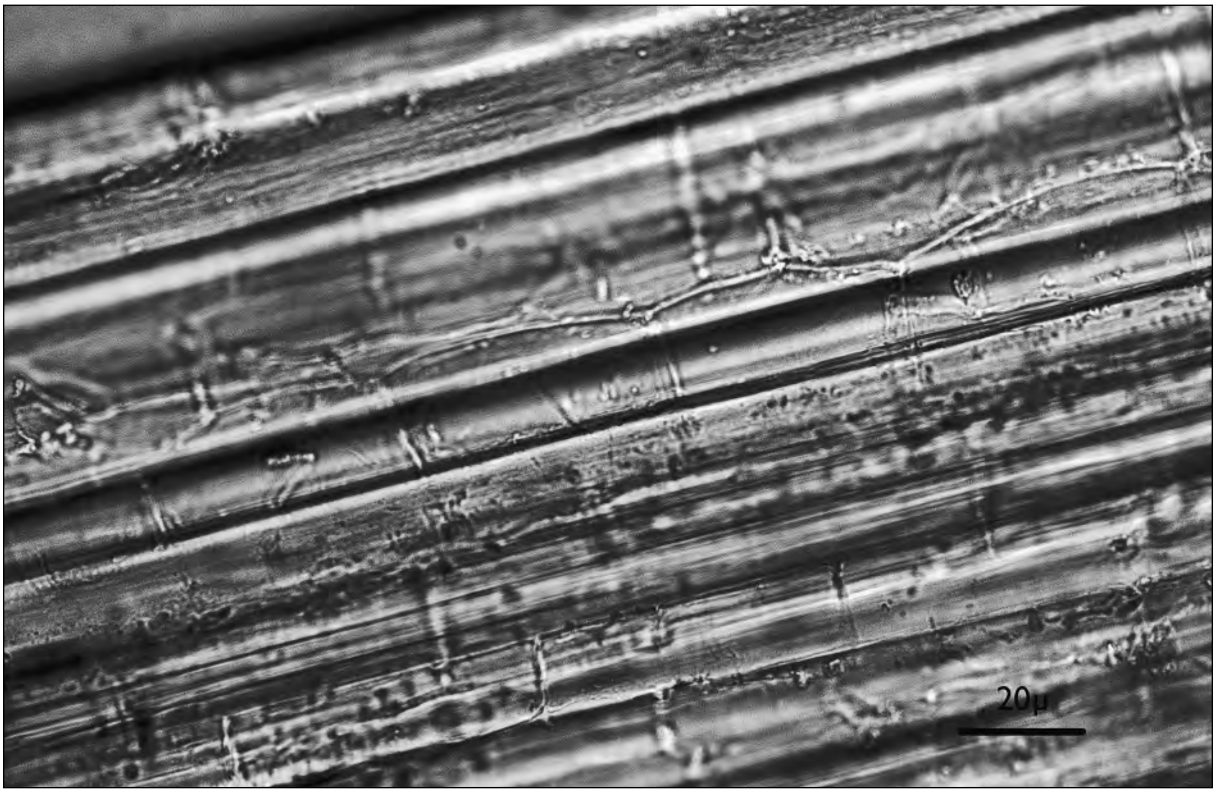

Fig. 110. Longitudinal view of hemp fibres, modern

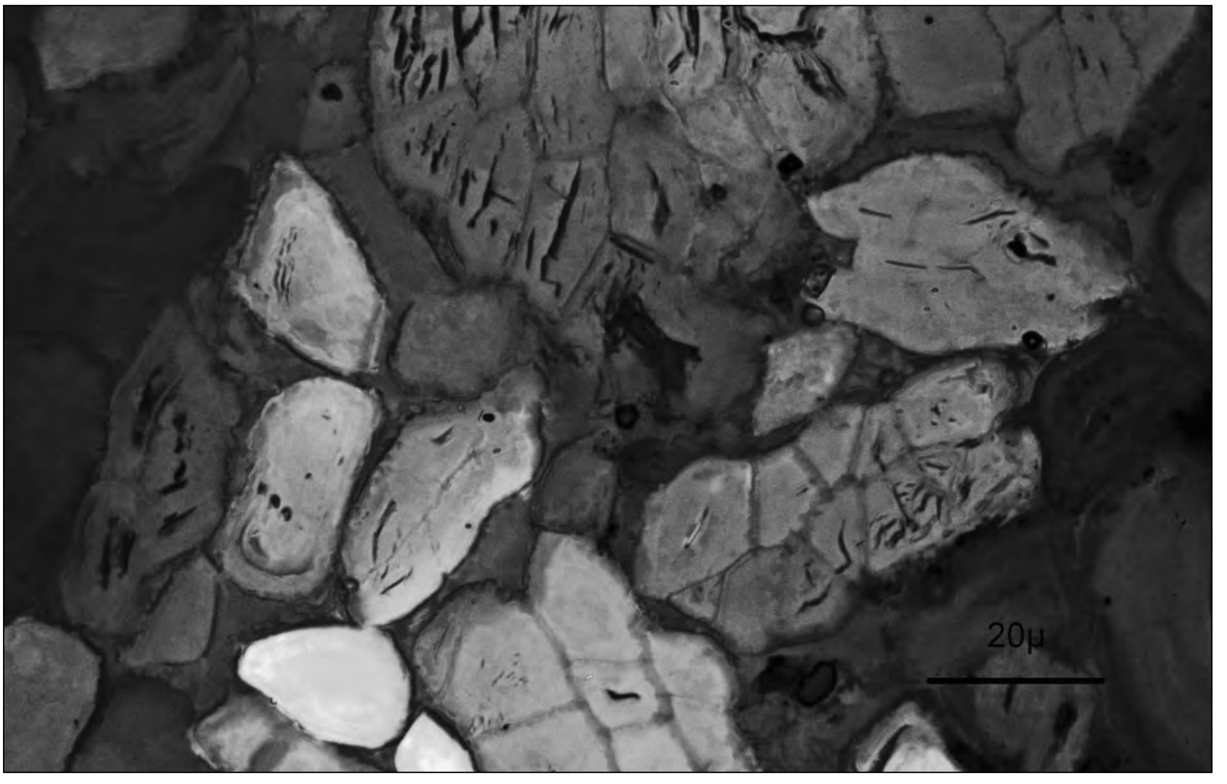

Fig. 111. Cross-section of hemp fibres. Photo W. Schoch

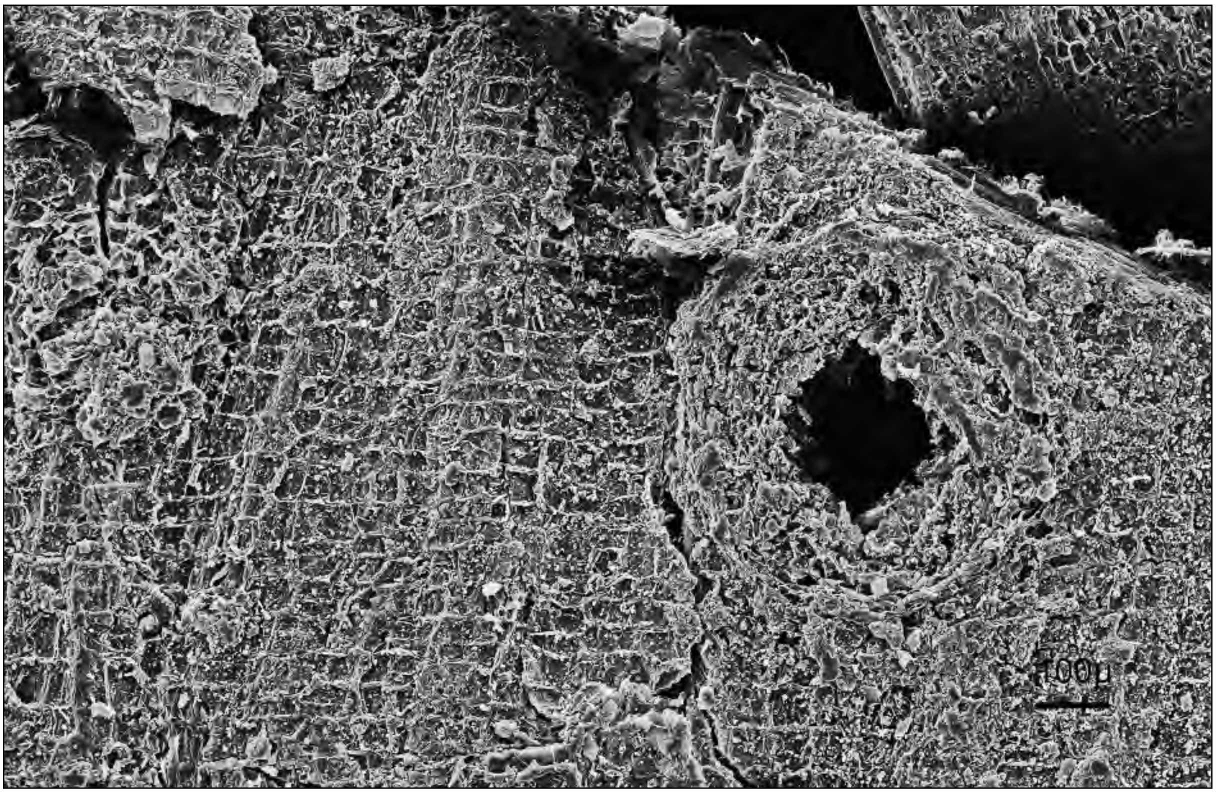

Fig. 112. Epidermis of hemp with the square epidermis cells and the "hole" of an epidermical hair, modern

3.2.7.4 Archaeology

The earliest of hemp finds date to the Iron Age. Botanically, seeds are often difficult to detect. A humid soil is needed and pollen analysis is difficult and often unclear when differentiating between Cannabis and Humulus (Bouby 2002; Mercuri *et al.* 2002; Brombacher – Klee 2008, 118). The tracking of chemicals such as carbinol in the soil can reveal places in which hemp retting took place (Lavrieux *et al.* 2013).

Fibres are generally difficult to differentiate from other bast fibres, especially from flax (see ch. 3.2.6.3). U. Körber-Grohne has found hemp in the Iron Age site of Hochdorf (D). She could determine this thanks to the stomata and the epidermal hairs (Körber-Grohne 1985). According to the pictures in Körber-Grohne's documentation of the pieces found there, the hemp fibres of the Iron Age seem to have been spliced like flax (Körber-Grohne 1988a). With the SEM, the direction of the Z-cuticula seemed a possible criterion and several samples could be determined, however, the direction of the fibre is not as clearly visible as it is with flax fibres (*Figs 114* and *115*). Rope or cordage is sometimes even easier if the epidermis has been preserved. In these cases, broken hairs can be visible as well as the stomata (*Figs 116, 117*). A rounded or split fibre end is rarely found, or when it is severe degradation has set making determination highly problematic. A split (gabled) end can be seen on a photo from a Pompeian textile (D'Orazio *et al.* 2000, 749, Fig. 6). Hemp fibres contain small crystals seen by light microscope or with the SEM (Herzog 1955, Taf. 159; *Figs 118* and *119*). A very special picture from a 7^{th} c. grave provides further information. According to the nodes that are visible, it is a plant fibre, but one which has shrunk and has the appearance of an accordion (*Fig. 120*). Heuser *et al.* 1927 described a reaction specific for hemp provoked by the cellulose solvent "Cuoxam" ([CuII(NH3)4](OH)2) (Heuser *et al.* 1927, 39). It is obvious in the context of this grave that around the decomposing body and accompanying copper alloys, the plant fibre contracted.

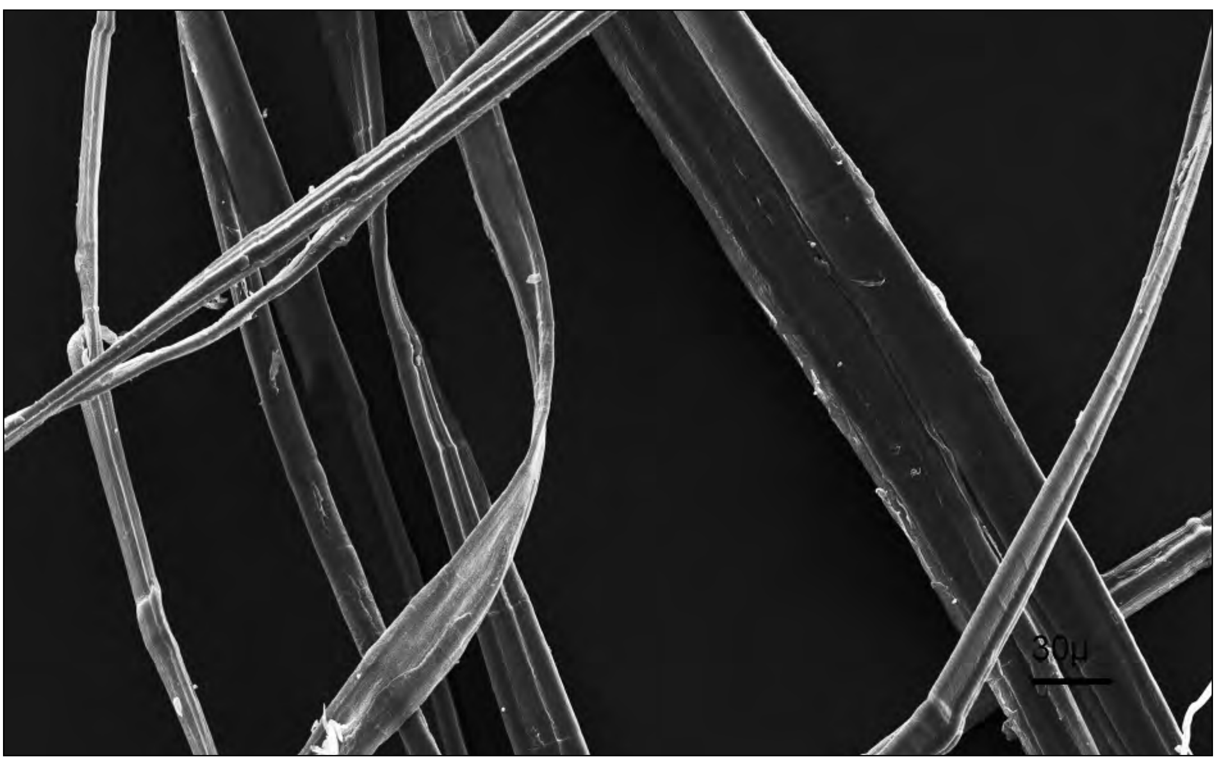

Fig. 113. Cottonized hemp, fibres turn "Z", modern

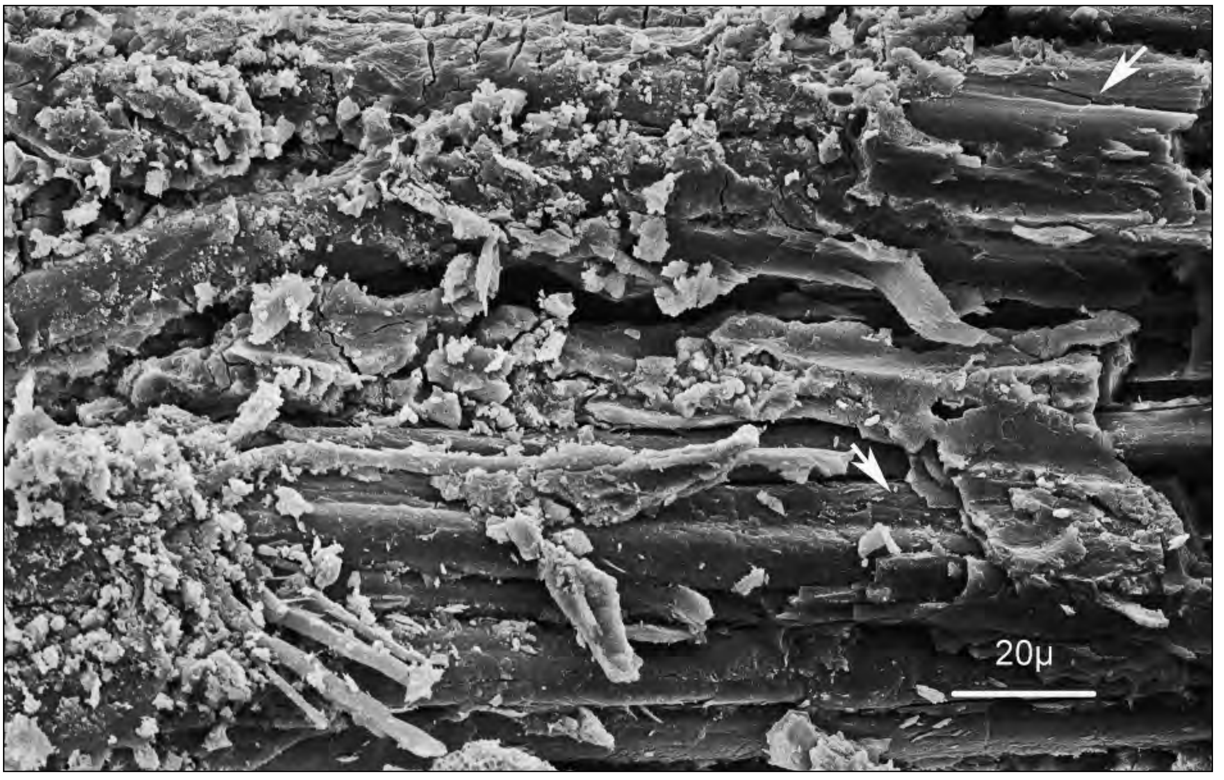

Fig. 114. Hemp fibres, some fibres with Z-direction of the cuticula (see arrows) and fine parallel nodes, Early Medieval, Dielsdorf (CH)

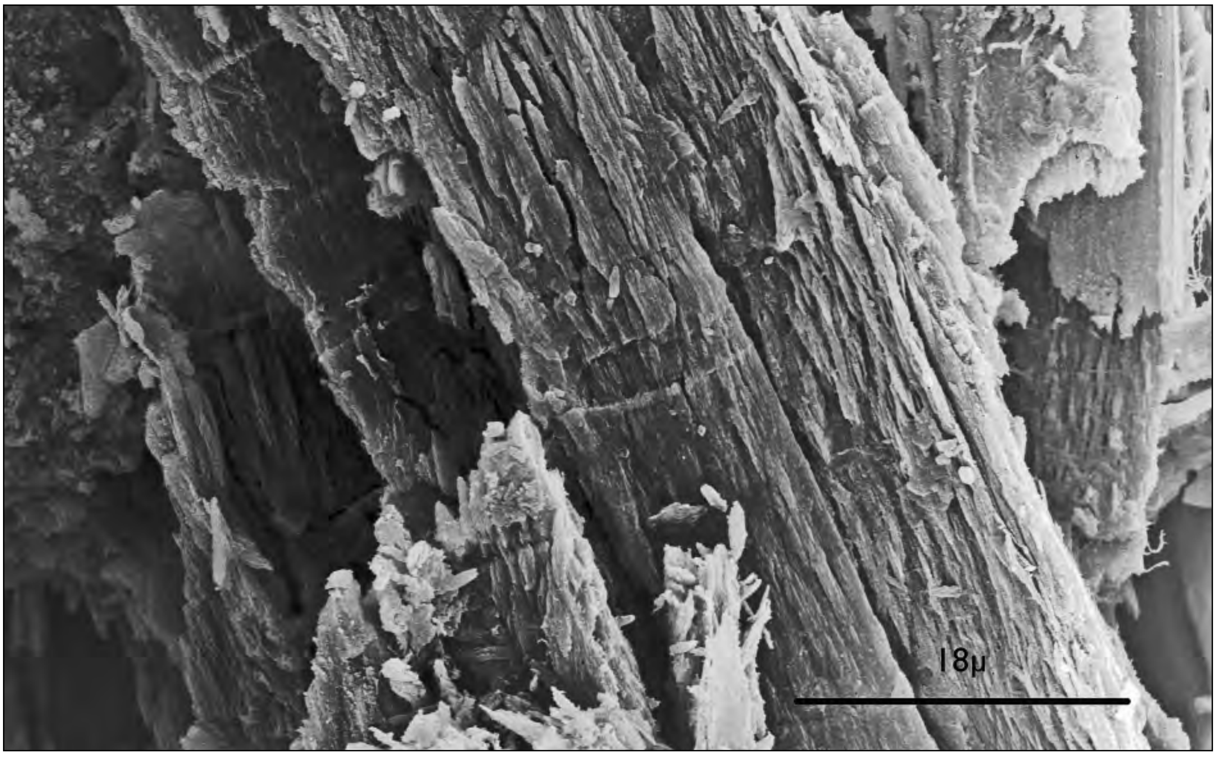

Fig. 115. Hemp fibres with Z-direction of the cuticula, Early Medieval, Köniz-Niderwangen (CH)

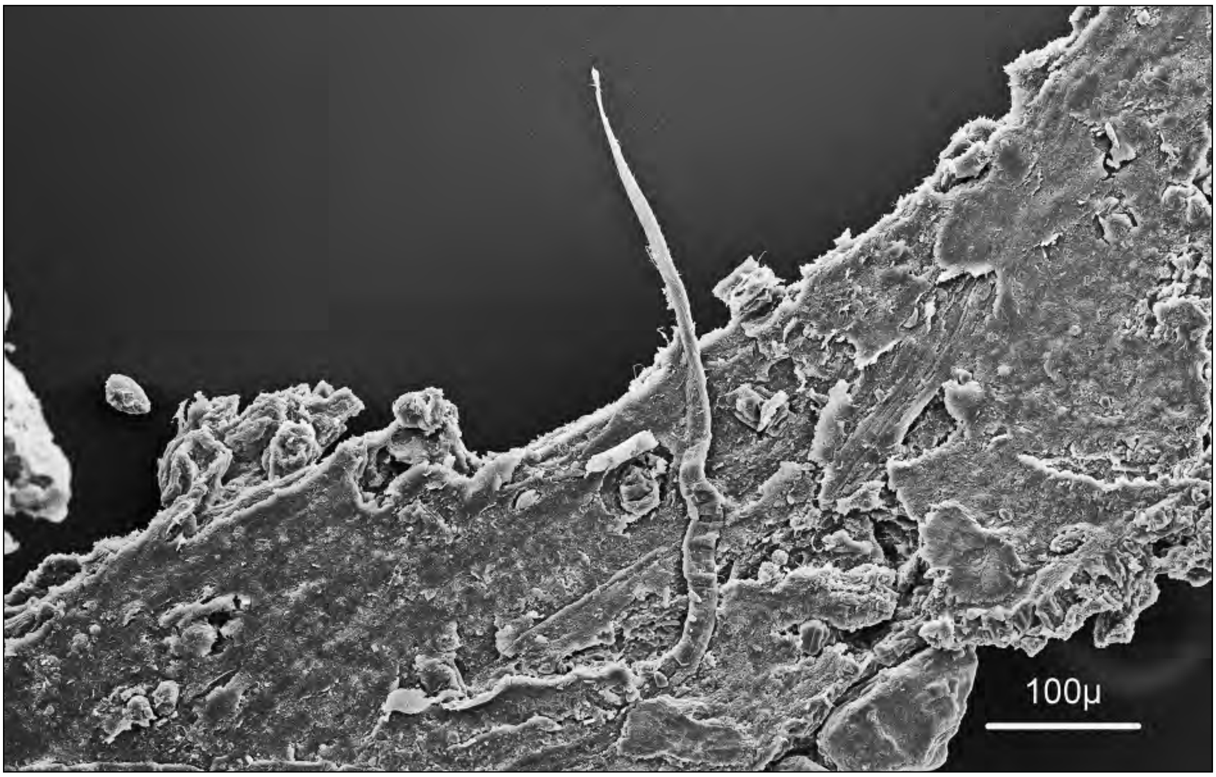

Fig. 116. Hemp cordage with visible hair of the epidermis, Early Medieval, Dor 2006 (Israel)

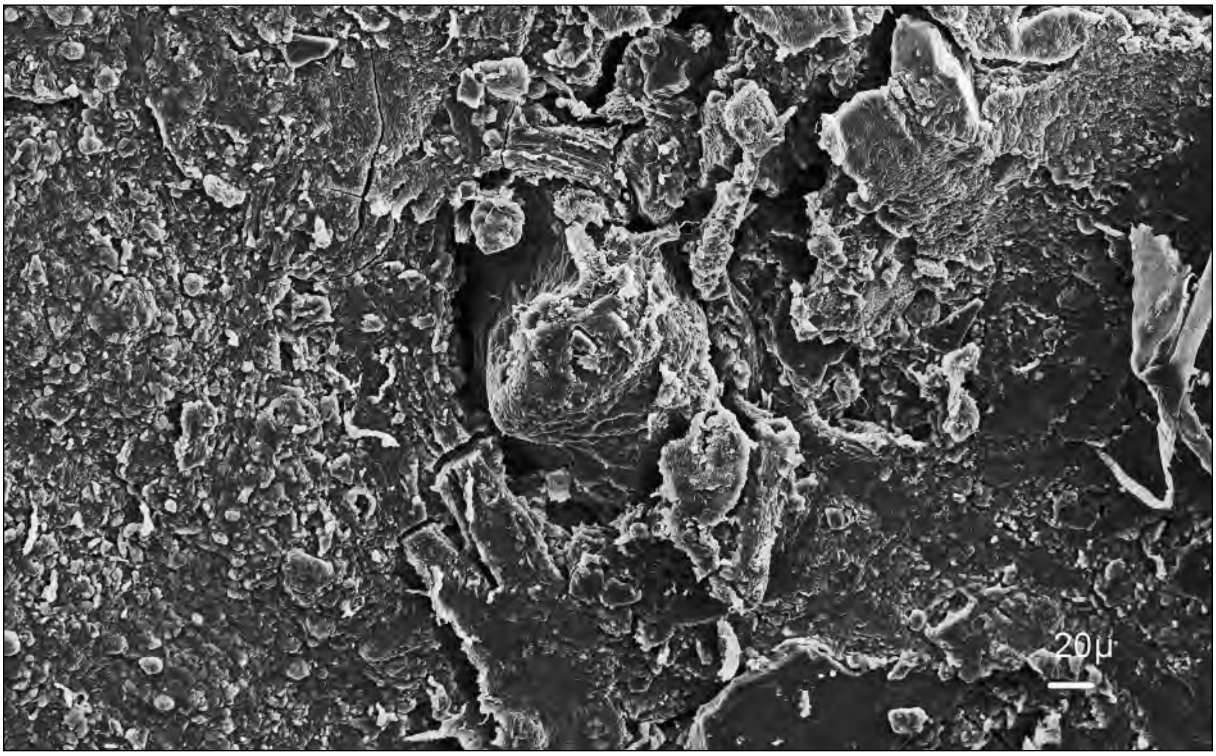

Fig. 117. Hemp cordage with hair bulb of an epidermis hair, Early Medieval, Dor 2006 (Israel)

Fig. 118. Hemp cordage seen with the light microscope, small crystals as black dots, Dor 2006 (Israel). This has to be verified at the SEM, as fungus can produce little black dots as well

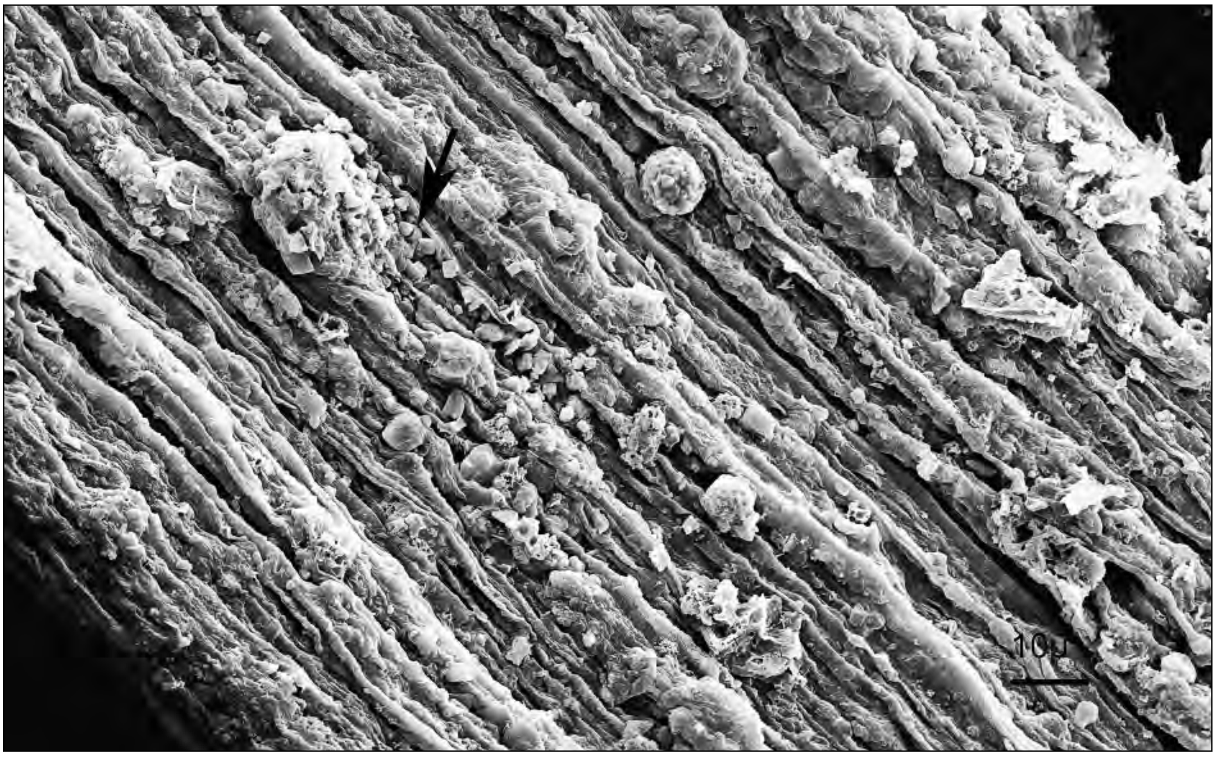

Fig. 119. Hemp cordage with crystals, Early Medieval, Dor 2006 (Israel)

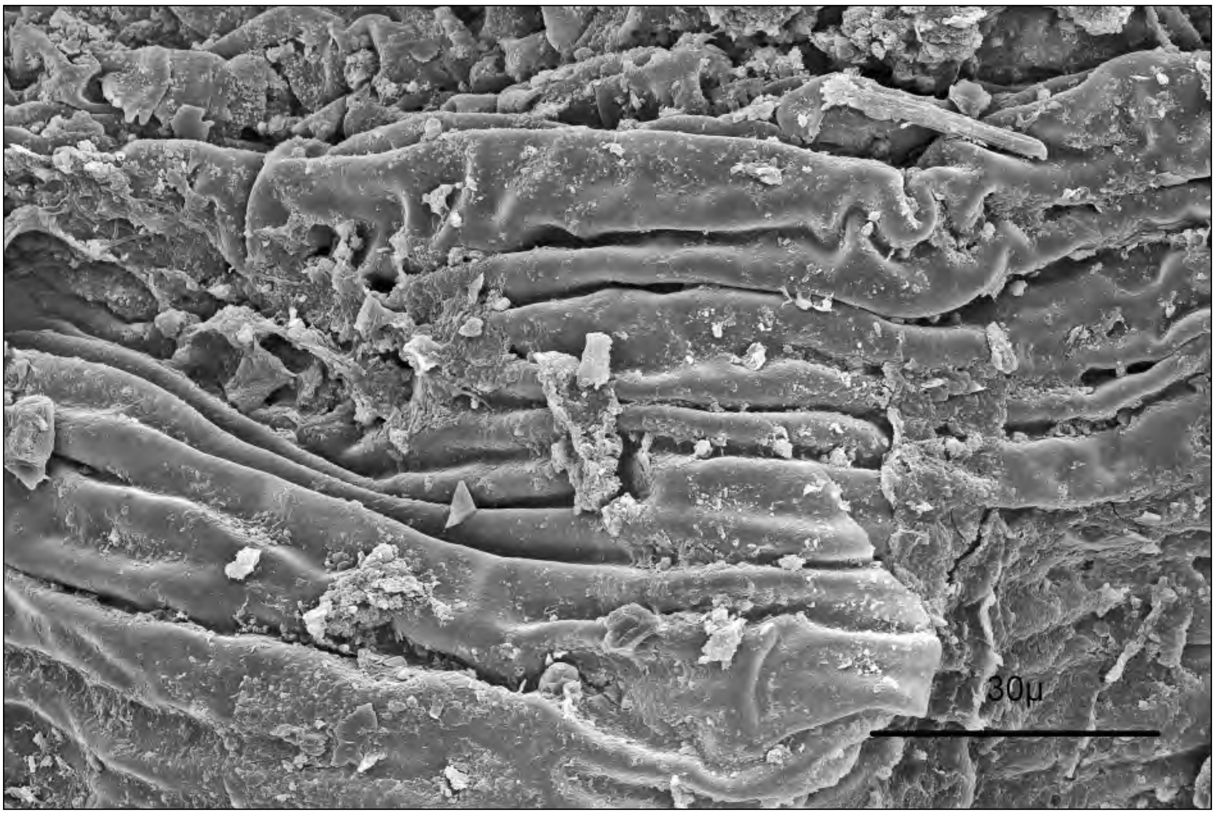

Fig. 120. Possible hemp fibres shrunk because of an reaction to acids, Baar-Früebergstrasse (CH)

3.2.8 Nettle *(Urtica dioica)*

3.2.8.1 Habitat

Nettle grows in rich soils, in Alpine regions up to about 2000m.

3.2.8.2 History

Nettles have been used since ancient times and still are, not only for medicinal purposes (Ilhami *et al.* 2004) but for nutritional ones – in teas and edible seeds – and for textile fibres as well (Randall 2003, 13; Bodros – Baley 2008). The use of the plant fibre has been described in Hans Christian Andersen's tale "The Wild Swans" in which the princess has to weave a textile of nettles in order to break the spell that her brother was put under.

Processing is similar to that of all bast fibres (see ch. 3.2.2). According to Bielenstein, the Tartars of the Crimea retted the nettles by breaking the stalks by hand, hitting them with a wooden mortar until the fibres were separated. In Baltic regions, nettles were cut during blossoming and processed green, the fibres being finer at this stage. The plants were dried and then the leaves stripped off. Retting, hackling and spinning were then carried out in the same manner as for flax (Bielenstein 1995, 27f.). The fibres will quickly rot if the stems are not taken out of the water at just the right moment. It is also possible to spin them green after the stems are dried, followed by boiling the spun thread. When the water turns green, the thread should be white (Heubach 1995, 54). Textiles made in Latvia were used for coats, gloves and stockings as well as for table cloths and bed linens (Bielenstein 1995, 27). In the German language the term “Nesselstoff” was certainly used as an original identification for a textile of nettle and it has been used as well for fine linen or cotton textiles (Bielenstein 1995, 29).

In 1876 the *“Nesselkommission”* was founded in Germany with the purpose of promoting the nettle as a fibre plant. The botanist G. Bredemann (D) bred about 170 varieties of fibre plants (Bredemann 1959). These were tall and branchless nettles. The nettle became even more important during World War I as flax had become rare. The Germans used it to construct tents, rucksacks, undershirts and socks and the unbleached (green) fibre for camouflage textiles (Bodros – Baley 2008). In 1940, 100 tons of nettle fibre were harvested. Industrial production was not continued for long after this, although it has increased in more recent times (Hartl – Vogl 2002).

During World War II, the British experimented with nettle fibres in aircraft production, specifically as an ingredient for a form of high-grade paper used as a reinforcing plastic for outer panels, gear wheels and other structural parts (Summerscales *et al.* 2010).

3.2.8.3 Fibre properties

Fibre diameter can be quite varied, from about 15µ to 30µ, and have a large lumen so that they collapse to kidney-shaped fibres. The epidermis shows a clear twist in the S-direction which is more visible than with flax fibres (*Fig. 121*).

The angle of the microfibrils is different from flax fibres: flax has 10°, nettle 3° (Bodros – Baley 2008, 2144). Nettle has regained its popularity in recent times, not the least reason is its better tensile properties than hemp and ramie (Bodros – Baley 2008, 2145; Bacci *et al.* 2009). The fibres are much stronger as well as being more environmentally friendly than cotton (Summerscales *et al.* 2010). Also, calcium oxalate crystals are smaller than cluster crystals.

3.2.8.4 Archaeology

In a Bronze Age grave in Voltofte (DK) a textile was found on a bronze vessel. The botanist Mogens Køie then investigated the Voltofte textile and found nettle fibre (Køie 1943). In 1942 another article was written about nettle by Margarete Hald (Hald 1942; Hald 1980). The textile was later re-analyzed, including strontium analysis. Fibre determination was confirmed as a result and even calcium oxalate crystals were found, something that is usually quite difficult to detect in archaeological material and processed fibres (Bergfjord *et al.* 2012). Having the strontium factor pointing to older rocks from the Precambian shields, it became clear that the textile could not have originated from Denmark; it rather pointed to the Alps. As geological layering is quite mixed in the Alps, strontium cannot attribute a sample to a specific spot. The vessel type on which the textile was found gave, in the end, the final geographical attribution of the textile to Southern Austria.

An Early Medieval find from Flurlingen (CH), a textile on the girdle plate in a girl’s grave, was thought to be of nettle as well. The fibres have a large lumen and are flat, much more irregular in size than flax (up to 30µ) and the cuticle turns in an S-direction (*Fig. 122*; Rast-Eicher *et al.*1995). A textile made of nettle was found in Malvaglia (CH), in a medieval refuge house in the mountains (Schoch 1986, 93).

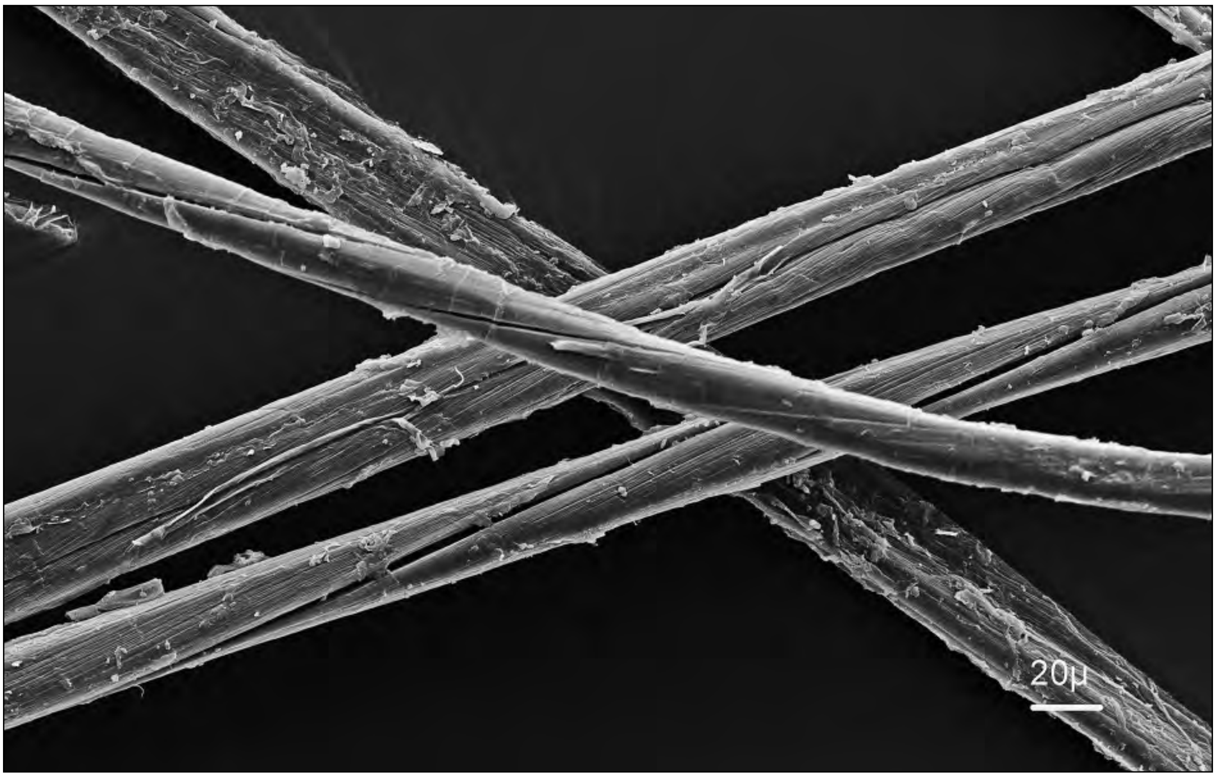

Fig. 121. Nettle fibres after water retting, modern

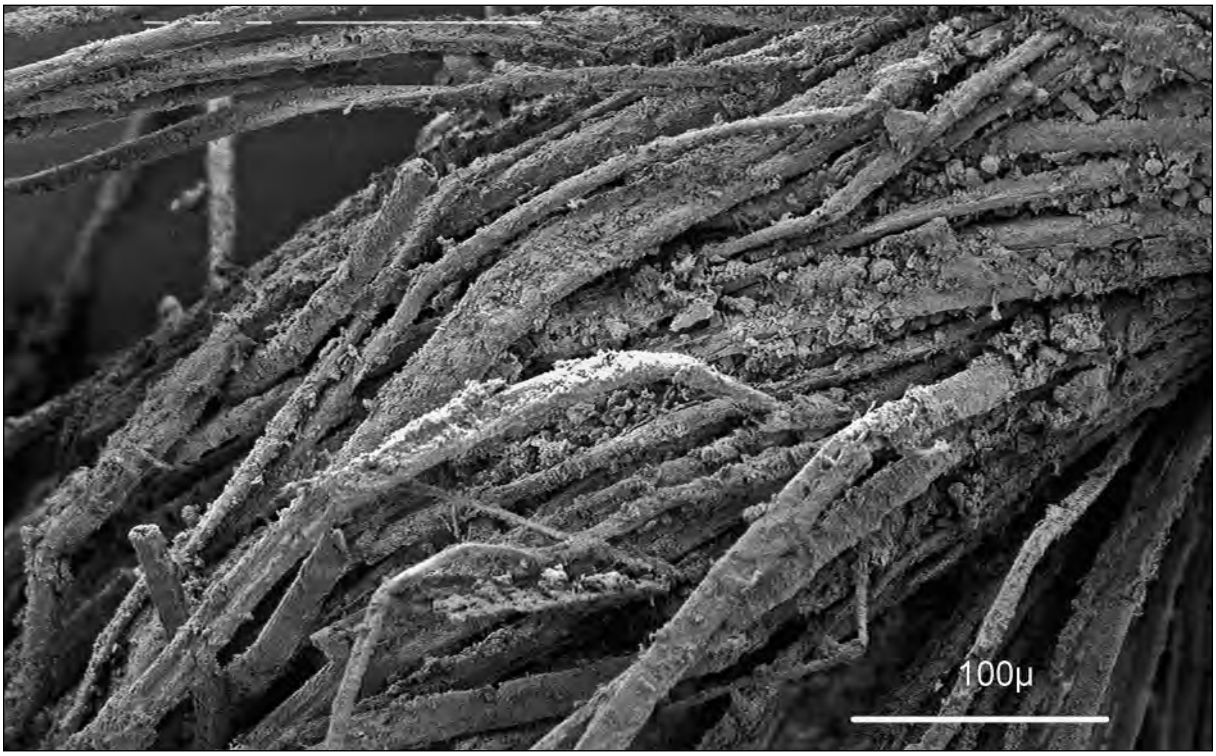

Fig. 122. Nettle fibres, Early Medieval, girdle plate, Flurlingen (CH). The fibres show larger diameters than flax, flatter cross-sections and clearly visible S-turn of the epidermis

3.2.9 Jute

3.2.9.1 Habitat

Depending upon the variety, comes mainly from India, Bangladesh, Pakistan and China.

3.2.9.2 History

Jute is today the most important renewable natural fibre (www.fao.org).

It is extracted by a retting process lasting a month. Today, the water from ponds where retting takes place can be recycled as fertilizer for a crop such as rice (Banerjee 2012).

Recent advancements in plant breeding include the search for ever higher fibre quality and shorter periods of cultivation (Banerjee 2012).

3.2.9.3 Fibre properties

Takes moisture easily and is therefore not water resistant. Fibre width: dm. 17–23µ, calcium oxalate solitary crystals. Seen with the light microscope, the fibres shows distinct stripes (*Fig. 123*).

3.2.9.4 Archaeology

Archaeologically it has become more important as time goes on, especially so in Modern Times as in the case of the "Mercure" ship excavation near Venice or another one near S. Malo (F) (*Fig. 124*). Rather than being an element in the manufacture of ropes (because of its particular fibre properties) it would more likely have been part of the merchant load being transported to Venice or Marseille (*Fig. 125*).

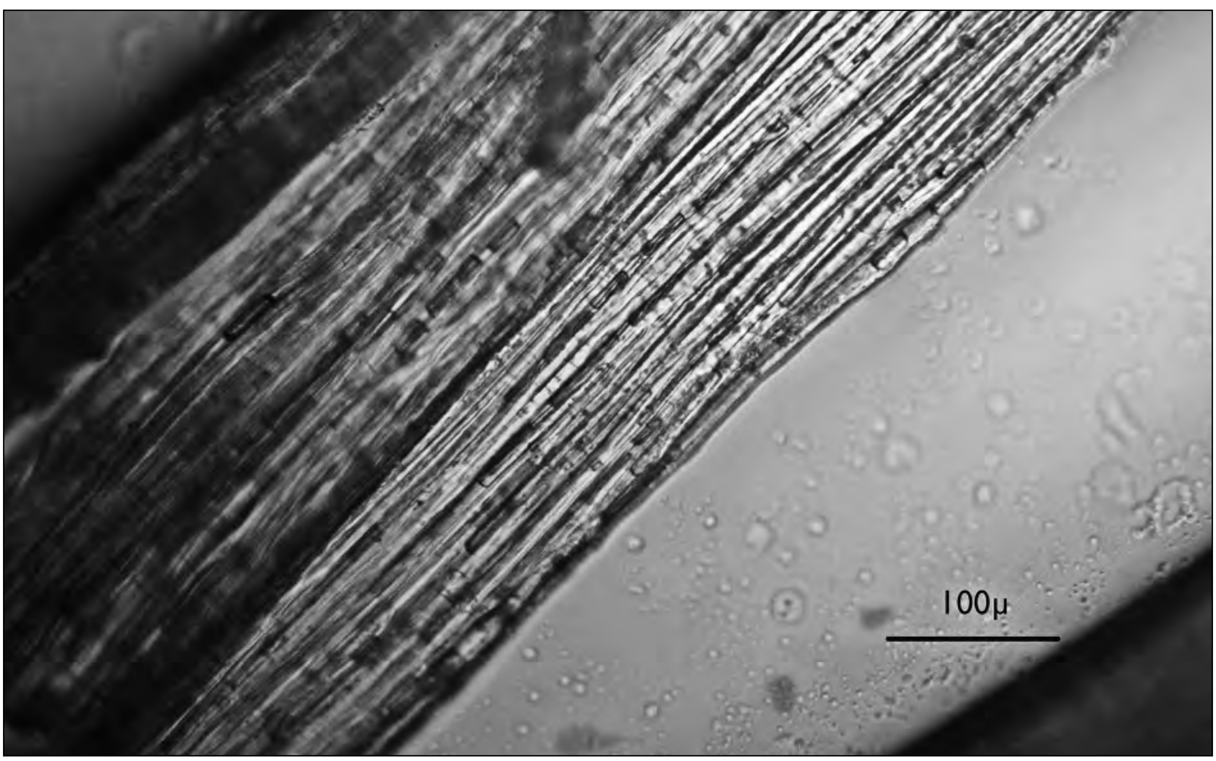

Fig. 123. Jute fibres, modern

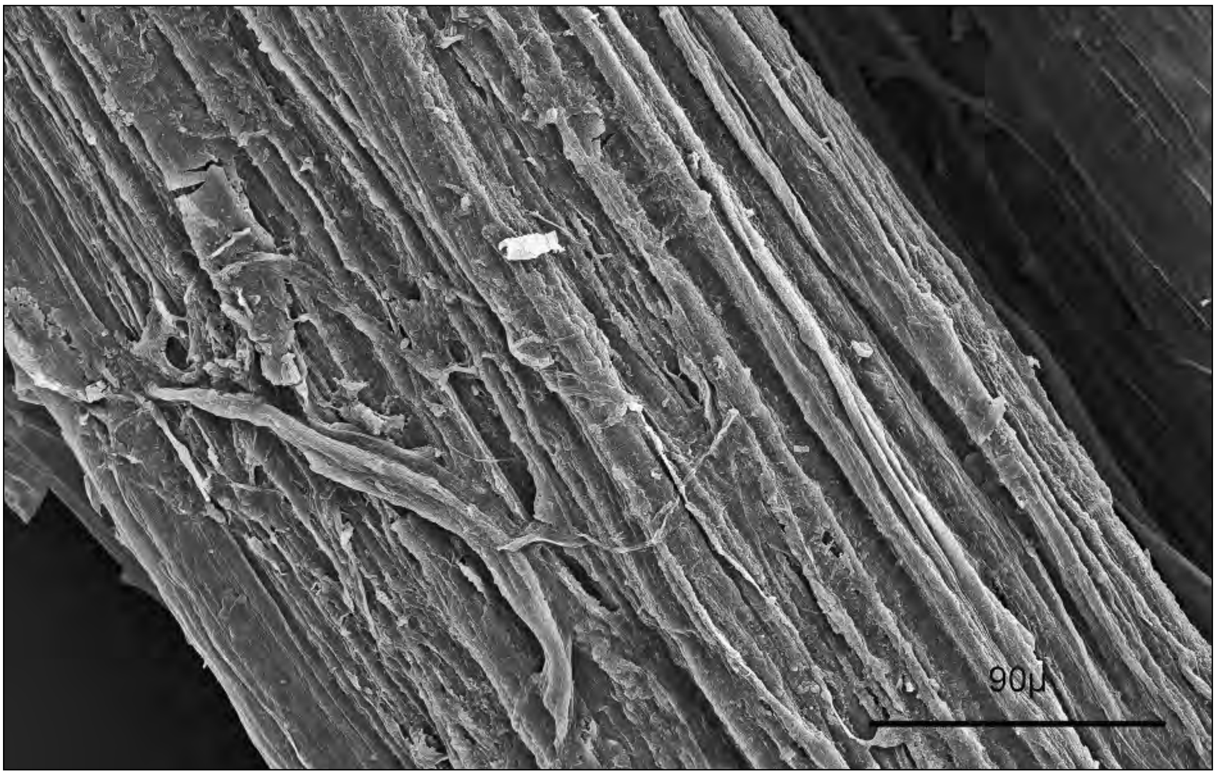

Fig. 124. Jute fibres, 18th c. cordage, probably from packing, from a sunken ship, S. Malo (F)

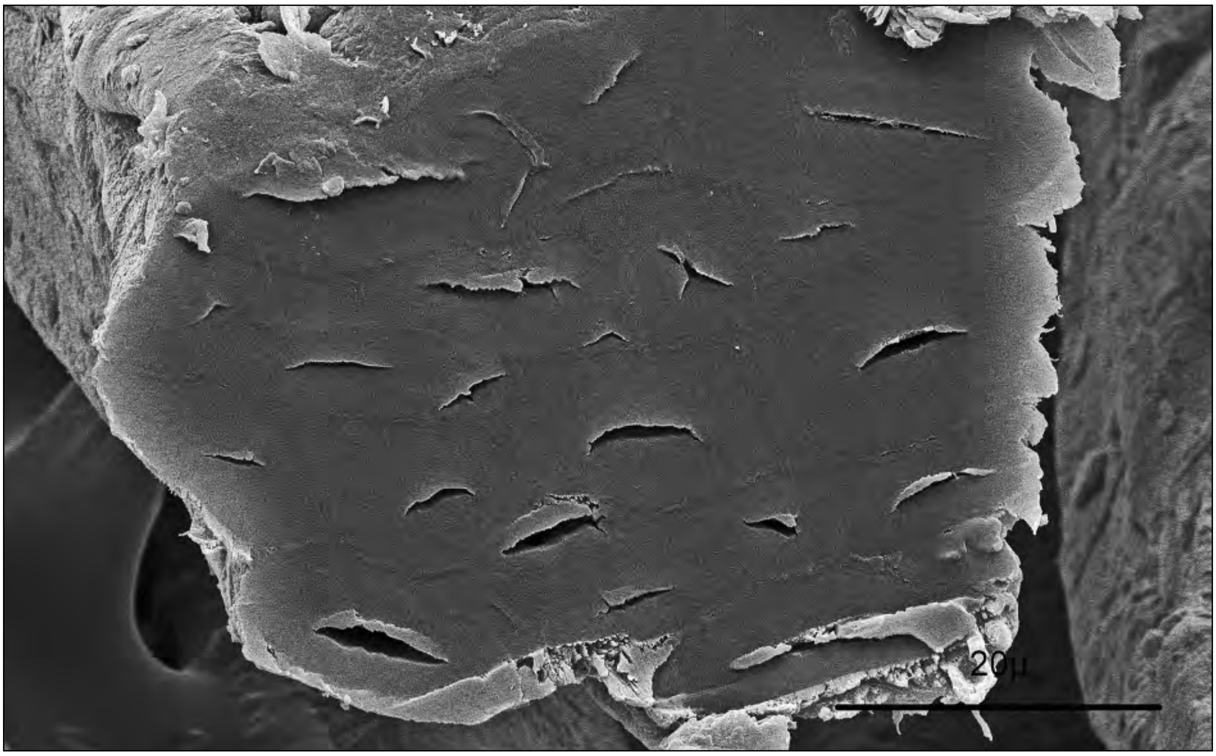

Fig. 125. Jute fibres, cross-section of a fibre bundle of a 18th c. cordage found on a sunken ship, S. Malo (F)

3.2.10 Ramie *(Boehmeria nivea)*

3.2.10.1 Habitat

Ramie is perennial, growing in Asia, China.

3.2.10.2 History

Ramie was already an important fibre in Prehistoric China (Kuhn 1988, 66 ff.). Ramie textiles were even more expensive than simple (tabby weave) silk textiles (Trombert 2000, 116). The Chinese processed green ramie to remove the fibre bundles, followed by soaking them in water and then splicing (Kuhn 1988, 67f.; Clarke 2010, 248). In Europe, Ramie became especially popular by the beginning of the 19th c., imported as "China gras" (Kuhn 1988, 66). In temperate or tropical climates Ramie can be harvested from three to four times a year.

3.2.10.3 Fibre properties

Ramie fibres are long, 40 to 150 cm, and compared to flax quite large with diameters of 10 to 25µ; the fibres are longer and stronger than flax fibres, irregular in shape and do not need to be bleached as they are white (Hofer 2000, 120f.). Unlike other bast fibres which are held together by lignin, ramie is held together with gum and pectins. The fibres are the longest and strongest known (Angelini *et al.* 2000) (*Figs 126* and *127*).

3.2.10.4 Archaeology

The cap of a girl in Moščejava Balka (RU), textile made of ramie and cotton (Ierusalimskaja 2002, p. 44, no 12).

3.2.11 Spanish broom *(Spartium Junceum)*

3.2.11.1 Habitat

Perennial shrub, frequently found south of the Alps and in the entire Mediterranean region. Grows on dry ground, even in salty soils.

3.2.11.2 History

Spanish brooms held a place of economic importance in areas of southern Europe, as in Spain or southern France. It adapted best to soil and climate conditions near the sea and was considered an important fibre plant as well as necessary winter feed for sheep and goats. It was also used to hold the ground in places where humus was difficult to grow. There has been a strong tradition of use in these southern areas, lasting at least until the 19th century (Olivier 2013).

It has also been used as a medicinal plant, containing the alkaloid spartein in the stem which has an analeptic effect on the muscular system. The contents of its flowers, which contain the anti-ulcerogenic saponin, are also incorporated into medicinal use (Bezić et al 2003). New research is considering further uses as a plant-fibre, especially for packaging material (Cassano *et al.* 2007).

Fibres have traditionally been prepared similarly to flax and hemp. According to the 18th century description by Boussonet, the plant was used after three years with the cut branches having been dried, then beaten, washed and retted in bundles (8-9 days), followed again by washing and beating. The fibres were then able to be easily stripped from the stem, dried and combed. Coarse fibres were used to weave packaging materials or to use fine fibres for textiles (Broussonet 1785).

3.2.11.3 Fibre properties

The long leafless branches are harvested after an autumn growing season. The fibres, 5–10µ wide, are arranged in bundles. As with ramie, Spanish broom fibres have a high content of cellulose. The fibres are regular in shape and, like all bast fibres, nodes are visible (*Fig. 128*).

3.2.11.4 Archaeology

Until now, there are no fibres that have been identified. It must be said that differentiation from other plant fibres – especially flax and hemp – is so difficult (except with FTIR), that they may easily be overlooked.

3.2.12 Others

3.2.12.1 Malva sylvestris:

Isidor of Seville reported in his Ethymology *"vestis molochinae"* that the warp was made of molochina, which others call *molocina* or *maluella* (Isid.Orig. 19.22.12). This fibre has been interpreted as *Malva sylvestris* by Blümner (Mommsen – Blümner 1893), however it may likely be another fibre; cotton as warp is not very probable. Among the *Malvaceae*, the fibre Kenaf (Hibiscus cannabinus) is used as fibre (see ch. 3.2.12.2). *Malva sylvestris* would show characteristic little holes in the fibre (*Fig. 129*).

3.2.12.2 Kenaf (Hibiscus cannabinus)

Kenaf is a bast fibre, a herbaceous plant of the *Malvaceae* family which originates from Central Africa. Known as well in Asia and India as "Mesta" and as "Java jute" in Indonesia. It has been cultivated since Prehistoric Times as food and for its fibres (Summerscales *et al.* 2010) (*Fig. 130*).

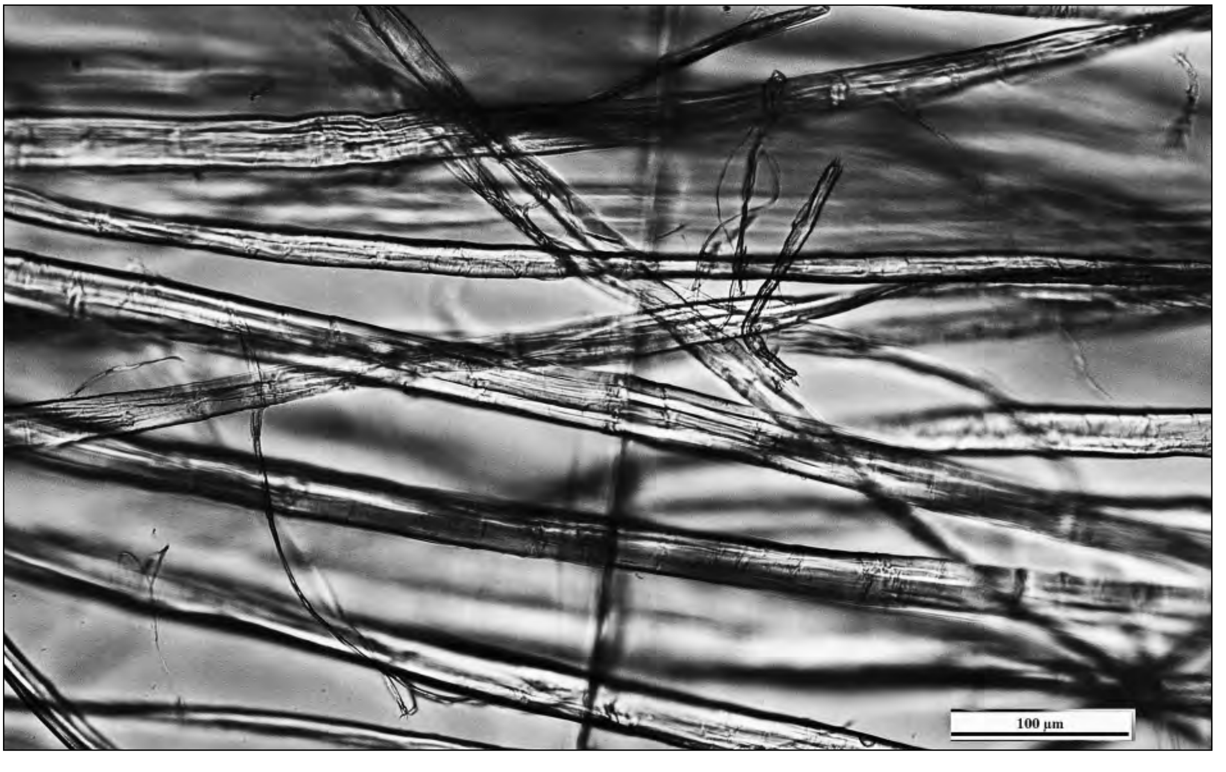

Fig. 126. Ramie fibres, with LM, modern

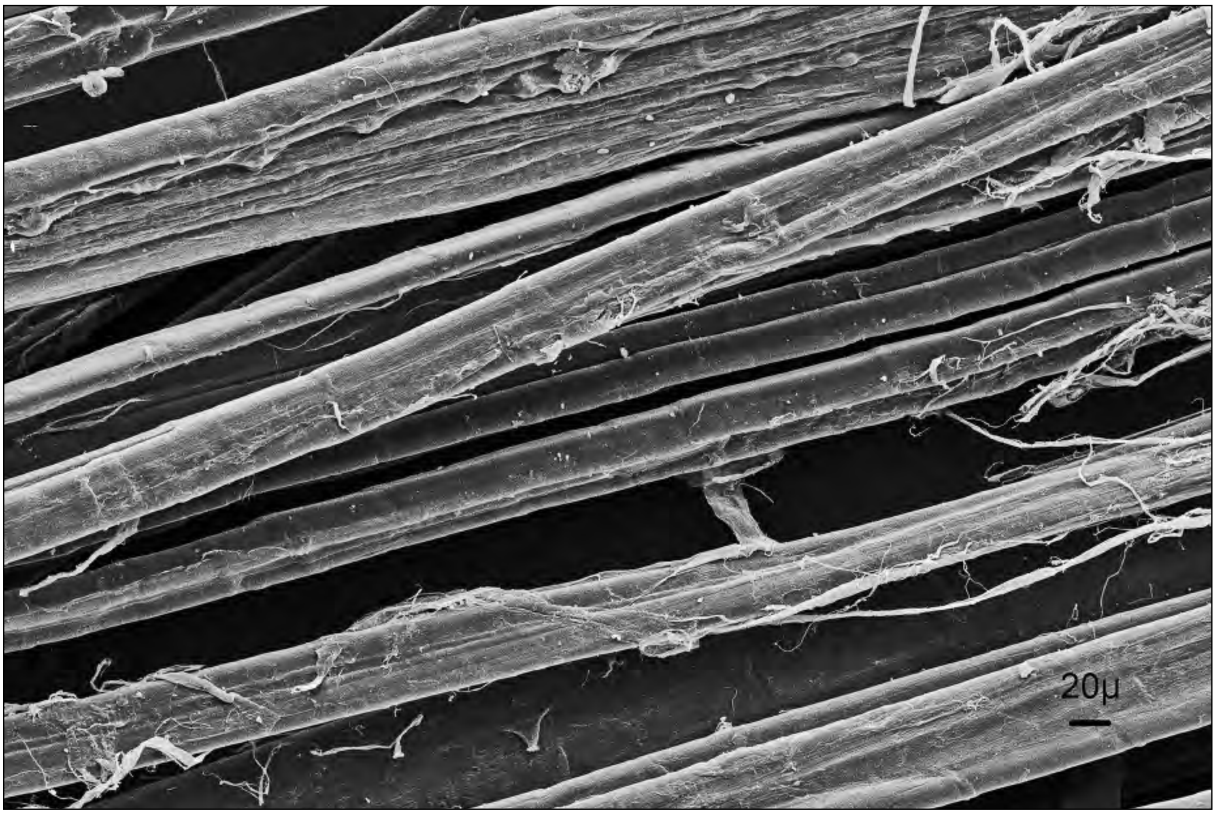

Fig. 127. Ramie fibres, modern

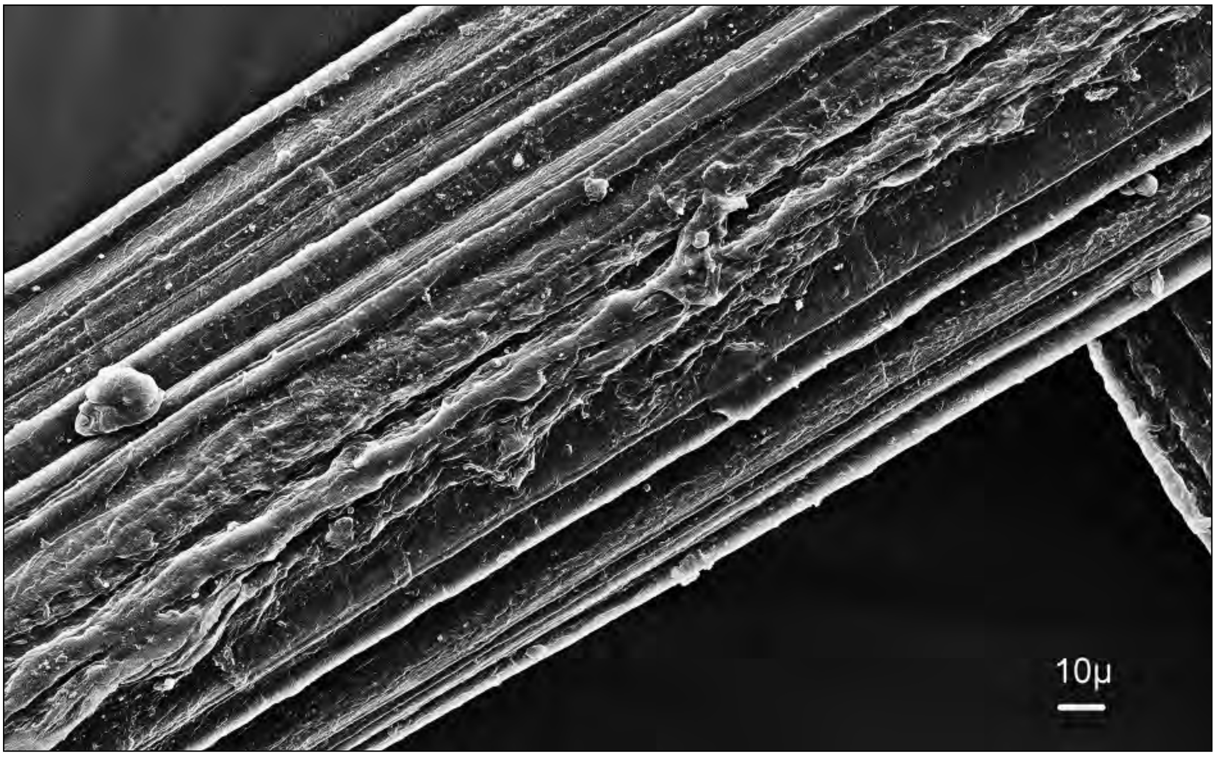

Fig. 128. Fibres of Spanish Broom, modern

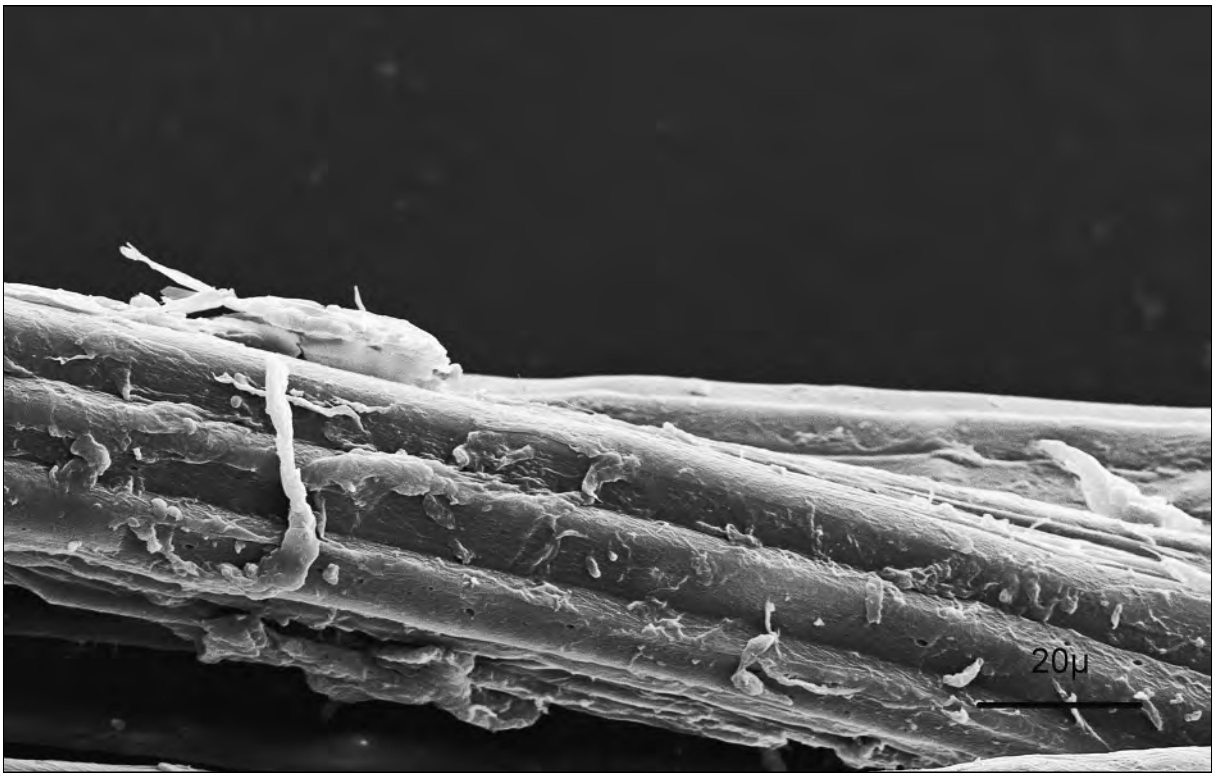

Fig. 129. Fibres of Malva sylvestris

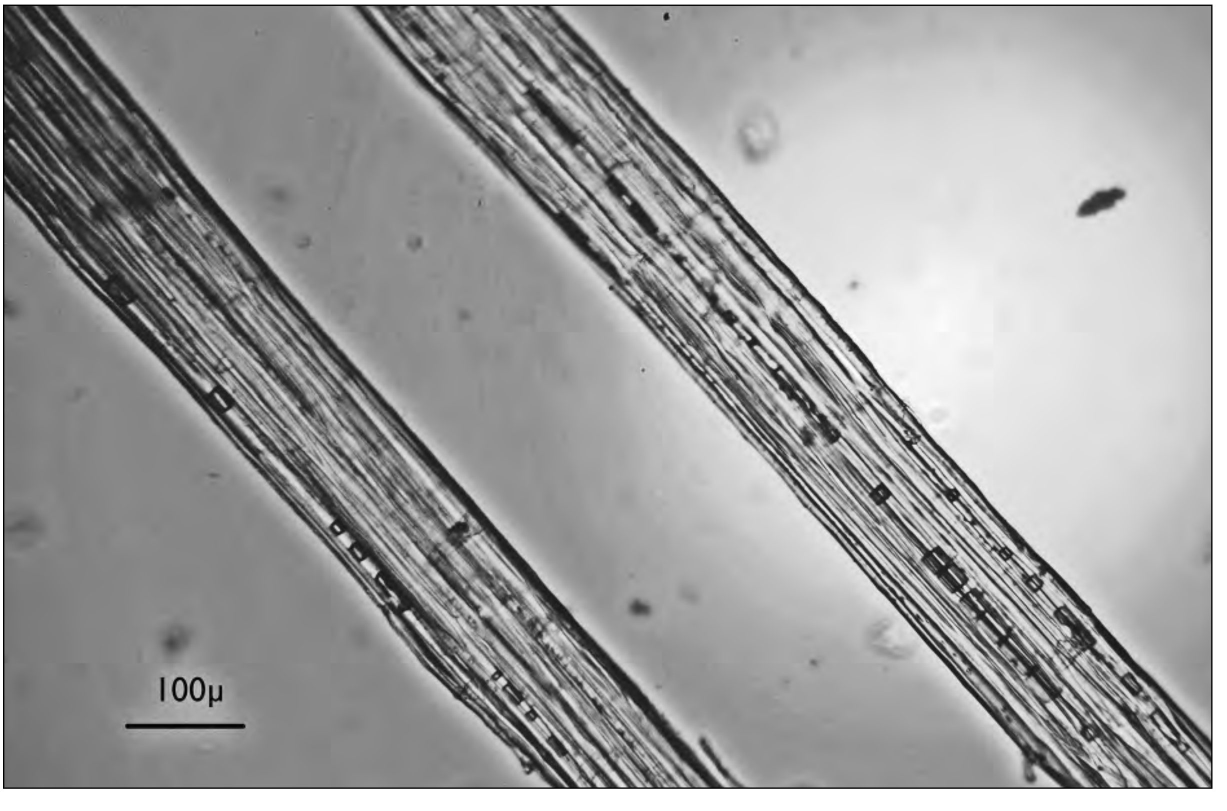

Fig. 130. Kenaf fibres, modern

3.3 Structural fibres

3.3.1 Cyperus Papyrus *(Cyperaceae)*

3.3.1.1 Habitat

Papyrus belongs to the sedges and grows in shallow water in Southern Europe and Africa.

3.3.1.2 History

Papyrus has been used as writing material since prehistory (Bagnall 1995; Leach 2009), but as well in the manufacture of ropes, sandals and mats (Borojevic – Mountain 2013). Herodotus reports, that the priest wore sandals made of papyrus (Hdt. 2,37, 3). Papyrus-paper was not invented by Alexander the Great in Alexandria as Pliny the Elder reports (Plin. nat. 13,21). *Papyri* paper sheets were already being made around 3000 BC (Leach 2009). Numerous *papyri* – paper sheets made of papyrus have been discovered and published in databases (see www.papyri.info). Most of them are dated to the Roman Period (1st to end of 3rd c. AD). Papyri have been used to write political, legal and administrative texts (Bagnall 1995, 58). It was Pliny the Elder in his 1st c. AD *Historia Naturalis* who described the processing of papyrus for paper sheets, an account which is generally accepted for its accuracy:

“Paper is made from the papyrus, by splitting it with a needle into very thin leaves, due care being taken that they should be as broad as possible. That of the first quality is taken from the center of the plant, and so in regular succession, according to the order of division. (…) All these various kinds of paper are made upon a table, moistened with Nile water; a liquid which, when in a muddy state, has the peculiar qualities of glue. This table being first inclined, leaves of papyrus are laid upon it lengthwise, as long, indeed, as the papyrus will admit of, the jagged edges being cut off at either end; after which a cross layer is placed over it,in the same way, in fact, that hurdles are made. When this is done, the leaves are pressed close together, and then dried in the sun; after which they are united to one another, the best sheets being always taken first, and the inferior ones added afterwards. There are never more than twenty of these sheets to a roll.” (Plin. nat. 13,23)

3.3.1.3 Fibre properties

The stalk of Papyrus is the best source with which to identify it, that is, if the cross-section of the stalk is well preserved and shows the alignment of the cell structure of the vascular bundles (Franceschi *et al.* 2004). The outer part can be utilized as a fibre for basketry, the inner part – the pith in the stem – for paper sheets. *Cyperus papyrus* which belong to the sedges (*Cyperaceae*) does not show a combination of short and long cells as the *Gramineae* does but only the long cells.

The fibres used for ropes or mats are made with the outer part with the epidermis; this contains *stomata,* or openings which are aligned in one row with a length of 40µ (*Fig. 131*). The cells are very much pitted. Paper sheets made of the inner part of the stem are constructed with the fibres pressed together using the spongy part of the pith.

Paper sheets have normally been so much beaten, pressed and glued – some covered with substances to smooth the surface – that determinable structures are difficult to spot. If a sheet is held to the light, fine lines may be visible and the spongy pith of the fibres evident. If closer analysis is needed then other methods, such as FTIR, are required.

3.3.1.4 Archaeology

As Franceschi *et al.* show, the vascular bundles are usually best for a determination of the plant, although they are not easily visible. Because of this Franceschi *et al.* have analyzed the fibres with thermal analysis (Franceschi *et al.* 2004).

Ropes and other objects made of the stalk are frequently found in Egyptian or other Near Eastern finds. A rope from Dor (Dor 2006, Israel) found on a sunken ship in the sea, has probably been made of *Cyperus papyrus* (Rast-Eicher, unpublished report 2012). Long cells in the absence of short cells point to *Cyperaceae*, and the stomata are aligned in one row (Brinkkemper – van der Heijden 1999) (*Fig. 132*).

3.3.2 Stipa tenacissima *(Poaceae = Gramineae)*

3.3.2.1 Habitat

North Africa, Spain and Portugal.

3.3.2.2 History

Among the grasses, many types and uses could be listed. The main characteristic of *Gramineae* is the combination of a short-and-long cell in the epidermis (Brinkkemper – van der Heijden 1999). More often than not, it is possible to tell no more than that of the presence of a *Gramineae* plant. Archaeological material is especially difficult to detect.

Stipa tenacissima is also called “Espartograss”, “halfa grass” or “Spanish grass”. It is often confused with *Lygeum spartum* which belongs botanically to the *Lygeae* (Barreña *et al.* 2006). Differentiation is not easy if only the fibres are present (Hayek 1902). By Antiquity grass fibres were an important material for cordages because of their resistance to rotting – something even Pliny the Elder evokes (Plin. nat. 19,8). There are two variants of grasses, one more spread out in North Africa, the other in Spain and Portugal (Barreña *et al.* 2006).

Espartograss has been used in England for the production of better grades of paper (Roberts – Etherington 1982, 93).

3.3.2.3 Fibre properties

Fibre bundles of about 200µ, the cellulose fibres dm. 5–10µ, length 2–3mm. The surface of the leaves is covered with small hairs which are often bent. The cells are 30–65µ x 20–25µ in size, about half are the long cells of *Lygeum spartum* (Hayek 1902) (*Figs 133* and *134*).

3.3.2.4 Archaeology

Stipa tenacissima has been found in different areas. Baskets from a ship at the Croatian coast have proved to be of Esparto grass (*Figs 135* and *136*). The size of the long cells seem to fit *Stipa tenacissima* and not *Lygeum spartum*. Other baskets made of this fibre have been found in Spain (Alfaro Giner 2008). A string found around a wine barrel from Eschenz (CH) has been – according to the size of the cells – determined to be *Lygeum spartum* (Rast-Eicher 2012b, 60) which would point to the probability that the barrel had been made in the south where this plant is common.

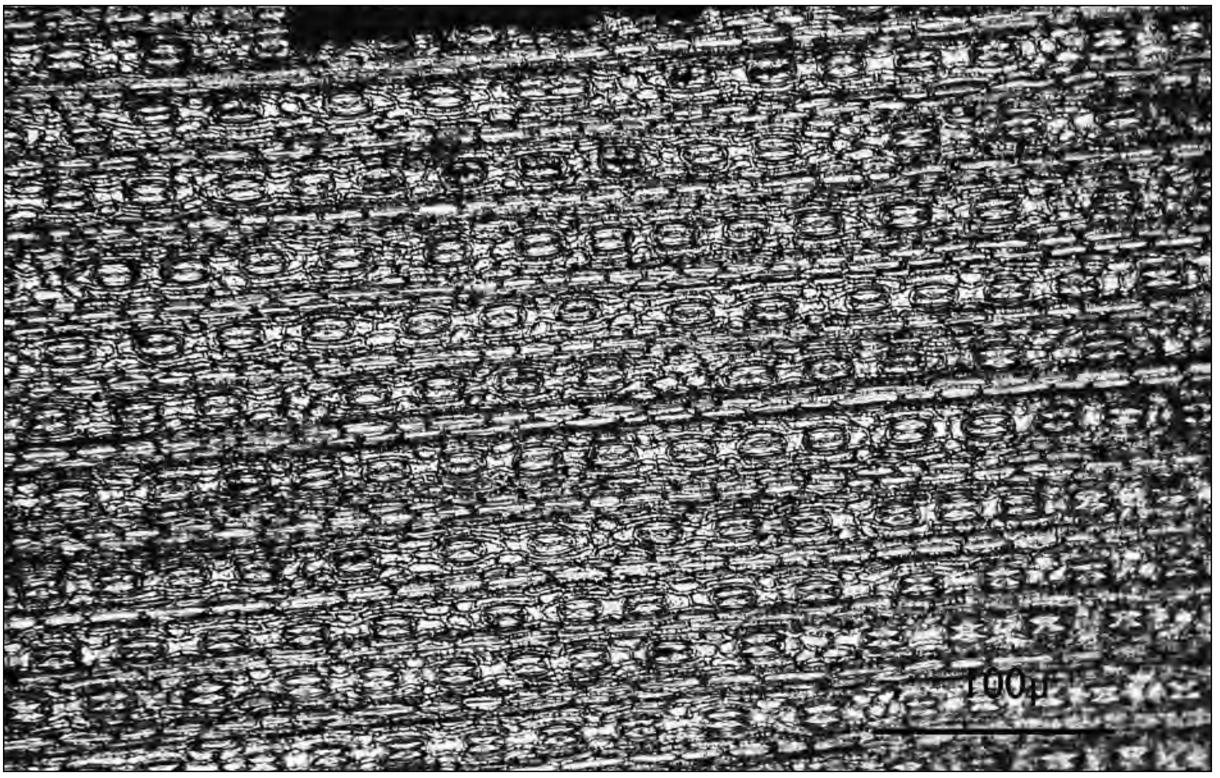

Fig. 131. Cyperus papyrus, epidermis with stomata

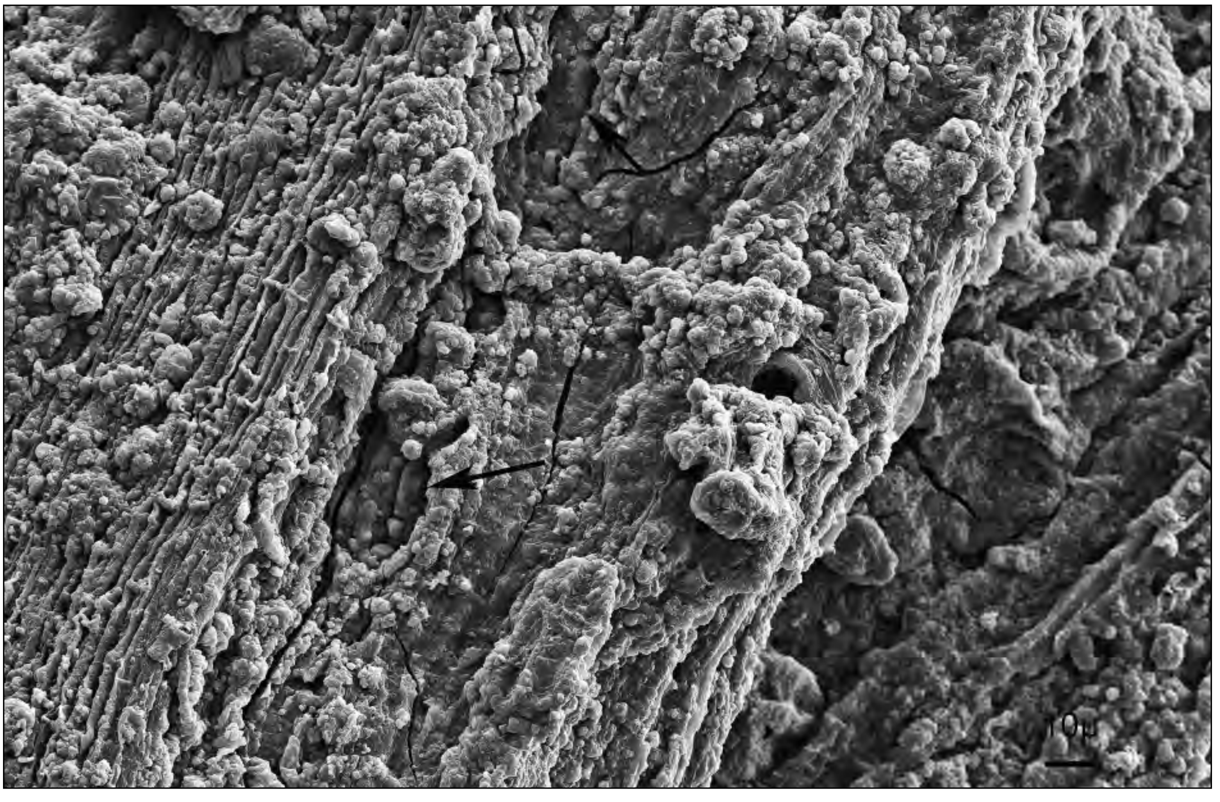

Fig. 132. Rope of Cyperus papyrus? with stomata, found in a ship, Dor 2006 (Israel)

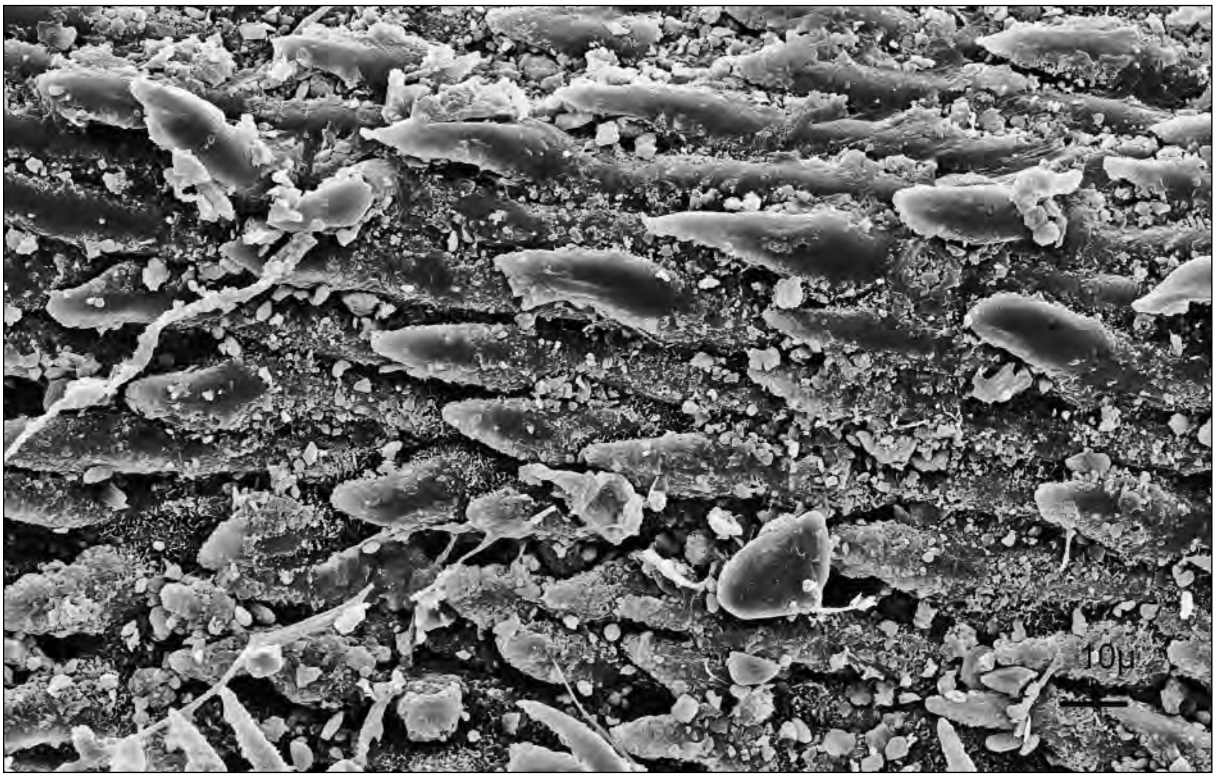

Fig. 133. Stipa tenacissima, leaf with hairs, modern

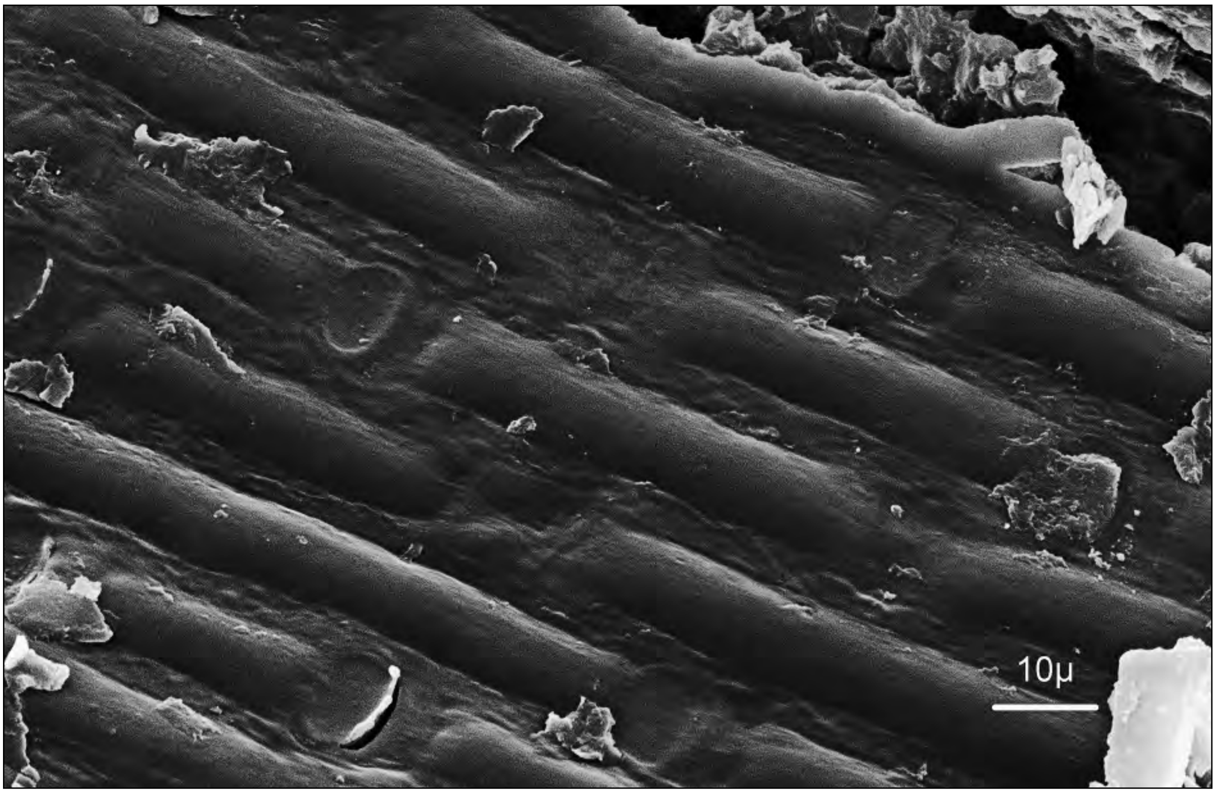

Fig. 134. Stipa tenacissima epidermis cells, visible the combination of long and short cell, modern

3.3.3 Phragmites australis *(Poaceae = Gramineae)*

3.3.3.1 Habitat

The plant is known as a common reed and grows in temperate climate wetlands all over the world.

3.3.3.2 History

Reed is a common grass for building and also, until recently, for roofs. The Neolithic inhabitants of lake dwellings incorporated reed to make large mats which were probably used as decorative coverings on either the inside or outside of their houses (Rast-Eicher – Dietrich 2015, 71). The Egyptians cut reed to use as a fine writing tool on papyrus paper. The "reed" is a tool in weaving, a part of the loom to space the warp threads. It was used together with the shuttle as one of the main inventions of the horizontal treadle loom, something not possible to use on a vertical loom. The stalk was split and bound, dent by dent, to wooden ribs (Windler – Rast-Eicher 1999/2000).

3.3.3.3 Fibre properties

The reed stalk can be identified in its cross-section (Herzog 1955, Taf. 210). The epidermis is a typical cell arrangement for *Gramineae* with a long and small cell and/or one silica cell (Brinkkemper – van der Heijden 1999, 435). The cell walls are undulated and the epidermis shows numerous little spikes (*Fig. 137*). Comparison with charred/uncharred cross-sections of the culm show the difficulty in accurately determining archaeological samples preserved in this way. The cells shrink, making cross-sections unrecognizable or comparable to modern plants (Herzog 1955, pl. 210; *Fig.* 138; see *Fig. 139*). Furthermore, the fine stomata disappear when charred. What remains are the spikes or fragments of spikes.

3.3.3.4 Archaeology

Early finds reported from the Levant have been analyzed: coiled baskets from Çatal Höyük were made with sedges and some with common reed (Wendrich – Ryan 2012).

Neolithic finds of mats made of reed which are woven with fine strips of lime bast in 2/2 twill have been dated to the 3rd mill. BC (Corded Ware culture; Rast-Eicher Dietrich 2015, 71). The twill is either simple or herringbone twill which creates a nice zig-zag design. They were found as large mats and probably used in the house construction.

Medieval finds of reeds, dated to the 13th/14th c. and documented in such places as Winterthur (CH) have been found, some of which still contain the warp threads in the spaces (Windler – Rast-Eicher 1999/2000; *Fig. 139*).

3.3.4 Juncus acutus *(Juncaceae)*

3.3.4.1 Habitat

Growing throughout the Mediterranean.

3.3.4.2 History

Rushes (*Juncaceae*) are herbaceous plants. Different sorts of rushes have been used in Egypt for basketry techniques, plants such as *Juncus acutus* (Spiny rush) or *Juncus arabicus* (Brinkkemper – van der Heijden 1999). The Romans used rushes for mattresses (Mart. 14,160). *Juncus sp.* was used in Medieval Europe for basketry and today is used mainly in the caning of chairs.

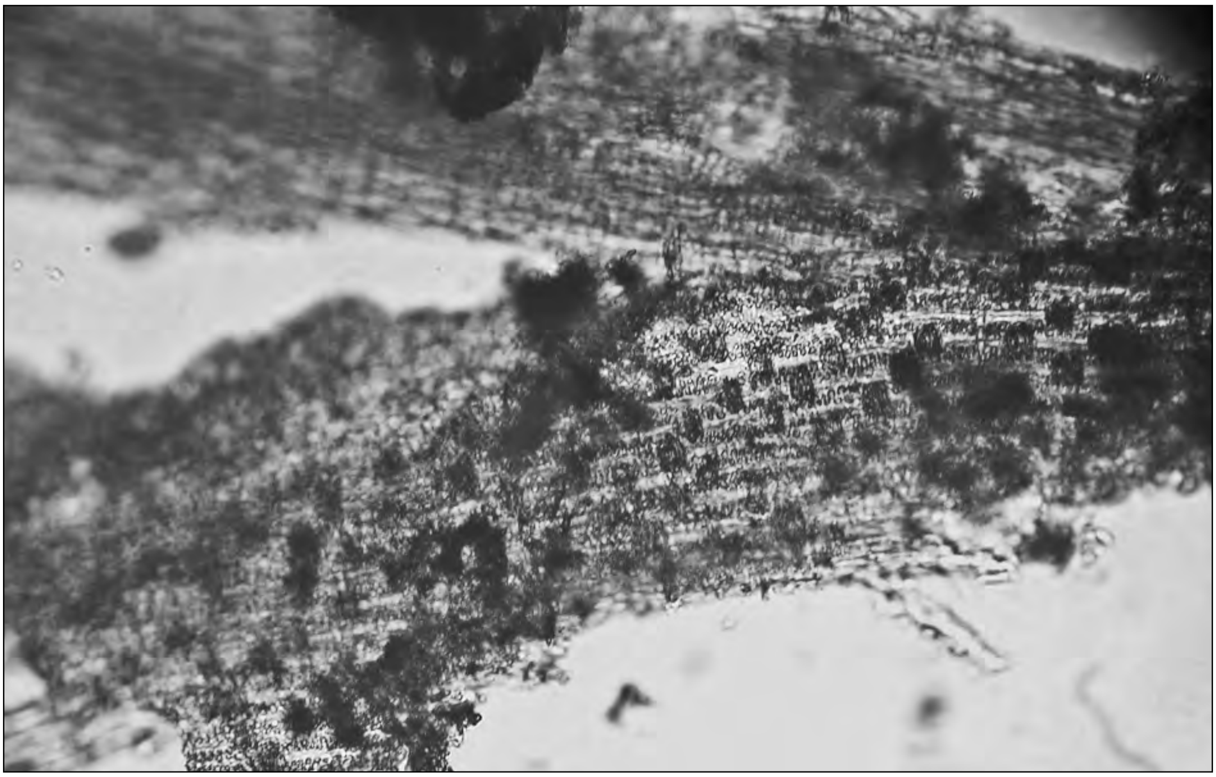

Fig. 135. Esparto grass, Stipa tenacissima, sewing thread of a basket, Zaton (HRV)

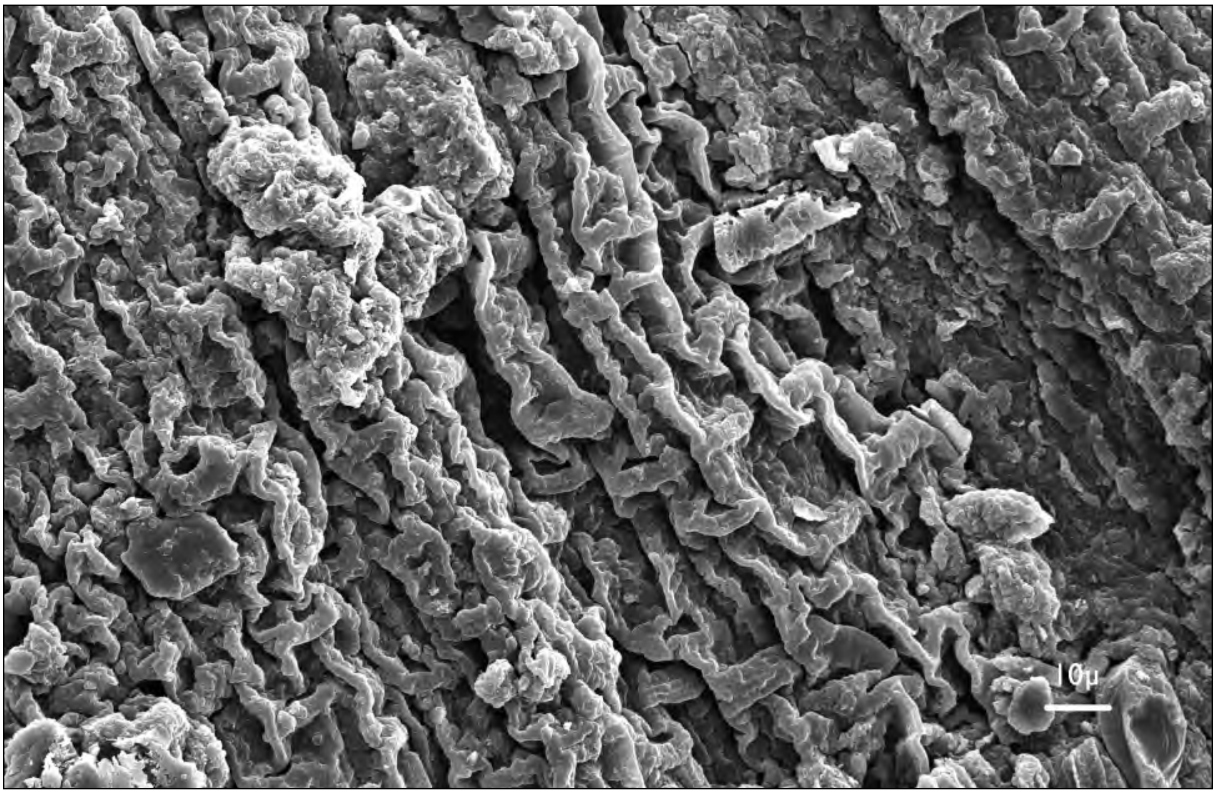

Fig. 136. Esparto grass, Stipa tenacissima, same sample as fig. 135, seen at the SEM, Zaton (HRV)

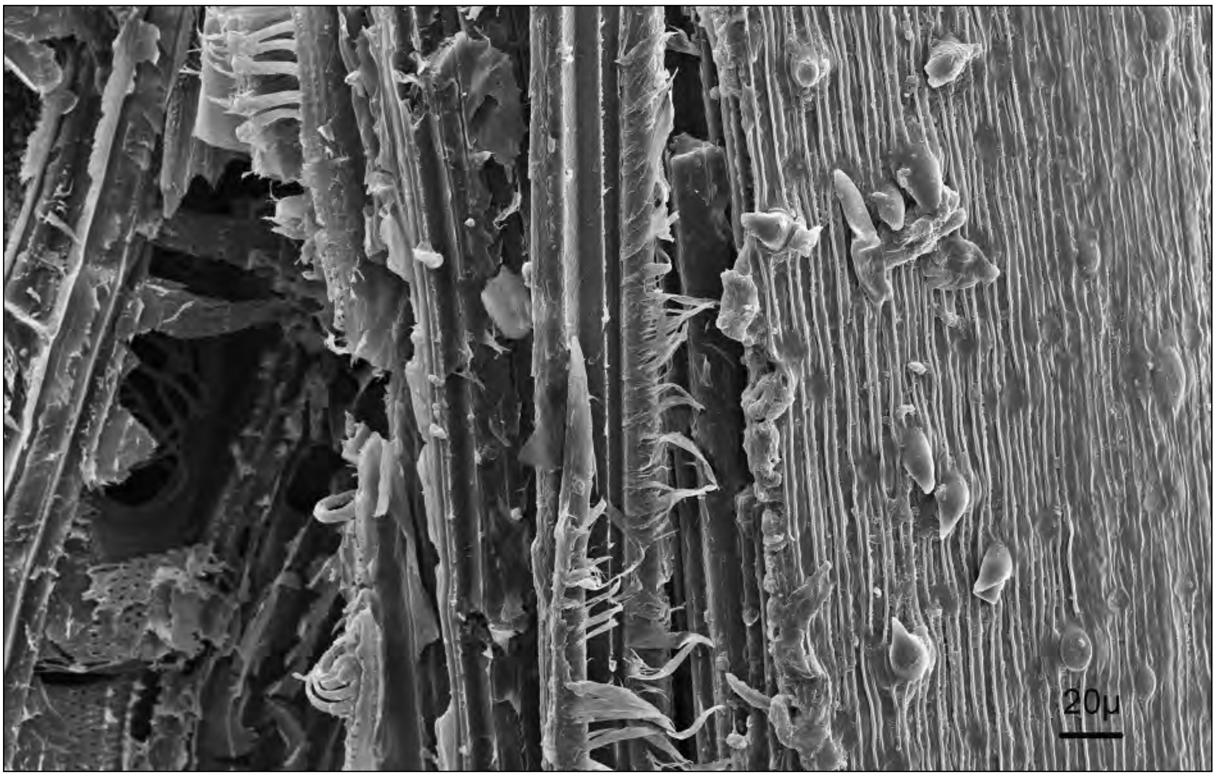

Fig. 137. Reed, outer side of epidermis with spikes, modern

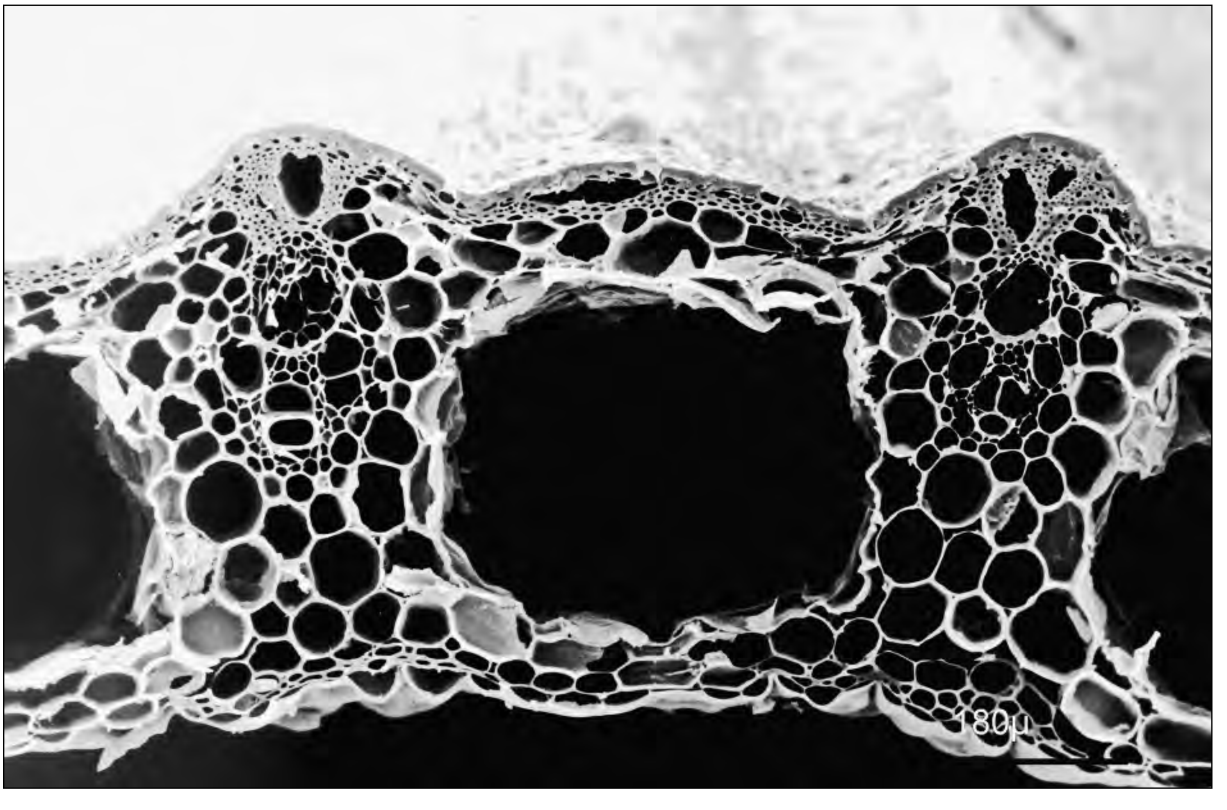

Fig. 138. Reed, cross-section, modern

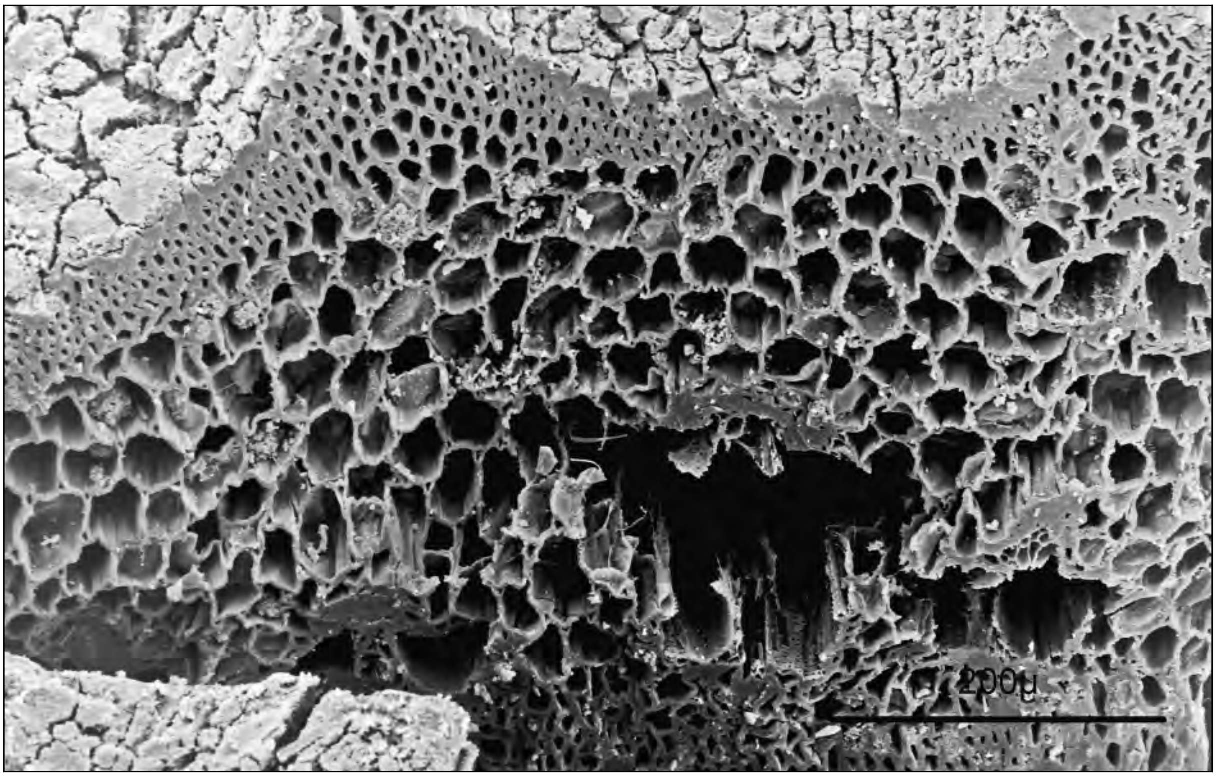

Fig. 139. Reed(?), cross-section charred, Medieval, Winterthur (CH)

3.3.4.3 Fibre properties

The *Juncaceae* are recognizable by the square cells of culm epidermis and the *stomata* (*Fig. 140*).

3.3.4.4 Archaeology

Basketry made of rushes have been found in Egypt (Wendrich 1999, 286). In the lake dwellings rushes are rarely found (*Fig. 141*).

3.3.5 Fruit fibre: Coir *(Cocos nucifera)*

3.3.5.1 Habitat

Coconut palm grows world-wide in tropical and subtropical areas.

3.3.5.2 History

The palm originates from the region of the Indian Ocean. Its coconut fruit has been widely dispersed from one area beach to another as the nut floats and is not damaged by sea water. While the fruit of the coconut is of economic importance coir, the fibre extracted from the husk of the shell, has been used for mats and ropes.

3.3.5.3 Fibre properties

Coir (*Cocos nucifera*) is not a bast fibre but one that envelopes the nut as a protective covering. The fibre, with dm. of 10–30 μ, is mostly employed in the construction of mats but also used to make ropes, brushes and caulking material (Slootmaker – Müssig 2010, 334). The fibre shows characteristic round cells when retted (*Fig. 142*)

3.3.5.4 Archaeology

The coir fibre is extracted by retting, which needs 9 months (!) in pits of brackish water. That coir has a very high resistance to rotting which makes it an especially significant archaeological find (Banerjee 2012). The retted fibres can be seen as fully visible round cells and are easy to recognize in archaeological material (*Fig. 143*). Coir has been documented in ships found in the Mediterranean. With numerous round cells as identifiers, it is easy to recognize. Another textile found in Pompeii has been determined to be made of coir fibre; fibre determination was made by burning the sample and analyzing the ash. The authors of the Pompeiian study report silica cells typical for coir, although in Fig. 8 of their article no silica cells are visible (D'Orazio 2000, Fig. 8).

3.4 Others

3.4.1 Moss

Moss has been used in a variety of contexts, from basketry to insulating material in Neolithic footware (Hochuli 2002). For basketry, a special kind of moss known in northern areas as Hair-moss (*Polytrichum commune*) is used. Hair-moss (in German "Großes Haarmützenmoos") was found to have been used for a twined cap found in the Roman fort of Vindolanda (GB) (Wild 1994). It seems as though the Roman soldiers at the northern frontier at Hadrian's wall were in need of rain hats! Hair moss has also been used for rope making in the Middle Ages (Beck *et al.* 2006).

In Early Medieval graves moss remains are quite often seen, found mostly under the bodies and probably having been used as filling material in mattresses and the like. The distinct form of the plant can preliminarily be recognized through the stereo-microscope (*Fig. 144*).

3.4.2 Wood

Wood can deteriorate into single fibres. With the stereo-microscope they may appear as straight hairs or fur. In most cases, when using the SEM, the difference becomes clear. The resin canal may be visible at times as well. Fibres which lie in a right angle to one another are usually indicators of wood (*Figs 145* and *146*).

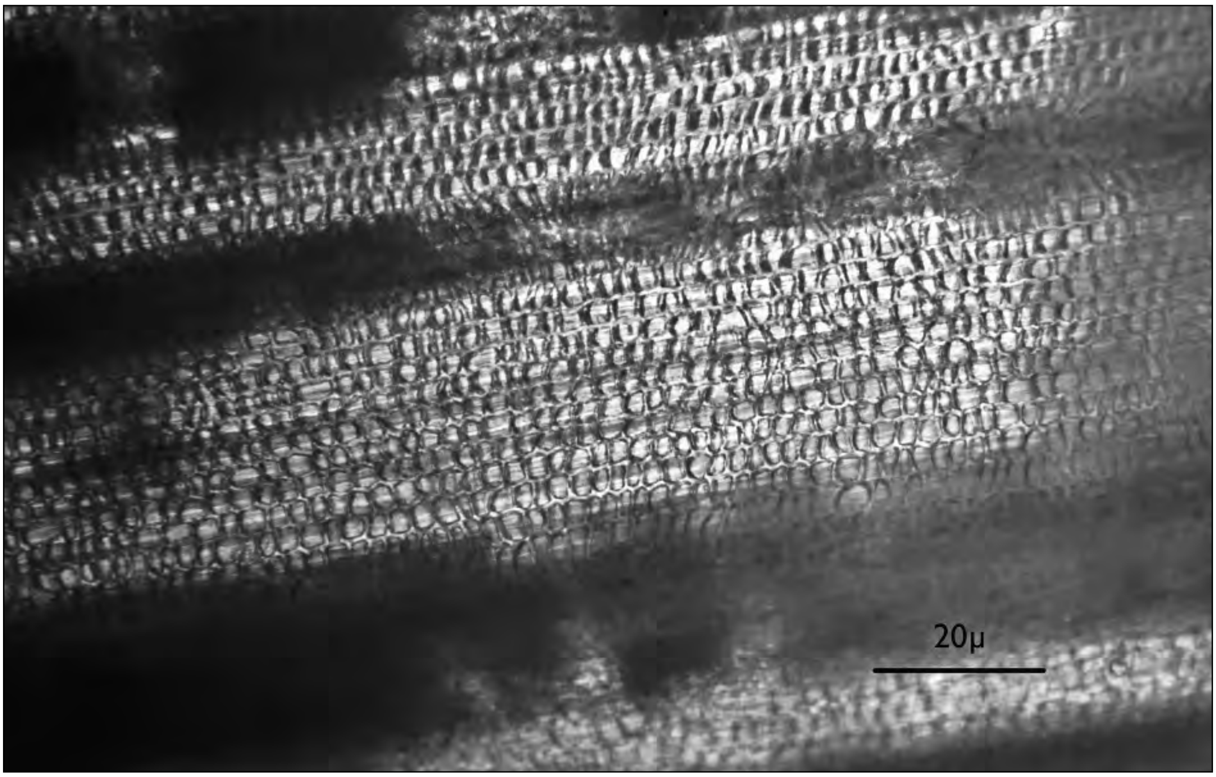

Fig. 140. Juncus acutus, epidermis with square cells, modern

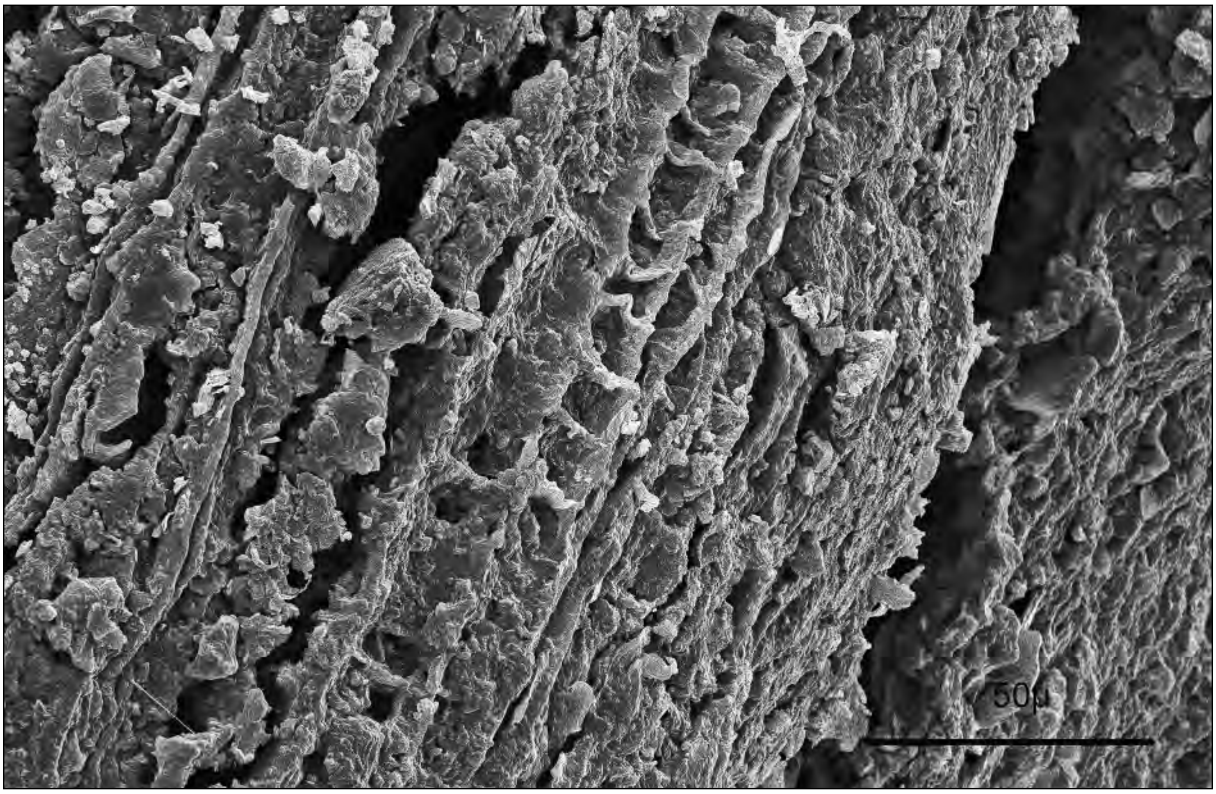

Fig. 141. Juncus sp., Neolithic, Steinhausen (CH)

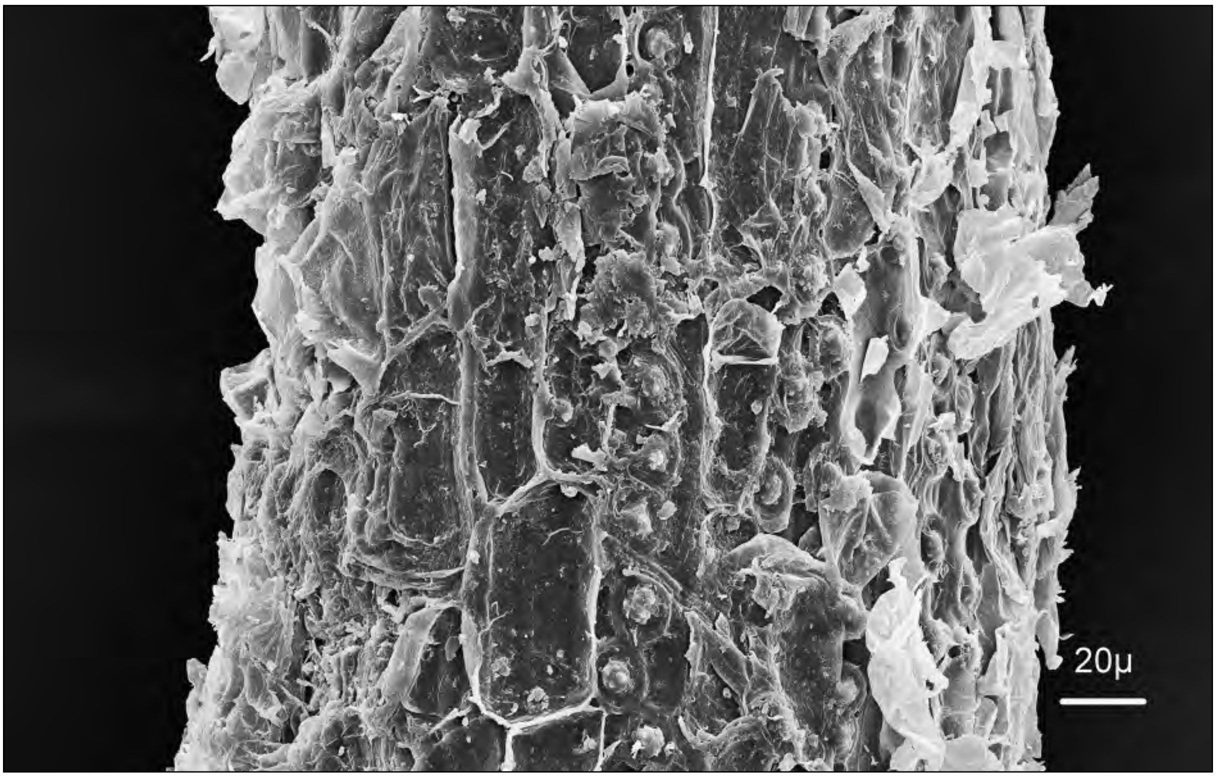

Fig. 142. Coir fibre, the layer of round cells is under the epidermis, modern

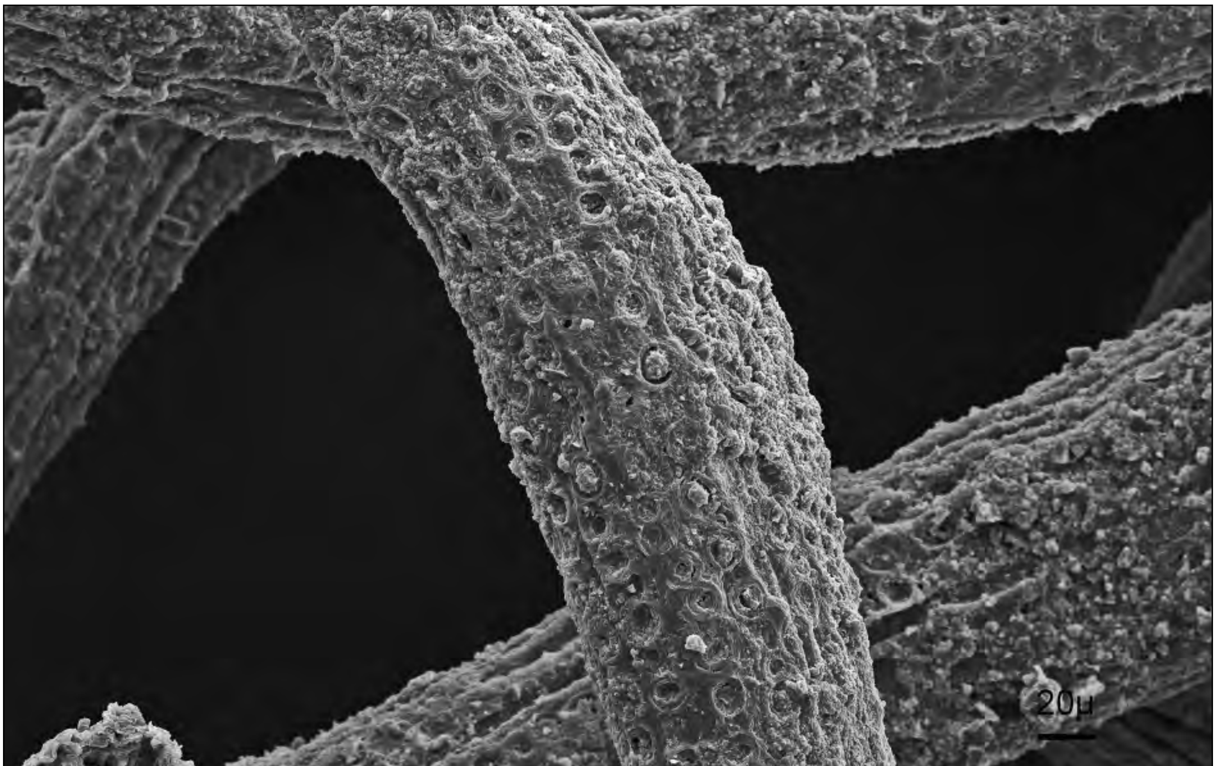

Fig. 143. Coir fibre, Dor C (Israel)

Fig. 144. Moss, modern

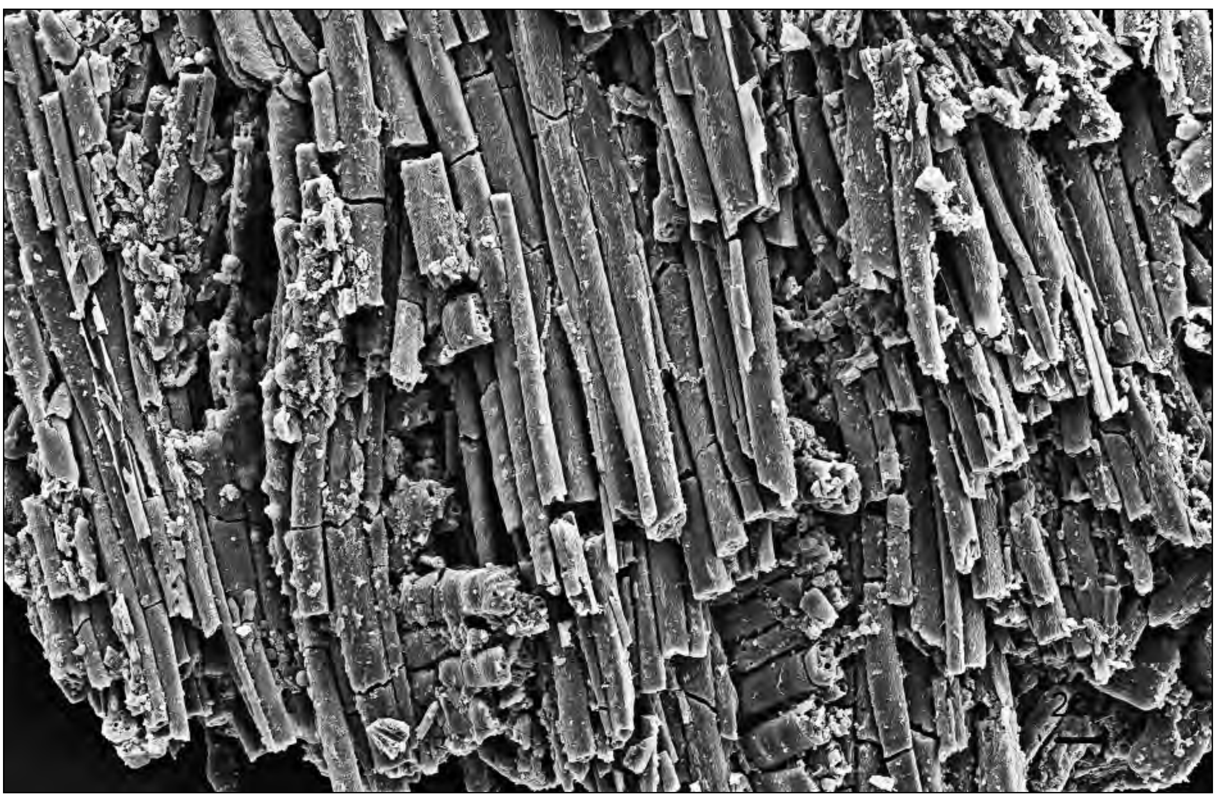

Fig. 145. Wood, Oberstammheim (CH), Iron Age

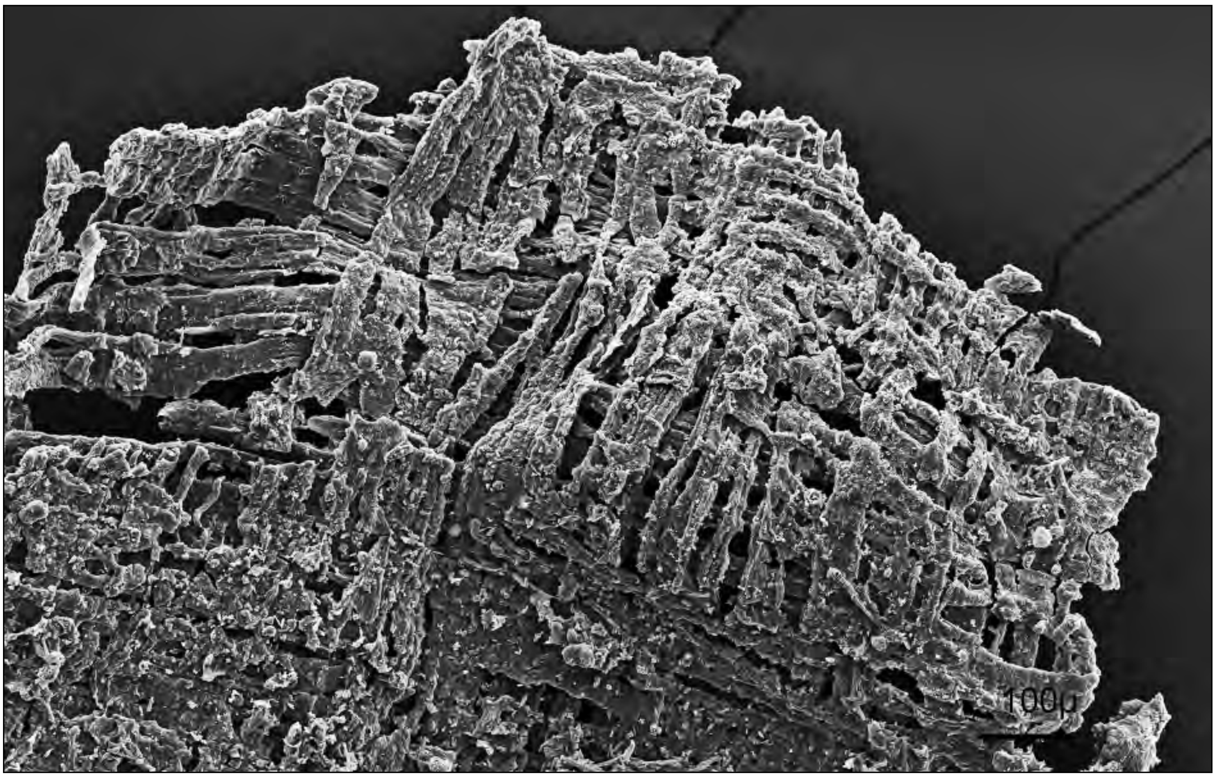

Fig. 146. Wood, very deteriorated, Early Medieval, Saint Denis/Paris (F).

4. Animal fibres and human hair

4.1 General comments on animal fibres

4.1.1 Introduction to animal skins and animal fibres

Skins are the outer protective epidermis of an animal. They can be scraped, dried and used as a raw hide. Fur or pelts are skins which have been processed into leather by the process of tanning the hide into a flexible and durable material. Having left hairs attached, these materials are also softer than rawhide. Remains of animal fibres can derive from fur or textiles. Skins and fur, or pelts (latin *pellis*), were essential for survival during long cold periods or regular winter seasons; in the early Holocene they were vital (Charles 1997). Even after wool textiles had come about during the late Neolithic Period, fur remained an important part of daily life and of the garments worn. Additionally, both skins and furs acquired meaning as a standing for a certain social status or as attributes for specific persons (e.g. Saint John the Baptist with his skin). In ancient texts simple skins often characterized persons of a low social class, while fur was a luxury item for the elite. Ancient Greek comedies depict goat skins for farmers and the poor (e.g. Aristoph. Birds, 935). In the Medieval Period furs were so commonplace that silk linings were even criticized unless used for specific purposes with pelts (Dasler 2004, 7).

Attitudes towards skins would vary from culture to culture. While they were considered everyday garments for the Germanic people, the Romans saw them as luxury materials – in the negative sense – or as attributes for non-Romans. Negative attributes were further characterized as being visible signs of a barbarian (fur as *topos* for the *barbarii*, Brather 2004, 117ff.). The Germans on Trajan's Column (Rome) were depicted with skins while the Goths were characterized as wearing furs (Plin. nat. 33,50; Tac. Ger. 17; Jordanes, Getica, 4/37; Leguilloux 2004). Romans had always been told to wear Roman garments only (Suet. Aug. 40, 59), but by the late Roman Period when the Goths had introduced their fashion into Southwestern Europe, furs had become established as affluent attire. And again, the Roman emperor sought to forbid this luxury (*indumenta pellium*) (Cod. Theod. 14,10,4). In some texts, especially in early Christian documents, it is even stressed that a person should not wear pelts if he is to be humble. As it is with Paulus Diaconus (Paul. 35) he describes the King receiving diplomats in "normal/simple clothing, without pelts" (*..vilibus coram vestibus sive pelliciis utebatur…)* (Schier 1951, 23). Other periods depict furs as items of luxury as well as everyday garments. Medieval and Early Modern sumptuary laws tried to regulate the use of skins, reserving the more expensive materials for the nobility or later on for the bourgeoisie (see also ch. 4.5.18).

Pelts were trade commodities and are mentioned as such in the texts of ancient authors, medieval commercial writings and Arabic authors. North-south trade was as important as east-west trade. The sea route linking Rome to India and Indonesia during the first centuries AD opened up the possibility of bringing skins along with their live hosts (wild lions, tigers and elephants) from India, this in addition to spices and precious stones. An example of hinterland trade from the coastal town of Broach in India shows how hunter-gatherers were involved with global trade, bringing products from the wild forests to the towns (Stiles 1993, 160). The Northern areas (Baltic countries, Scandinavia and Siberia) and Eastern Europe were selling numerous amounts of skins. Novgorod in Russia (later Moscow) was as well a considerable center for the fur trade and pelts were sold from here to Western Europe (Hanseatic League!), Byzantium and Persia. Texts on birch bark from Novgorod (RU) give information about trade routes and prices. The live animals were hunted using blunt arrow-heads or caught in traps to limit damage to the furs (Kovalev 2002, 39). Skins were brought by backpack via skis, on sleds pulled by dogs or on elkback to the markets of Novgorod (Kovalev 2002, 21f.; 157; 263). The fur trade was so enormous and old Russia so dependent upon this resource-bound economy that colonization and exploitation of the Eurasian North developed to a great extent. (The end result of this expansion is evident even today where dependency is now rather upon oil and gas.) Huge amounts of furs packed in barrels of 5,000 to 10,000 pelts were sold to Western Europe in exchange for iron, weapons, salt, wine and other goods (Etkind 2011). Due to a lack of silver, furs were considered currency in the West as well as the East. Doctors in Moscow, for example, were often partially paid in furs (Etkind 2011, 168). Second to Russia, Western Europe was engaged in the fur market by selling mostly to North America (Wien 1990). In the North and the East, the commercial unit for pelts was 40 pieces (= 1 timber; German: *Zimmer*), whereas in the Mediterranean units of 100 pieces were sold (Delort 1978, 14). Skins of mustelids were a currency for the Slavic people: *kuna* means marten, but also a certain amount of money or 1/22 of a Grivna which was the amount of skins for one Dirhem (Gunda 1972). Furs continued to be held as currency in more remote places as well: on the Färöer Islands (DK), people paid in sheep skins as recently as 1856 (Schier 1950, 301ff)! One should be aware, however, that written texts reflect for the most part long distance trade; animals such as red fox or wolverine were hunted for the local market and therefore not mentioned in trade lists.

Animal fibres – not only sheep wool – were used for textiles, either as pure yarn or as blended yarn. Animal fibres utilized as such were represented only by a few species. All in all, however, there were in these days far more such fibres processed for textile use than can be imagined today. Examples have been found in archaeology and confirmed by ancient texts (see chapters 4.4.2; 4.3.6). The most important fibre, though, is sheep wool. Latin texts describe woven garments called *vestis* (wool or linen) which, importantly, are differentiated from those identified as *pellis* (pelts). Even so, fine fibres deriving from wild animals were used to create incredibly expensive garments meant for an elite class (see ch. 4.3.6) (Atzbach 2005). Today, it is hardly possible to imagine the kinds of fibres the Ancients were able to combine, this due to the fact that the variety of fibres that can be processed by hand is simply not possible with modern industrial fibre manufacture.

4.1.2 Domestication and analysis

Domestication was first developed in the Near East, initially with the controlled cultivation of plants (10^{th} mill. BC for wheat and 9^{th} mill. for flax) followed by the breeding of animals (cattle, sheep 7^{th} mill BC), all of which might have developed in response to changes in climate, population growth and other adaptations to the environment (Smith 2011). To consider an animal for domestication, the following conditions must be met: its survival in a new environment and adaptation to a new environment, ability to breed in captivity, acceptance of human masters and ease in tending (Clutton-Brock 1989, 15). Flight animals, such as deer, are not ideal. Domestication can come about in steps with selective breeding and gradual changes to body size, overall appearance (e.g.tails for the sheep), specific dimensions for teeth and horns, and general behavioral changes (dog!). Changes in body size are the most important criteria in archaeozoology (Clutton-Brock 1989, 21). A long-time undertaking carried out by the Russian Academy of Science experimented with the breeding of domesticated foxes. After 40 years, researchers there could demonstrate that a single trait – non-aggressive behavior – could be achieved through genetic selection. Changes in morphology could be detected in some of these domesticated foxes as well: coat color, floppy ears and rolled, shorter tails were evident. Behavioral changes such as reduced flight distances and more temperate behavior towards humans were also indicated (Kukekova *et al.* 2004).

DNA analysis now allows us to trace development in time and space from archaeological material, but these analyses are based on bones, not fibres.

The changes to fleece by breeding sheep has had an impact on hair morphology (Meyer *et al.* 2002, 30). Fibre types, dimensions and medulla shapes became different with domestication. This is especially evident in sheep as they have been bred for milk, meat and wool (Helmer – Vigne 2007; Arbuckle *et al.* 2009). The wild ancestor species exists nowadays only in limited cases and breeds that were intermediate to the final stock are not even known. Comparisons of archaeological materials with modern materials does not always lead to accurate determinations.

4.1.3 Domestic and wild animals in the fibre analysis

By the 21st century BC, scores of animals that had existed in prehistory were now extinct. A variant of rabbit reported by Pliny the Elder, for example, was lost (see chapter 4.4.2). By the 17th century AD, many more species had died out, an example being the aurochs which was gone by the early 1600's. Fibres from these animals cannot be securely determined today. And while skeleton remains can be better studied (archaeozoology), differences between extinct animals and those living today are often not possible to determine. Through breeding, the morphology of certain animals took on changes. Domesticated sheep differ from wild sheep, and the wool of modern day sheep is quite different from that of ancient sheep. Fibre scale pattern and medulla from ancient sheep wool resembles that of the wool of wild sheep. White wool, developed over centuries through breeding, no longer resembles that which came from animals of the ancient world. Fibre analysis shows differences between domesticated and wild goats in lower fibre growth, nutritional stress being a possible factor affecting fibre characteristics (Vineis *et al.* 2008).

4.1.4 Ancient terms and names

Terms used by ancient writers are oftentimes difficult to comprehend. Greek and Roman authors may not have correctly identified animal breeds or species, confusing hares with rabbits, for example (see chapter 4.4.2.2). The Medieval Period saw further complications linked to terms and various translations. What is, for example, a *ponticus mouse*? Is it a mouse or a rat? Ermine? Marten? (Schwentner 1953). Or *werk of Helsinck*? (Delort 1978, 77). Which hairs are the medieval *harmaker* of north German towns dealing with? Sheep? Goat? Cattle? What does the Old English term *skynnan mid paelle* mean? "Skin covered with textile" as Gale Owen Crocker suggests (Owen Crocker 1998, 36)? Medieval translations of lists were not always correct, especially those from Slavic languages being translated into German, French or Italian. The linguistic root '*kun*' for marten types in the Slavic language became in some instances the Latin root 'cun' for *cuniculum* and so changed the species of animal on the list. In such texts, comparisons of prices and colors are important and mistakes can be spotted (Delort 1978, 15). Garment names often do not specify the animal species – the terms *pellis* or *pilece,* or in modern times the French *pelisse* (luxurious fur cape), are used as nouns and not exact determinations of species (Owen-Crocker 2014).

4.1.5 Archaeological material

Archaeological finds are the most important source from which to research ancient garments and fibres. This is in part due to the rarity or unreliability of written sources (encyclopedias not having been comprised until about 1700). With scientific analysis, a world of special fibres found within textiles and skins opened up. With SEM, a more precise analysis of processing techniques has become possible – the *chaîne opératoire* becomes visible; scale direction for wool can be determined and whether or not silk has been degummed, for example. Unlike skins, textiles have fibres that can be selected. Wool measurements, for instance, help to determine if all fibre types were used for a textile (see ch. 2).

Archaeological material, having been buried in the ground or concealed within reliquaries for centuries, will have decomposed to the extent that fibre comparison with like modern materials will be challenging (see ch. 2.2). Poor preservation may affect the scales, the medulla or the entire fibre and all factors will certainly limit accurate determination. Analysis will reveal information about fibre selection and processing, although not all fibre types may be present. Fibre blends are not excluded in textiles.

4.1.6 Hair morphology: a research history

Hair is a complex protein fibre starting in the dermal pore with several layers of different tissue (see ch. 1 and *Fig. 1*). The outer part of the cylinder is the cuticle with scales, the inner part the cortex with cortical cells (fibrilles) (Popescu – Höcker 2007) (see *Fig. 2* and *3*). There are two main hair types: the primary fibres (German: *Deckhaare*) and secondary fibres (German: *Unterhaare, Wollhaare*). The scales are not decorative – they fulfill a specific function for the animal in keeping dirt out. Otter fibres, for example, close like a zipper to keep the skin dry (Kuhn – Meyer 2010).

Hair morphology was first described towards the end of the 19th century (Waldeyer 1884). In 1920 Hausman published a classification of the medulla and the structure of scales (Hausman 1920). At that time, analysis was based on light microscopy, but even with modern microscopy techniques such as scanning electron microscopy (SEM) or transmission electron microscopy (TEM), scale patterns and the medulla types are the main criteria. Using SEM pictures (longitudinal views and cross-sections), Olga Chernova published a photo atlas of animal fibres (although in Russian, with species in Latin) (Chernova – Teslikova 2004), another atlas exists online (Galatík *et al.* 2011). Several other atlases have been published about animal fibres and their determinations. In *Table 1*, the main ones are listed chronologically and discussed, with questions being asked as to which animals and hair types are present, and whether or not only textile fibres are in evidence. Is there an overview? Is there a discussion? Some atlases are compiled as primary research sources on fibres, others as technical information for the textile industry. None, however, included information on extinct animals such as the woolly mammoth. The combination of scale structure and medulla has been described by Lochte, with a discussion of the different hair types – as one of the few! – and similarities in the morphology of other animals (Lochte 1938). Wildman used the same methods, but restricted discussion to textile fibres (Wildman 1954). Von Bergen & Krauss proceeded more generally with textile fibres including also plant fibres (v. Bergen – Krauss 1942). The authors of older books very often based their theories on an immense practical knowledge of fibres, which is why these books are full of important details and still very useful. Scale measurements were started in the 1920's, having become far more developed today with the use of computer-assisted programs. With the SEM, for instance, scale height has become an important indicator when differentiating between fine wools and cashmere (Robson 2000). Meyer *et al.* published an atlas with methods of computer-assisted scale and fibre measurements based on the primary hairs, this to enable the determination of animal species (Meyer *et al.* 2002). Sessions *et al.* presented a key form for mammals which focuses on fibre width and scale pattern of the guard hair but includes as well the scale pattern of the underhair (Sessions *et al.* 2009).

Tab. 1. Fibre atlas (LM: Light Microscopy; SEM: Scanning Electron Microscopy)

Author	Animals /fibres	Fibre types described	+/-
Lochte 1938	mammals	all	+ very good description of all fibre types + discussion of difficulties and similar hair types – book unfortunately predates SEM
v. Bergen/ Krauss 1942	textile fibres (incl. plants)	all	+ basic information, short, LM
Wildman 1954	textile fibres	all	+ good and lengthy description of treated animals + methodical introduction, but preparation with imprint not made today anymore + basic information to the skin – made for the 20th c. industry, not for historical material, therefore few animals – no discussion of similar morphologies
Appleyard 1978	animal fibres	all	+ cross-sections – missing animals (e.g. horse)
Teerink 1991	West European mammels	all, photos of primary hairs only	+ large corpus of mammals + all hair types + combination scale and medulla types + cross-sections + shows the change of scale patterns along the hair – only wild animals, no domesticated animals – not complete, e.g. bear, horse is missing
Meyer 2002	West European mammels	primary hairs	+ new method with computer assisted measurements – no domesticated mammals – primary hairs only included in measurements and pictures – medulla described, but no LM photos – medulla description not exact, e.g. „granulated" missing (cattle)
Chernova 2004	mammals	primary hairs	+ world-wide, large body + longitudinal & cross-section with medulla – no domesticated animals – no underhair
www.furskin.cz	mammels	all	+ arge body of mammals + skins as well – not always the important views – no discussion of similarities to other animals – no LM – no cross-sections

4.2 Insectivora

4.2.1 Common mole *(Talpa europaea)*

4.2.1.1 Habitat

In the underground tunnels and fertile soils of forests, grasslands and pastures; habitats do not include the acidity of bogs or sandy soils.

4.2.1.2 History

Moleskin has a velvety texture but a poor fur quality. The dense and straight fur has nevertheless been much appreciated, especially in the Modern Period. Aristotle reported that moles had a thick skin (Arist. Hist. An. 4,8). In classical Greece they were sold on the Athenian market most probably as pelts and in addition to fox and otter pelts (enumerated, Aristoph. Ach. 887). Moleskins were used in antiquity for bed covers "*cubicularia*" (Plin. nat. 8,92). Right up to the 20th century there were still molecatchers making a living selling the skins. It was during these more modern times that the mole species was being imported into Europe from North America. Moleskins were made into tobacco bags, trimmings, collars, muffs, bed covers and even powder puffs (Meyer's Konversationslexikon, Bd. 13, 460f.; Hauchecorne 1927, 444). With the introduction of the modern sewing machine during the 1890's, the use of moleskin expanded further as a feature of textile fashion. Fine leather parts could be sewn without loss. The thickness of the skin made the use of these small animals possible but it took many to manufacture a single item. Ladies' muffs, for example, needed 40 skins; a coat about 600 (Hauchecorne 1927, 442ff.). By the first half of the 19th century moleskin had become a term unto itself for a specific textile, one of a heavy linen/cotton fabric (linen warp, cotton weft, then only cotton) with pile on one side and in some cases with a very dense warp and weft (German: *Barchent*).

A record of the pelt market in London near the turn of the 19th century stated the trading of one million moleskins. In reaction to this and to prevent the extinction of the species, Bavaria forbade the killing of these animals beginning in 1920.

4.2.1.3 Fibre properties

Moleskin is a dense, silky and dark coat with underhair (8–15µ) and guard hair (up to 40µ). The medulla is a uniserial ladder with fibres that are round to oval. The guard hair becomes flat and broad towards the tip, a feature which prevents dirt from penetrating the skin. There is no clear direction to the fibres, with vertical and single fibres being in the follicle – moles walk both forward and backward which keeps the pelt density consistent (Toldt 1928). The scales are also not symmetric; a longitudinal division of the fibre will show one half having petals and the other smooth horizontal margins (*Fig. 147*). This is a unique fibre type not seen on any other animal, making the mole easily detectible among animal fibres. As a purely functional property, this fibre type bends easily which helps keep the animal clean in its underground existence.

4.2.1.4 Archaeology

Up to now, moleskins have not been found in archaeological material.

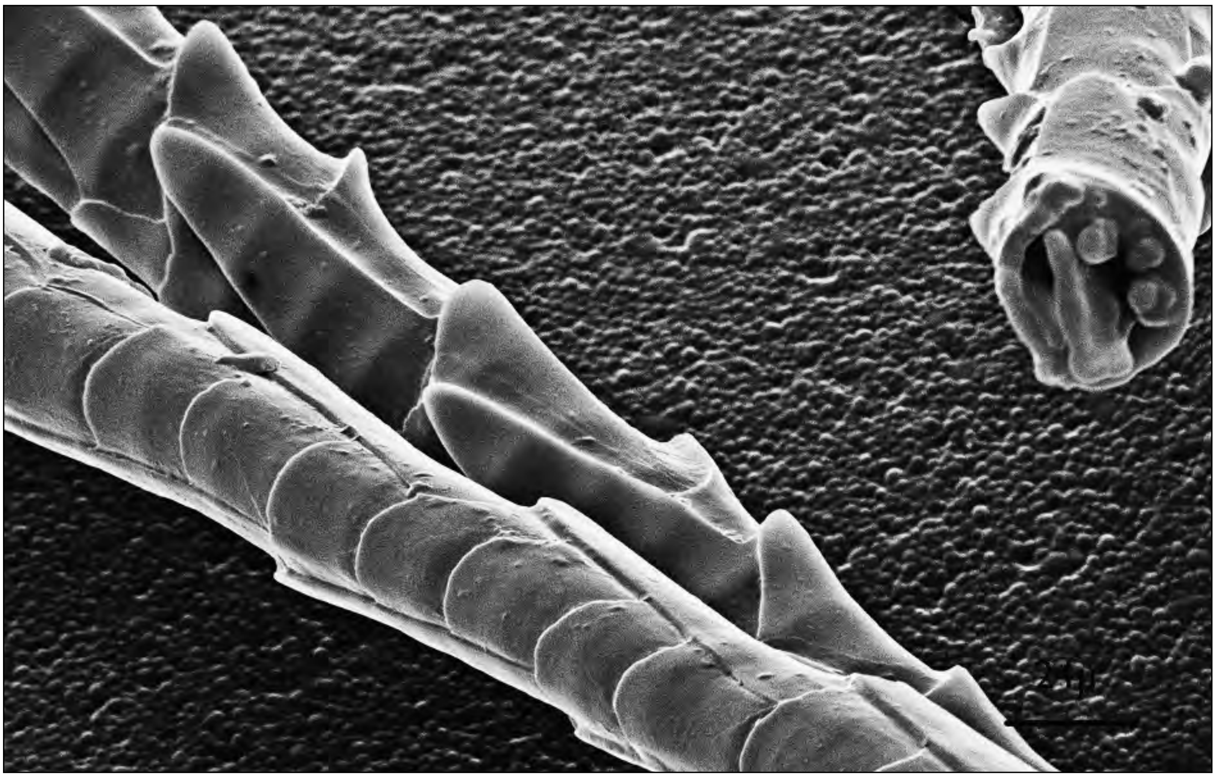

Fig. 147. Fibres of Talpa europea, modern

4.2.2 Desman *(Desmana moschata and Galemys pyrenaicus)*

4.2.2.1 Habitat

The desman belongs to the mole family and is adapted to a semiaquatic environment.

The Russian Desman *(Desmana moschata)* lives in Russian rivers, feeding on shellfish and insects. In certain regions of Russia, the desman has been overtaken by the newly introduced muskrat (Scoptsov 1967). Building construction, pollution and illegal fishing have all contributed to the disappearance of this animal (Pryde 1986).

The Pyrenean Desman (*Galemys pyrenaicus*) lives in the Pyrenees, in mountainous areas from northern Spain to Portugal and in small mountain rivers up to 1200 meters. It was made nearly extinct by the proliferation of minks that had escaped from a farm. The Pyrenean Desman has never been important to the pelt market (Franke – Kroll 1976, 244).

4.2.2.2 History

In the Medieval Period the desman was highly praised and sold as “silver bisam” (German: *Silberbisam* or *Bisamspitzmaus*: Meier’s Konversationslexikon, Bd. 17, 1909, 275). Their skins were used for linings and trimmings. What was especially important was the white-silvery belly which, unlike usual skinning procedures, was cut from the middle of the back (Franke – Kroll 1976, 243).

4.2.2.3 Fibre properties

- *Galemys pyrenaicus* has 3 types of fibres: woolly underhair (dm. 10µ, elongated scales), straight guard-hairs (dm up to 135µ) and bristles (up to 150µ which are broader towards the tip). The broad and flat distal part of the kemp fibre without medulla differentiates the Pyrenean Desman from the mole (Talpa europea) (Poduschka – Richard 1985).
- *Desmana moschata*: Fine fibres of dm. 10–15µ show irregular cross-section and scale pattern along the shaft; medulla with uniserial ladder. Coarser fibres 30–60µ with horizontal lines and fine rippled towards the tip. Fine fibres with horizontal scales, petal or diagonal petal patterns. Primary hairs of dm. 60–90µ, oval to flat cross-sections and mostly without medulla (*Fig. 148*).

4.2.2.4 Archaeology

To date, desman skins have not been found in archaeological material.

4.3 Rodentia

4.3.1 Fat dormouse *(Glis glis)*

4.3.1.1 Habitat

Forests up to 1500m, hedges, gardens with trees.

4.3.1.2 History

The Romans kept and fattened the dormouse in so-called *gliraria* (Varro rust. 3,2,14). The Roman cook Apicius wrote down a recipe for the filled and grilled meat of *glires* (Apicius 1981, Nr. 397). In the Medieval Period dormouse enclosures are no longer known (Zeuner 1963, 415), except in Venice where the pelts were often used and the meat eaten (Delort 1978, 168). The skin was of less good quality than the grey squirrel but it was nevertheless incorporated with the more expensive furs (Krünitz 1773–1858, "Siebenschläfer").

4.3.1.3 Fibre properties

Brown to grey, primary hair (dm 25–70µ), smooth scale margins, coronal arrangement, interrupted uniserial ladder type medulla with rounded spaces and granular filling, cross-section oval/elliptical. Fine fibres (dm 12–25µ) with straight margins (*Fig. 149*).

4.3.1.4 Archaeology

In the 10th century grave of Starigrad/Oldenburg (D) a fur has been documented as being in the sheath of an iron knife, probably used to hold the blade fast within the sheath (Gabriel – Farke 2003, 171).

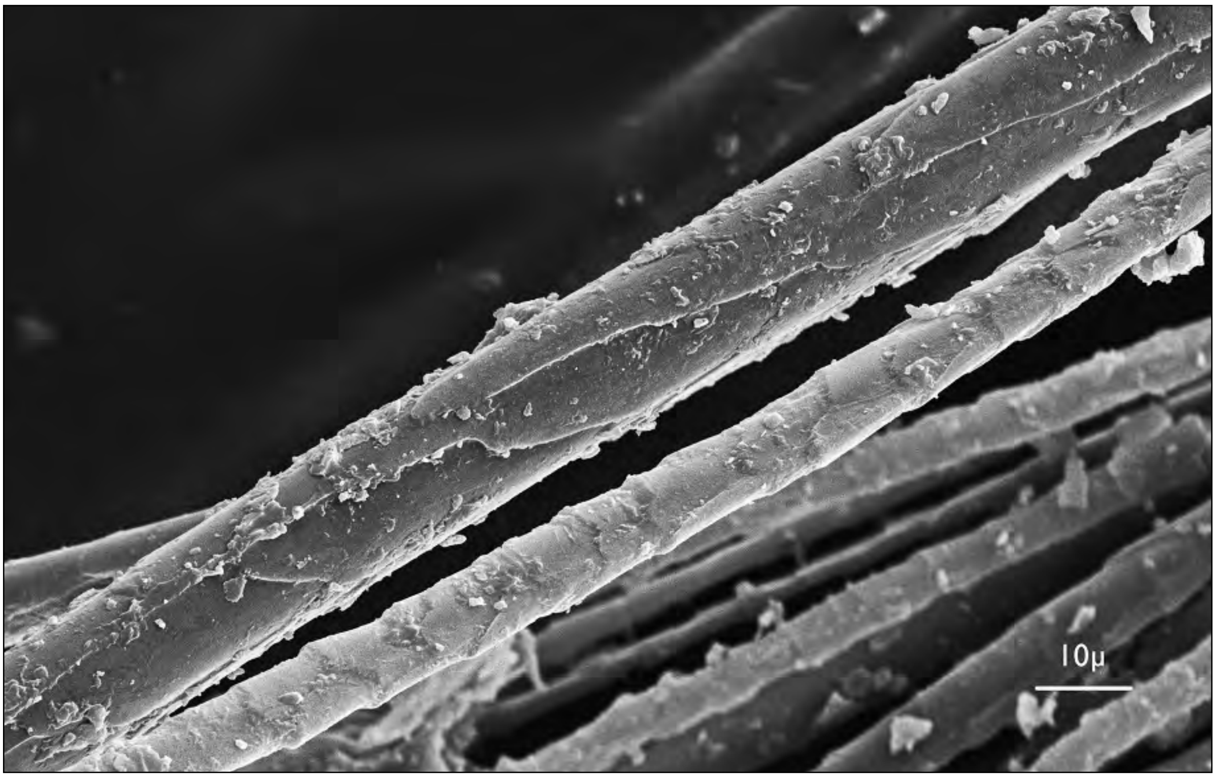

Fig. 148. Fine fibres of Desman moschata, modern

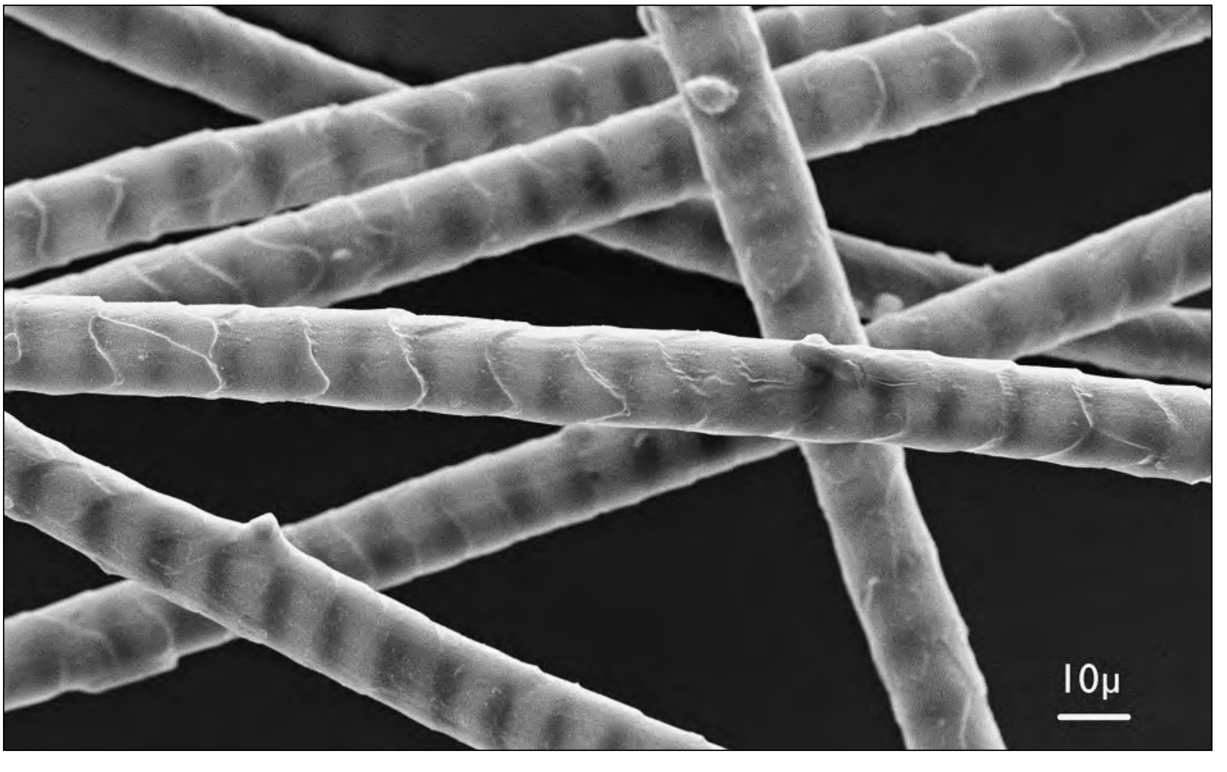

Fig. 149. Fibres of the flat dormouse.
The uniserial ladder type medulla can even been seen on the SEM photo

4.3.2 Mouse *(Mus musculus sp.)*

4.3.2.1 Habitat

In buildings during cold months, in fields during summer.

4.3.2.2 History

According to the history of domestication, mice came from India and followed the domestication of plants. It is assumed that grain storage attracted the animals (Driscoll *et al.* 2009). Together with mice, cats arrived as well (s. chapter 4.5.23).

4.3.2.3 Fibre properties

Brown-grey fur, dm of primary hair 30–50µ, medulla with fine irregular net, scale petals to coronal, smooth scale margins, fine fibres 8–15µ, with cornet-like to flat scales (*Fig. 150*).

4.3.2.4 Archaeology

Mouse fibres have been found in the glacier of Lenk-Schnidejoch (CH), found in a pellet spit up by birds of prey (eagle etc) (unpublished).

4.3.3 Red squirrel *(Sciurus vulgaris)*

4.3.3.1 Habitat

Squirrels are abundantly found in forests as well as in household gardens. A variant with grey-white skin, known as the "grey squirrel", lives in Scandinavia and Siberia.

4.3.3.2 History

The red squirrel is a most common animal with the fur of the Russian variant having been very much praised. The grey squirrel, with its grey back and white belly, was used for trimming and lining and was imported in great quantities from Scandinavia and Siberia to Western Europe (Davey 1895, 90; Delort 1978). It is not mentioned during the Roman Period. Early texts about the fur trade from Novgorod (RU) prove there was active hunting for these pelts during the Early Medieval Period. In the *Knytlinga saga* a merchant promises 8000 grey squirrels for King Knut of Denmark (Kovalev 2002).

In the Middle Ages, squirrel fur was called *"vair"* (French: *ménu-ver*, *vair, petit gris*; German: *miniver*); in Old English *graschynnene* (Owen-Crocker 1998, 37), and was used as an imitation for ermine (Mérindol 1992a; Reichstein 1986). Several qualities were distinguished from one another according to color and fibre quality. The pelts were sewn together in cup-shaped pieces, alternating the white and grey (the so-called *"klokwerk"* (German), *"vai da campanella"* (Ital.) (Delort 1978, 39). During the 11th century, squirrels were also sent from Novgorod to the Bishop of Paderborn (Kovalev 2002, 75f.). Archaeozoological records show a peak in squirrel trade during the 10th-11th centuries for Great Britain (Fairnell 2003, 32f.). The amount of squirrel pelts traded greatly increased between 1285 and 1288. King Edward I, for instance, bought 119'300 pelts (Dasler 2004). And in 1391 London (GB) imported 350'960 squirrel skins (Etkind 2011, 167).

As for the type of textile being manufactured, Early Medieval depictions relay an alternate wave pattern, followed later by triangular shaped patterns. The alternating of grey and white colored fur was produced in heraldry or in blue-white triangle designs with other incorporated colors. According to 12th century depictions (e.g. in the Bible of Cîteaux) squirrel fur was used in the linings of coats and as tunics made entirely of fur. The colored garments of nobles as seen on the Bayeux tapestry, for instance, may depict such fur tunics (Phoenix 2010, 196ff.).

In Early Modern times Russian pelts were sold by the thousands and divided into four qualities (Krünitz 1773–1858, "Fehe"). In the Late Medieval and Early Modern Periods sumptuary laws classified squirrels as being for garments for women or the lower classes (Zitzelsperger 2010, 177). *Feh-Haube* (in German) means a specific hat worn by women in Regensburg (Germany) (Krünitz 1773-1858, "Feh-Haube"). Garments for royalty or the upper classes needed a large quantity of pelts: for one coat, Charles VI or Louis d'Orléans (F) needed as many as 4500 squirrel pelts for a final product weighing 8–10 kg (Delort 1978, t1, 294)!

In Norse mythology, the squirrel Ratatosk was the messenger, running up and down the holy tree Yggdrasil between the eagle (in the sky) and the serpent (on the ground). In Irish mythology the goddess Medb and the squirrel on her shoulder were the messengers between earth and sky (Sax 2001, 33).

4.3.3.3 Fibre properties

Winter fur is blue-grey on the back, white on the belly. Primary hair 25–100µ, scales coronal to single chevron, medulla net-like with large round spaces, cross-section oval to reniform; fine fibres dm 8–15µ, aster-like cross-sections, scales with raised edges, uniserial ladder type medulla in fine fibres, multiserial in larger fibres. The medulla is important to differentiate from hare; the scales have shorter chevron than hare (Keller 1980) (*Figs 151* and *152*).

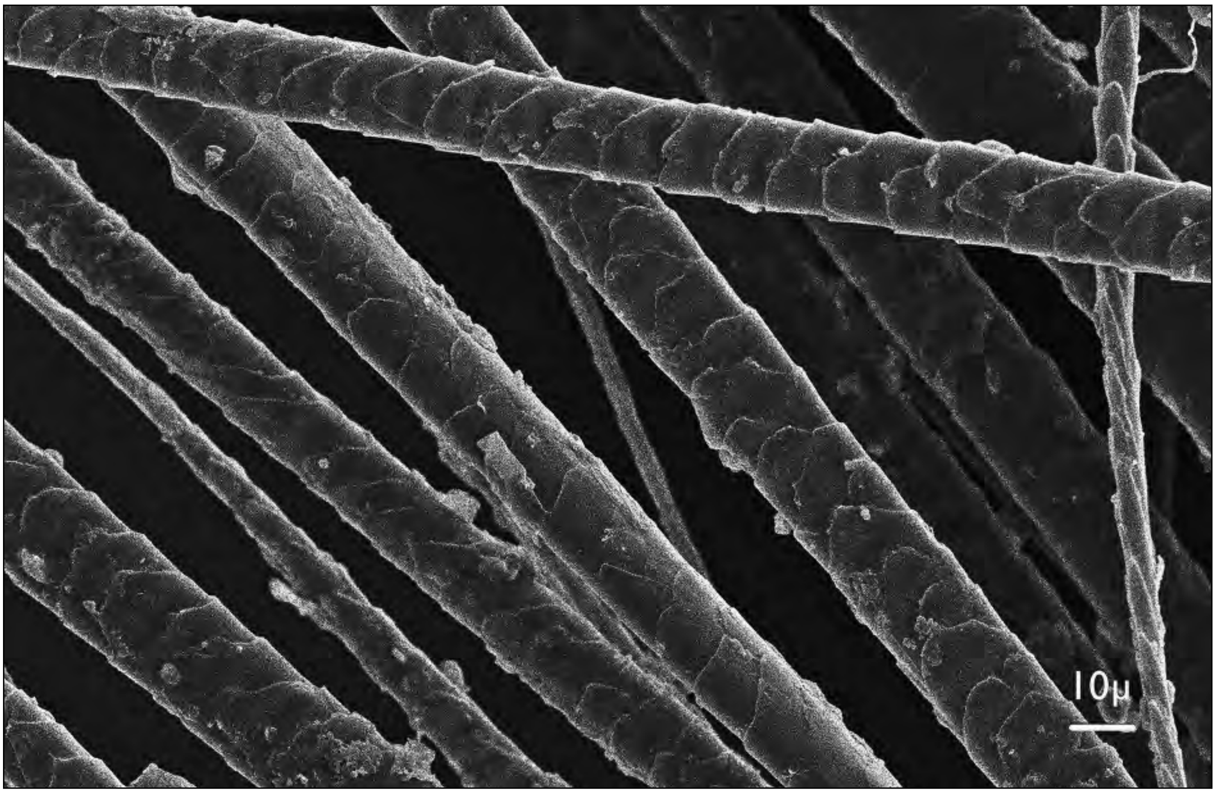

Fig. 150. Fibres of a mouse (Mus musculus?), modern

4.3.3.4 Archaeology

Indirect proof for a coat (or at least a trimming) of squirrel skin dated to the Mesolithic Period has been found in Italy (Liguria). Bones from 400 squirrel tails were found in a child's grave, in the vertical axe of the body (BERNARDINI 1978, 54). In Pazyryk (Altai, RU), grey squirrel has been found at the back of a coat (Olon-Kurin burial 10; MOLODIN *et al.* 2009). The kaftans of rich men from Moščevaja Balka are often lined with squirrel (IERUSALIMSKAJA 1996, 47; 151, Kat. 139). Squirrel has been found in grave 507 of Birka (GEIJER 1938).

4.3.4 Long-Clawed ground-squirrel *(Spermophilopsis leptodactylus)*

4.3.4.1 Habitat

Iran, central Asia.

4.3.4.2 History

The long-clawed ground squirrel (German: Zieselmaus) was not a primary pelt in Russia, but often used and sold as very solid skin for garments and sacs (SCHWENTNER 1953; FRANKE – KROLL 1976, 171). According to travel reports of the 18^{th} c., the animal was often kept as a pet in Russia and Siberia (STÅHLBERG – SVANBERG 2011, 365).

4.3.4.3 Fibre properties

Yellow-brown or grey winter pelt, primary hairs up to 100µ, scales round or single-chevron, wide medulla, cross-section round to flattened (tip); fine fibres 7–25µ, ladder-type medulla.

4.3.4.4 Archaeology

Up to now, skins have not been recorded in archaeological material.

4.3.5 Marmot *(Marmota marmota)*

4.3.5.1 Habitat

Alpine regions 800–3000m, high pasture.

4.3.5.2 History

Even today, marmots are hunted for their meat and the oil they produce – the latter is sold in pharmacies as an anti-rheumatic ointment. The pelts did not have much importance (DELORT 1978, 133), although it has been used for bags, hunting sacs and hats (KRÜNITZ 1773–1858, "Murmeltier"; FRANKE – KROLL 1976, 168).

4.3.5.3 Fibre properties

Fibre diameter 70–120µ, underwool 10–15µ, medulla with wide lattice and round spaces, unserial ladder. The scales have regular to irregular wave forms (*Figs 153* and *154*).

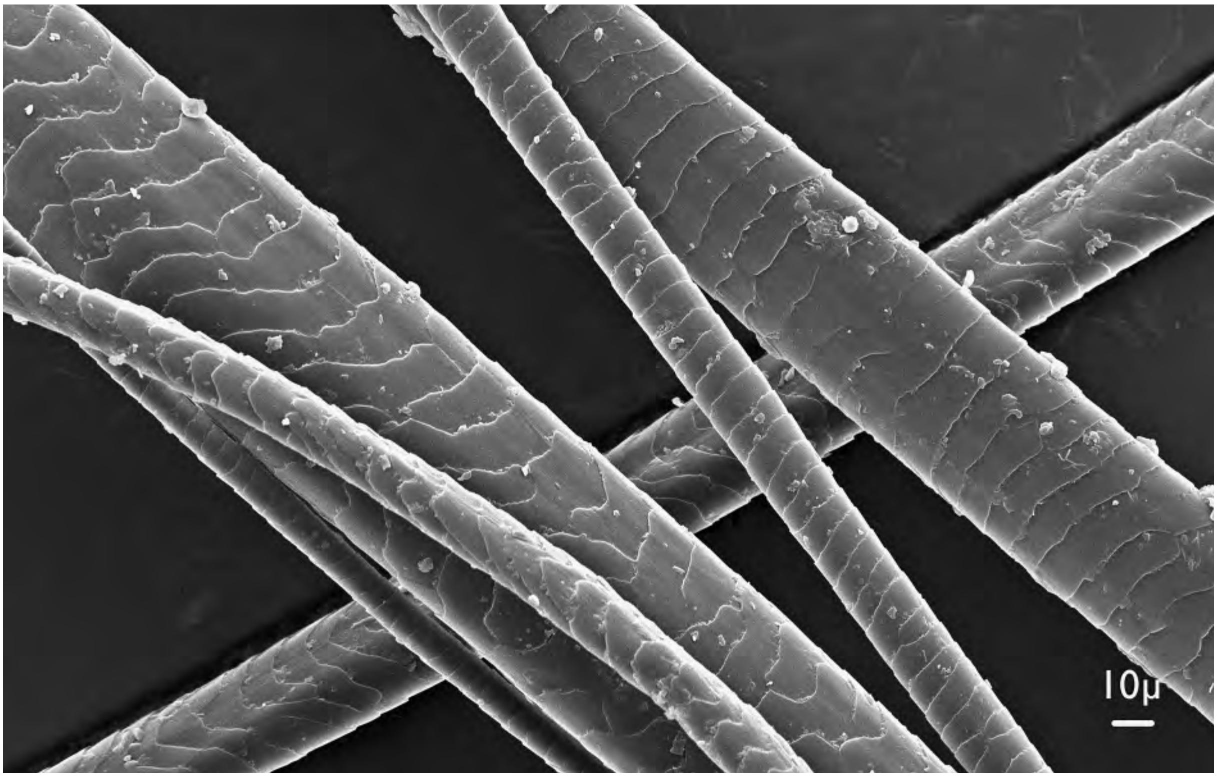

Fig. 151. Squirrel fibres

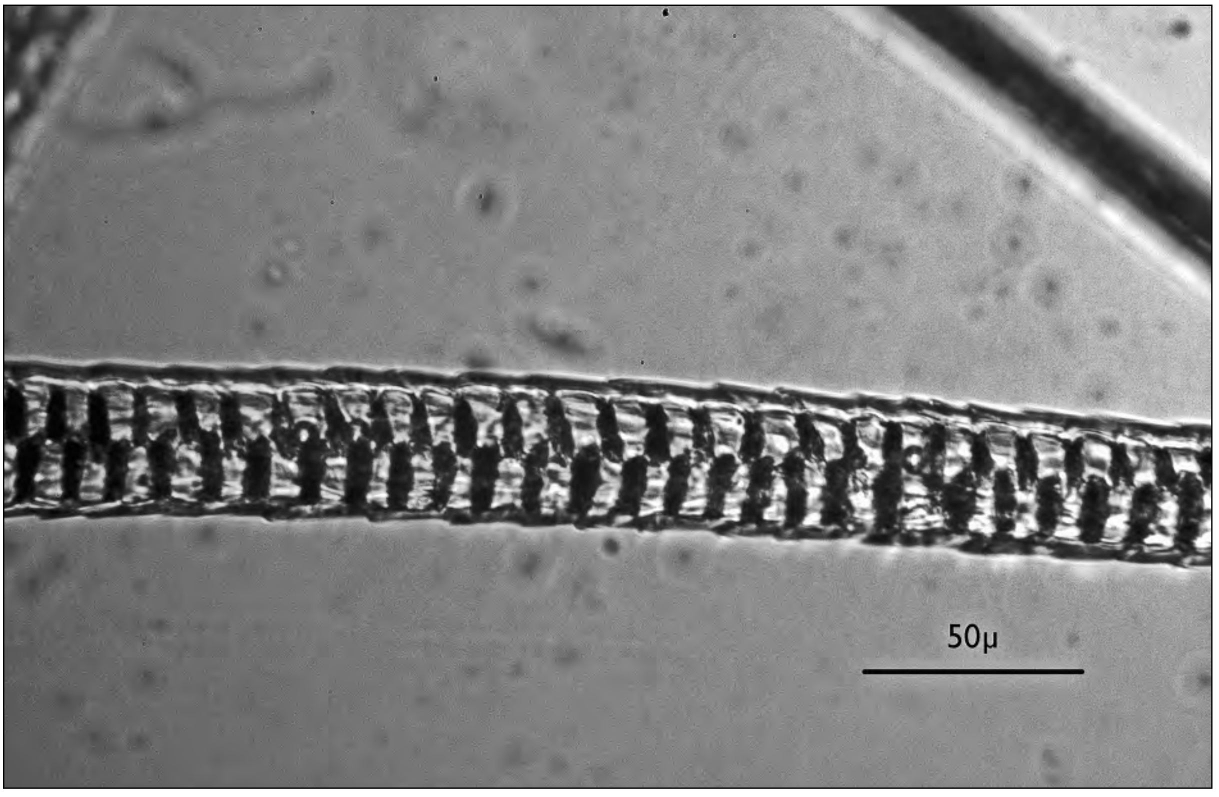

Fig. 152. Squirrel fibre, medium size with multiserial ladder medulla type

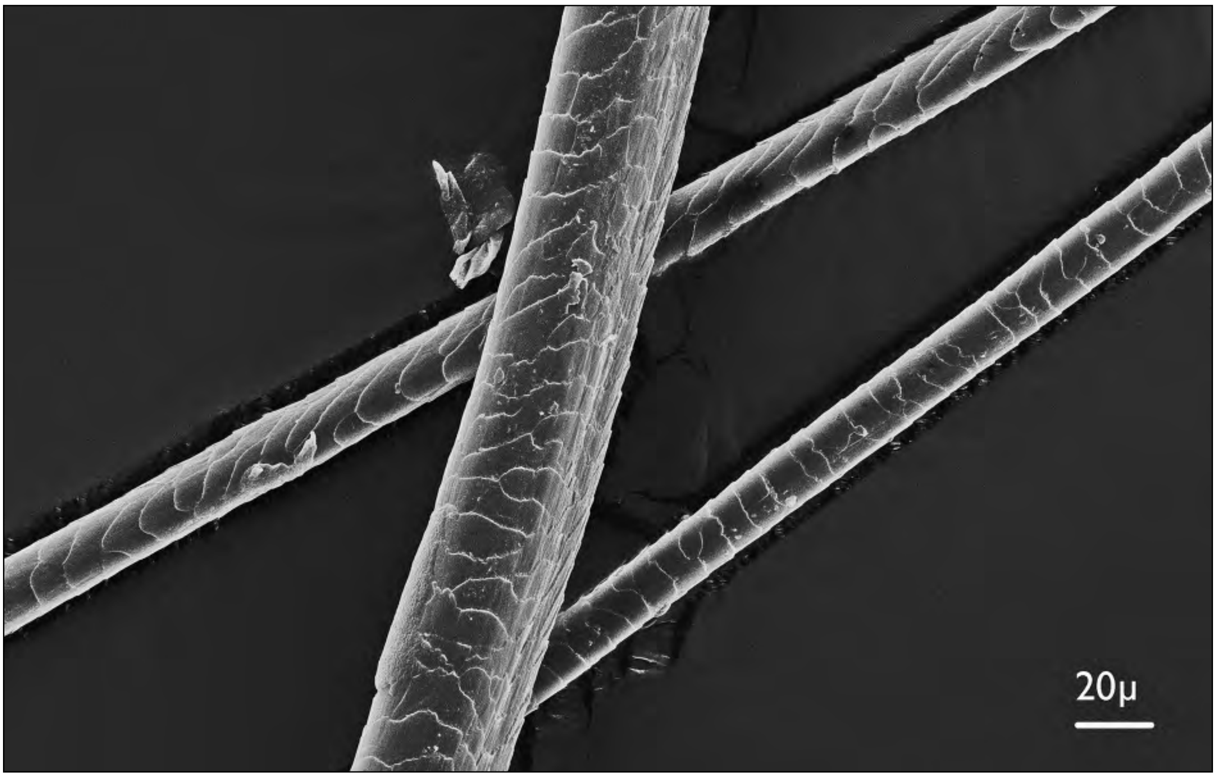

Fig. 153. Marmot fibres, modern

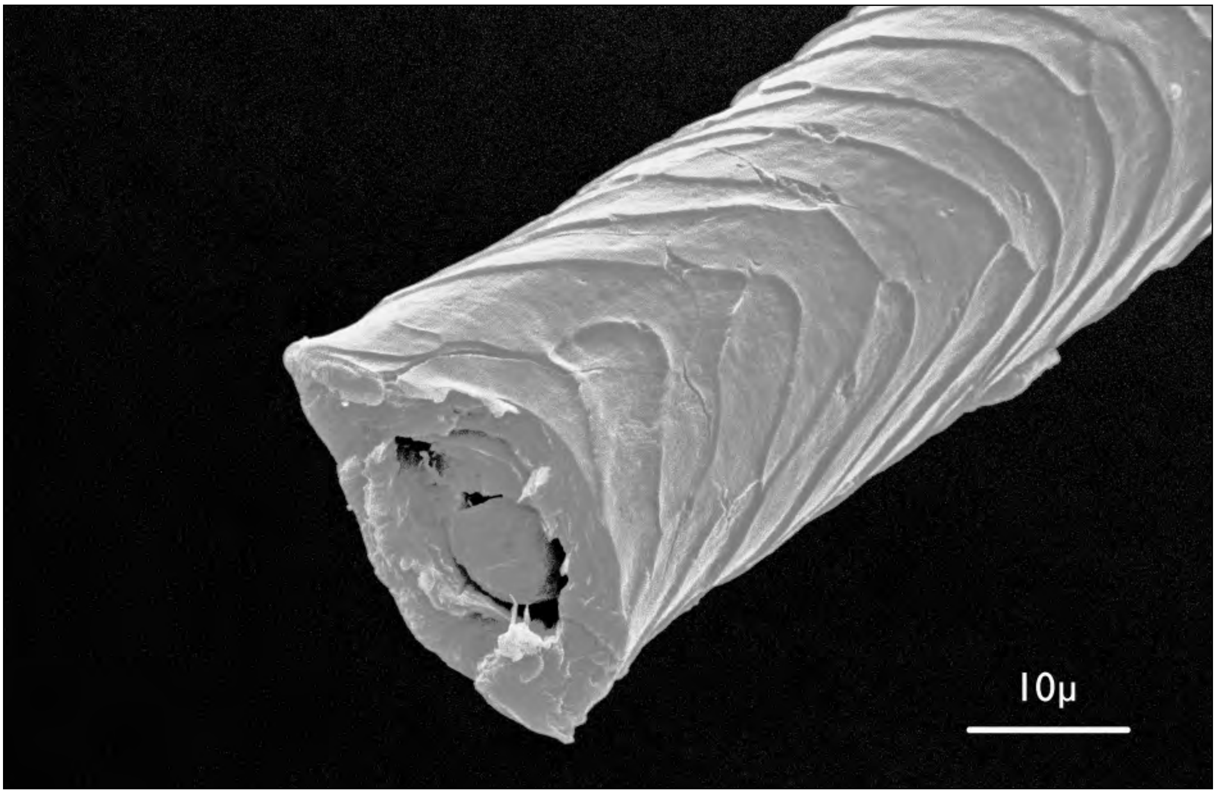

Fig. 154. Marmot fibres with cross-section, modern

4.3.5.4 Archaeology

Marmot has been found in the Viking Age burial of Mammen dated AD 970-971 (Østergård 1991, 124). It has been mentioned by Østergård and Munksgaard (Munksgaard 1991, 152) and identified by Appleyard (information Lise Bender Jørgensen, January 2015). Marmot skin has been documented in a grave from Pazyryk, found in a coat together with sheep and sable skin (Olon Kurin, RU) (Jahresbericht DAI 2006, Fig. 4). Another analysis of this material, however, did not reveal marmot (Molodin *et al.* 2009).

4.3.6 Beaver (europ.) *(Castor fiber)*

4.3.6.1 Habitat

Semiaquatic rodent, living at slow or still water or rivers. Uses trees/vegetation to construct dams and lodges in the water. It is the only animal in Europe which causes considerable change to the landscape with its habitat construction.

4.3.6.2 History

The beaver is actually the largest rodent in Europe (Duval *et al.* 2011). The beaver has been hunted for meat and fur since the Paleolithic Period (Schmitzberger – Pucher 2003). Pelt quality was at its highest from December to March (Duval *et al.* 2011, 11). Certain Neolithic settlements contained remarkable amounts of beaver bones, Zürich-Mythenschloss (CH) being one with numerous small animal bones found ("squirrel, beaver, hare, hedgehog") indicating that they were hunted. Bones of lower jaws found in the Neolithic settlements of Twann (CH), Burgäschisee (CH) or Mondsee (A) show that they were employed as specific tools (Schmitzberger – Pucher 2003). Castoreum, a secretion produced by beavers from their consumption of the willow tree, was used as medicine – it apparently contained a compound similar to salicylic acid and was employed as a pain reliever (Kitchener – Conroy 1997, 104). Today it is still used as an extract in the perfume industry (Duval *et al.* 2011, 12). Herodot reports on the *Budinoi*, a nomadic people living near the Skythians north of the Black Sea at the river Tanais (Don), as hunting otters and beavers. The furs were sewn as fringe on their skin garments (Hdt. IV, 109). In Etruscan culture, specialized hunts for beavers were practiced (Wilkens 1999, 144). In England, a "beaver-clan", the *Bibroci,* was known, which may have been a remnant of Celtic totemism (Caes. Gall. V, 21).

Ever since Antiquity, the beaver has been mentioned as a source of fur or textile fibre, with the Latin name being either *"fiber"* or "castor" (*Table 2*). According to Claudianus, beaver fibre was woven as *"birrus"* into the Gallic coat – a special variant of fibre which cost six gold coins:

Claudianus, Carm. min. 10

De birro castoreo

Nominis umbra manet veteris; nam dicere birrum,
si Castor iuret, castoreum nequeo.
Sex emptus solidis! Quid sit, iam scire potestis:
Si mihi nulla fides, credite vel pretio.

It is an enormous amount for a garment owing to the fact that – as a contemporary of Claudianus states – one solidus makes a modest year‘s living, two solidi even a very good living (Cassian. Conl. 9, 5, 5). If we compare the price of beaver fur (*“pellis”*) in the Price Edict of Diocletian to others on the list, it clearly states that a beaver skin itself did not cost a lot. It must have been the processing of the textiles that made the difference (Mommsen – Blümner1893, 124). Ambrosius, Bishop of Milan in the 4th century AD, and Isidor, Bishop of Seville at the end of the 6th /7th century, both talk of garments *“vestis”* rather than fur *“pellis”*. Ambrosius uses the word *“castor”*. Isidor, who lived in the Gothic part of Spain, uses the word *“fiber”* for the beaver (Castor fiber). Sidonius Appolinarius, Bishop of Clermond-Ferrand/F, is the only one who probably meant skin and not a textile. He laments about the Goths who are going to church wearing beaver skins. Nicephoros II wore a garment made of beaver fibre at his coronation in AD 936 (Gilroy 1853, 310).

Table 2. Written sources of the Roman Period with beaver clothing

Edict of Diocletian	ca. AD 300		pellis castorina
Ambrosius of Milan	339-397	De dign. sacerdot. 4	castorinas et sericas vestes
Claudianus	370-404/5	Carm. min. 10	birrus castoreus
Sidonius Appollinarius	431-479	Epist., Buch V, Brief VII	castorinati at litanias
Isidor of Seville	560–636	Orig. XIX, 12 (1-20)	fibrinae [vestis]

According to the Early Medieval Germanic law (*lex Alemannorum*) special dogs were trained for the beaver hunt. Teeth found in early medieval graves (e.g. Schleitheim-Hebsack (CH) grave 637) point to the apotropaic function of teeth (Burzler *et al.* 2002, Band 2, Taf. 77, Nr. 637.29). Ibn Hawqal, an Arabic writer of the 10th century, reports on the export of beaver furs from the Slavic countries to Spain (Ducène 2005, 218). In the Middle Ages in general, however, beaver pelts do not seem to be of first priority. In any case, a beaver skin cost 120x more than a lambskin (Delort 1978, 109). Kiev at this time was the center of pelt production, with beaver pelts being used often in Russian fashion, even until modern times. During the Middle Ages and Early Modern Period, beaver was also hunted for meat as the church allowed it, along with fish, as acceptable for meals during fasting days. Beaver fur was classified as one of the best fur qualities. In Russia there even existed a guild of the beaver hunter (Franke – Kroll 1976, 186). Beavers were either shot with blunt arrowheads or caught with a dig, net or steel trap, all so as not to damage the fur (19th c.) (Kovalev 2002, 148ff.). By the Late Medieval Period, beaver became ever more rare (in GB from the 12th c.; Fairnell 2003, 31) and their pelts began to be imported in great quantities from North America. Fur production for hats in Europe became especially important. High demand, in combination with changes in weather patterns that were detrimental to beaver habitats, eventually caused the beaver population to decline drastically in the Americas as well (Varekamp 2006).

Beaver fibre continued, nevertheless, to be used in later periods. Felting was one important use, having continued from a practice hundreds of years old. It is best described by Chaucer in his 14th century Canterbury Tales where a *"flaundryssh beaver hat"* (Chaucer) worn by a merchant exhibited his superior social status (line 272). The Jews had long worn high hats of trimmed beaver which was dyed black (Davey 1895, 10).

During Modern Times, beaver fibres were used most frequently in hat felts, but incorporated as well in knittings and textiles (Allaire 1999). The preparation of beaver fibres for use in textiles has been described in Modern Period texts. Treatment of the fur included soaking with mercury nitrate causing poisoning of the hatters ("mad as a hatter") (Varekamp 2006). Such processing difficulties caused the practice to be given up. Soon enough, the industrial spinning machine took the place of so many of the old methods (Rast-Eicher 2014).

4.3.6.3 Fibre properties

Beaver skin contains about 35‘000 fine fibres/cm², a number which is only topped by the otter. *Fig. 155* shows how the fine fibre bunches stem out from one follicle. These fine fibres (dm. 10µm) are round and show a characteristic scale pattern of small waves in the diagonal or horizontal direction to the fibre axe (*Fig. 156*). Beaver fibres are readily recognizable by this distinct wave structure. Medium fibres, (dm. 60 um) have a scale pattern with irregular waves with the large fibres being elliptical and showing rippled waves (*Fig. 157*). The medulla is difficult to spot by light microscopy as the fibres are strongly pigmented (brown/dark brown) (*Fig. 158*).

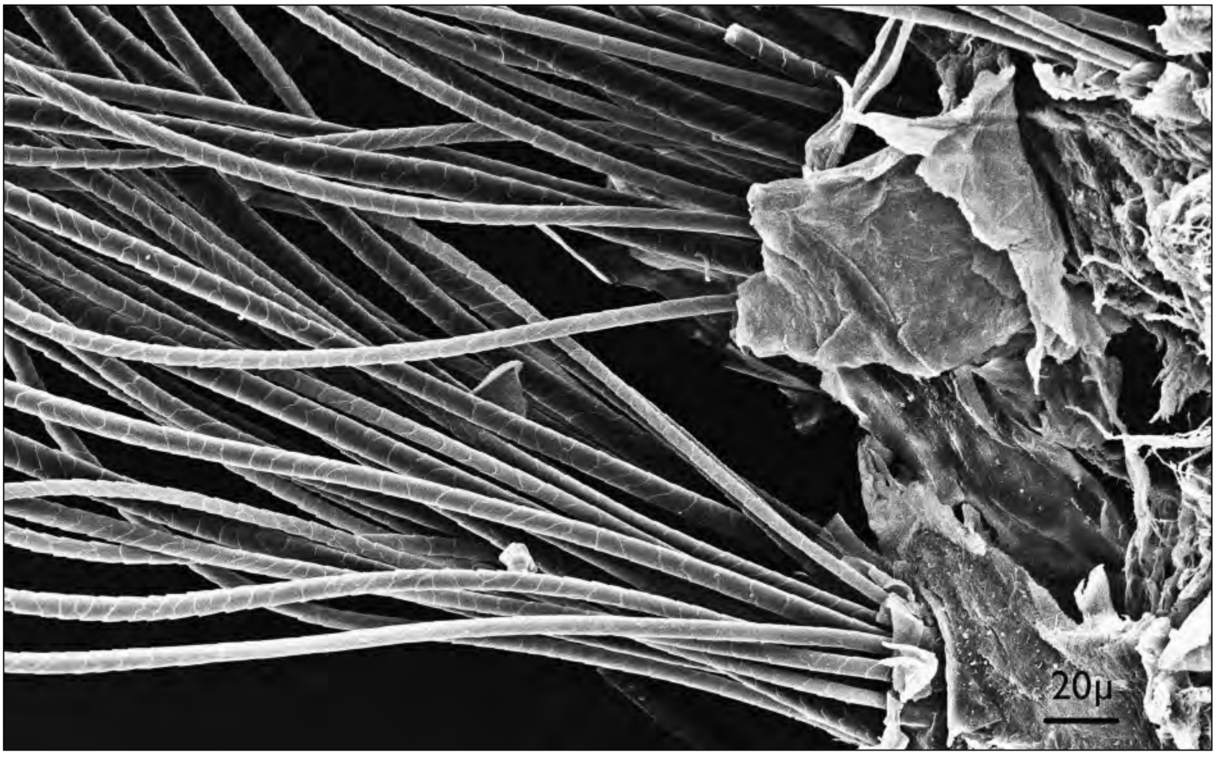

Fig. 155. Fine beaver fibres emerging out of the skin (follicle), modern

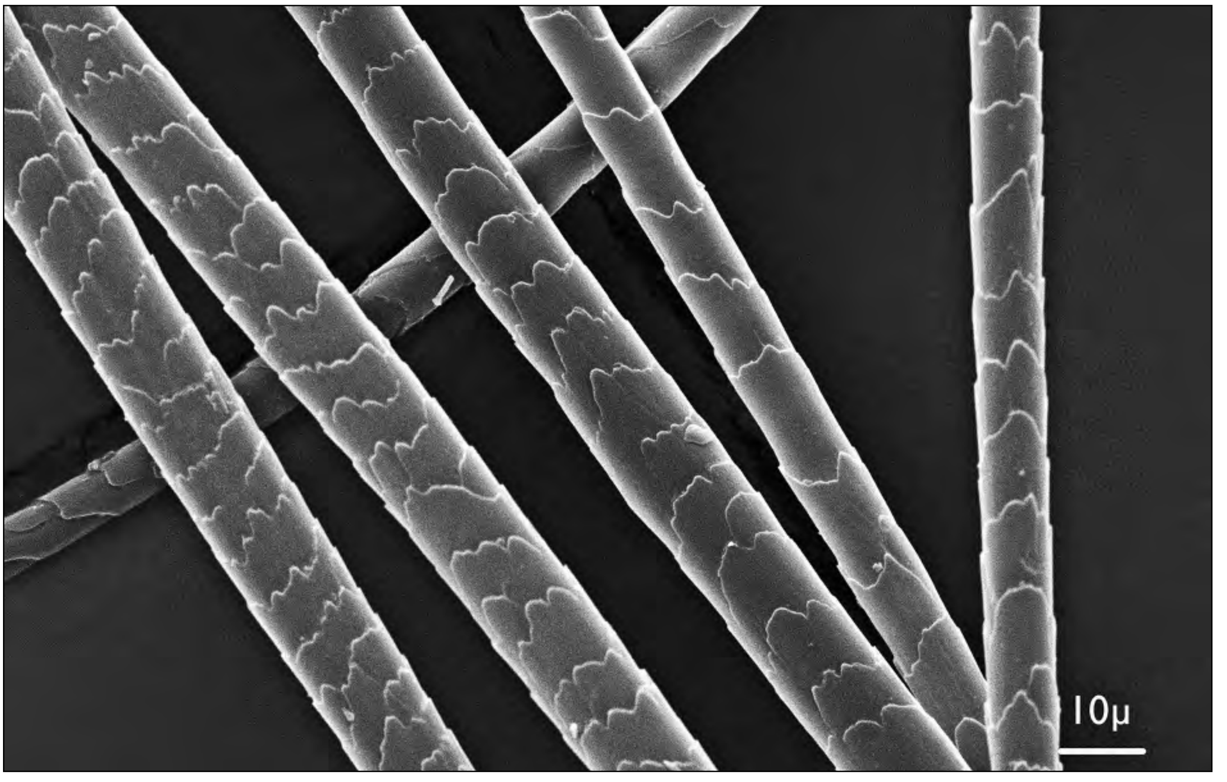

Fig. 156. Fine beaver fibres, modern

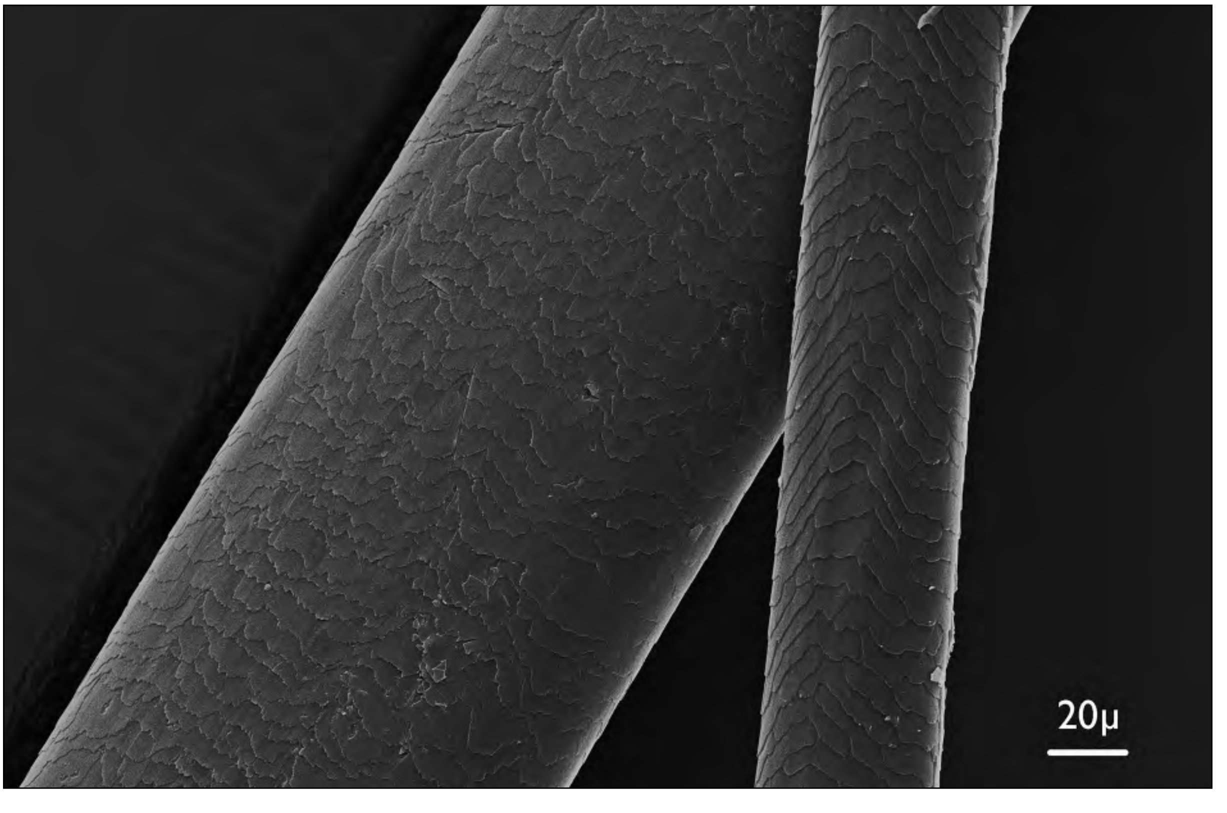

Fig. 157. Coarse and medium beaver fibre, modern

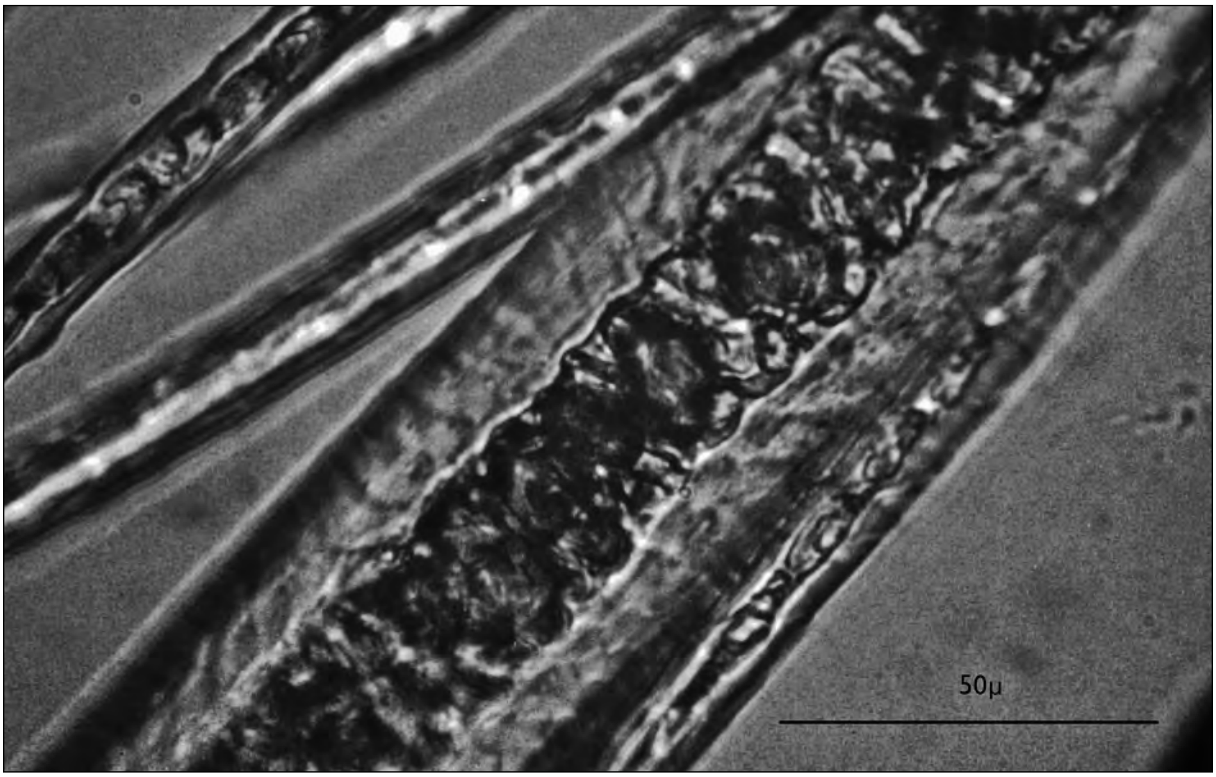

Fig. 158. Beaver fibre seen by light microscopy, modern

4.3.6.4 Archaeology

Key find

Thus far, the only known textile made from beaver fibre is that which has been found in the grave of Queen Arnegundis († 580/581) in Saint Denis/Paris (F). Up-to-date analysis of the textile in 2006-2009 gave proof of this, its placement being second from the top after the linen shroud (Rast-Eicher – Périn 2011; Rast-Eicher 2014). It had been described previously by Albert France-Lanord in analysis from the 1950's as felted (*"pelucheux"*) (Fleury – France-Lanord 1998, 156, Fig. 25). It appears to be felted – fine fibres cover the surface – which is also an appearance that can come about when a garment is very much worn. Initial inspection did not attract special attention. Something, however, seemed suspicious about it, especially as no color had been detected. Fibre analysis at the time showed a unique kind of fine fibre which was not recognizable as something used with blended yarns. Later analysis under the SEM also could not match this fine fibre to other speciality fibres; it was not clear if the scale pattern had been compromised due to deterioration. Thanks to a medium fibre that could be analyzed the animal species was found to be beaver (*Fig. 159*, see also *Fig. 157*). Fine fibres with the aforementioned typical wave structure had been found in several other samples (*Fig. 160*). An additional sample was then needed to check if it was fur or a blended textile yarn, and it turned out to be a blended yarn with wool. Written sources were also found, confirming that the ancient Romans knew this type of garment well (see *Table 2*). One poem, written by Claudianus, even made it clear that it was used for a *"birrus"* (see above).

Other finds

As with rabbit, beaver has certainly been used for garments of skin and fur. In the Viking settlement of Birka (S), skins have been found in graves (Geijer 1976, graves 539, 619 on a fibula, 968). These can well be associated with what was at the time a large Northern European fur trade going extensively to Siberia. Medieval texts report that the Volga Bulgars, who were middlemen between the northern countries and the Islamic regions in the south, wore coats made of beaver pelts that were turned inside out (Kovalev 2002, 173). Another beaver skin – a bag in which a lyre was placed – has been reported discovered in a ship burial from Sutton Hoo (GB) (Carver 2007, 127).

4.3.7 Brown rat *(Rattus norvegicus)*

4.3.7.1 Habitat

Close to water (sea, river, sewage tunnels) and to humans (in cellars, garbage).

4.3.7.2 History

The brown rat is a bearer of many pathogens and it is thought to have been the main source of plague bacteria. These were transmitted by rat fleas and as yet unknown in the Europe of the time. In Modern Times selective breeding has led to laboratory/pet rats (albinos) and *R. norvegicus* does not seem to belong to the same species as *rattus rattus* (Wilson – Reeder 2005).

4.3.7.3 Fibre properties

Primary hairs are of a dm. 50–120µ, underhair 15–25µ and longer fibres have a flat tip. Scales of the primary hair petal are in the basal area, then there are smooth waves up to the tip. The medulla ladder type is found around gas pockets. Tips of the under-wool are transparent with successive brown pigment; primary hairs are black.

4.3.7.4 Archaeology

Rat skin or fibre use is not known in an archaeological context.

4.3.8 Black rat *(Rattus rattus)*

4.3.8.1 Habitat

In settlements, houses, stables.

4.3.8.2 History

The plague was first thought to have originated in Central Asia but it proliferated in Europe. The black rat (*Rattus rattus*) and the brown rat (*Rattus norvegicus*) were endemic to both areas and were known in the Roman and Anglo-Saxon Periods (remains from Roman and Anglo-Saxon archaeological layers having been found in York in the UK (Dobney – Harwood 1999, 379). Recent investigations indicate that the probable origin of the bubonic plague was in Egypt. The Nile rat (*Arvicanthis niloticus*) was a primary host for the carrier flea as was the later, newly introduced *Rattus rattus.* The plague has been described in written sources from the 5th century B.C. (Thukydides) and late 6th century (Procopius), as well as from the middle of the 2nd millennium B.C. (according to recent finds in a workman‘s village in Amarna, Egypt) (Panagiokatopulu 2004).

As with mice, rats were deemed to have both a good and evil reason for being. On the one side, ancient fables would depict these rodents as abettors in freeing both humans and animals. On the other side they were responsible for the fouling of the floors and walls of houses. The medieval tale of the piper of Hamelin, having been recounted by the Grimm brothers and others, takes place in a village where rats become so numerous that the villagers are obliged to call the piper, who leads the rodents with his pipe to the river where they drown. When coming to collect payment from the villagers, they refuse, and so he picks up his pipe once again only this time he leads the children into a mountain (Sax 2001, 203f.).

The discovery of the plague bacillus in rats by Alexandre Yersin in 1894, put the rat definitely on the "black list".

4.3.8.3 Fibre properties

Primary hair up to 120µ, under-wool 10–20µ and medulla with uni- or multiserial ladder, depending on its place in the fibre (basal, medium, tip). The scales of the pH are wavy to rippled; short fibres have petal scales in the basal area (*Figs 161* and *162*).

4.3.8.4 Archaeology

No rat skin or fibre use is known.

4.4 Lagomorpha

4.4.1 Introduction to hare and rabbit

There are three types of lagomorphs living today in Europe: the rabbit, *Oryctolagus cuniculus*, and two other species, *Lepus europaeus* and *Lepus timidus*. The ancients did not differentiate between rabbit and hare and were not often aware of the biological differences (see ch. 4.4.2.2). It wasn't only the overall appearance of these animals that was similar but also the minute fibres having qualities so alike that they can hardly be differentiated. Even the finest fibres are medullated, which is quite unusual among the textile fibres. The ladder-like medulla with air chambers can hold substantial amounts of air, thus sustaining more warmth. It is for this reason that the blended yarns of modern textiles have rabbit fibres mixed in with other fibres such as mohair, cashmere or fine sheep wool (Junges 1955; Wortman *et al.* 1989). Cotton can also mix with rabbit to enhance the thermal comfort of a fabric (Oglakcioglu *et al.* 2009). With all these blended yarns, rabbit fibres can be distinguished from cashmere and fine sheep wool as being medullated and not round (cashmere and fine sheep wool are non-medullated and round).

Rabbit and hare fibres are very difficult to distinguish from each other by scale pattern (see *Figs 163 & 167*). Their similarity is with the cuticle cells which show a single or double chevron pattern and sharp diagonals or, for larger fibres, a mosaic. The medulla structures show a slight difference, however, the rabbit medulla having the appearance of stacked cubes in a nearly continuous line on the side and the hare having a medulla structure consisting of disks with gaps in between (see *Figs 164 & 168*) (Lochte 1938, 235). According to A. Keller, there might also be confusion with squirrel (Keller 1980), even though squirrel scales are much less diagonal and the medulla is different (see ch. 4.3.3.3).

4.4.2.1 Habitat

Open land and sandy soils, forest borders, hedges, gardens.

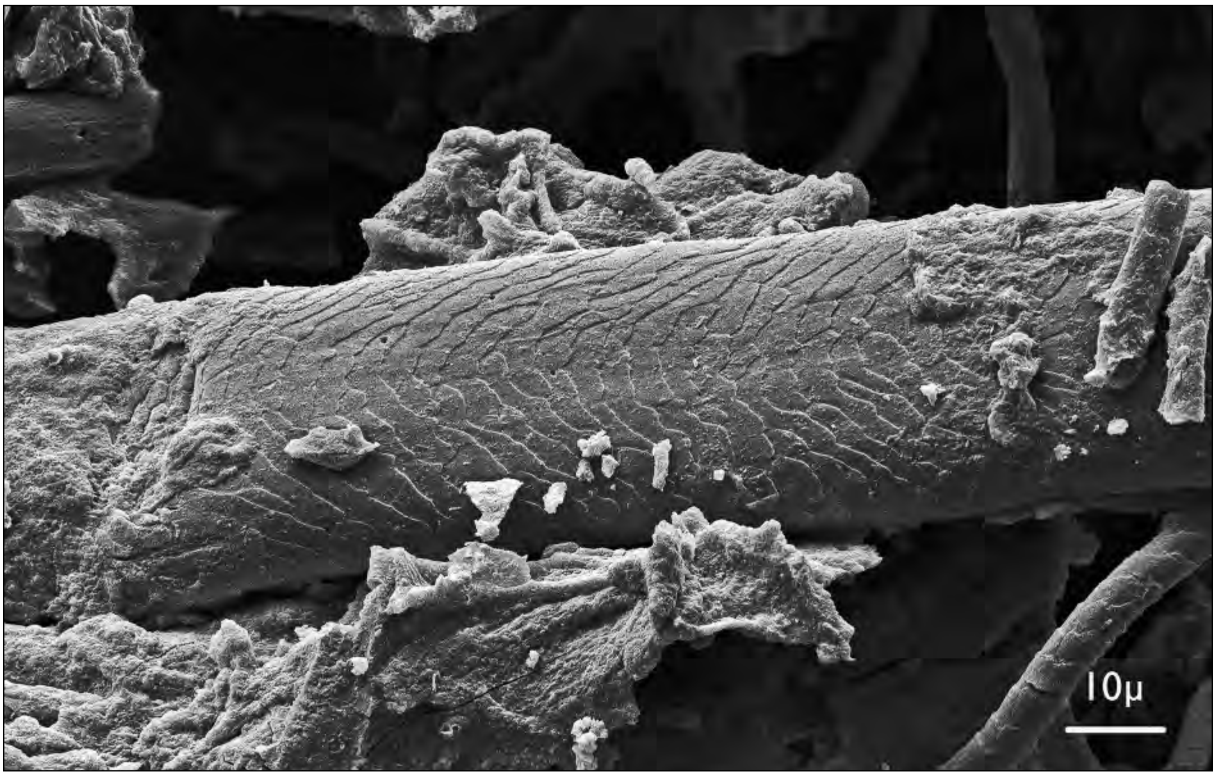

Fig. 159. Medium and fine beaver fibres, 6th c., Saint Denis/Paris (F)

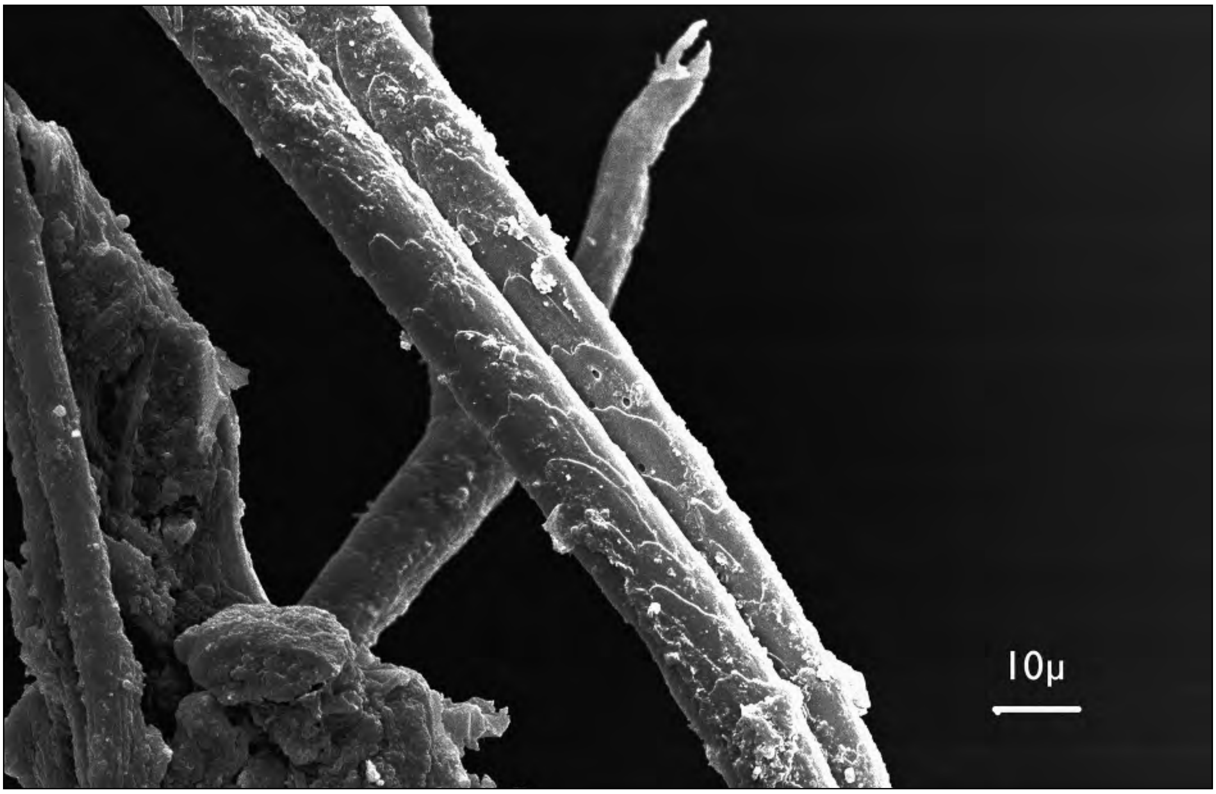

Fig. 160. Fine beaver fibres, 6th c., Saint Denis/Paris (F)

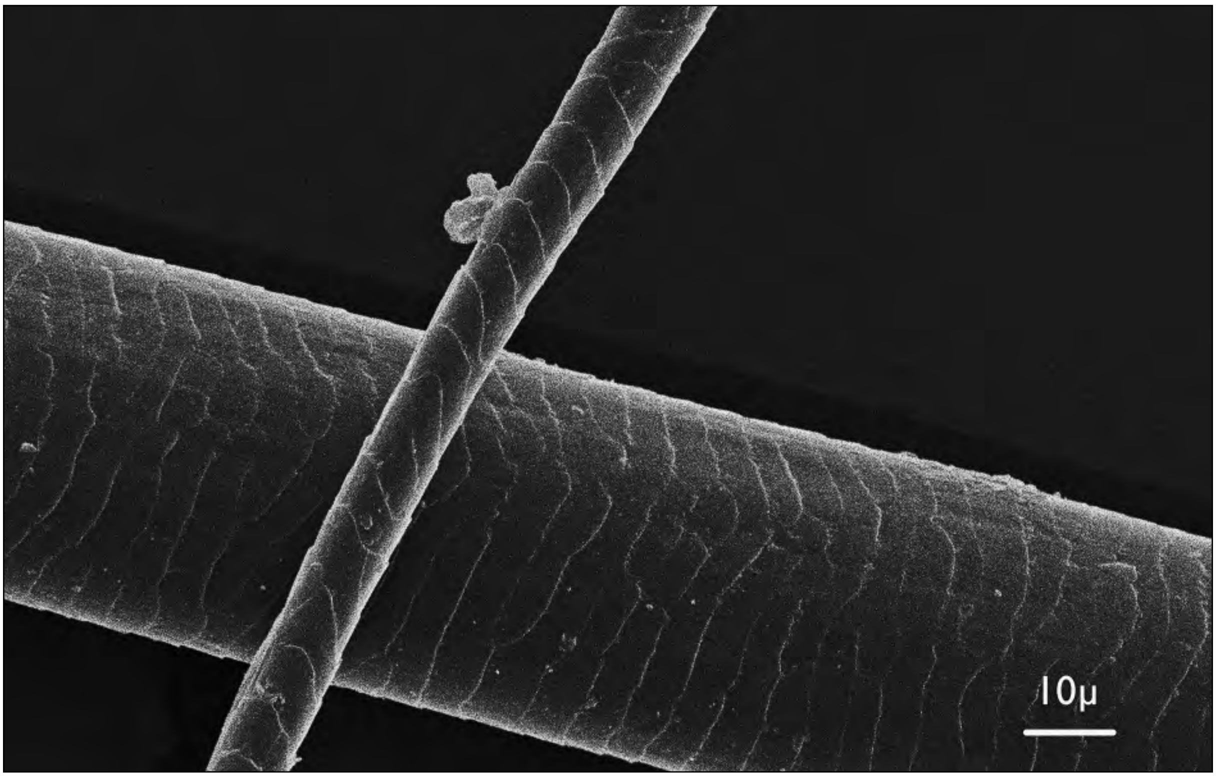

Fig. 161. Fibres of the black rat (Rattus rattus), modern, coarse and fine

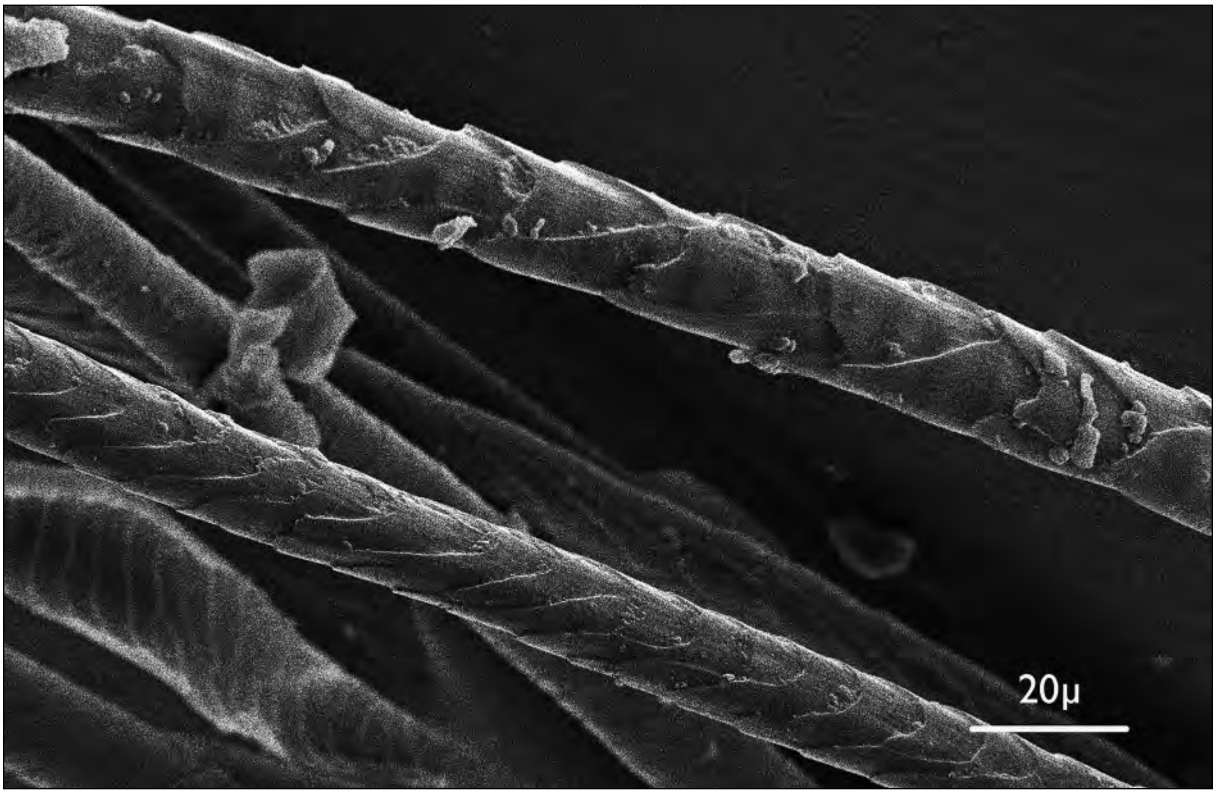

Fig. 162. Fibres of the black rat (Rattus rattus), modern, medium

4.4.2 Rabbit *(Oryctolagus cuniculus)*

4.4.2.2 History

DNA analyses have revealed that the rabbit species found its origins in Spain. Two lineages are the only survivors to be found in Western Europe today (Hardy *et al.* 1995; Monnerot *et al.* 1994; Lopez-Martinez 2008). The wild rabbit was hunted during European prehistory (Paleolithic to Neolithic) where it inhabited only Spain and Southern France. The species had retreated during glaciation in early Holocene and by the Classical Antiquity era. According to ancient Greek sources, it is not always clear if the Greeks differentiated between rabbit and hare – biological distinctions were confusing (Arist. Hist. An. 3,10,13; 4,28,3). Polybios (ca. 204 BC) records in his description of Corsica that there were foxes, wild sheep and rabbits (κυνικλοι). He marks a difference between rabbit and hare by stating, "At a distance it looks like a small hare, but when you take it in your hands there is a great difference between the two, both in appearance and in flavor; it lives for the most part underground" (Polyb. 12,2). It seems to be the first clear distinction in the ancient texts. However, osteological analyses have shown that no rabbits of the species *Oryctolagus cuniculus* lived on this island. It was, rather, another lagomorph that was then abundant on Corsica and Sardinia, the *Prolagus sardus* (a species that has now become extinct (Monnerot *et al.* 1994, 177).

According to Caesar, domesticated rabbits were farmed in Britain but not eaten (Caes. Gall. 5,12). Celtic people did not eat rabbit which might be explained by their totemism beliefs. It would not have been possible, in their eyes, to eat an animal which represented a clan (Birkhan 1997, 877ff.). The Romans kept rabbits and hares in *leporariae*, which are large enclosures (Varro rust. 3,2). There, they lived partly tamed but not wholly domesticated. Strabo reports (about 50 BC) that rabbits were very destructive in Spain and people began to hunt them by employing "wild weasels", or ferrets, from Africa (Strab. Geogr. 3,2,6). This practice using ferrets is also mentioned by Pliny the Elder (Plin. nat. 8,55). He relays as well that rabbit fibres were difficult to spin for textiles (he talks of *vestes* – garments), because of the short staple (Plin. Nat. 8,81(55)). In the Edict of Diocletian (ca. AD 300), rabbit/hare garments are noted, all of them belonging to highly priced textiles and fibres (Lauffer 1971) (*Table 3*). *Strictoria* were long and close-fitting undergarments. *Dursualis,* according to Blümner's definitions, are the fibres from the back of the animal (Mommsen – Blümner 1893, 156), a description which corresponds to the future quality controls of the Early Modern era for beaver fibres (see below). *Dalmaticamafortium* was a short coat originating from the eastern Adriatic region.

In the Early Medieval Period, rabbit meat was forbidden by Pope Zacharias (755 AD) to be eaten in his belief that it evoked erotic feelings. Regardless of this edict, the rabbit population had its most significant domestic increase, during the 9th-12th centuries (Monnerot 1994). They were kept in warrens for the noble class to hunt. Nets were employed as part of the sport with a mind to protect the fragile pelt (Delort 1978, 187). Rabbits were also kept in medieval monasteries, housed in hutches which enabled controlled breeding; the rabbit was now certainly domesticated and an important food supply. In 1309, the cost of a rabbit was as much as a piglet (Brehm's Thierleben 1883, 476–481). It was one of the few domesticated species in Western Europe and dissimilar to the type of domesticated animals found in the Near East. Rabbit bones have been found in Viking castles (Grand Besle, Normandie/F; Trelleborg, Tønder Amt/DK) (Benecke 1994, 360). In the Early Modern Period rabbit breeds began to exhibit different colors (Salaschek 2009, 10–39). Rabbits with silver hair (rather than the common brown) were first documented by Darwin and dated to 1631. The well-known Angora rabbit is long-haired due to a mutation that came about in the second half of the 18th century (Salaschek 2009, 26). Angora (long hairs) were brought by sailors to Bordeaux (France) in 1723 (Zeuner 1963, 414).

Rabbits and hares were then a symbol of fertility and the erotic (*luxuria*). In the Early Modern Period, the white rabbit appears in paintings of Mary (e.g. Tizian "The Madonna of the Rabbit", 1530, Louvre/Paris) being not only the symbol of fertility but of Mary's purity and virginity.

Table 3. Rabbit garments or fibres in Roman texts

Plinius nat.	23–79 AD	8.19	vestes leporino pilo
Edict of Diocletian	ca. 300 AD	19.73a	strictoria leporina durs[ulalis] un[ncias ...
id.		19.73c	dalmaticamafortium leporinum clavans [purpurae] po.unum semis
id.	25.11	ἐρέας λαγείας μιγῆς (lana leporina)	

4.4.2.3 Fibre properties

Rabbit and hare fibres have about the same diameters: the finer fibres measure about 10um, the coarser up to 30um. The scales show a typical diagonal, single or double chevorn-shape or horizontal waved design (*Fig. 163*). They are not round, except for the head (Keller 1980). These fibres offer some of the best insulation with a minimum of weight (Haigh 1946; Junges 1955; Van den Broeck *et al.* 2001). The Angora is well known as a speciality fibre (Vineis *et al.* 2011). Felt constructed with rabbit fibres is warmer, smoother and softer than that of camel hair or wool (Shakyawar *et al.* 2007). Rabbit fibre is usually medullated and typically uniserial to multiserial (*Fig. 164*; see also *Figs 167–170*). Medullated fibres hold air and therefore have very good thermal properties. On the other hand, medulla weakens the stability of a fibre (Junges 1955; Herrmann *et al.* 1996). Today's Angora breeds have no medulla in fibres below 10µm and are often used in wool or cotton blends (Oglakcioglu *et al.* 2009; Vineis *et al.* 2011). Modern studies show a considerable variation along the hair shaft of modern rabbit (Van den Broeck *et al.* 2001).

4.4.2.4 Archaeology

Key find

The cemetery of Kallnach-Bergweg (canton of Bern/Switzerland) was excavated in 1988/89. It is situated in the Swiss plateau, about 20 km north of Bern. In Antiquity this area was just near the Roman traffic axis from western to eastern Switzerland and was situated in a former Roman building that was used up until the Late Antique Period (4th/5th c. AD). The Early Medieval part of the cemetery comprises 150 graves, that date from the 6th to the 11th c. AD. with 46 of them containing objects. Ten of the graves proved to contain textile remnants which had been preserved by fibre mineralization (fibres can be preserved by being replaced by associated metal corrosion products). In cataloging these textiles, Christiane Kissling (Kissling – Ulrich-Bochsler 2006, 80) added additional documentation from using SEM analyses carried out in 1994 (Rast-Eicher 1996a, Fig. 1). Grave 42, containing a female and dated from the 7th century, wore an iron buckle with silver inlay and earrings made of bronze (Kissling – Ulrich-Bochsler 2006, 97). On the upper side of the buckle, textile remains have been documented. On top of a balanced linen tabby, another tabby was found that did not at first sight seem exceptional. Fibre analysis later showed it to be blended textile with wool (warp) and rabbit hair (weft) (Rast-Eicher 2014, Fig. 4) (*Fig. 165*). Luckily, the medulla structure of one fibre was visible, despite the fact that the epidermis had disappeared and the fibre was in fact metal-replaced; under this structure the mineralized scales were visible (*Fig. 166*). The medulla consisted of a stacked-cube-like chain. It can be best compared to the modern wild rabbit medulla and not to the hare (see *Figs 167–170*). It can be assumed, then, that the textile had been woven with rabbit fibre. The softness of the fabric indicates a weft thread and it does not seem to be a fibre blend. Ancient written sources, especially the Edict of Diocletian, make the interpretation of the garment as *dalmaticamafortium* a possibility (Lauffer 1971; see *Table 3*).

Other finds

An ancient Roman find has been reported from Pompeii (D'Orazio 2000, 748, Fig. 3) and fibre on the figure does not show the diagonal scales which are typical for lagomorphs. John Peter Wild mentions rabbit hair from Basel (Switzerland; Wild 1970, 19).

In a grave from Bülach (canton of Zurich/Switzerland), a woman of wealth belonging to the elite of the 7th century is entombed in the church there. From her clothing a fibre with a typical diagonal scale pattern for rabbit/hare has been found. The remnants of the cloth belong very probably to the leggings as it was found with fasteners. Unfortunately, only one badly preserved fibre was visible and so has to be treated with utmost caution (Amrein *et al.* 1999, 92f.).

Rabbit was not only used as textile fibre, of course, but also as fur. An example is a skin that has been documented from a 7th century grave in Flurlingen (Switzerland) which was found under a girdle plate, deposited between the legs of the deceased. The SEM image shows the identifying diagonal scale pattern (Bader *et al.* 1999/2000, 108, Fig. 30a). The shoes of the German Queen Gisela (989–1043) were found to be made of a mixed textile of silk and rabbit (Meissner 2011 with comment by Rast-Eicher, 2015). Two important finds coming from burials in Las Huelgas (E) are one, a lining from the garment tunic of Fernando de la Cerda († 1275) and another, a lining from the surcoat of Eleanor of Castile († 1244), both of which are made of rabbit skin (Kania 2010, 294; 426).

4.4.3 Hare *(Lepus europaeus)*

4.4.3.1 Habitat

Wide spread, prefers open land together with hiding places (hedges, trees).

4.4.3.2 History

As mentioned, the ancient Greeks did not know the difference between the hare and the rabbit (see also the chapter on rabbit). An interesting fact is that the two species are incompatible and will tend to fight one another with the rabbits usually being the stronger combatant (Zeuner 1963, 409).
The symbolic meaning of the hare is very old. Already in the Neolithic Period they were placed in votive or burial depots, probably honored as a symbol of fertility. But their increased presence in Neolithic graves has been interpreted as due to an expansion of open landscape (Schmitzberger 2009, 42f). In the fables of the Greek Aesop, the hare is a trickster. In "The Tortoise and the Hare" there is a race; the hare is so confident of winning that he wastes time and fools around while the tortoise, walking at a slow but steady pace, ends up arriving at the finish line first.

Pliny the Elder stated in the 1st century AD that hares were capable of superfoetation (Plin. nat. 5,81). In Christianity, the hare has been a symbol for the vigilance of God. A depiction for this can be found, for instance, in the Gothic era Dome of Magdeburg (D) (Postmann 1997). Carvings in wooden chairs there depict three hares hiding between the sleeping apostles. The depiction of three hares with conjoined ears arranged around a central point is a symbol of the Trinity (interestingly composed of three animals of the same species!). Such a symbol is depicted in the Dome of Paderborn (D) where three hares with conjoined ears run in a circle. This is a very old motif, having been found in 6th c. Buddhist depictions of the Silk Road as well as on medieval coins (Whitfield 2004, 15). Stemming from the 17th century, the hare has become a symbol for Easter.

4.4.3.3 Fibre properties

Hare has not often been used as its skin is not durable. On the other hand, arctic hare and especially rabbit is much stronger (Delort 1978, 129). The fibre properties are very similar to the ones of rabbit and squirrel (see chapter 4.4.2): multiple ladder medulla in larger fibres and the strongly diagonal structure with single or double chevron of the scales are characteristic (*Figs 167–170*).

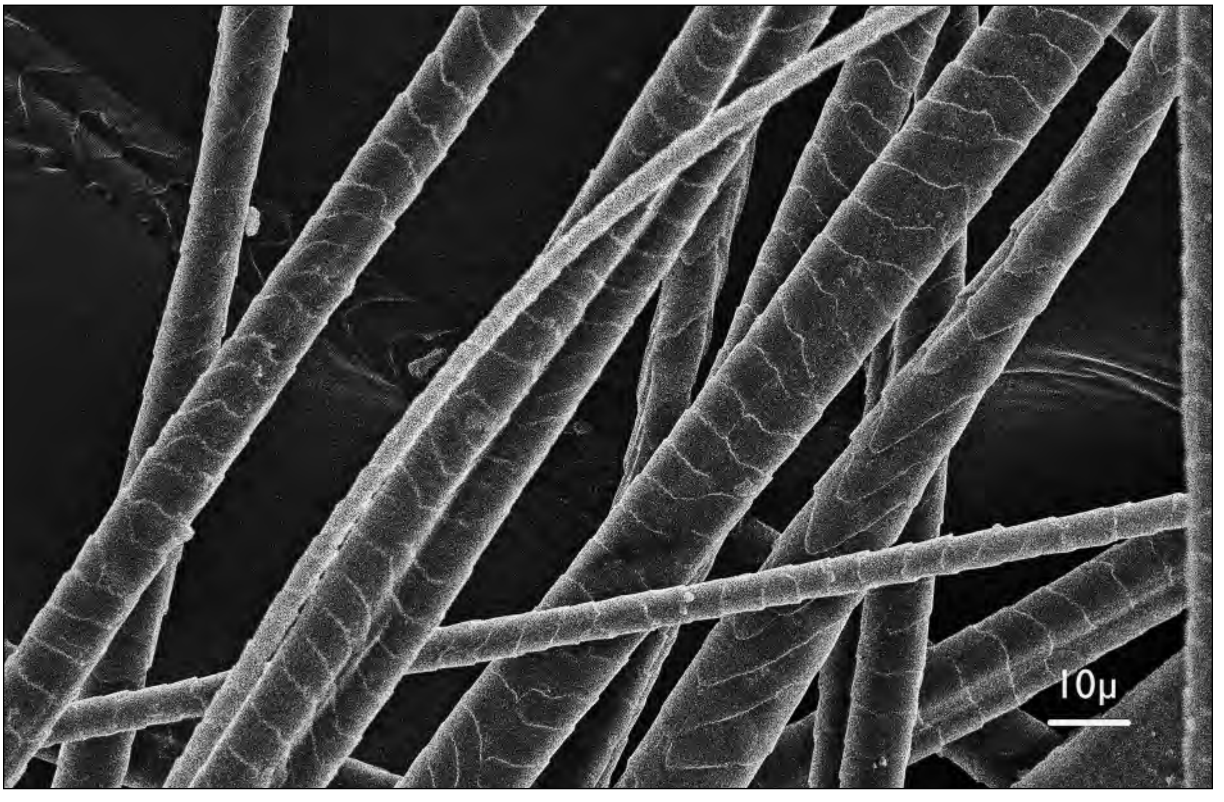

Fig. 163. Rabbit fibres, modern

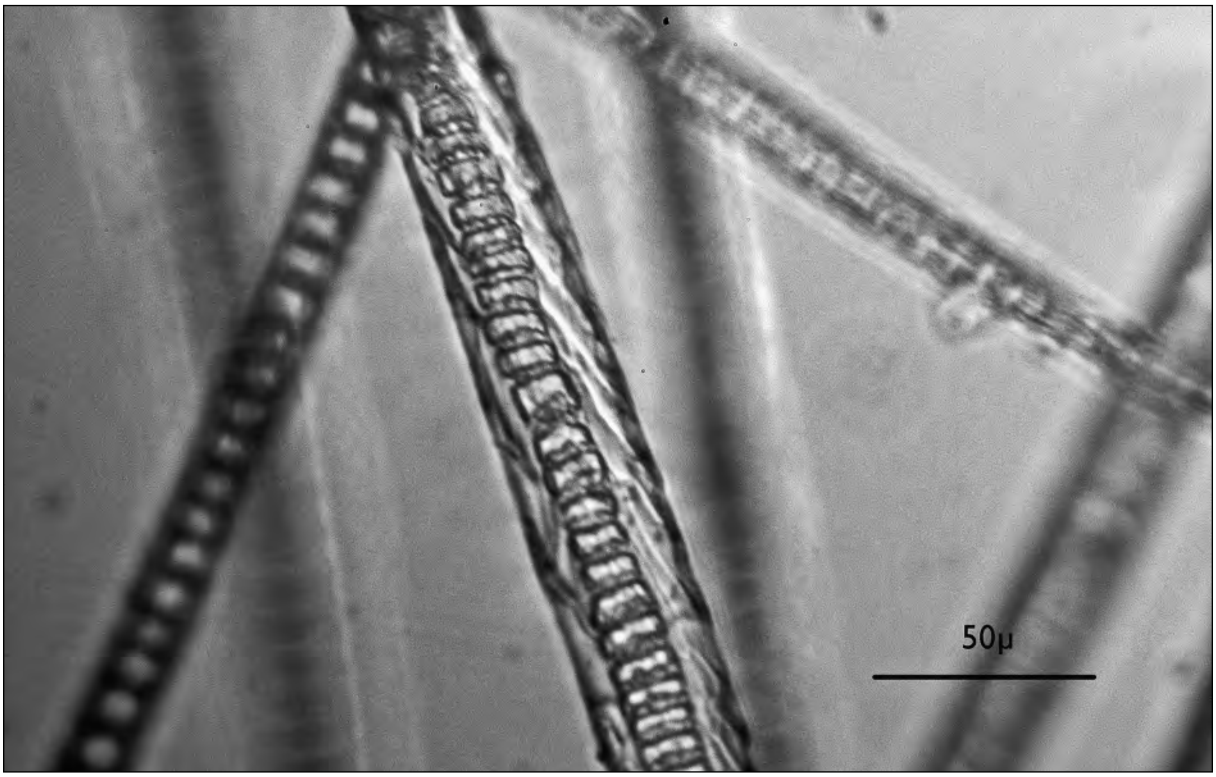

Fig. 164. Rabbit fibres, modern, seen with the light microscope

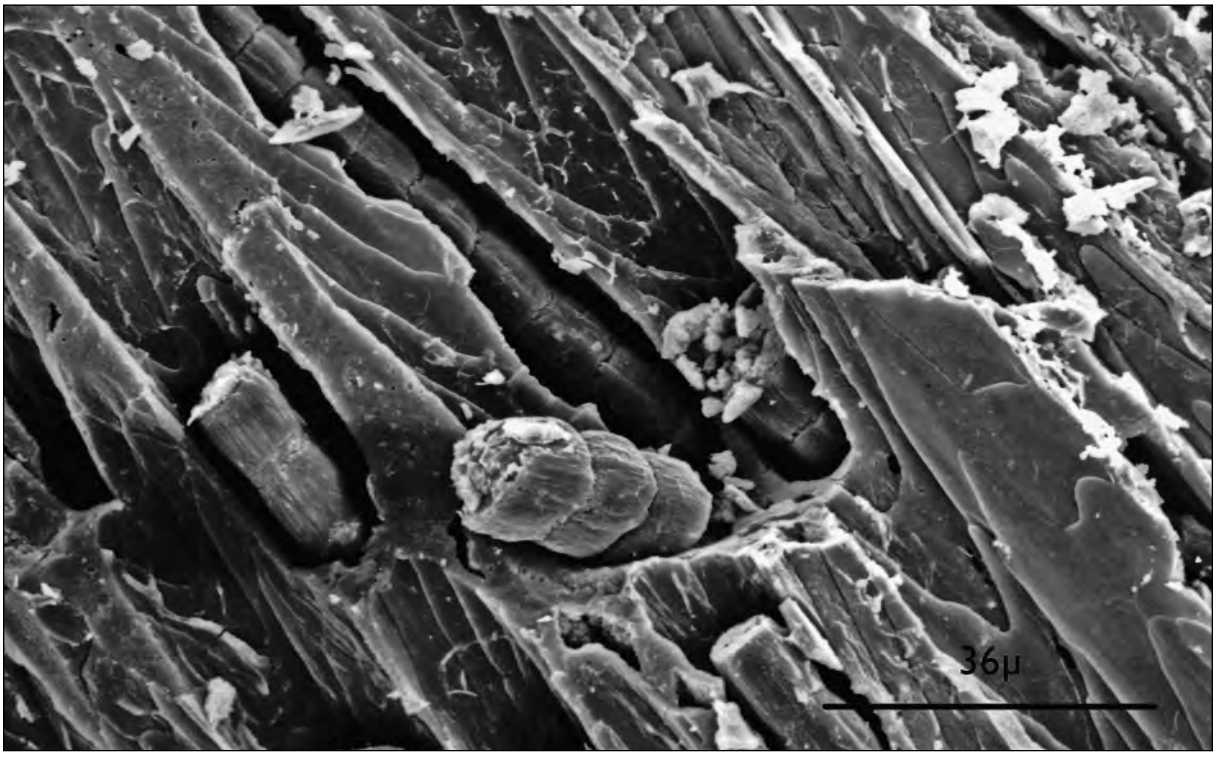

Fig. 165. Rabbit fibres found in a 7th c. textile of Kallnach (CH)

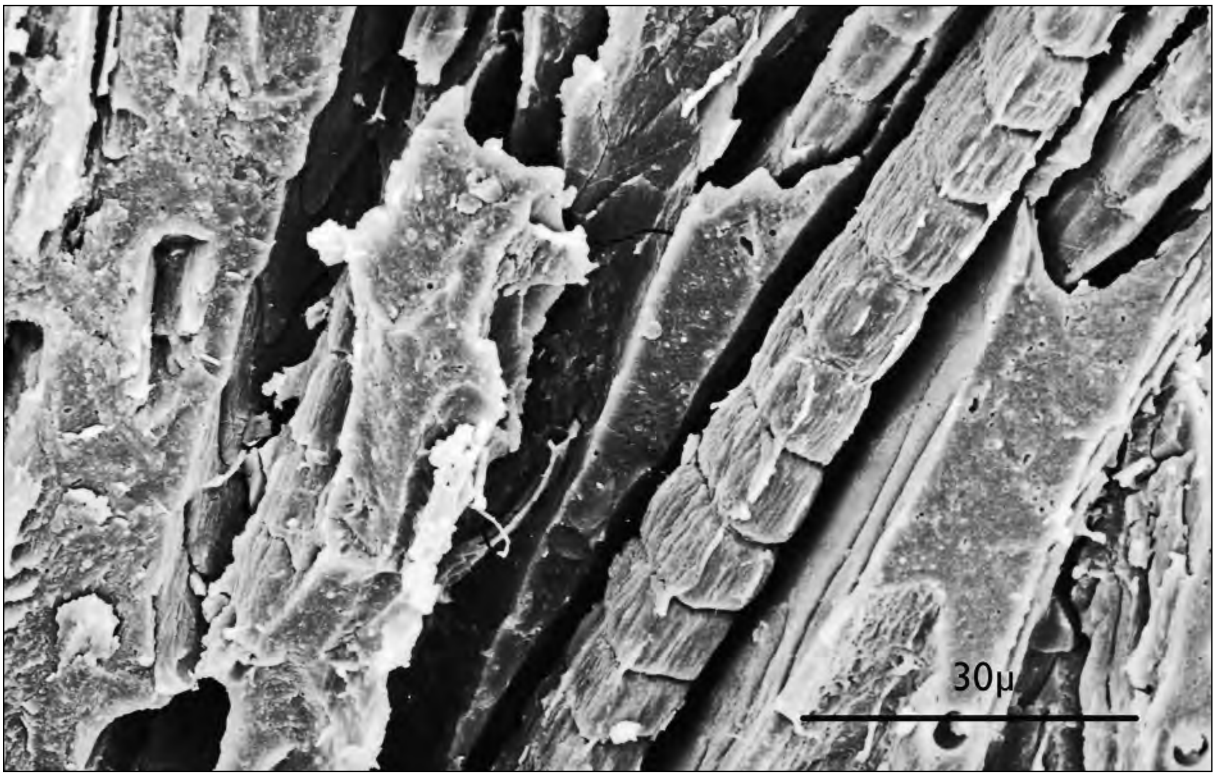

Fig. 166. Rabbit fibres found in a 7th c. textile of Kallnach (CH), detail with remains of the ladder type medulla

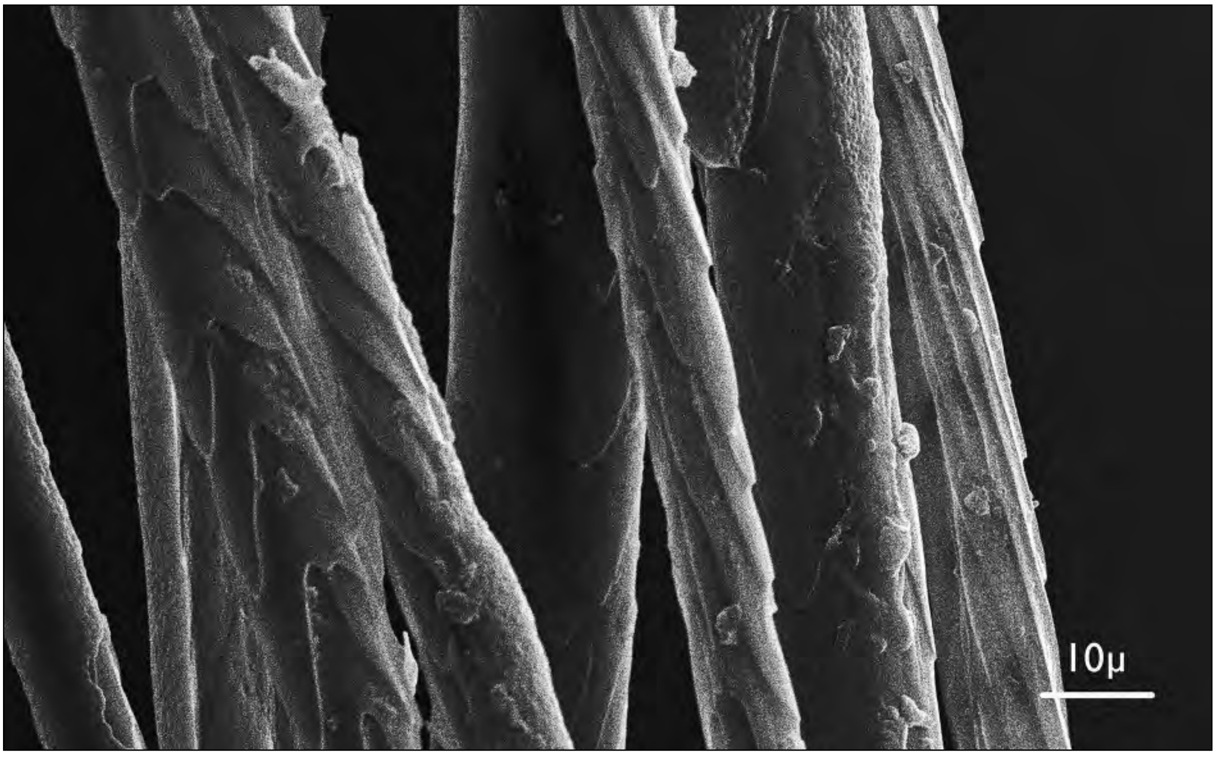

Fig. 167. Hare fibres, modern

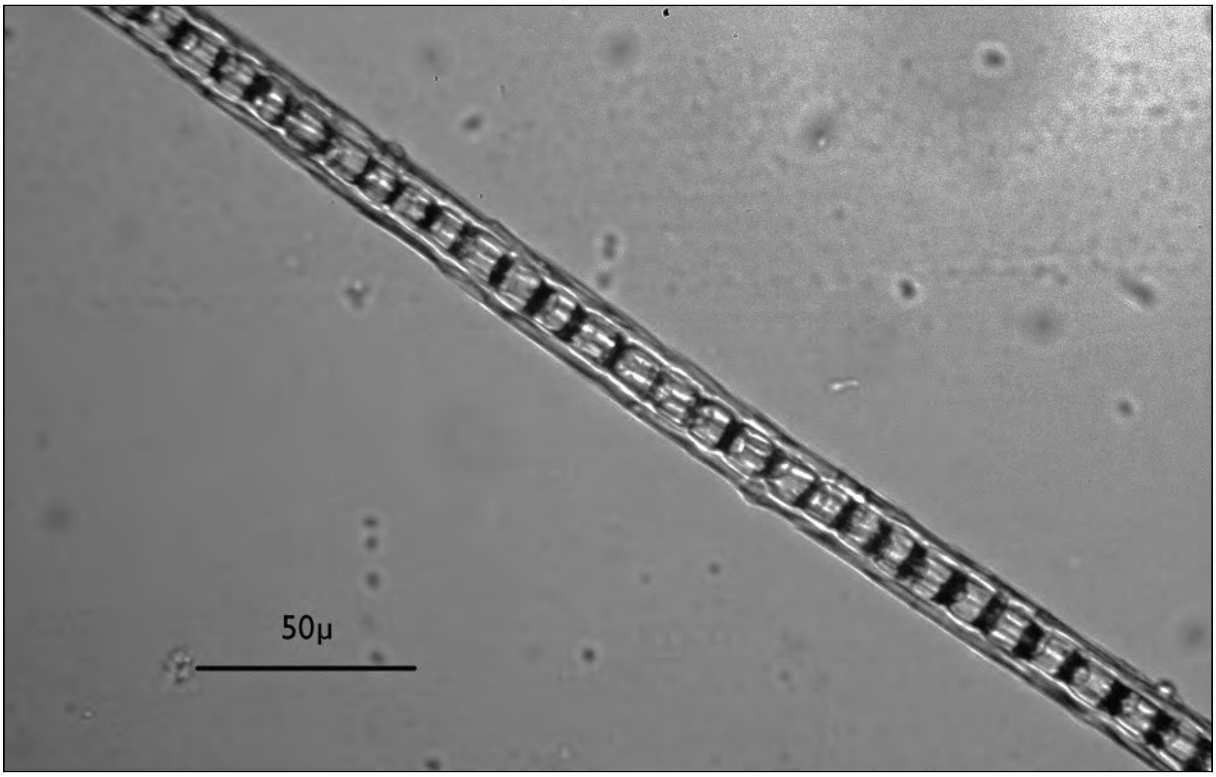

Fig. 168. Fine hare fibre with uniserial ladder medulla, modern

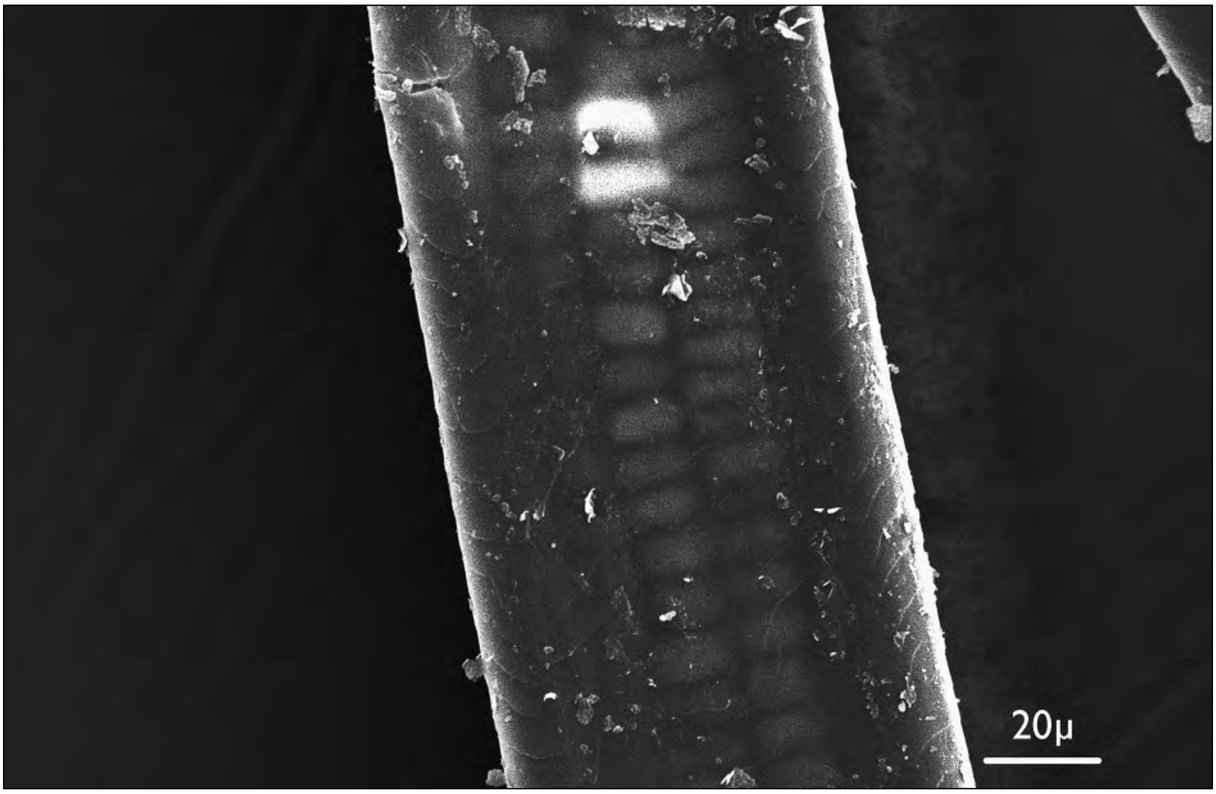

Fig. 169. Hare fibre, the multiserial medulla can even be seen with the SEM, modern

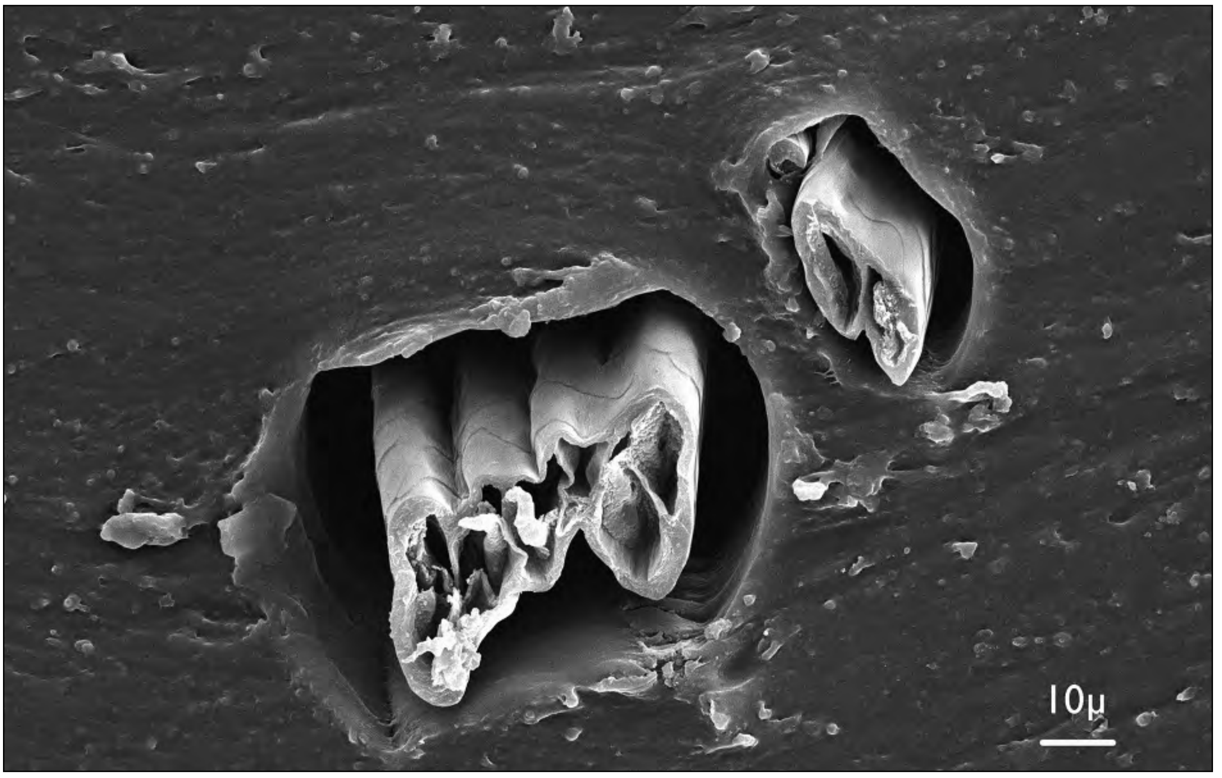

Fig. 170. Hare fibre, cross-section with multiserial medulla, modern

4.4.3.4 Archaeology

Hare fibres have been found as pelt remains in the an Early Medieval Migration Period chamber grave of a burial at Evebø-Eide (N). It is uncertain which part of the garment it belonged to (Raknes Pedersen 1982, 80).

4.4.4 Arctic hare *(Lepus timidus)*

4.4.4.1 Habitat

Alpine and Arctic regions.

4.4.4.2 History

The Iberian Peninsula has seen introgressive hybridization (in genetics, that is gene flow from one species into the gene pool of another) of hares during climate transitions. A new genetic variation stemming from the Iberian hare (*Lepus granatensis)* and the native European hare (*Lepus europaeus)* is evidence of this. The Arctic hare has long been extinct (Melo-Ferreira *et al.* 2005; Alves *et al.* 2008). In prehistoric times it was hunted for its fur-bearing qualities (Pucher 2010, 21; Charles 1997, 255) and preferably shot with blunt arrows (Kovalev 2002, 149ff., note 121). In the Medieval Period, the Northern people (Sami) shot Arctic hares with straight arrows and the trade name given on lists was *"lepus de Norveia"*. In texts from Finland and Russia, Artic hare was in second place after squirrel as one of the important exports from Novgorod (RU). The skin was called "rex" (Delort 1978, 134).

4.4.4.3 Fibre properties

Scale structure is very similar to hare fibres (see chapter 4.4.3.3), with the fine fibres (dm. 10–15μ) having a large medulla, the medium and large fibres having a diameter of 60–80μ. It's white fibres are the most significant sign that differentiates it from the hare (*Figs 171* and *172*).

4.4.4.4 Archaeology

A medieval textile found in Greenland (DK) has been found to be made of blended yarns from goat and Arctic hare fibres (Walton Rogers 2009, 82f.).

4.5 Carnivora

4.5.1 Introduction zu Canidae

Canidae are very difficult to distinguish from one another, not only between their fibres but from an archaeozoological perspective as well. Wolf-dogs can present confusing signals, for instance, by being descendants of extinct species or by being related to similar sized cousins such as the fox (Larson *et al.* 2012). The inbreeding of wolves with dogs, as one example, makes identification of ancient material problematic. The domestication of the wolf has been very much discussed but there are new theories about the beginnings of collaboration between man and dog. At the very least this occurred during the Upper Paleolithic Period (25 000–12 000 years ago) (Benecke 1994; Driscoll – MacDonald 2010). Hunting and herding sheep were initial collaborations. The dog – or maybe in earlier times the tamed wolf – seems to have been, in any case, man‘s most important friend (Power 2012).

Modern breeds very probably have few scale patterns in common with ancient dogs. In modern fibre atlases the authors rely on modern species and their scale patterns, which is to say that the medulla is the best source of distinguishing between the different species of fox, wolf and dog. Fox has the largest medulla, wolf a half-wide medulla and dog filling one fifth of the diameter only (Lochte 1938, 182). This is certainly correct for modern animals but it is doubtful when considering archaeological finds.

Other questions arise distinguishing between marten types (see also chapter 4.5.13 and *Table 4*). The Mustelids (excepting badgers) have a similar scale pattern (petal form). *Canidae,* however, also have a scale pattern of distinct diagonals (diagonal petals) and irregular waves, which is not the case for Mustelids. This is the most important difference. *Canidae,* furthermore, have a different medulla type (Keller 1981; Tóth 2002, Tab 1; *see Table 4*).

Canidae are difficult to differentiate from one another (see also “wolf”; Keller 1984). *Canidae sp.* have also been reported in “Ötzi's” clothing (Hollemeyer *et al.* 2012). An object found in Greenland has been described as a blended yarn of wool and *canid sp.* (Walton Rogers 2009, 83).

4.5.2 Red fox *(Vulpes vulpes)*

4.5.2.1 Habitat

Mostly forests up to mountain regions, but also in settlements and towns.

4.5.2.2 History

The fox is an animal that adapts easily to human life and is today very commonly seen in towns. Throughout history fox hide was the most common pelt, being used in most cases for lower social status articles (Zitzelsperger 2010, 177). In Early Prehistoric periods the fox was an essential part of the subsistence system of hunter-gatherer societies, it being used more importantly for skins than for food. Paleolithic finds already show that foxes were commonly trapped. Skinning can be identified in early bone assemblages both by marks on the bones and by the lack of the paws being used as part of the pelt (Charles 1997, 259f.). Foxes were used for covers and coats and locally available. In Antiquity the Thracians wore hats made of fox hide (Brentjes 1968). The silver fox is a Russian variant of the red fox and belonged, right up to the 20th century, to the category of most valued pelt (Franke – Kroll 1976, 156; Davey 1895, 81).

A long running experiment carried out by the Russian Academy of Science has tested the breeding of domesticated foxes. After 40 years researchers could demonstrate that tamed behavior is due to genetic selection. The morphology of these domesticated (selected) foxes was found to have changed as well – coat color, ear floppiness, rolled and shorter tails as well as neurological variations differed from such traits in untamed foxes (Kukekova *et al.* 2004).

In tales from very early on, the fox was known as a clever trickster. A Babylonian tablet from the middle of the 2nd millenium BC has written on it the *"fable of a fox"*. Most of the tale is lost, but the conclusion is clear: the fox wins against a wolf and a dog. "Renard the Fox" is a medieval character taken up in tales by the likes of Geoffrey Chaucer and Jean de la Fontaine; in all the fox manages to overrule both the wolf and the bear (Sax 2001, 117f.).

4.5.2.3 Fibre properties

Primary hairs (brown) have diameters of 50–120µ and a light yellow under-wool has diameters of 15–30µ. The scales of the fine fibres show petal, diagonal petal or horizontal form; the primary hairs start with petal scales which become a wave pattern and then finely rippled. The diagonal petal is characteristic for canidae. The large medulla is amorphous with large air gaps in the primary hairs and of a uniserial ladder-type in the fine fibres (*Figs 173* and *174*). See also chapter 4.5.13 and *Table 4*.

4.5.2.4 Archaeology

The Iron Age bog burial at Lindow/Cheshire (GB) seemed to contain no textile remains – the deceased may have had linen clothing which would not have survived the acid conditions of the bog – but did have an armband of fox fur (Wincott Heckett 2012, 432). Fox was supposedly the skin found in a 7th c. grave in Flurlingen (CH). The material has been metal-replaced and so visible in the negative only but the scales show a petal and diagonal form (Bader *et al.* 2002, 70f.) (*Fig. 175*; see also ch. 4.5.1) The skin found in the Merovingian grave 41 of Saint Denis/Paris (F) was published as fox (Fleury – France-Lanord 1998, 172) but later proved to be otter (see ch. 4.5.22).

4.5.3 Arctic fox *(Alopex lagopus)*

4.5.3.1 Habitat

Arctic, circumpolar regions in northern Europe and Siberia. With global warming and the intrusion of the red fox to more arctic regions, the arctic fox is retreating further north (Fuglei – Ims 2008).

4.5.3.2 History

Jordanes wrote about sapphire-like pelts, which two Germanic peoples, the *Suebi* and *Thyringi*, were trading to Rome. These must have been the shiny blue-grey skins of the arctic fox: *"Alio vero gens ibi moratur Suehans, quae velud Thyringi equis utuntur eximiis. Hi quoque sunt, qui in usibus Romanorum sappherinas pelles commercio interveniente per alias innumera gentes transmittunt, famosi pellium decora nigridine."* (Jordanes, Getica 3,21).

The Arctic fox is smaller than the red fox. Today they are being bred for their fur. Arctic fox, as with beavers and hares, was shot with blunt arrowheads (Kovalev 2002, 203). Written sources from the Middle Ages do not clearly identify the Arctic fox. *"Voss"* was written to mean "all colors". The Arctic fox seems to have been traded from Scandinavia and not from Novgorod (RU) (Delort 1978, 139).

Recently, the Chinese textile industry published work on the fabrication of blended yarns with Arctic fox and Tencel® for underwear (Sun *et al.* 2007).

4.5.3.3 Fibre properties

The Arctic fox has primary hairs that show fine rippled scales, dm. 40µ. These fine fibres have diamond petal scales, dm. 10–20µ, some with very marked three-dimensional scales. The medulla of the primary hairs is amorphous with air-gaps and one of the fine fibres has a uniserial ladder. Its distinction from mustelides is possible by the very distinct diagonal petal which no mustelid shows (see introduction, ch. 4.5.1) (*Figs 176* and *177*).

4.5.3.4 Archaeology

Up to now, no finds recorded in Europe. See chapter 4.5.1.1.

4.5.4 Wolverine *(Gulo gulo)*

4.5.4.1 Habitat

Middle and North Scandinavia, tundra and taiga regions of Eurasia.

4.5.4.2 History

The Scandinavian name *jerv* (or *järv*) (German: *Vielfrass*) means "rock cat". According to Delort, wolverine was not traded in great numbers during the Middle Ages (Delort 1978, 161) but was more traditionally hunted for the fur. It was also certainly known to the prehistoric hunter-gatherer (Charles 1997, 263), and has been found among the bones in Viking Age Birka (S) (Ericson *et al.* 1988, 85).

4.5.4.3 Fibre properties

The fibres (dm. 20–100µ) are brown to black; the fine fibres of dm. 15–20µ have horizontal smooth margins, medium fibres of dm. 20–30µ distinct petals, and the primary hairs have very fine rippled scales with narrow margins (dm. 60–100µ) (*Fig. 178*). The medulla is wide with large spaces and the fine fibres are not medullated. As they don't become frosted white from contact with human perspiration, the fibres were used for trimming in hats and hoods by the Inuits (Franke – Kroll 1976, 59; Charles 1997, 263).

4.5.4.4 Archaeology

No skins of wolverine are recorded yet.

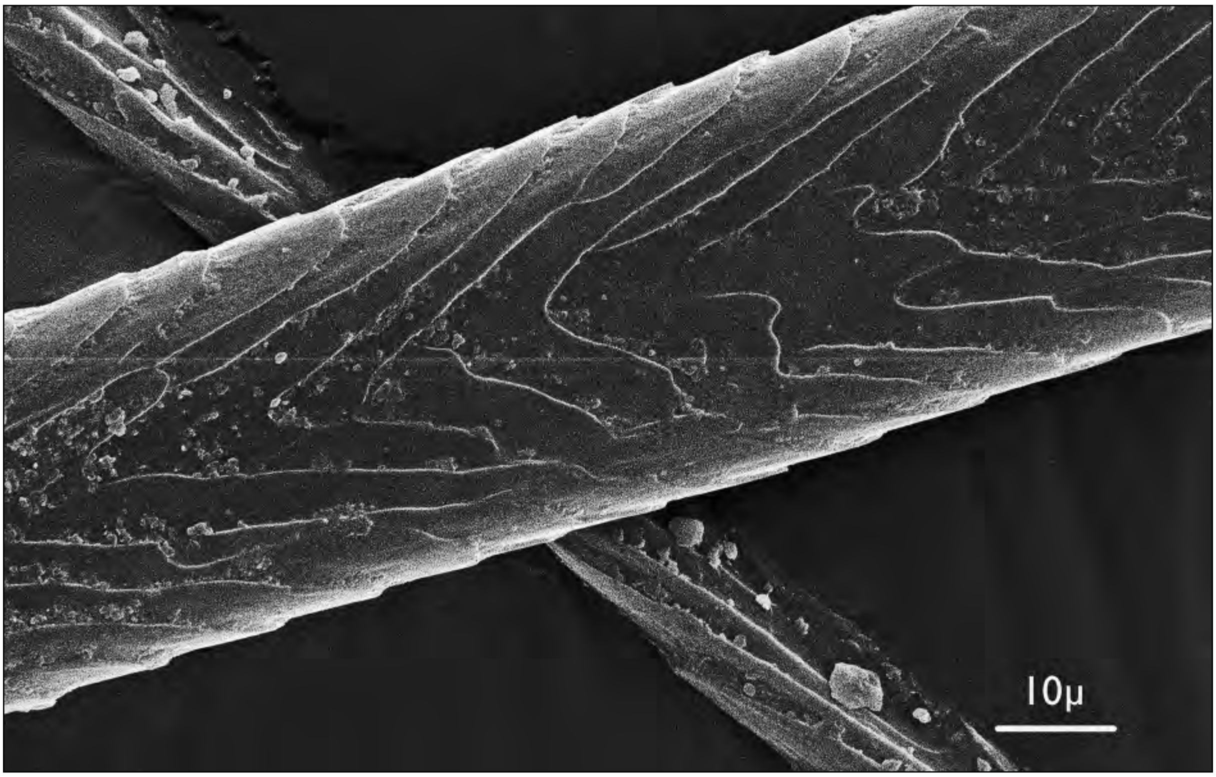

Fig. 171. Fibres of Arctic hare, modern

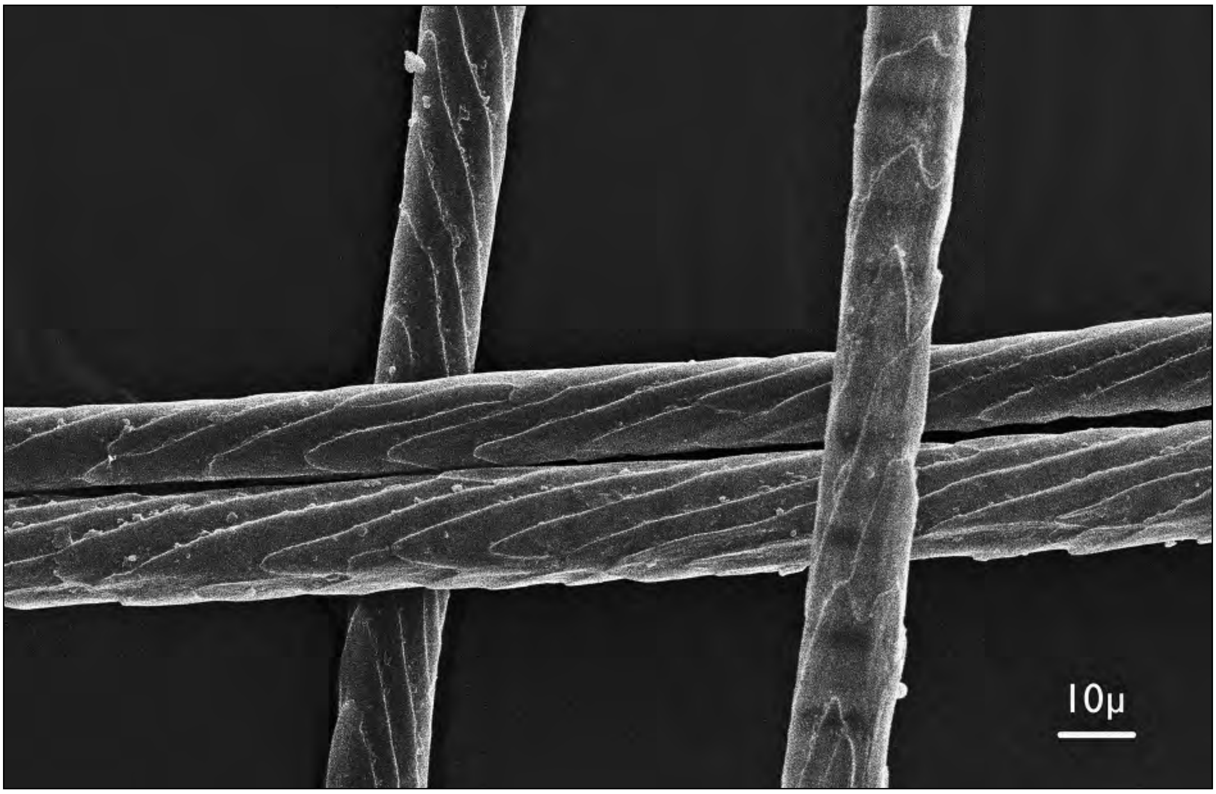

Fig. 172. Fibres of Arctic hare, modern

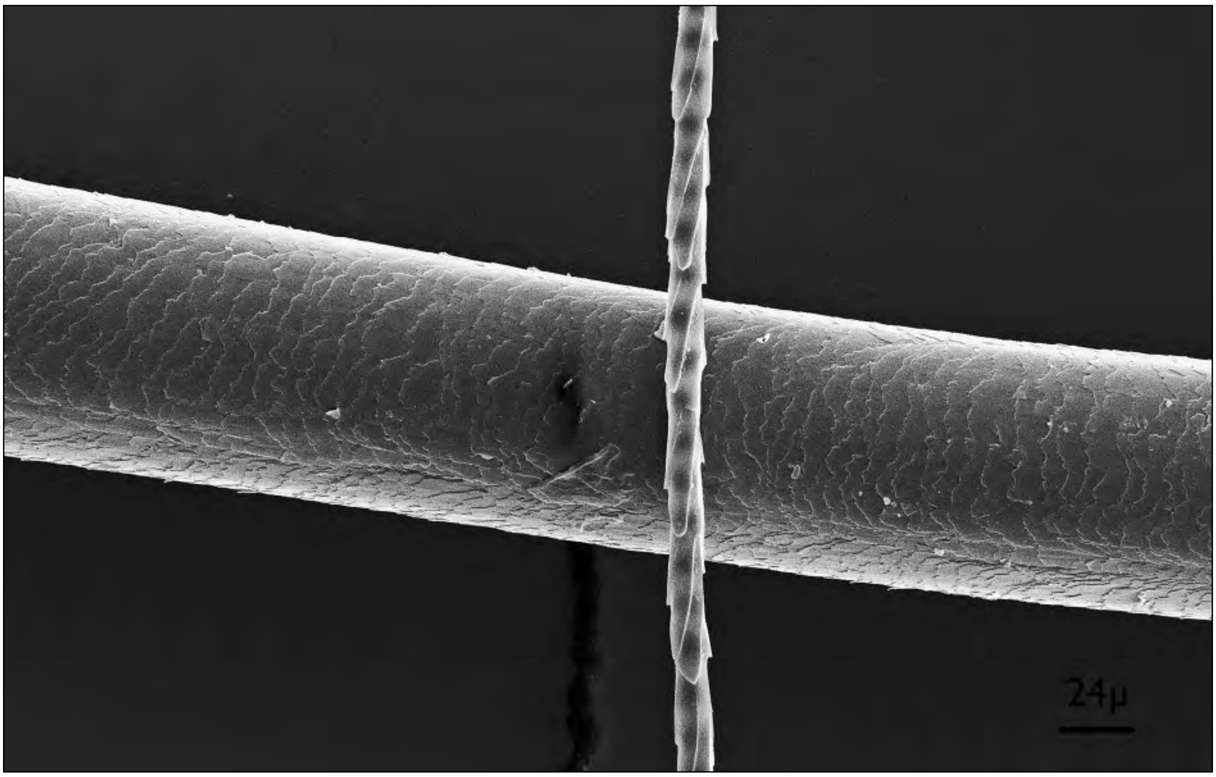

Fig. 173. Red fox fibres, modern

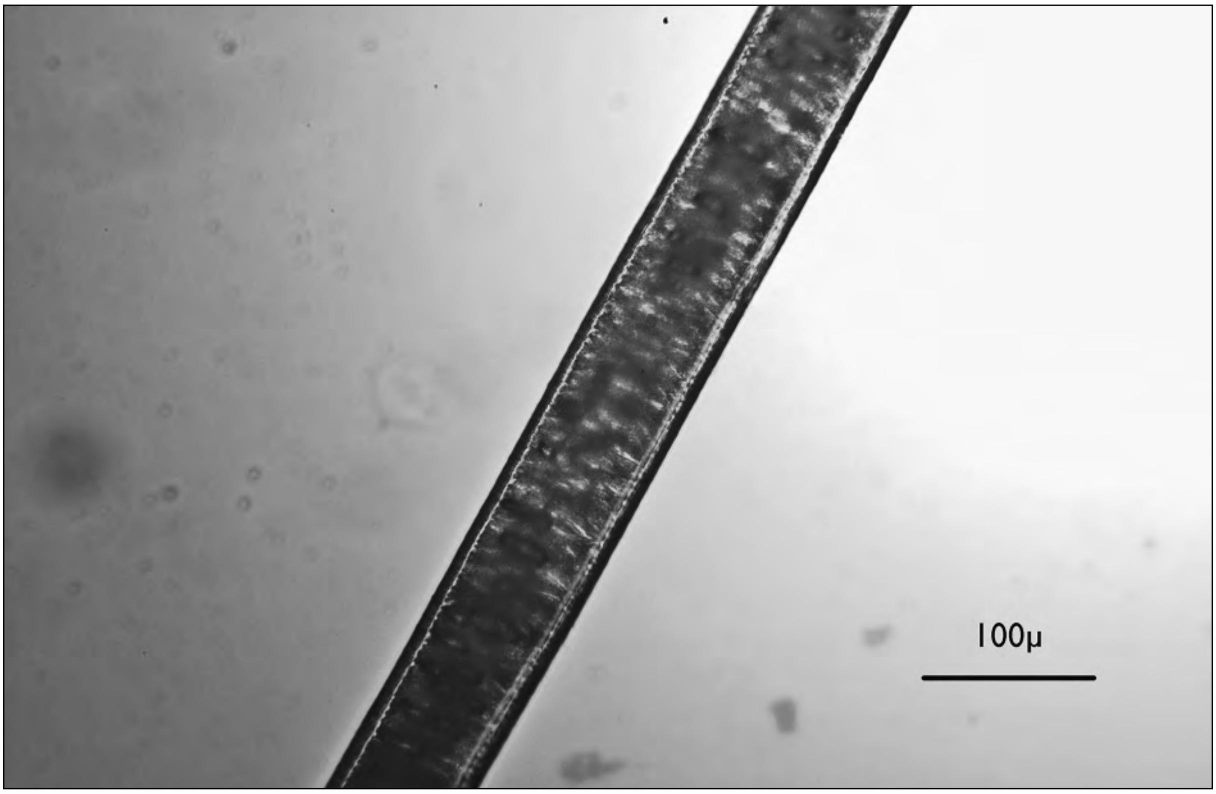

Fig. 174. Red fox, cross-section, modern

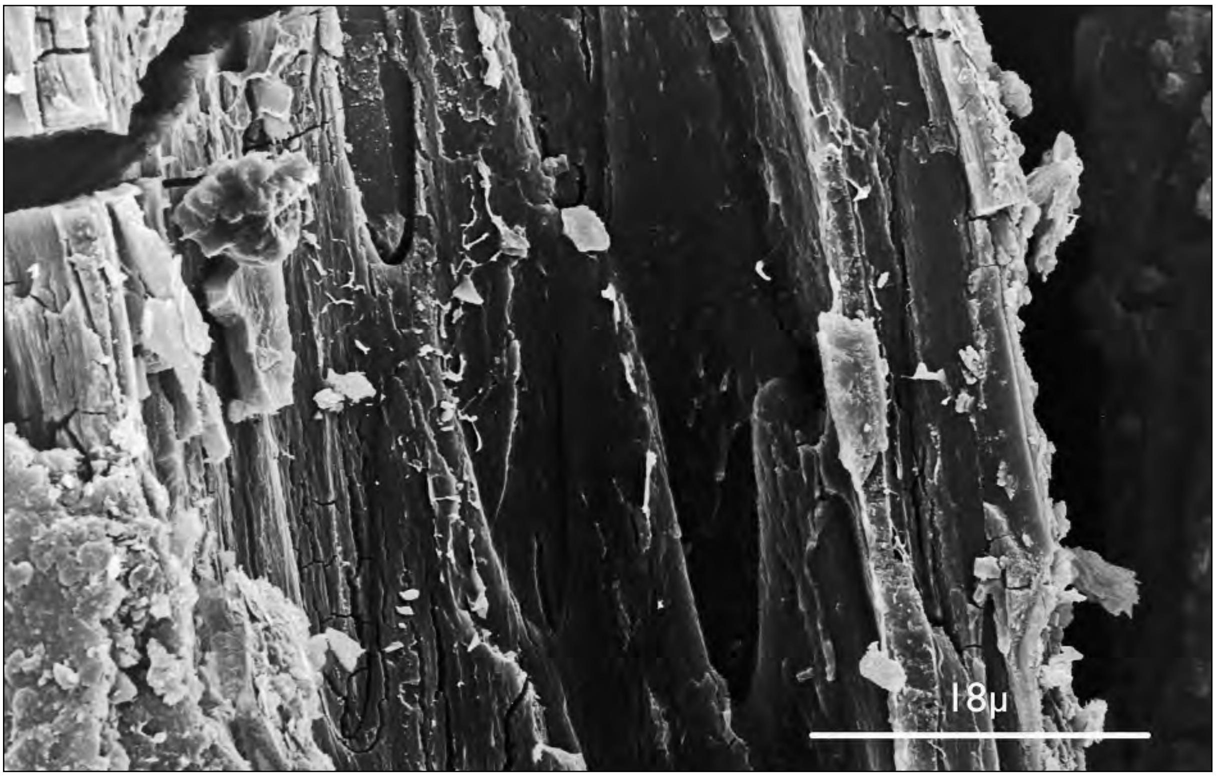

Fig. 175. Red fox, 7th c. grave from Flurlingen (CH)

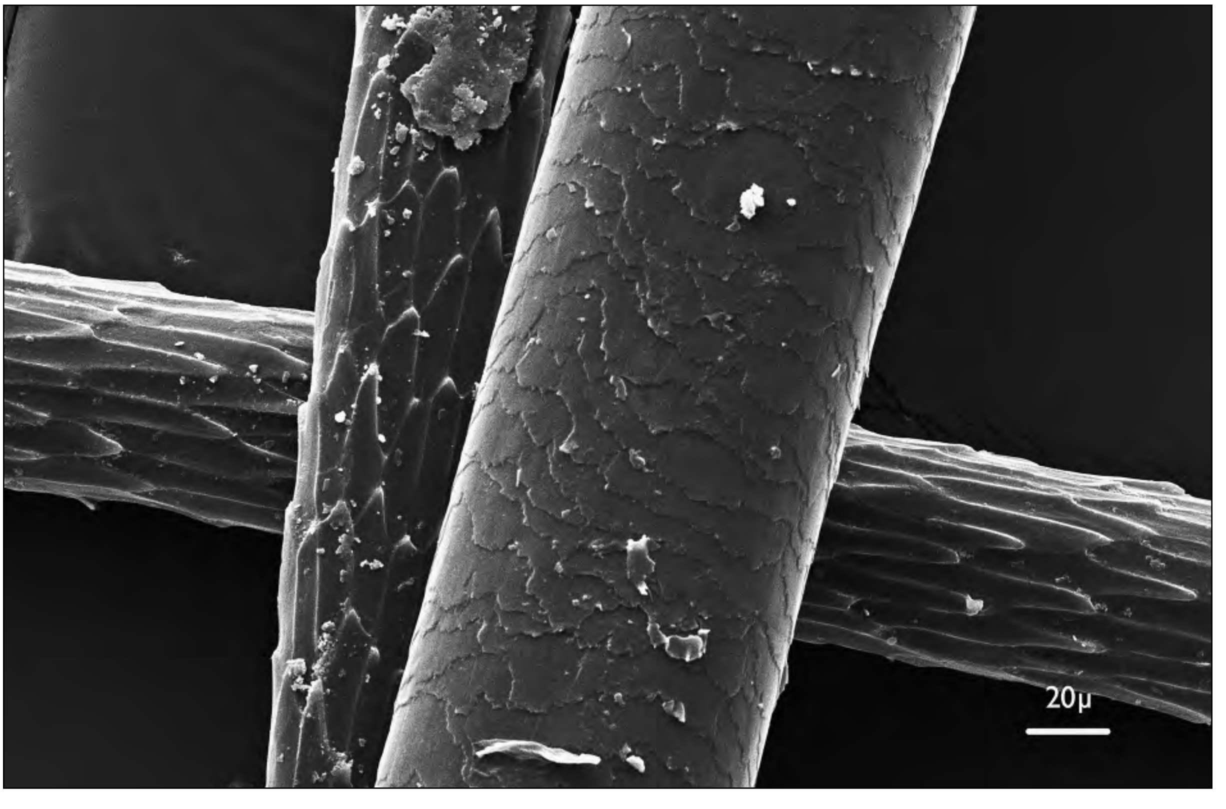

Fig. 176. Arctic fox, coarse fibres, modern

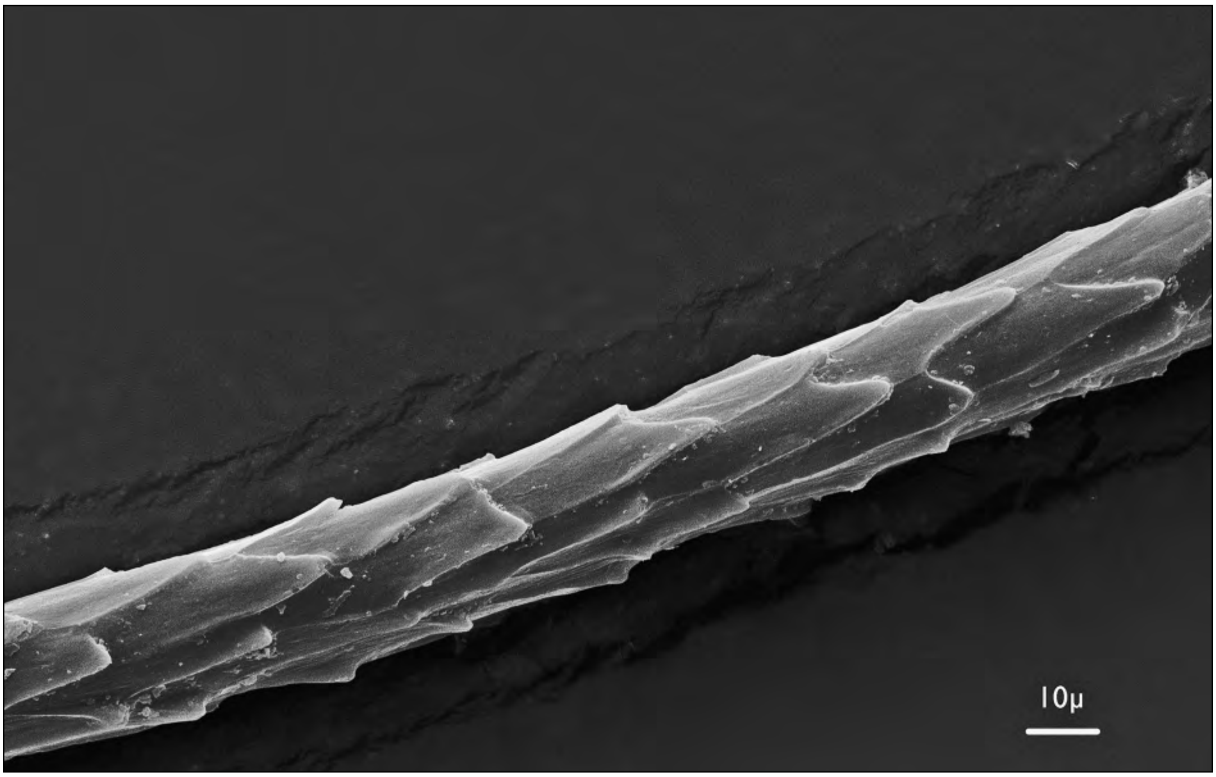

Fig. 177. Arctic fox, fine fibre, modern

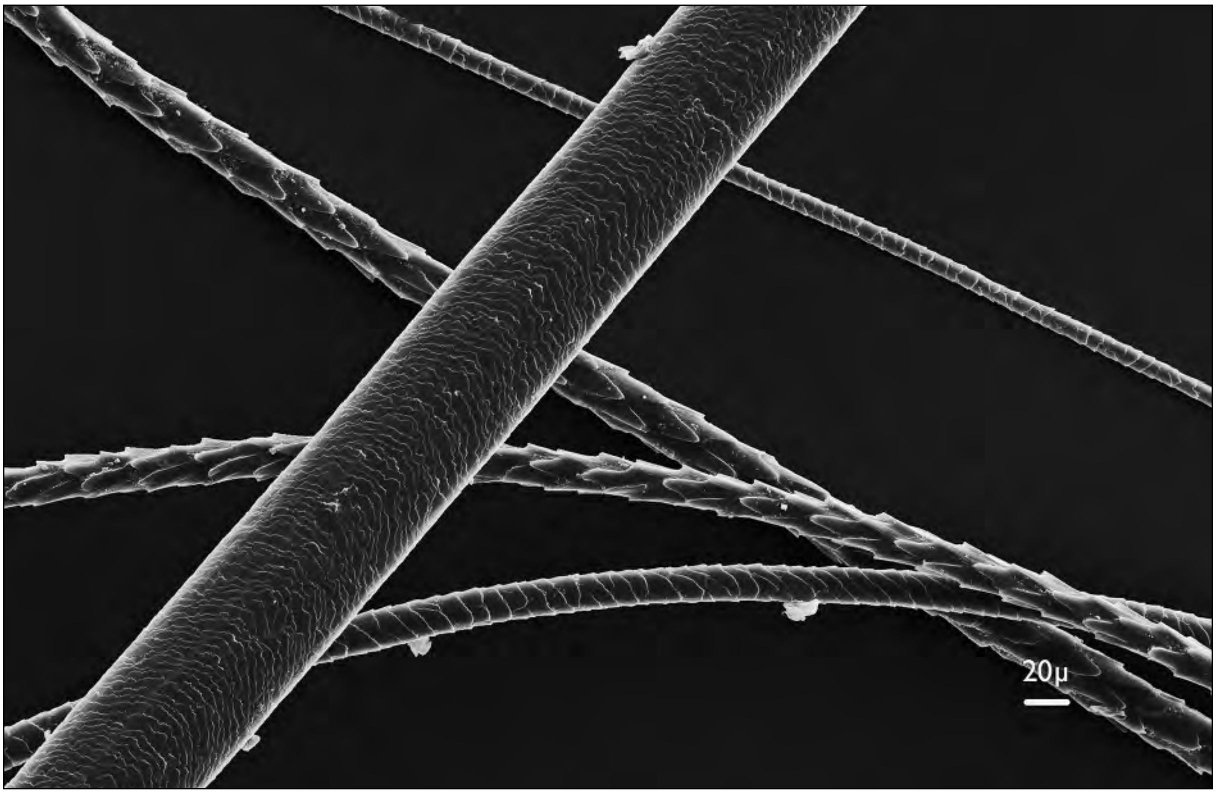

Fig. 178. Wolverine fibres, modern

4.5.5 Dog *(Canis lupus familiaris)*

4.5.5.1 History

The dog is the most ancient of the domesticated animal, the only pre-agricultural domesticate and long-term friend of humans going back to at least the Upper Paleolithic Period (25 000–12 000 years ago) (Benecke 1994; Driscoll – MacDonald 2010). Some "dogs" found in Europe are dated as far back as 31 000 BP (Germonpré *et al.* 2009). Morphological changes which are important for domesticates are not, however, always clear (Benecke 1994, 35; Pluskowski 2006). They are certainly present in 12 000 BP in the Levant, but variations of the wolf-dog are quite difficult to determine and this date represents a consensus. In addition to this it is known that wolves were tamed in the Late Paleolithic/Early Mesolithic Periods (Benecke 1994, 30). New DNA studies suggest several areas of domestication (Larson *et al.* 2012). Morphological changes in size during the Pleistocene was probably due to climate change (Dayan 1994). Wolves and jackals present in Western Europe were easily tamed but not necessarily domesticated (Zeuner 1963, 83). The exact date of domestication (as opposed to taming!) is difficult to tell through osteology. DNA studies have revealed that the dog originates from the grey wolf and there are traces of interbreeding in Europe with the jackal and the European wolf. There is further evidence of a haplotype for the small dog in the Near East (Driscoll – MacDonald 2010; Gray *et al.* 2010; Larson *et al.* 2012).

Protein analyses of Mesolithic dogs have revealed a change in food sources from both the sea and the land, this probably due to location changes during the different seasons of the year (Schulting – Richards 2002). In Skateholm (Scania, S), dogs were even given individual burials (Fahlander 2008, 36).

In the Neolithic Period small dogs (h: 40 cm) were quite frequently found at the lake dwellings. Dogs were employed for hunting, resided as pets or utilized for ritual purposes (Ewersen – Ramminger 2015). From the Neolithic up to the Roman Period dog inhumations are well known (Gräslund 2004). Homer (8th c. BC) tells the touching story of the hunting dog Argos, who, just before dying, was the first to recognize Odysseus arriving at home (Hom. Od. 17,290). Xenophon (4th BC), in his book *"On hunting"*, describes the hunting dog and how appearance differentiates quality animals from lesser types: they should be large in body and fleshy at the shoulders and hips but with small ears and thin hair, thus enabling agility, speed and strength (Xen. kyn. 4). The Greeks used dog skins to make strips (Aristoph. Wasps, 230). Contrary to the Celts who did not fear their own reincarnation, the Greeks were afraid of being reborn as a dog and beaten (Birkhan 1997, 915). Diogenes was the master of the "Cynics", his school named in Greek as "doglike" or living like dogs in society but not belonging to them (Sax 2001, 89).

Roman writers describe several breeds and their uses for different purposes. Large dogs were engaged to guard the house; quick and strong dogs were for sheep herding or for hunting; small dogs were for use in towns (Col. 7,12; Mart. 14,200). These identities have been confirmed in archaeological material found at Pompeii (I) (Zedda *et al.* 2006). Columella advises having a black dog in the house so that thieves will not see him and to have a white one with the sheep so that he can be distinguished from the wolves. Pliny the Elder reports that the Gauls were crossbreeding dogs with wolves to produce strong hunting dogs. They were used as pack leaders (Plin. nat. 8,61,12). Dog burials from Prehistoric and Early Historic times, were carried out quite frequently. The animals were either placed together with a human body or given a burial of their own. Burial inscriptions and grave goods for dogs are also found from the Roman Period (Teegen 2014)!

In the Early Medieval *"Lex Alemannorum"* (a law code of the Alamanni) several breeds are listed – sheepdog, guard dog, windhound – for the rabbit/hare hunt and other breeds for bear hunting etc…

Penalties are also stated for stealing or killing a dog (Lex Alemannorum 78, 1-6). The most expensive dog is the pack leader. In some of the medieval laws (e.g. *lex Salica*, *lex Frisonum*) specific types are enumerated and a few are now known as breeds. For example, *canis veltrarius* (*veltrus leporarius* or *veltrus porcarius*) was given over for a bird or beaver hunting dog. The "Hovawart" was employed best as a guard dog. Other specialty dogs were used for mining. Certain breeds were designated to protect individual saints: Rochus, Vitus, and Hubertus (Scorza Barcellona 1999). Islamic writers of the 11th-12th centuries report the use of dogsleds in the North (Kovalev 2002, 261; Kovalev 2003, 59f.). In the 12th c. Hildegard von Bingen (12th c.) proposed the manufacture of shoes made from dog skin. Even in Early Modern Times dog skin continued to be used for shoes (Riha 2012). During the 19th century, poor workers wore warm dog skins (Blaschitz 1999; Krünitz 1773–1858, "Hundehautgerber"). From Russia, China and Mongolia "dog rugs", "dog mats" and "dog robes" were sent to Western Europe and America (Franke – Kroll 1976, 128).

Today, according to DNA analyses, most of the breeds, even the "very old" are not genetically connected to the ancient/basal breed. Genetic bottlenecks in the Holocene (also as a result of the wars of the 20th century) necessitated inbreeding across a number of different species and this caused important genetic fluctuations. One result that could be said of this is that dogs found in today's Italian "old breeds", are no longer closely linked to the Italian wolf (Verginelli *et al.* 2005). One of the basal breed species is the "Finnish Spitz" (*Fig. 179*), with nearly all of the remaining basal breeds having roots in the Near East, the exception being the "Alaskan Malamut" (Larson *et al.* 2012). However, nearly all of the remaining Basal breeds have their roots in the Near East. Dog teeth and objects of dog bone – such as the Early Medieval pendants from Grave 120, Basel-Kleinhüningen (CH) – are quite frequently found in archaeological sites (Giesler-Müller 1992, Taf. 24).

Dogs were given symbolic meaning in accompanying the deceased. In Egyptian mythology, dogs were associated with the underworld and death as well as with the moon (as opposed to cats being affiliated with the sun god Ra). In Greco-Roman mythology Cerberus guarded the entrance of the underworld. The Ancients had a fear that dead bodies would be eaten by dogs (Sax 2001, 85ff.). Because of their superior sense of smell, dogs were thought to be able to foresee the future – and death. With this came negative connotations that dogs were symbols for evil (Sax 2001, 86).

4.5.5.2 Fibre properties

The scales (double coat) are rippled to diagonal petals (*Fig. 179* and *181*), the medulla is usually smaller than that of wolf or fox (s. *Fig. 84*) and it is filled with tiny air chambers (*Fig. 180*). Fibre cross-sections are round to oval (Lochte 1938, 182–186). A possible explanation for the existence of archaeological materials that show clear distinctions from modern dogs may be that there was inbreeding between wolves and jackals. Dog hair has an unpleasant odor when wet and was perhaps for that reason not often used.

4.5.5.3 Archaeology

Margarete Hald reports a cap made of dog skin from Søgaards Mose (DK) (Hald 1980, 34). See also chapter 4.5.1.

4.5.6 Jackal *(Canis aureus)*

4.5.6.1 Habitat

East and Southeastern Europe, Austria, open land, arid zones. Jackals become more common again, especially in Southeastern Europe, 2015 even in Switzerland.

4.5.6.2 History

Jackals were well known in Antiquity, but there are no fossil remains in Europe. For archaeozoologists, jackal bones are difficult to distinguish from small dog bones. They inhabited for the most part large areas of Eastern and Southeastern Europe but also as far north as Western Austria. In Egypt, another variety of jackal existed (Zeuner 1963, 82). Pelts were not of very good quality and mostly used as covers (Franke – Kroll 1976, 130). In the Early Modern Period, jackals were tamed and kept like dogs in Russia and in the Caucasus (Ståhlberg – Svanberg 2011).

Anubis is the jackal-headed god of the Egyptians, protector of embalming and the dead. The figure is taken up later by the Eastern Orthodox church where St. Christopher is depicted with a dog head (Sax 2001, 89).

4.5.6.3 Fibre properties

Fine fibres 10–20µ, scale petal to diagonal petal; primary hairs have dm. of 60–80µ, with horizontal and finely rippled scales. The fibres are difficult to differentiate from wolf. See also chapter 4.5.13 (*Fig. 182*).

4.5.6.4 Archaeology

No finds of fibres recorded yet. See chapter 4.5.1.1

4.5.7 Wolf *(Canis lupus)*

4.5.7.1 Habitat

Woodland, steppe, alpine regions.

4.5.7.2 History

Before the invention of firearms, and until the dwindling of forests, wolves were abundant in Europe (Zeuner 1963, 82). In archaeozoology, wolves are quite difficult to recognize as the skeletal remains are similar to the ones of dogs (Pluskowski 2006). In a Paleolithic context, wolf bones found in caves that show skinning marks exemplify the probable use of the pelts (Charles 1997, 258). The feeding of Romulus and Remus (Rome) by a she wolf, represents the close relation between humans and wolves.

In Euripides' play *"Rheus"*, Dolon is wearing a grey wolfskin and is, indeed, disguised as a wolf. Polybius also reports about a garment of the *Velites*, a headpiece covered with a wolfskin for "protection and identification" (Polyb. 6,22). Paulus Diakonus wrote of the masks of the Langobards as *"cynocephali"* (Paul. 1,11). In Early Medieval art, wolves are clearly depicted as having a long nose and a tail (e.g. sword of Obrigheim, Germany, see Quast 1997, 437).

In the Carolingian *"Capitulare de villis"*, wolves are said to be hunted with the pelts having to be delivered to the king (MGH *Capitularia regum francorum*, Band 1, S. 89, cap. 62). Amulets with wolf teeth were believed to protect children from bad dreams in the night and adults from demons and epilepsy (Hansmann – Kriss-Rettenbeck 1966, 10; Quast 1997, 437).

Wolf pelts were used as trimming, in the lining of coats, for bedcovers and carpets (Franke – Kroll 1976, 127).

Even in the Middle Ages, complete wolf skeletons are rare whereas the skeletons of dogs are frequently found. Large dogs could be related in some way to wolves, with the animal also possibly being a hybrid. Travel reports from the 18th c. describe the taming of wolf puppies in Russia and Siberia. They were kept almost as pets until they reached maturity but were then killed for their pelts (Ståhlberg – Svanberg 2011, 365). Wild populations, unfortunately, became extinct in England in the 14th century and in the rest of Europe by the 18th–20th centuries (Pluskowski 2006, 285). Present day, however, is seeing the reintroduction of the wolf in Western Europe.

4.5.7.3 Fibre properties

There are varying colors, this especially evident with the Siberian wolf which is grey-white and dense. Primary hairs are irregularly waved (diagonal waves or petals as with all canidae) and rippled, medium fibres with chevron-petal-like scales and fine ones coronal to petals (*Fig. 183*). The medulla is a fine network with spaces. Differentiation from other canides: wolf shows a medium size medulla (*Fig. 184*) (fox: large; dog: medium; see also chapter 4.5.1). See also chapter 4.5.13.

4.5.7.4 Archaeology

No finds of fibres recorded yet. See chapter 4.5.1.

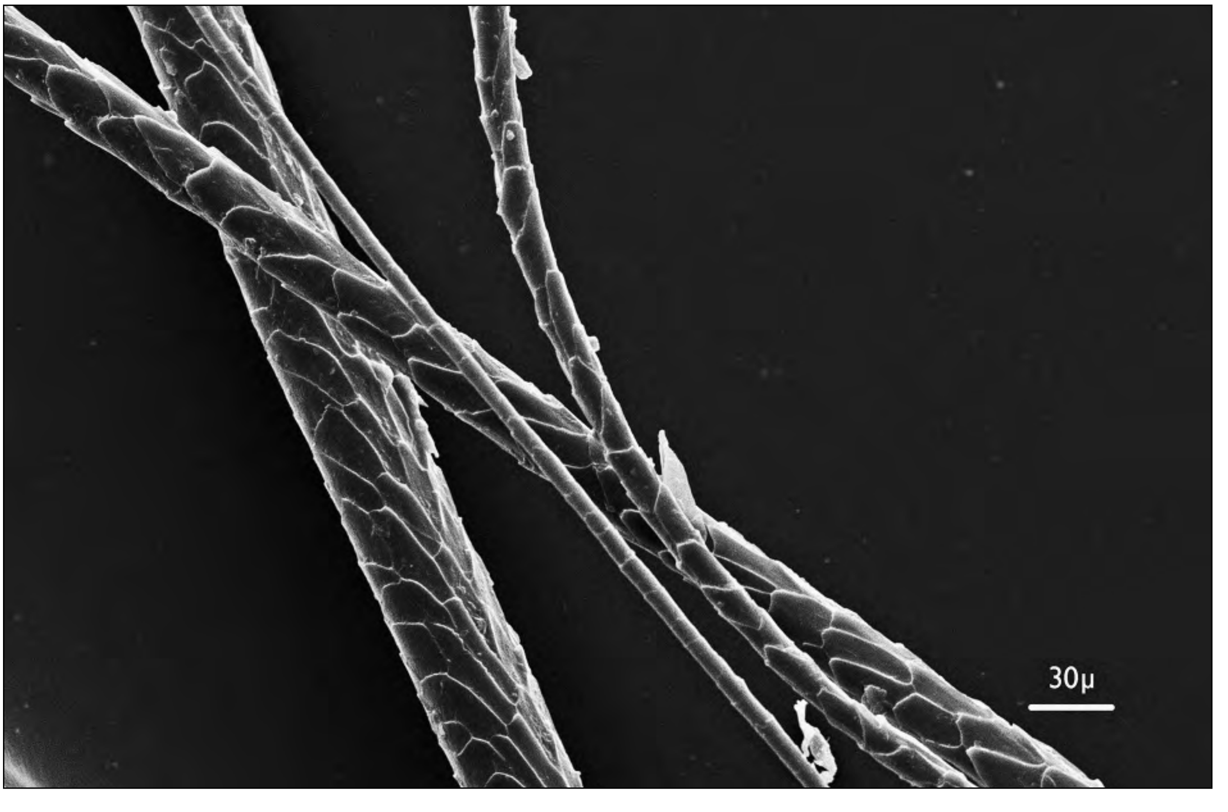

Fig. 179. Dog fibres (Finnish Spitz), modern

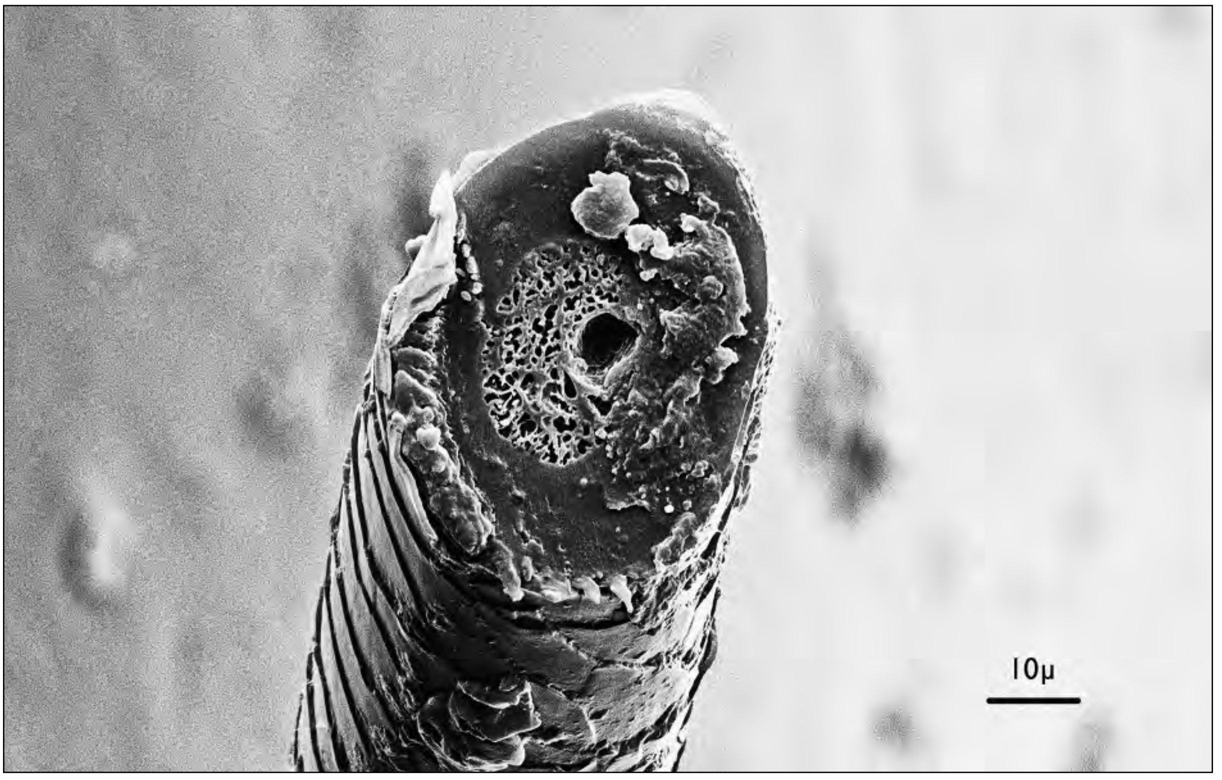

Fig. 180. Dog fibres (poodle), cross-section, modern

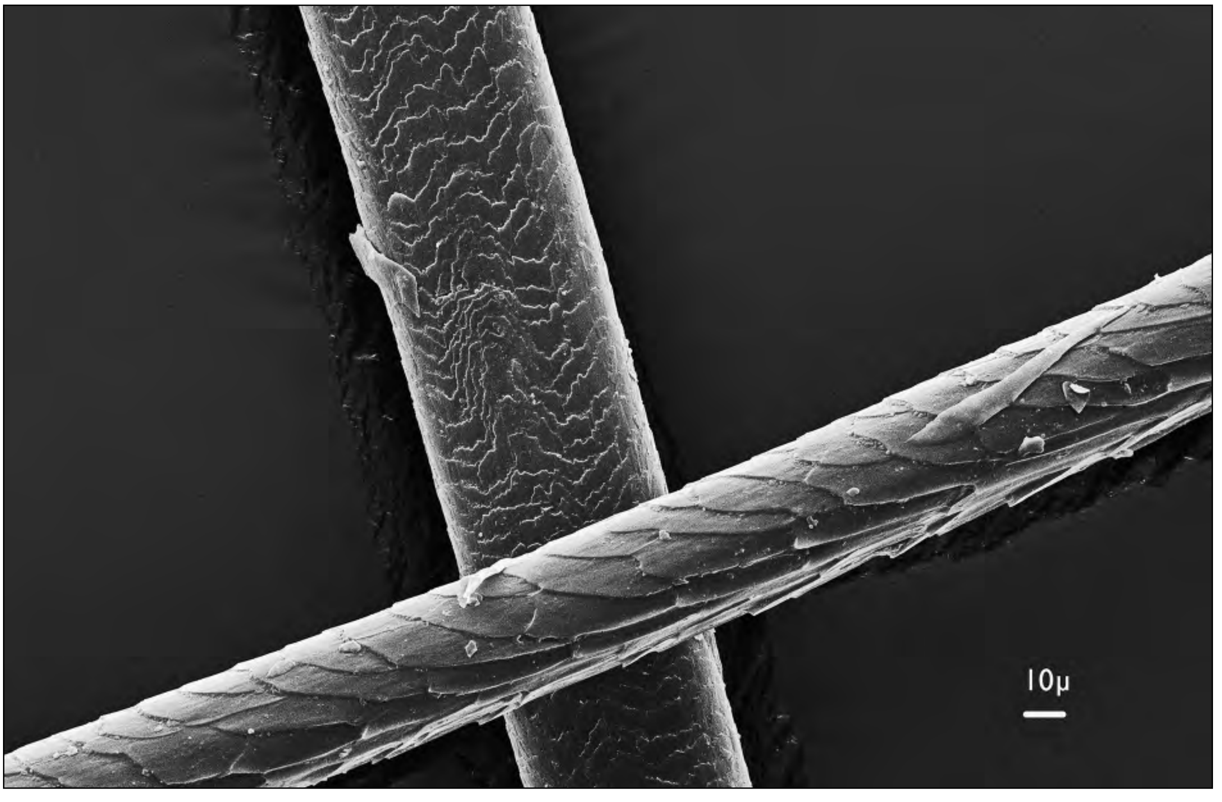

Fig. 181. Dog fibres (poodle), modern

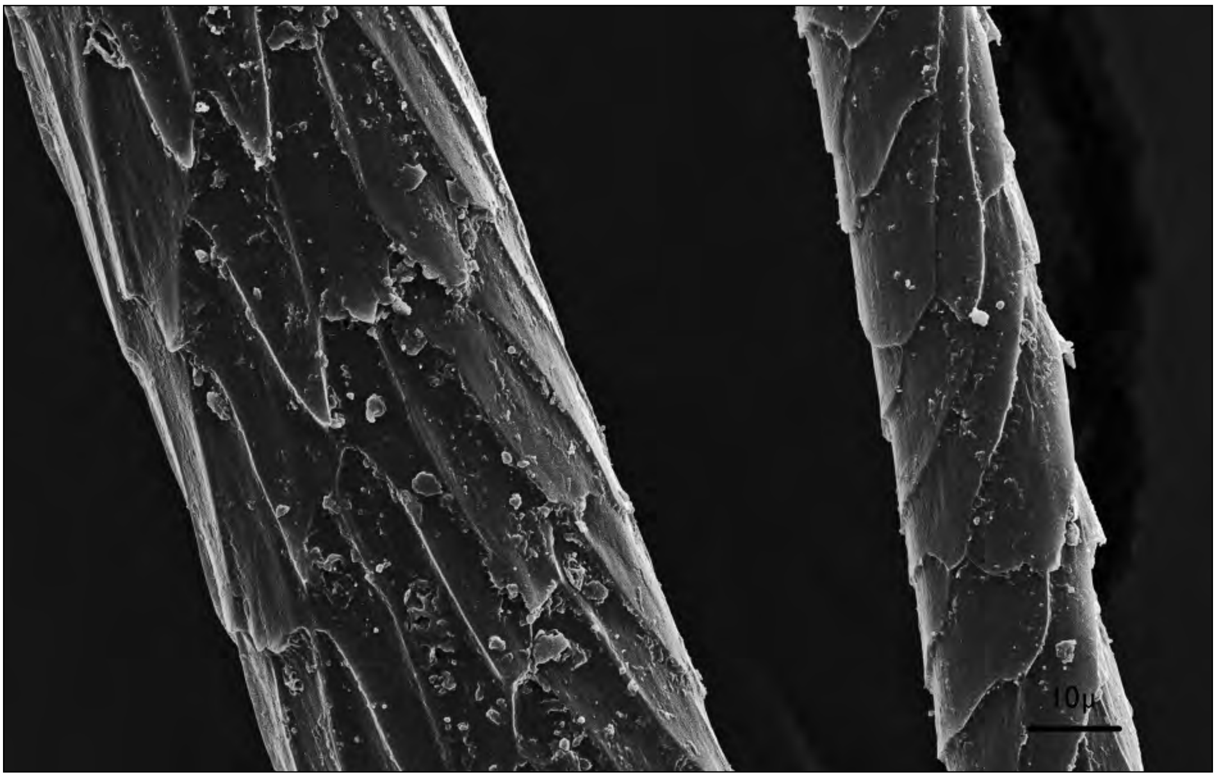

Fig. 182. Jackal fibres, modern

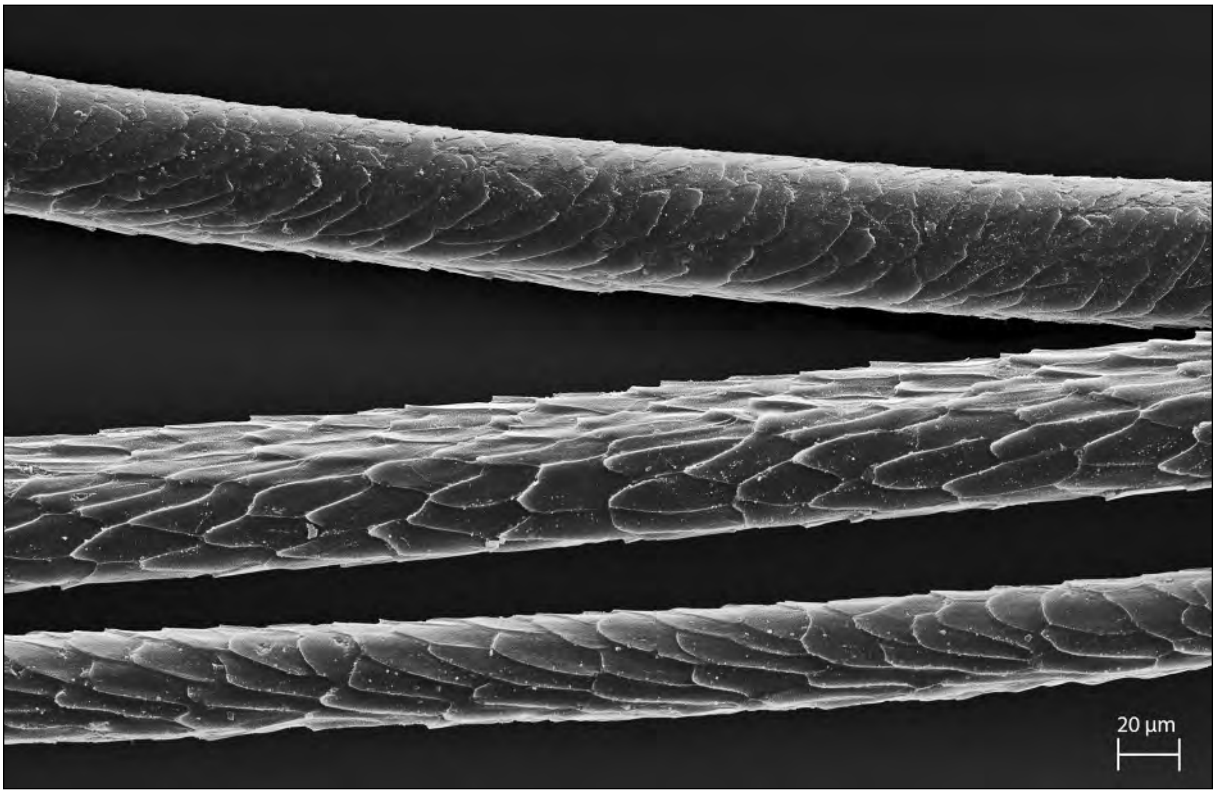

Fig. 183. Wolf fibres, modern

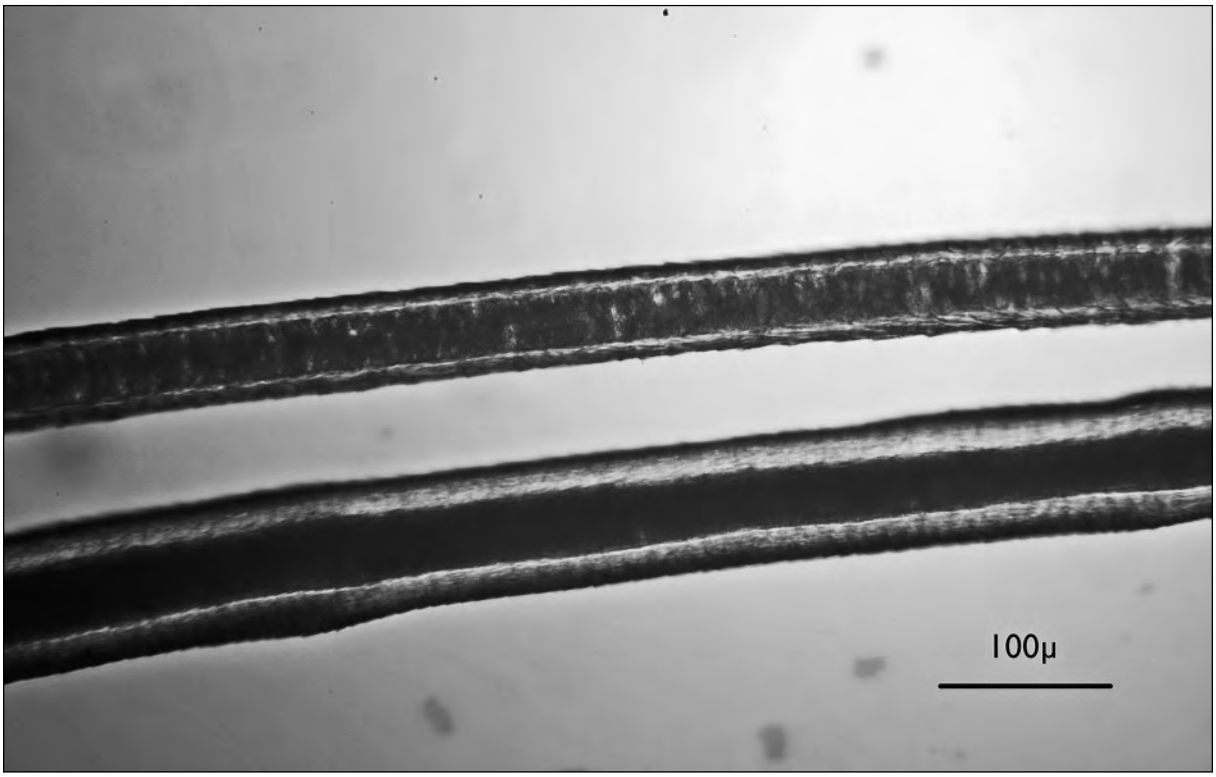

Fig. 184. Wolf fibres seen with the LM, modern

4.5.8 Bear *(Ursus arctos)*

4.5.8.1 Habitat

The bear lives in forests as well as open land and alpine regions. It has been extinct in many regions of Europe for centuries but is making a comeback in Central Europe, mostly through Italy and Slovenia. A few bear populations today remain intact and proliferate (not without conflicts with shepherds and farmers). From the point of view of conservation genetics, it is the most thoroughly studied animal (Swenson *et al.* 2011). In Scandinavia, the bear population has became smaller during the 20th c., but they have not become extinct there. (http://www.rovdata.no/Brunbj%C3%B8rn/Bestandsstatus.aspx)

4.5.8.2 History

From very early on – by the Paleolithic Period – bears were symbolic of strength. They were included in rituals and ornamentally figured in amulets (bear tooth) (Hansmann – Kriss-Rettenbeck 1966, 102). Bears had to be hunted with very good projectiles or at times when they were found hibernating in their dens during winter. Skin quality was best in late autumn and winter and the fat was used as well (Charles 1997). Bear stamps of the Early Neolithic settlement of Çatal Höyük (Turkey) show the importance of these animals for Neolithic settlers (Türkcan 2007; Hodder 2011, plate 23). In the Neolithic settlement of Arbon-Bleiche (CH) probable skins could be theoretically identified, as carbonized bones of paws have been found within housing structures showing possibly that skins kept in houses had not been taken out when the village burnt down (Deschler-Erb – Marti-Grädel 2004, 206). The Parthians are reported to have worn bear skins and bear skulls as helmets (Davey 1895, 83). Bear skins have been used especially in Germanic graves since the Bronze Age, most of them east of the Rhine, or in Shamanic rituals known around the Arctic Circle (Wamers 2009). One example is the bear skin – interpreted with the remains of four paws – of the grave of Clemency (LUX) dated to the 1st c. BC (Metzler *et al.* 1991). Similar burials with bear skins have been found in Scandinavia (Wamers 2009, 20). In Celtic mythology, bears are not so important. The link between King Arthur and the bear is a later invention (Birkhan 1997, 712). The Romans kept bears for fights with gladiators, bears being the most commonly used animal in the arena up to the Byzantine Period (Wamers 2009). Barbarians depicted on Trajan‘s Column in Rome, are wearing bear skins. The Romans employed brown bears for fights in the circus (Sen. De ira, 2,31,6). By the Early Medieval Period it is clear that bears have become tamed – Alemanic law states a fee being charged for the killing or stealing a bear (Lex Alamannorum 25,1).

Masks found in the Viking town of Haithabu could be interpreted as being part of a “bear dance” which was a Shamanic ritual in Northern Europe (Wamers 2009). Inga Hägg has published them as wolf masks (Hägg 1985).

Birth during hibernation would associate the bear with that of a mother goddess (Sax 2001, 26).

Bear skins, as the largest and heaviest pelts in Europe, were used for many things: as ground covers to sleep on, as coats for coach men and as covers on Russian sledges; cub furs were used for the trimming and lining of coats (Davey 1895, 83ff). In more modern times bear skins have been used in the construction of the hats for the life guards of the royalty in both England and Denmark. According to travel reports of the 18th c., bears were tamed in Russia and Poland and kept for public entertainment (Ståhlberg – Svanberg 2011, 371).

4.5.8.3 Fibre properties

Fine fibres measure 15–25µ, medium fibres 80–150µ. The scale pattern shows diamond petals in the basal part of the fine fibres, then horizontal lines with straight borders of the scales where further up they become rippled wave. Medium fibres have narrow rippled scales. The medulla is amorphous with periodic small gaps. Bear fibres could be especially confused with those of the badger (*Meles meles*) having fine rippled primary hairs and an amorphous medulla. However, the badger does not show the diamond petal in the basal part of the fine fibres. The medulla of bear fibres is quite different from Mustelids – the fine fibres of the Mustelid show at least the ladder-type medulla (see chapter 4.5.13). Lochte also describes that the scales of bear fibres tend to stand out. SEM images confirm this: the fringes of the scales stand out, which give out charges under the SEM and leave a white border at the fringe of the scales (Lochte 1938, 193) (*Figs 185–188*).

4.5.8.4 Archaeology

Bear skin has been found in “Ötzi’s” clothing, with the cap and the shoe sole being made from this material (Hollemeyer *et al.* 2012). A bag found in the salt-mines of Dürrnberg (A) is made of bear skin according to W. Groenman (Kyrle determined calf) (Stöllner 1999, 154, no 146; 155, no 151). In a mineralized context, some fibres found from an Iron Age tumulus on a metal object (Hallstatt period of Altheim (D) have proven to be bear skin (*Figs 189* and *190*) (Rast-Eicher in prep. – Altheim). Thanks to the fine fibres with the diamond-petal scales in the basal part of the fibre, as well as the amorphous medulla type, the differentiation to other animals was quite clear.

In the medieval finds of Greenland, the skins of brown bears (!) have been documented. According to written sources, they were used as carpets (Østergård 2009, 120).

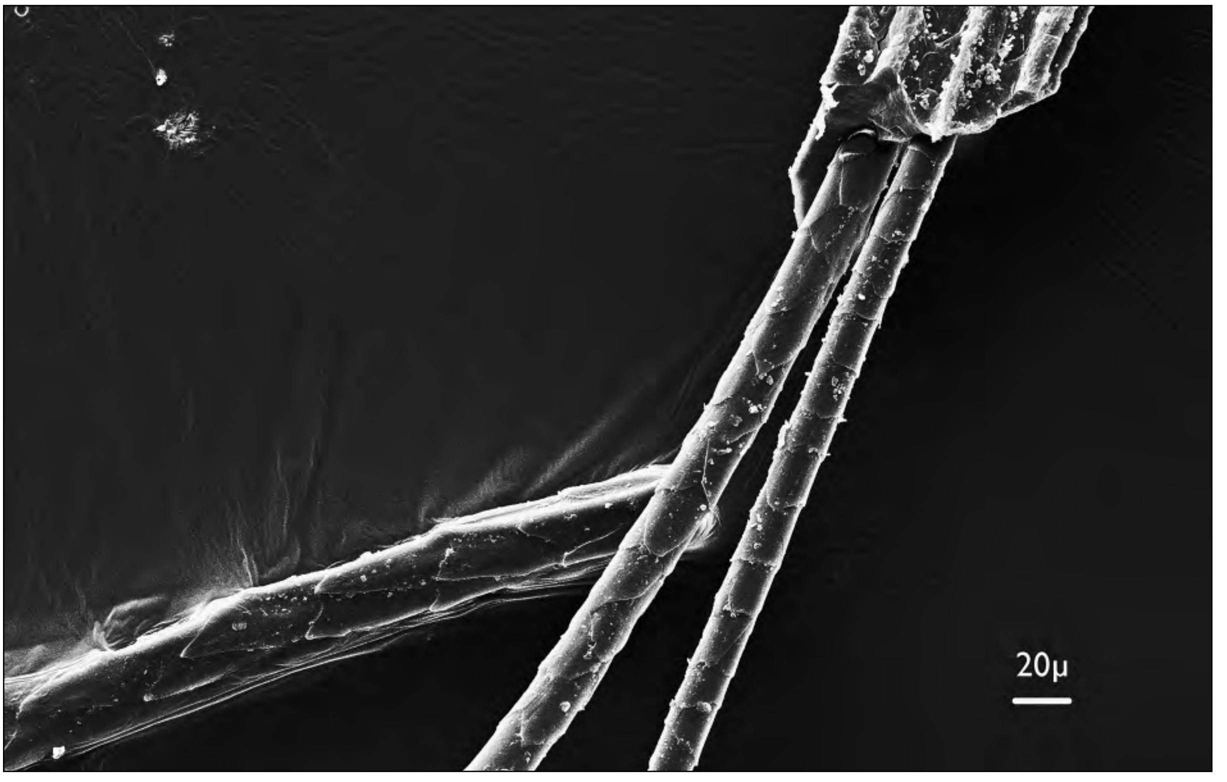

Fig. 185. Bear fibres, modern. Basal part with diamond petal scales

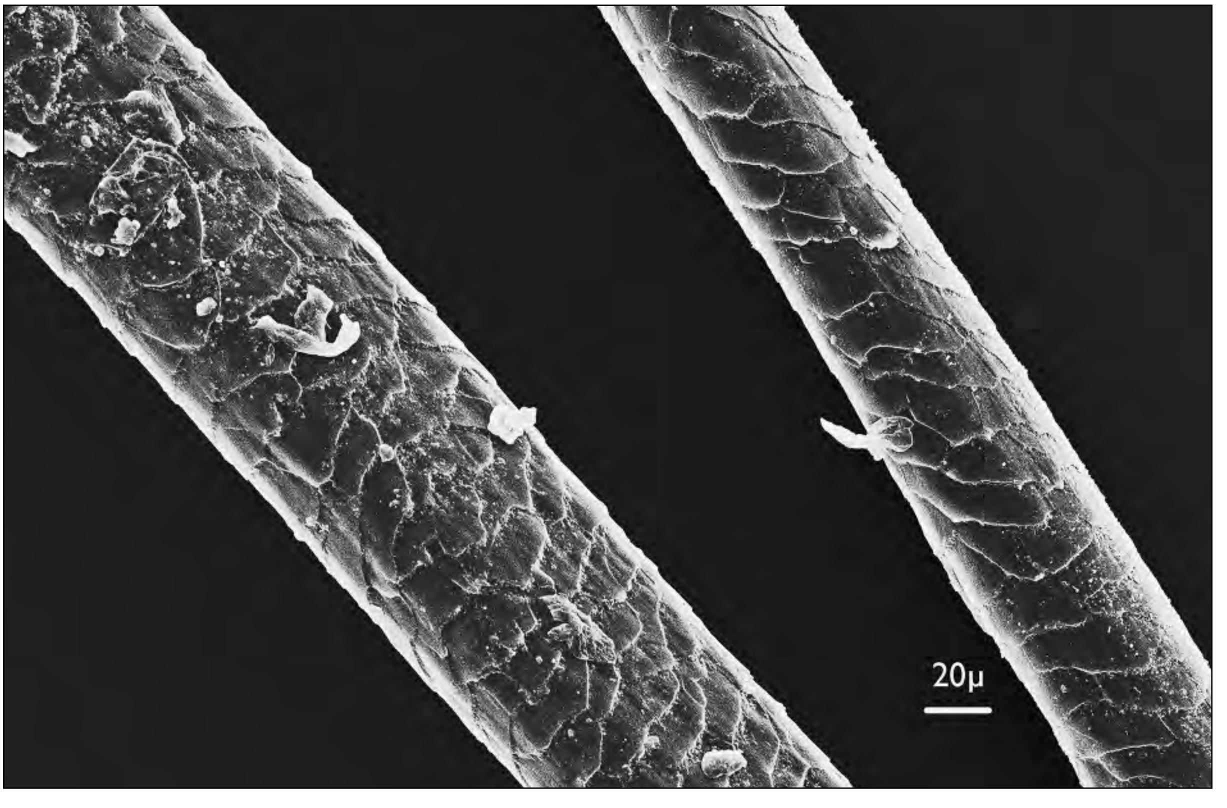

Fig. 186. Bear fibres, modern. Intermediate part

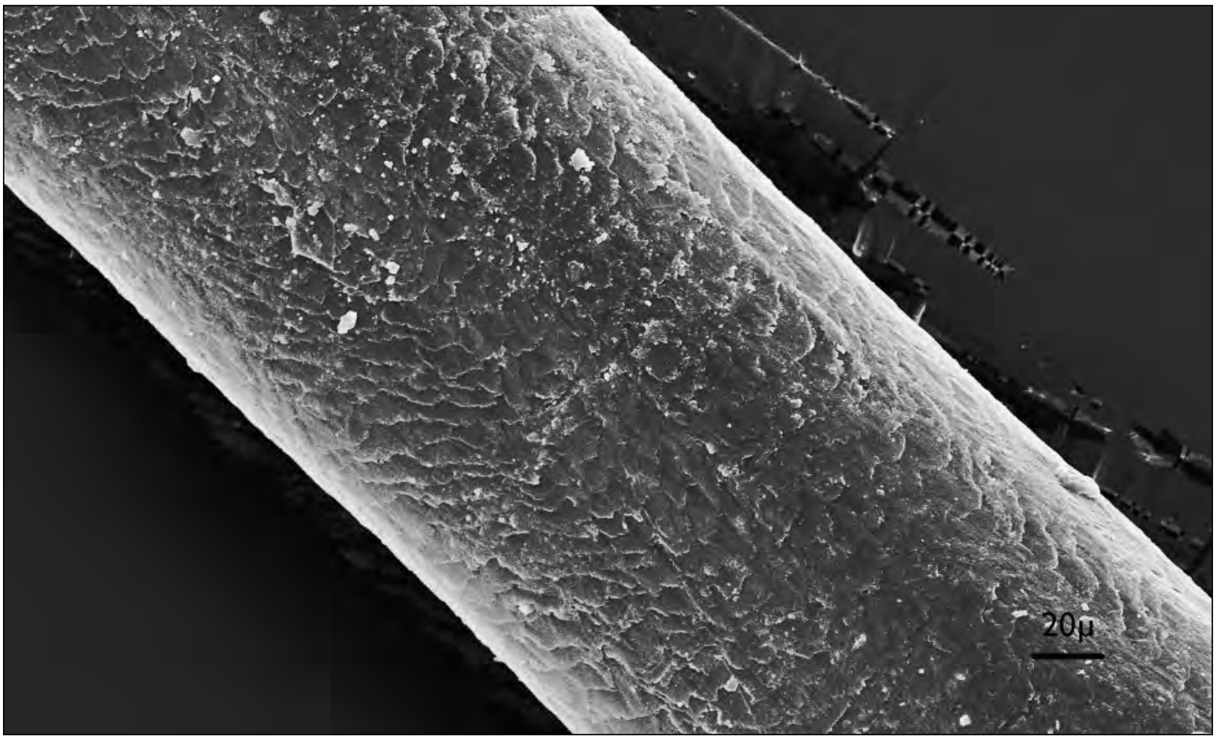

Fig. 187. Bear fibres, coarse, modern

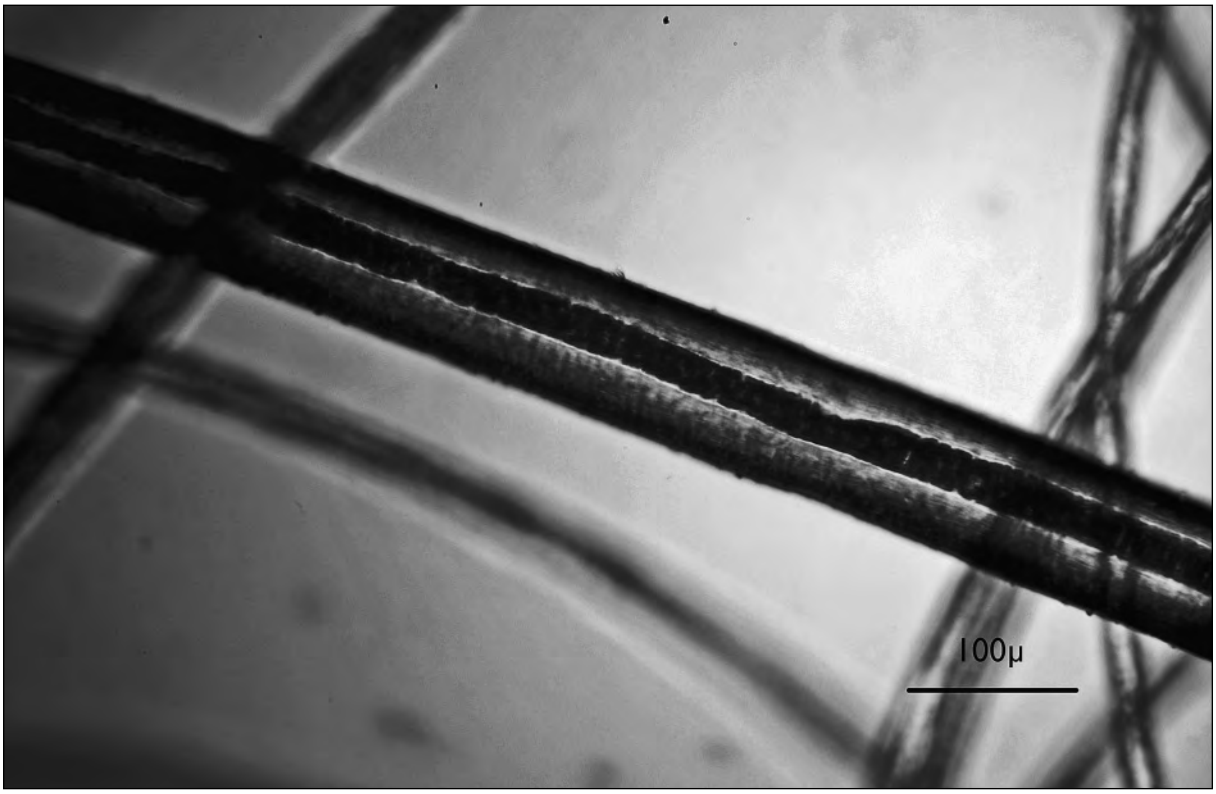

Fig. 188. Bear fibres, seen by LM, modern

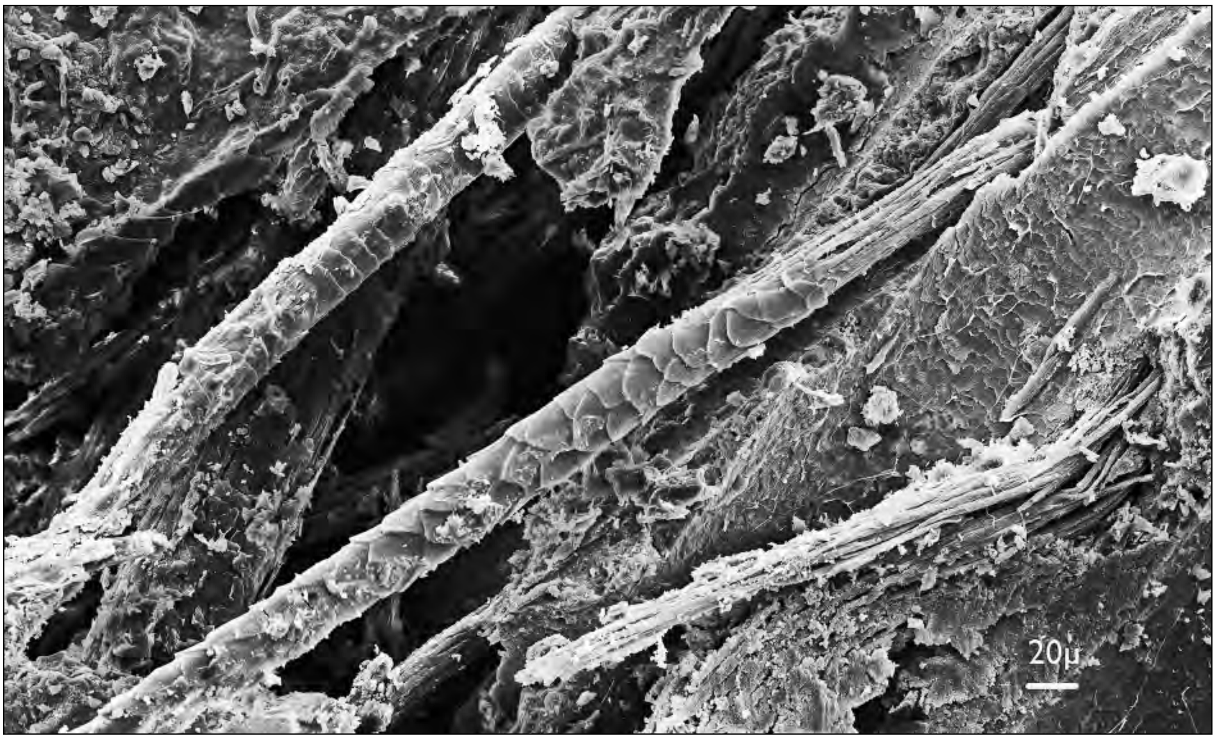

Fig. 189. Bear fibres, Iron Age, Altheim (D). In the centre fibre coming out of skin (basal part) with diamond petal scales, next on the right a coarse fibre with fine rippled scales

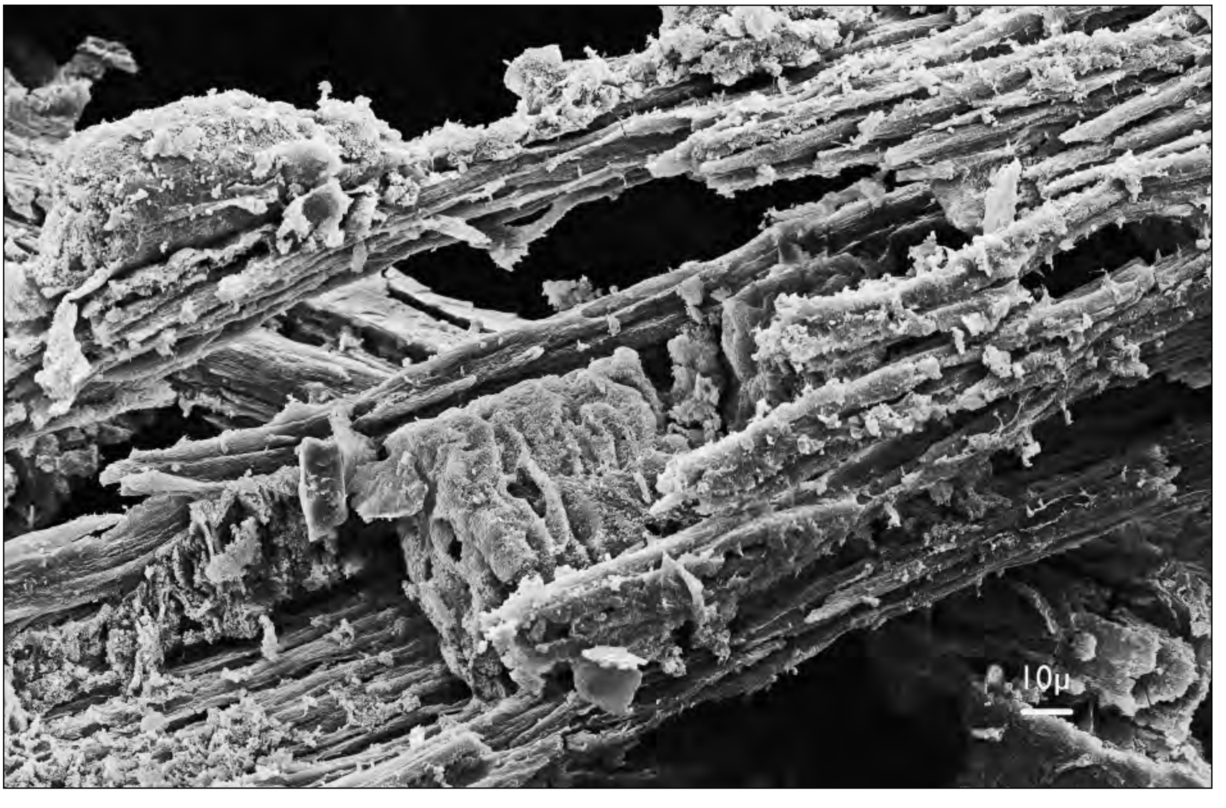

Fig. 190. Bear fibres, Iron Age, Altheim (D). Broken fibre with amorphous medulla

4.5.9 Polar bear *(Ursus maritimus)*

4.5.9.1 Habitat

Arctic, circumpolar, as well on Spitzbergen; distribution is determined by pack ice; bears can swim long distances.

4.5.9.2 History

According to recent DNA research, polar bears were often found to be hybrids of the brown bear (Edwards *et al.* 2011).

Calp. Siculus, living in the 1st century AD during Nero's reign, wrote about a viewing of bears hunting seals in the water: *"aequoreos ego cum certantibus ursis spectavi vitulos"* (Calp. Ecl. 7, 65–66). The descripton of their hunting grounds as being in water and their prey being seals is an obvious sign that these were polar bears of the type that we know today. Ancient Rome saw polar bears being kept for pleasure and exhibitions – nothing seems impossible for the Romans!

Compared with brown bears, polar bears were not often named in medieval sources; this might well have been due to the fact that they are more dangerous and difficult to hunt (Delort 1978, 122). Sources also show that they were nevertheless trapped or killed in Iceland and Greenland during the Middle Ages. The skins were used in these two Arctic regions for many articles but especially in the churches as rag mats to stand upon or for the priest's clothing. The live animal was also highly praised and brought to rulers of the ancient world. As with the white falcon, polar bears were animals of the frigid North and elite persons wanted to possess them. The oldest written source on the importation of polar bears to Northern Europe dates to the end of the 9th century (quoted in Oleson 1950, 48, note 5). From Europe they were sent to other countries as diplomatic gifts. Henry III (England) received a bear and let it swim and fish in the Thames (!). Frederick II (Germany) gave a polar bear as a present to Sultan El-Kamil from Damaskus in 1233/34, having probably gotten it from Hakon of Norway. In the late Medieval Period polar bears appear on maps, explaining the geographical location of Greenland (Oleson 1950).

According to travel reports from the 18th c., polar bears were kept as pets by a nobleman of St. Petersburg (RU) (Ståhlberg – Svanberg 2011, 370).

Even in modern times, polar bear hides are used for garments. In a "list of games" from the 1970's, Greenlanders that killed a bear would have to share the hide, and when put to use in the making of pants it had to be cut it in a very specific way (Rosing-Asvid 2002, 17).

4.5.9.3 Fibre properties

Polar bears have a thick layer of underfur with longer intermediate hairs which, after molting in summertime, turn from pure white to a yellowish white. Fibres measure dm. 20µ for fine fibres, 30–50µ for intermediate and 80–100µ for primary hairs. The fibres are medullated (dark disks, coarse granulate). The scales show smooth margins in the basal part and become rippled further up (Lochte 1938, 195). The medulla is amorphous with gaps, similar to the brown bear (*Fig. 191*).

4.5.9.4 Archaeology

On Greenland, fibres from a medieval bear skin have been found in a settlement (Østergård 2009, 120).

4.5.10 Seals

The following are hunted in Northern Europe: the ringed seal (*Phoca hispida; Phoca groenlandica)*, grey seal (*Halichoerus grypus)*, spotted seal (*Phoca vitulina L.*) and harp seal (*Pagophilus groenlandicus*). Sealskin clothing has been known for a long time – bones have been found in Mesolithic layers in Sicily (Wilkens 1999, 145). A Neolithic burial site at Västerbjers (Gotland, S) revealed a woman wearing a coat/cloak with a fringe decoration of seal teeth (Martinsson-Wallin – Wallin 2010).

The Ancient Greeks were familiar with seal skins, most probably with the Mediterranean seal *Monachus monachus*. Homer tells the story of Menelaos who had to catch Proteus on Pharos (the island near Alexandria). Disguised as seals using fresh sealskins he and his three companions managed to catch Proteus when he came out of the sea to count his seal flock (Hom. Od. 4,9–10). In his *History*, Herodotus describes the people at the Caspian Sea wearing clothing made of sealskin (Hdt. 1,202). Tacitus reports that the Germans also used "furs of sea animals" (Tac. agricola 17,101). On Greenland the harp seal *(Phoca groenlandica*) and the seal *Phoca vitulina* were most appreciated. In the Viking Period seals were hunted (bone finds from Haithabu) as they were later in the Middle Ages in the nearby Schleswig (D). Seals were probably hunted on land with harpoons when they were birthing their young or in open water (Reichstein 2003a).

In the Middle Ages, the Greenlanders had to pay their taxes to the Norwegian King with seal skins (Østergård 2009, 119). Unfortunately, seals are not differentiated from other skins in the ancient texts. Seal skins were used until modern times for tents, clothing, dog-harnesses, ropes, shoes, bags, boats and covers for boats (Clark 1946). Traded "furseals" were mostly those from sea lions, specifically the northern sea lion (*Callorhinus ursinus*) (Franke – Kroll 1976, 320). In modern times, as they became more threatened as a species and would become nearly extinct, seals have come under protection from hunting (e.g. North Pacific Seal Convention, 1835 and 1911). Until 1914, London (firm Fouke) had the largest sealskin market. The tanning process involved the removal of the coarse fibres, and in the 19th and 20th centuries these fibres were also dyed black. Pelts were traded as "greenlanders" regardless of their origin, and baby seals as "whitecoats" (Franke – Kroll 1976, 323, 328). In the 20th century, sealskins were affixed to skis for ski touring. By the 1970's they were replaced by mohair and later still with artificial fibre "skins".

4.5.11 Harp seal or saddleback seal *(Phoca groenlandica)*

4.5.11.1 Habitat

The harp seal lives in the Northern Atlantic or in the Arctic Ocean.

4.5.11.2 History

Baby seals were called *"whitecoat"*, having white hair until they were able to swim. Pelts from 3–8 week-old animals are known as *"Beaters"*, the ones from 2–3 year-olds "Bedlamer" or "Midling", the older animals "Harpseals" (Franke – Kroll 1976, 329).

4.5.11.3 Fibre properties

The cross-section of seal fibres is very characteristic flattened and elliptic. Fibre diameter about 40–60µ, the scales irregular waves (*Figs 192* and *193*).

4.5.11.4 Archaeology

In the churchyard of Herjolfsnaes on Greenland a sealskin covered the deceased in a grave (Østergård 2009, 120).

Fig. 191. Polar bear fibres, modern

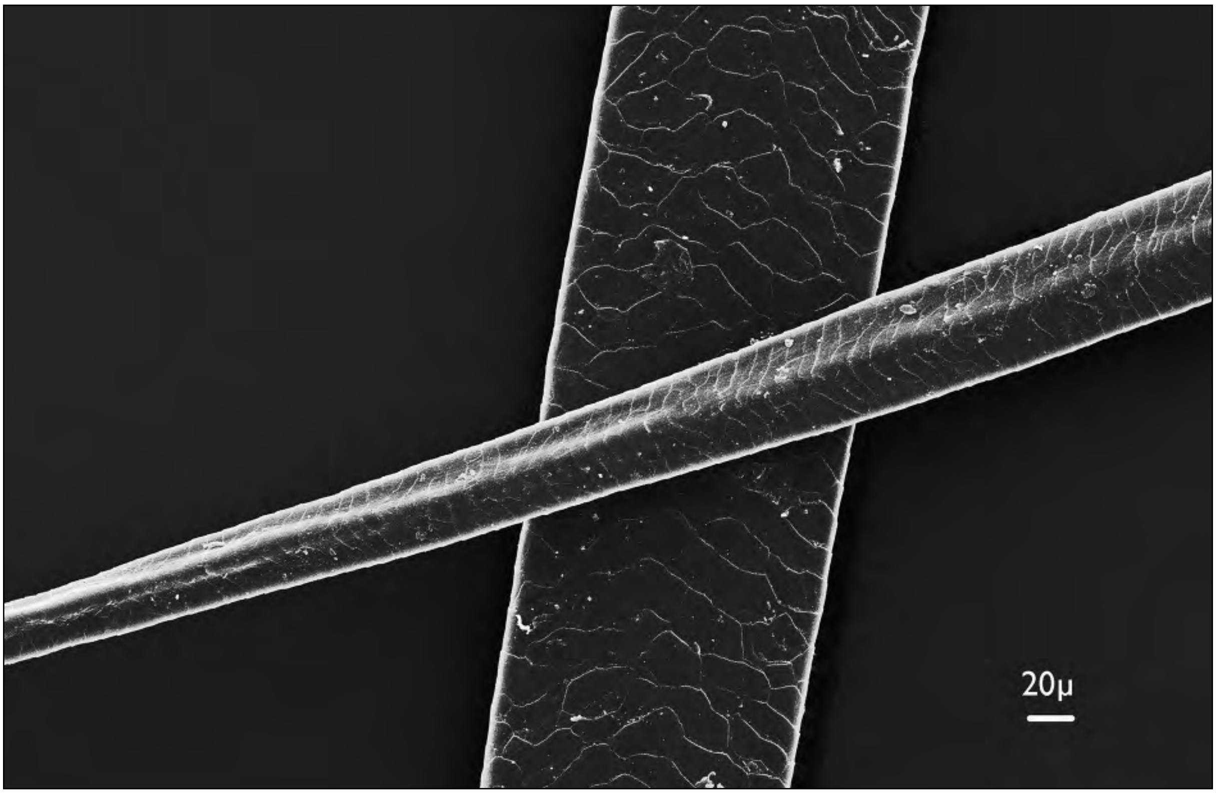

Fig. 192. Seal fibres, modern

Fig. 193. Seal fibres, cross-section, modern

4.5.12 Harbour seal *(Phoca vitulina)*

4.5.12.1 Habitat

Northern Hemisphere, in the Atlantic or Pacific, the Baltic and the North Sea. Common at the European coasts as far south as Northern Spain.

4.5.12.2 History

see ch. 4.5.10

4.5.12.3 Fibre properties

Short and stiff primary hairs, diameter 100µ up to 1000µ, scales have the form of a regular mosaic to irregular waves (Meyer *et al.* 2002, 196). The cross-section is flattened and elliptical.

4.5.12.4 Archaeology

No finds recorded.

4.5.13 Mustelidae: general introduction

4.5.13.1 General remarks

Mustelids are important fur animals and were used during the whole of Prehistory and History. Their fur is still in use today. Skinning marks on bones are examples of some of the earliest remains that have been found for use as pelts. In a Paleolithic context, marten bones are rarely found but for the Mesolithic there are more examples of skinning marks (Charles 1997, 266). At the Mesolithic Ertebølle site of Tybrind Vig (DK), 5th mill. BC, the skeletons of 13 pine martens were found in a heap, presumably thrown there after skinning and showing that the animals were most likely caught at the same time (Andersen 2013, 69).

Jordanes (6th c. AD), who has written to us about the Gothic people, described the marten trade in Eastern Europe: *"Alio vero gens ibi moratur Suehans, quae velud Thyringi equis utuntur eximiis. Hi quoque sunt, qui in usibus Romanorum sappherinas pelles commercio interveniente per alias innumera gentes transmittunt, famosi pellium decora nigridine* (Jordanes, Getica 3,21). *Hunugari autem hinc sunt noti, quia ab ipsis pellium murinarum venit commercium: quos virorum formidavit audacia."* (Jordanes, Getica 5,37). The people from Thuringia dealt with many other tribes in (sapphire-colored?) pelts, these probably being from the Arctic fox (see ch. 4.5.3). The Thuringians were also famous for the black pelts they wore. These may well have been marten, although due to the color and quality would more probably have been sable (see chapter 4.5.18). The "Hunugari" (people from Hungary) were also dealing with marten pelts, the *pellium murinarum*. In Eastern European countries at a much later time – during the Middle Ages – marten pelts were even used as a sort of currency. The Slavic word *kuna* means "marten" but also a certain amount of money – the amount of skins for one Dirhem (arab. coin) (Gunda 1972, 283; Kovalev 2003).

Innumerable marten pelts have been traded throughout history, some of them restricted to the garments of royalty or for other nobles. Even today, pelts such as the American mink are bred commercially and are one of the most expensive furs on the market.

4.5.13.2 Fibres

The mustelids have a dense and shiny fur and, as with the otter, have up to 70 000 fine underhairs per cm^2. Excepting the badger and otter, these fibres are, unfortunately, quite difficult to differentiate. Detailed identification is reliant on three criteria: mean length, maximum diameter and index of the medulla (ratio medulla : diameter) (Tóth 2002). Clear characterization of archaeological finds, therefore, is nearly impossible. To differentiate from the *canidae* the most important identifying mark has to do with the medulla – or the ladder type for martens (except badger) – which is characteristic from the multicellular/amorphous medulla of the canidae (Keller 1981; Tóth 2002) (*Table 4*).

Tóth (Tóth 2002, 244) defined a combination of criteria to determine *mustelidae*, when:

- hairs have no bands (no clear color change in one or more parts of the hair)
- the medullar index is 0.7–0.8 (medulla dm : hair dm)
- the scale pattern changes from the base to the tip from mosaic – diamond petal – regular/irregular wave.
- the medulla pattern changes from the base to the tip from unicellular ladder – irregular ladder, cloisonné – fragmented.

4.5.13.3 Archaeology

In archaeological material all criteria will be difficult to see (except *Meles meles*). However, in metal replaced material the change of scale pattern along the hair could be recognized and is an important way to identify at least the sub-family of the *mustelidae*. All finds of mustelids are skins and not fibres of blended yarns. Prehistoric skins have been found in the salt mines of Hallstatt (A). The scale pattern will lead to an identification of mustelids but it is not clear (*Figs 194* and *195*). A small fragment of skin shows how dense the fibres grow out of one follicle. One skin has been found in Flaach (CH) and is dated to the beginning of the 6th c. AD (Rast-Eicher 2012a, 56f.); it was highly visible on a silver arm ring of the deceased. This can be interpreted as a lining or trimming of the sleeve (*Fig. 196*). In a grave of the same period (around 500 AD) from Unterhaching (Bavaria/D) in the rich grave 5, a mustelid skin was found on an iron chain placed close to one of the hands of the deceased (Nowak-Böck – v.Looz 2013, Abb. 37). Both are examples of a rich woman's grave. Another case comes from a man's grave of the 7th c. The fibres were found on arrowheads and initially determined as mustelid (Cooper *et al.* 2010, 159). However, the proportion of scale length-to-width of the fine fibres points to otter (see ch. 4.5.22).

Tab. 4.: Mustelide, canides and cats: after Keller 1981; Tóth 2002; Meyer et al. 2002

Species	Scales	Medulla	Cross-section	Medulla:dm
Vulpes vulpes	broad petal-irregular wave; diagonal wave	ladder-mulitcell./cloisonné larger than for *Canis lupus* rounded/oval cells tip without medulla, long tip	round-oval	0.75
Canis lupus	broad petal-irregular wave, diagonal wave	multicellular-cloisonné	round	
Meles Meles	regular-irregular wave diamond petal absent	amorphous/granulated	oval	0.5
Lutra lutra	petal-regular wave very long petals	unicellular ladder fine fibres without	elongated-oval	0.6-0.7
Felis sylvestris	regular wave-mosaic no petals in shaft	irregular uni-> multicellular spindle-like, large cells	round-oval	0.75
Martes martes	mosaic -diamond petal–wave	ladder to cloisonné	oval-oblong	0.7-0.8
Martes erminea	mosaic -diamond petal–wave	unicellular ladder	oval-oblong	0.7-0.8
Martes nivalis	mosaic -diamond petal–wave	unicellular ladder	oval-oblong	0.7-0.8
Martes foina	mosaic -diamond petal–wave	unicellular – multic. ladder	oval-oblong	0.7-0.8
Martes putorius	mosaic -diamond petal–wave	unicellular – multic. ladder	oblong	0.7-0.8
Martes zibellina	mosaic -diamond petal–wave	unicellular – multic. ladder	oblong	0.7-0.8

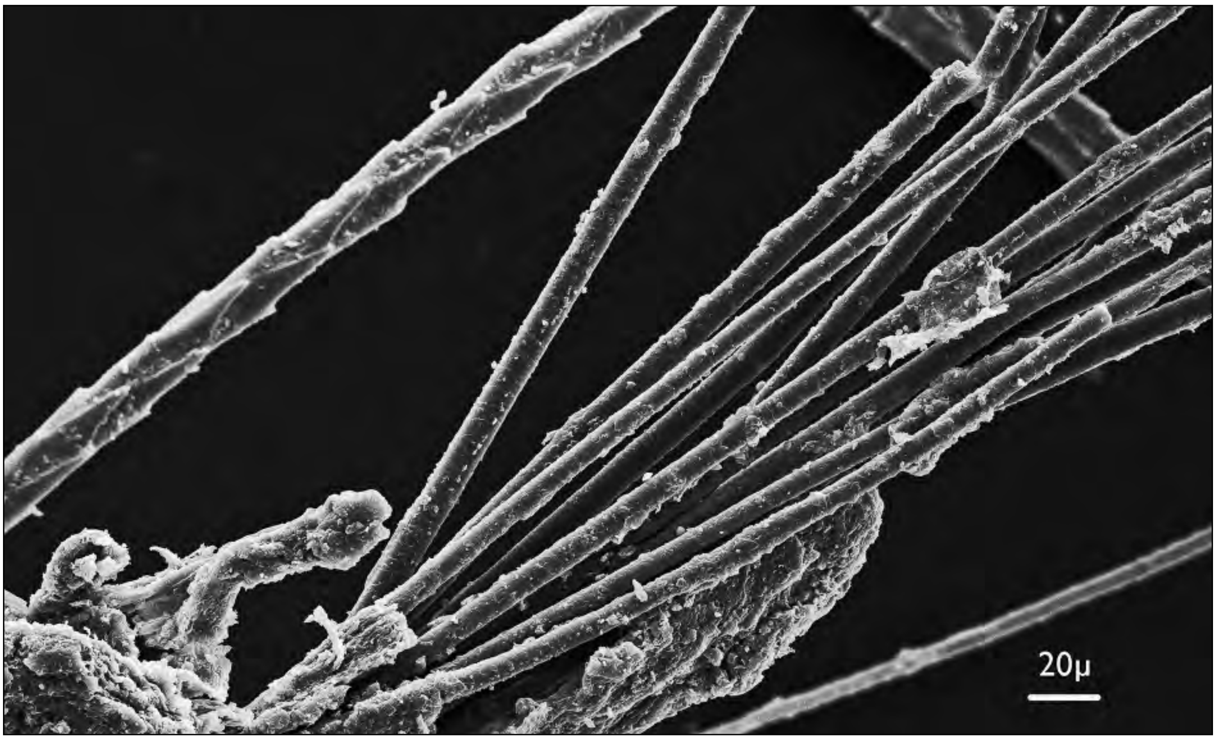

Fig. 194. Mustelidae sp., sable?, Hallstatt (A). NHM 77736

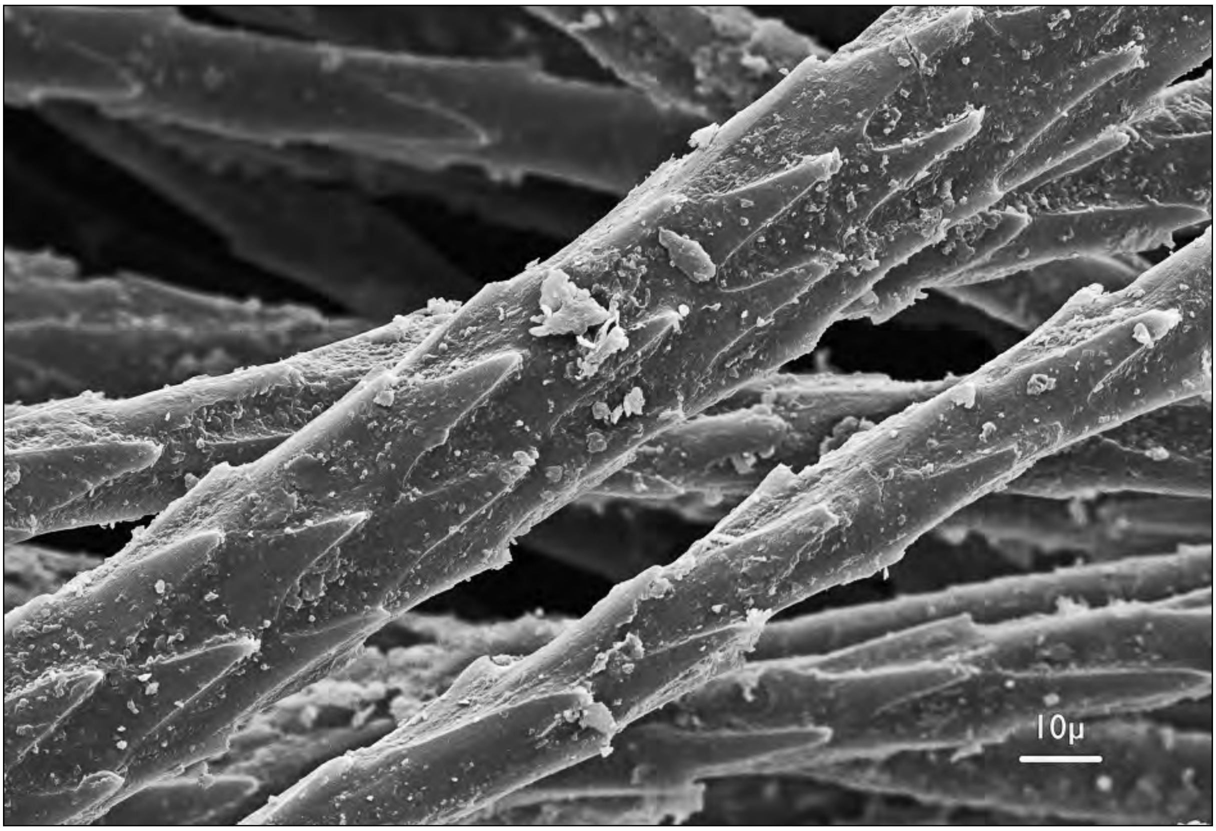

Fig. 195. Mustelidae sp., sable? same sample as Fig. 194, Hallstatt (A)

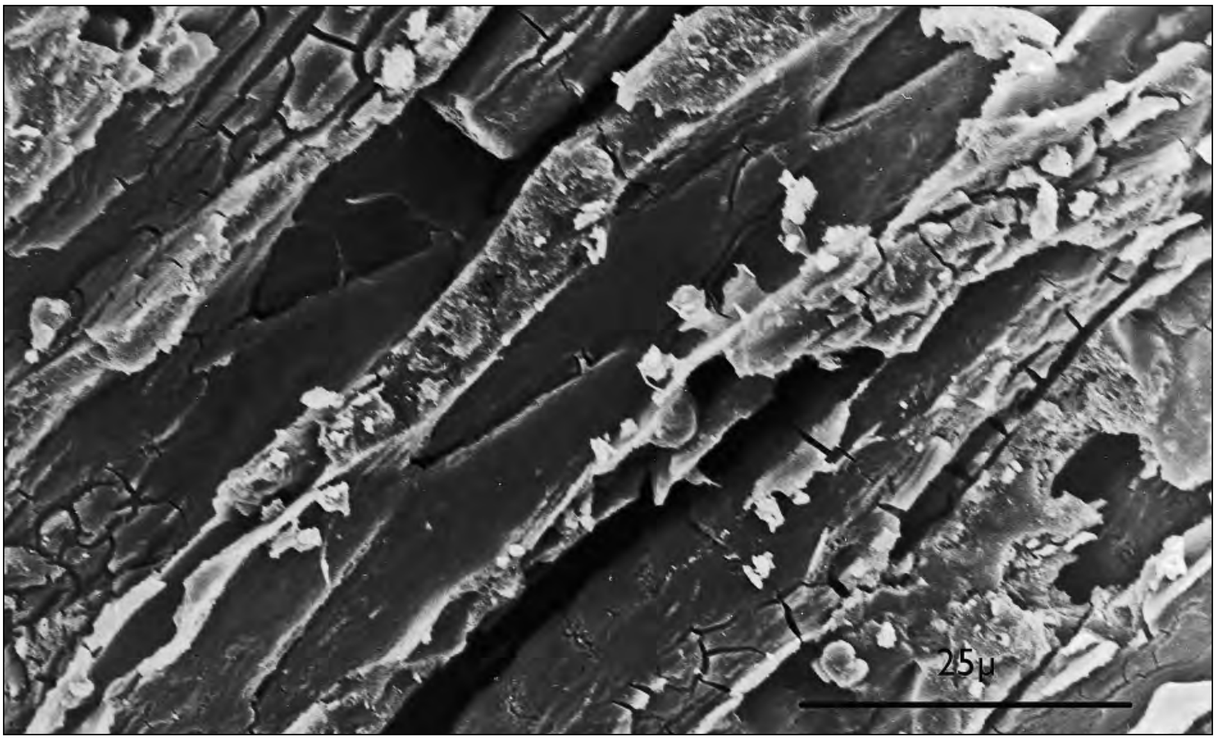

Fig. 196. Mustelidae sp., mineralized, scales seen as negative imprint, Early Medieval grave, Flaach (CH)

4.5.14 Badger *(Meles meles)*

4.5.14.1 Habitat

In forests (different types), hedges.

4.5.14.2 History

Badger skin was throughout history not of great value although the leather seems to have proven durable as it was used for bags and shoes. The medieval abbess, Hildegard von Bingen, recorded (Hildegard von Bingen, Physica, 7, 28; text ed. by Riha 2012): *"Das Dachsfell enthält grosse Kraft. Schuhe daraus verhelfen zu gesunden Füssen und Schenkeln."..."Der Dachs ist warm und hat ein stilles Gehaben, er hat fast so starke Kräfte in sich wie ein Löwe. Umgürte die nackte Haut und alle Krankheit wird in dir aufhören und eine neue gefährliche Krankheit wird dich in dieser Zeit nicht befallen"*. ("Badger skin contains strong forces. Shoes made of it help to have healthy feet and legs."...."Badger is warm and soft, it has nearly as much force as a lion. Put a belt on your naked skin, and all diseases will stop, and another new illness will not begin.")

Skin has been used for bags and the fibres are well known today for use in shaving brushes or as decoration on hats. The purse of the Sottish costume is made of badger skin.

4.5.14.3 Fibre properties

Badger fibres have a white tip and base. Primary hairs are coarse and elliptic (100–200μ), under-hair have a dm. of 25–49μ. The cuticles shows rippled margins and the medulla structure resembles that of the one for cattle (Lochte 1938, 170). Badger have a mustelid-like diamond petal at the shaft, but the cloisonné pattern and fine rippled margins are absent (Tóth 2002), see also *Table 4*. According to Körber-Grohne the fibres are often split (Körber-Grohne 1985, 112–114). Important for determination are the fine "tooth"-like appendices at the basal part of fibres, mentioned also by Lochte (Lochte 1938, 170), which probably come from the splitting. The rippled cuticle is difficult to differentiate from horse fibres. The medulla (about 1/2 width) is granulated, similar to cattle, dark or light, and becomes smaller towards the tip (*Figs 197* and *198*).

4.5.14.4 Archaeology

The earliest finds of badger are from among the material of the "princely" tomb from Eberdingen-Hochdorf (D), dated to the Hallstatt Period (Körber-Grohne 1988a, 78; Banck-Burgess 1999 cat. 135, 137, 389, 406, 448, 468, 823). There are fur as well as textile remains, in some cases it not being clear which was which.

In a more recent excavation from Langenthal-Unterhard (CH), badger fur was found on the arm ring of the deceased (Rast-Eicher 2008a, 168). A badger skeleton, as well as his tunnel into the funerary chamber, revealed that the tumulus had been used as his (second-hand) home. The badger fibre was very clearly determined with a fine rippling and a little "tooth" at one of the fibres (*Fig. 199*). Otherwise, a differentiation from horse would have been difficult. The Langenthal badger raises the question whether the Hochdorf badger fur and fibres derive from a similar "new" inhabitant of the grave-chamber.

4.5.15 Stone marten *(Martes foina)*

4.5.15.1 Habitat

Rocky mountain regions and forests, parks, houses.

4.5.15.2 History

Foynes is the old French name for marten pelts. The fur is coarser than the pine marten, the under-wool whitish. Depending upon their origin, pelt color varies, with those coming from Russia, Armenia and Bulgaria being especially dark (Franke – Kroll 1976, 47). The pelts were sold from Central and Western European countries, not from the North (Delort 1978, 168). In 1384, in the lists of the Great Wardrobe, 11'305 skins are noted with most being "foynes" and "budge" (Hayward 2014, *"foynes"*).

4.5.15.3 Fibre properties

Fibre diameter of the fine fibres is 15–20μ), primary hair up to 100μ. The scales are similar to the ones of the otter (*Lutra lutra*) but the medulla type is different, having a V-shape and roundish gas spaces, a dark medulla and an oval shape to the cross-section of the coarse hairs. Scales of the primary hair are from basal diamond petal to irregular wave in the upper part (*Figs 200* and *201*).

4.5.15.4 Archaeology

see ch. 4.5.13
A skin garment from Møgelmose, Jutland, found 1857 and dated between 400 and 120 BC, has been identified as pine marten by H.M. Appleyard; later investigations do however suggest an identification as goat skin (Ørsted Brandt *et al.* 2014).

4.5.16 Western polecat *(Mustela putiorus L.)*

4.5.16.1 Habitat

Woodlands, near water and in buildings.

4.5.16.2 History

Aesop (6th c. BC) wrote down two tales about weasels: "The mice and the weasel" and "The bat and the weasels". The Romans tamed polecats to hunt rabbits in Spain (Strab. Geogr. 3,2,4/168; 6/144). Isidor was identifying them as *furo*, something that has remained in the scientific naming of the sub-species (Isid. Orig. 12,2,39).

In the Middle Ages pelts were used by those of a lower social status (Zitzelsperger 2010, 177). The presence of polecat bones, especially in castles, points to the use of rabbit warrens (Benecke 1994, 184; Fairnell 2003).

The tamed polecat is a sub-species (*Mustela putiorus furo*), also known as the English "fitch". Castrated males will tend to have odorless pelts. In the Middle Ages rabbits were hunted with ferrets (law in England by Richard II; Zeuner 1963, 401).

4.5.16.3 Fibre properties

The pelt usually has an odor which can be removed through processing. Fibre diameters for primary hairs are 40–60µ, fine fibre 10–15µ. Medulla in the dark primary hairs have a coarse net with numerous fine spaces. Pigment is found in fine lines. The scales of the fine fibres are rather cornet-like than petals; coarse fibres range in shape from a large diamond to finely rippled. A cross-section of the primary hairs shows an oval shape.

4.5.16.4 Archaeology

see ch. 4.5.13

4.5.17 Pine marten *(Martes martes)*

4.5.17.1 Habitat

Lives in Europe, Turkey, Himalajas, in forests, also alpine woods.

4.5.17.2 History

Bones are found in settlements from the Stone Age which shows that the use of skin can be admitted into evidence (Reichstein 2003b). In Tybrind Vig (DK) e.g., a late Mesolithic area of the Ertebølle culture in Denmark, evidence of crush marks on marten skulls could show that these come from hunting which was done either by trapping or by attack from a dog (Trolle 2013, 454f.). Even in modern times such pelts were given as gifts (Franke – Kroll 1976, 45). The highest quality pelts came from Scandinavia. Marten pelts were used for garments but also in the trimming of fur hats, especially for nobles. Also, they were dyed black and sold as sable (Meyer's Konversationslexikon 1885-1892, "Marder"). Marten pelts were occasionally used to pay taxes, especially in Slavic countries, the so-called *"marturina"* (Delort 1978, 157). In the 10th century, marten skins, *"deleq"*, were equivalent to Arab coins (1 *deleq* = 21/2 *Dirhem*) (Schier 1950, 307).

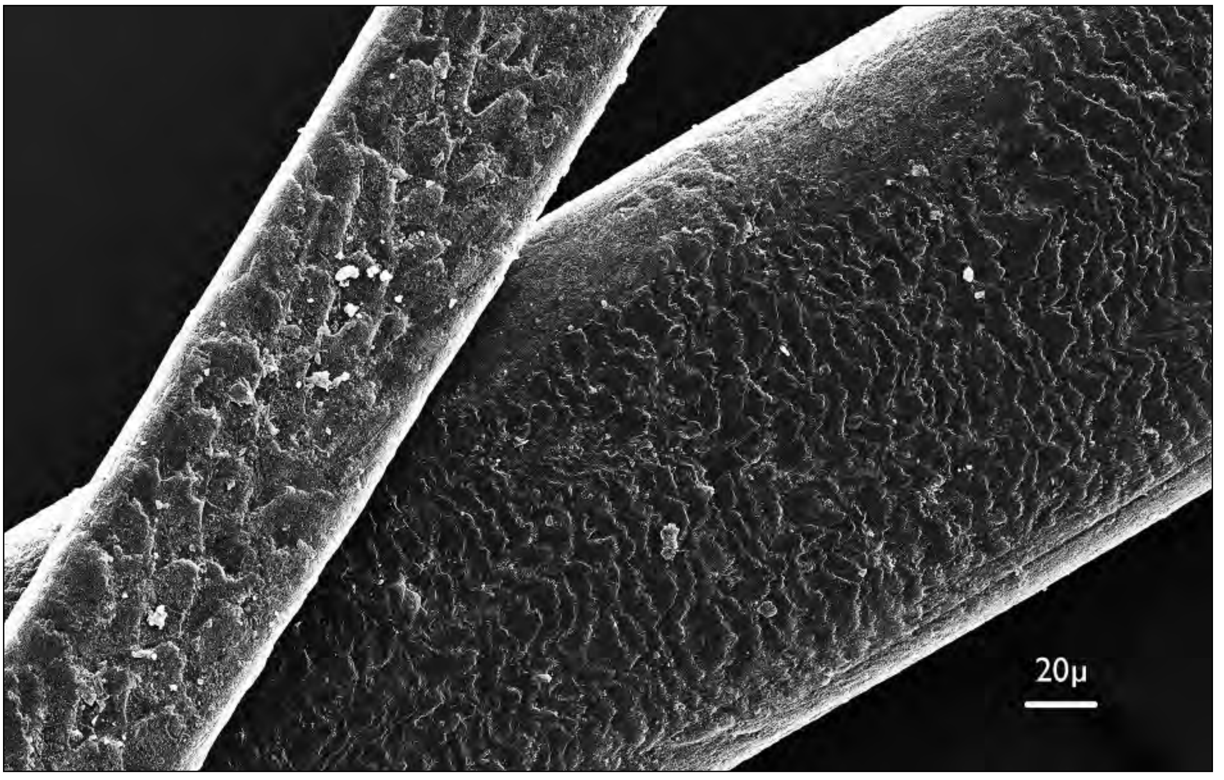

Fig. 197. Badger fibres, modern

Fig. 198. Badger fibres, split fibre, modern

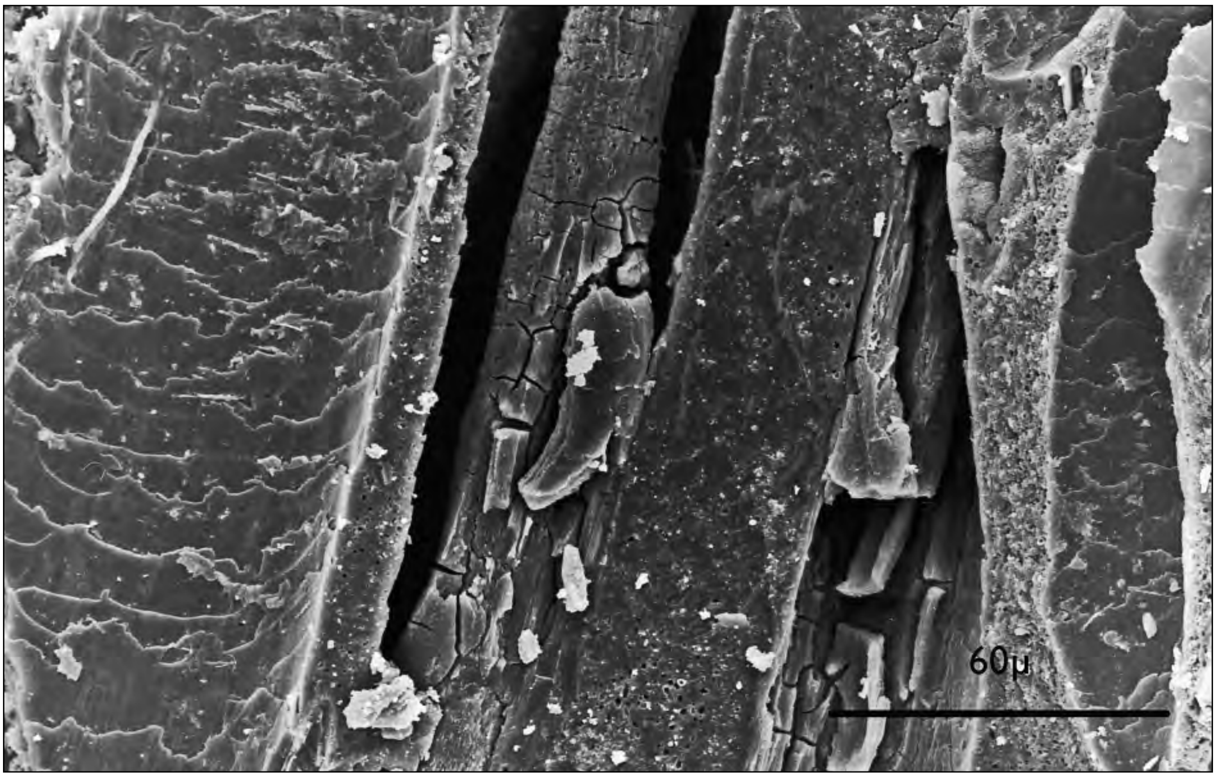

Fig. 199. Badger fibres, mineralised, one fibre split, „tooth"-like remain, Iron Age grave, Langenthal-Unterhard (CH)

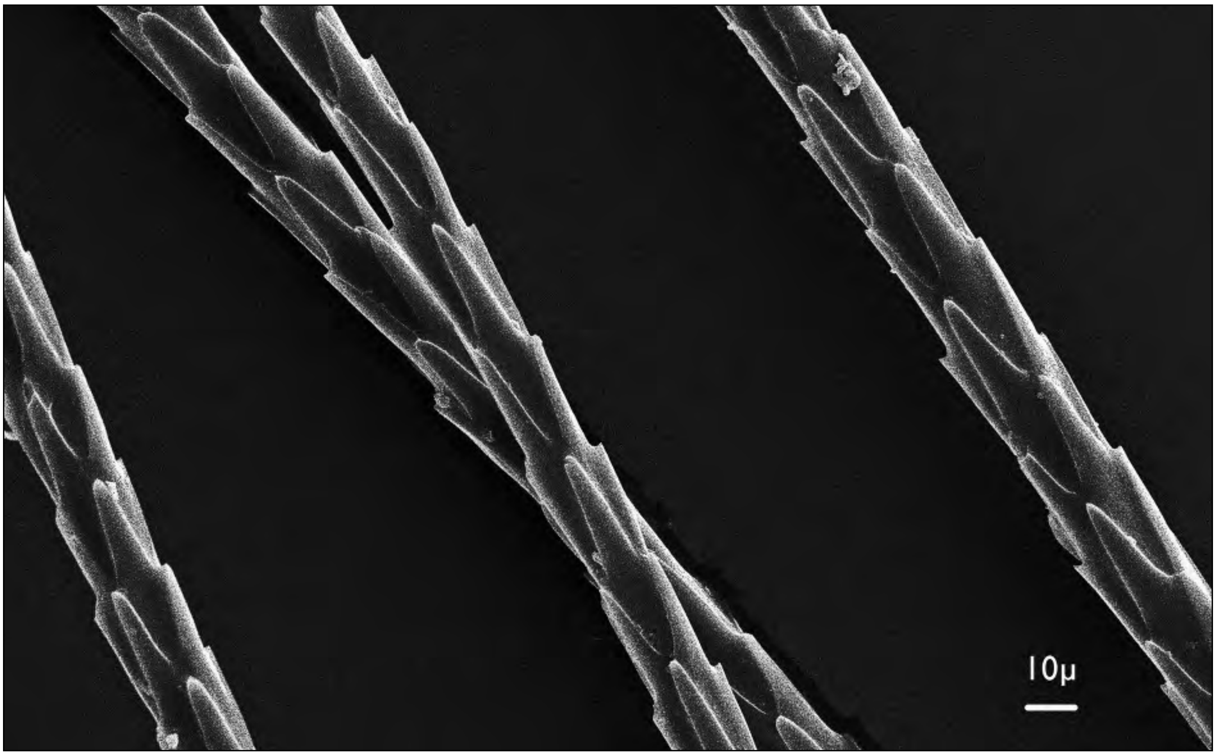

Fig. 200. Stone marten fibres, modern

Fig. 201. Stone marten fibres, cross-section of primary hair, modern

4.5.17.3 Fibre properties

Fine glossy pelt, finer than stone marten. They are naturally brown in color and may be dyed to resemble sable. As with all martens, they may be let out or used in various patterns for coats,for whole-skin scarves and even "little" furs. Fine fibres were of 10–15µ, coarser fibres 20–40µ, with primary hairs up to 80µ. For scale and medulla pattern see *Table 4*. The medulla has fine pigments (Keller 1981) (*Figs 202–205*).

4.5.17.4 Archaeology

see ch. 4.5.13

4.5.18 Sable *(Martes zibellina)*

4.5.18.1 Habitat

From Scandinavia to China, in taiga forests of the North, conifer forests, flatlands and in mountain regions.

4.5.18.2 History

The name "sable" is borrowed from the old Russian word *"sobol"* (Kovalev 2002, 76). In 9th century Byzantium, sables were the most valued pelt. A "fur-road" had been established from the Finno-Ugarian peoples of the Aral Sea to the south (Byzantines, Sassanian) (Kovalev 2003). Another route was installed by the Norwegians to the south. The kings desired the black fur and had hats, kaftans and coats made from it. Very early Arab coins (Dirham) were to reach Novgorod as well (Kovalev 2002, 45ff., 85). In the Middle Ages furs were brought by Genovese merchants to the Near East. European rulers also valued sable robes and silks with sable trimmings.

Considered a most precious fur, sable made up garments that belonged to such noblemen as Charlemagne (*Murinae pelles,* Einhard, Vita Caroli magni, 23; see also quotation in chapter 4.5.22). In the Medieval Period sable was even included in the monetary system of the Slavic people to pay taxes, as well as holding value per pelt. In Kiev and Novgorod (RU) pelts were even calculated at a certain value to be used as currency (Ducène 2005, 224). Trade to the south by the Bulgars was important as was the trade of the Hanse from Novgorod (Kovalev 2002). A carved wooden church chair from Lübeck of the 2nd quarter of the 15th c. depicts a Hanse merchant of Novgorod (RU) with a sable (Lübeck, St. Annen Museum, Inv. 33). A very large amount of sables were hunted in Siberia, most markedly after Moscow became the center of fur trade after 1478 (Etkind 2011, 168) where it became the most expensive pelt of Russia. In the 17th century alone more than seven million pelts were estimated to have been brought from Siberia to Moscow (Etkind 2011, 167). The use of sable has been controlled and regulated, limited to persons with a certain social status. There is, as well, a differentiation in pelt quality from between the belly and the back of the animal (in German: *Rückenmarder*, *Kehlmarder*). The former is brown/black in color, the latter grey/white. Of prime quality was the back and it was reserved for the nobility (Zitzelsperger 2010, 177). In England, Henry VIII allowed sable for the nobility from the rank of Earl (Davey 1895). That is why, in order to clarify his rank, Hamlet presents himself as wearing this fur: *"I'll have a suit of sables"* (Shakespeare, Hamlet, act 3, scene 2). In heraldry, sables are black. Up to the 17th century, the imperial crown of the Russian tsar was a hat made of sable fur decorated with gold and precious stones (Franke – Kroll 1976, 49). According to travel reports from the 18th c., sable were kept as pets in Russian and Siberian households, It was easy to tame as a young animal but difficult to keep (i.e. it fought with the cats and was active at night) (Ståhlberg – Svanberg 2011, 366).

Today, the sable is a well-known animal, farmed in many countries as a source of precious fur (Monakhov 2011).

4.5.18.3 Fibre properties

The sable is larger and darker, and the pelt more lustrous than other martens. The fibres are pigmented, the fine fibres dm. 10–15µ, the primary hairs 40–60µ. The structure of the fibre (scales, medulla) is very similar to the pine marten or European mink (*Martes martes*) (Lochte 1938, 160), see also *Table 4*, *Figs 206* and *207*.

4.5.18.4 Archaeology

Sable has been found in a coat from the Olon-Kurin 10 burial in Pazyryk (Molodin *et al.* 2009). The determination was made from the general appearance of the pelage, its color, and then microscopic comparisons with modern material. See also ch. 4.5.13.

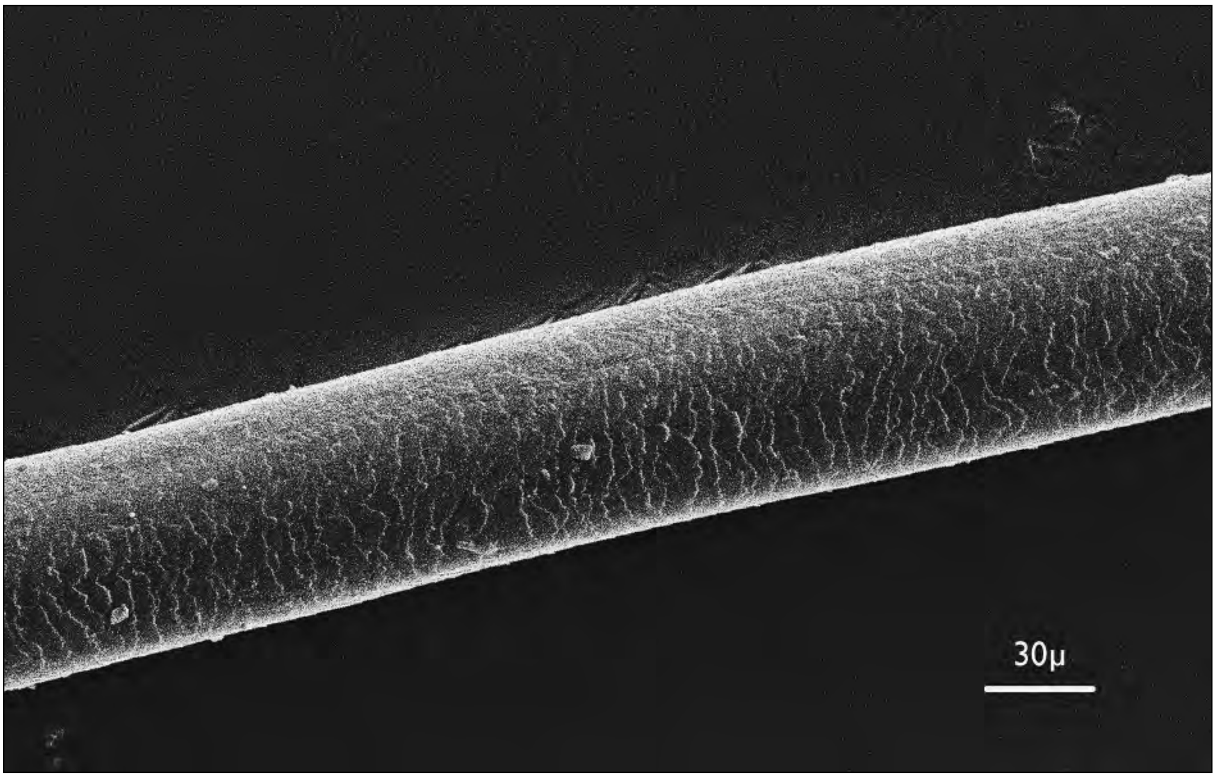

Fig. 202. Pine marten, primary hair, modern

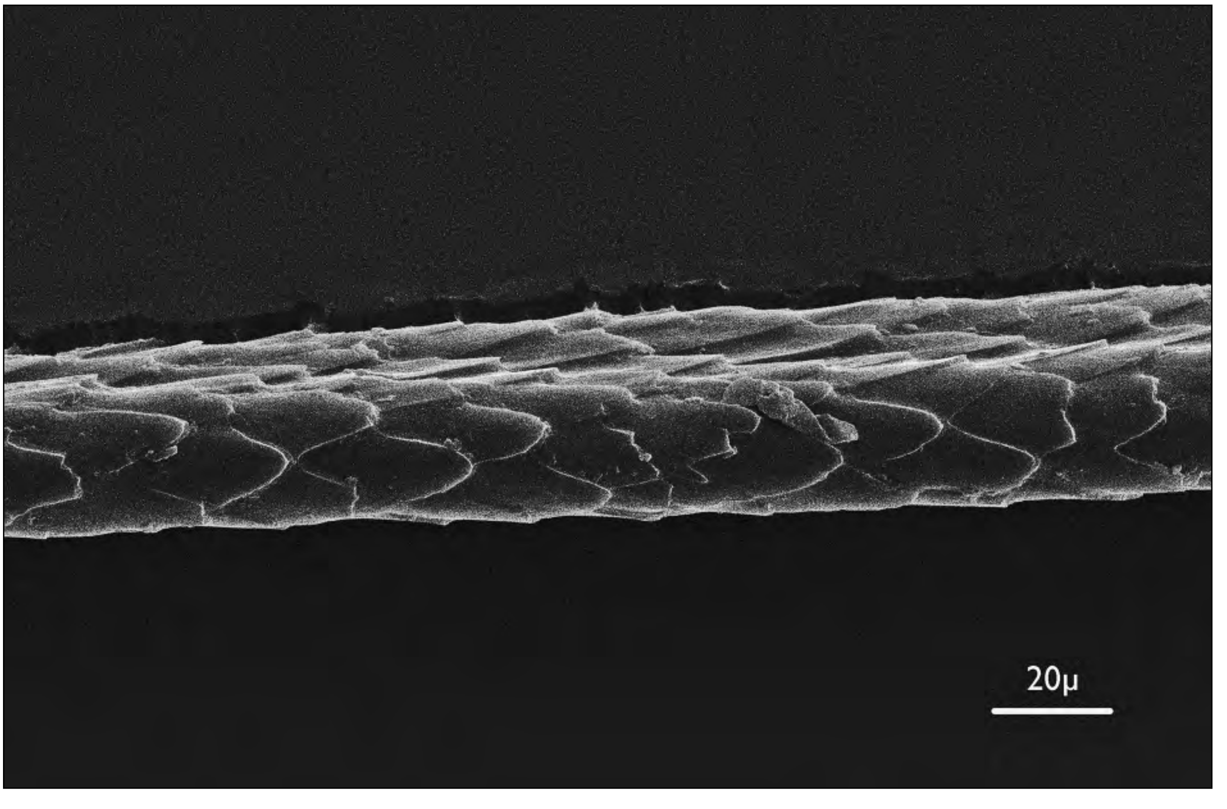

Fig. 203. Pine marten, intermediate fibres, modern

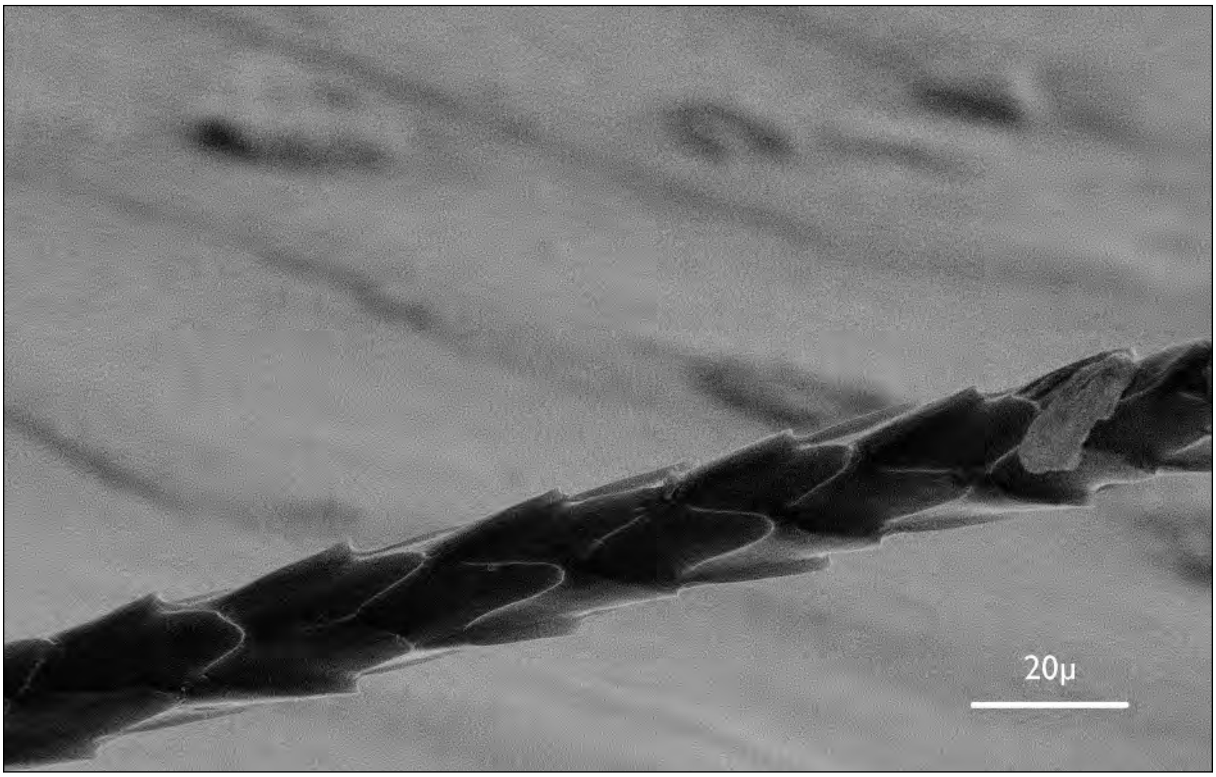

Fig. 204. Pine marten, fine fibre, modern

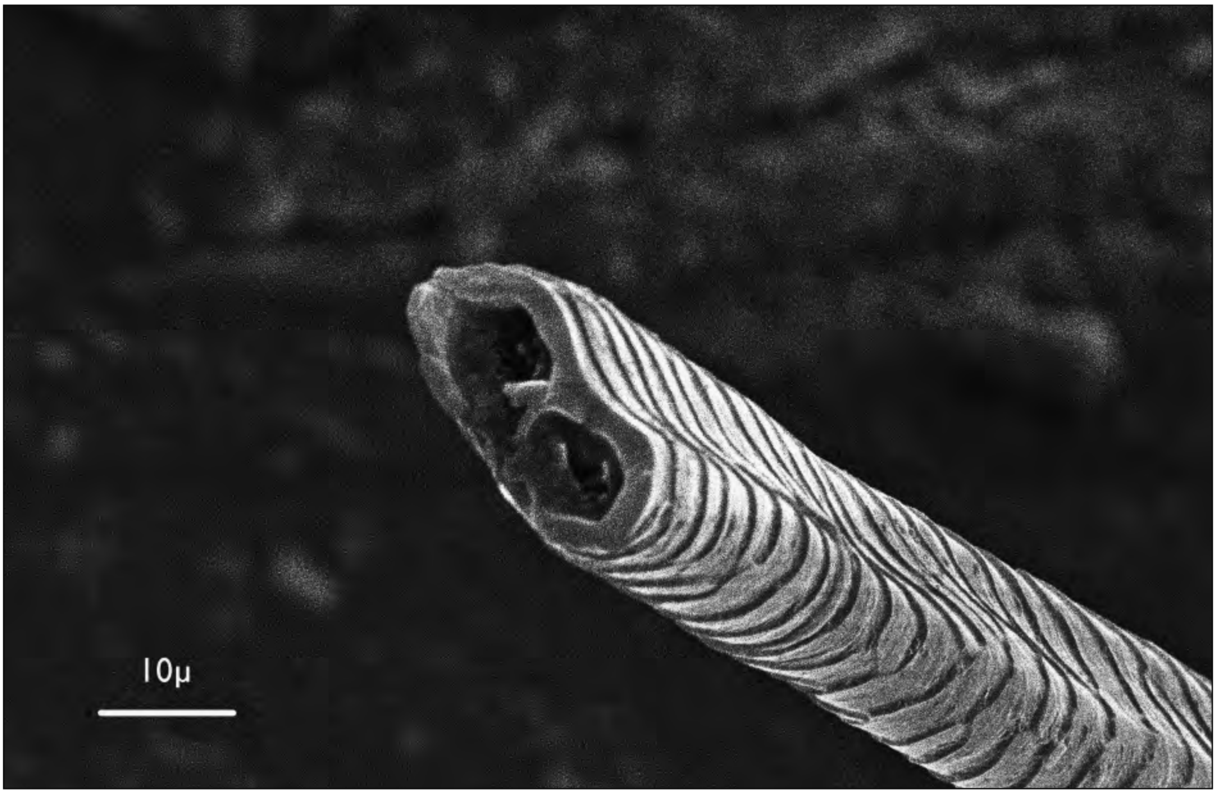

Fig. 205 Pine marten, cross-section, modern

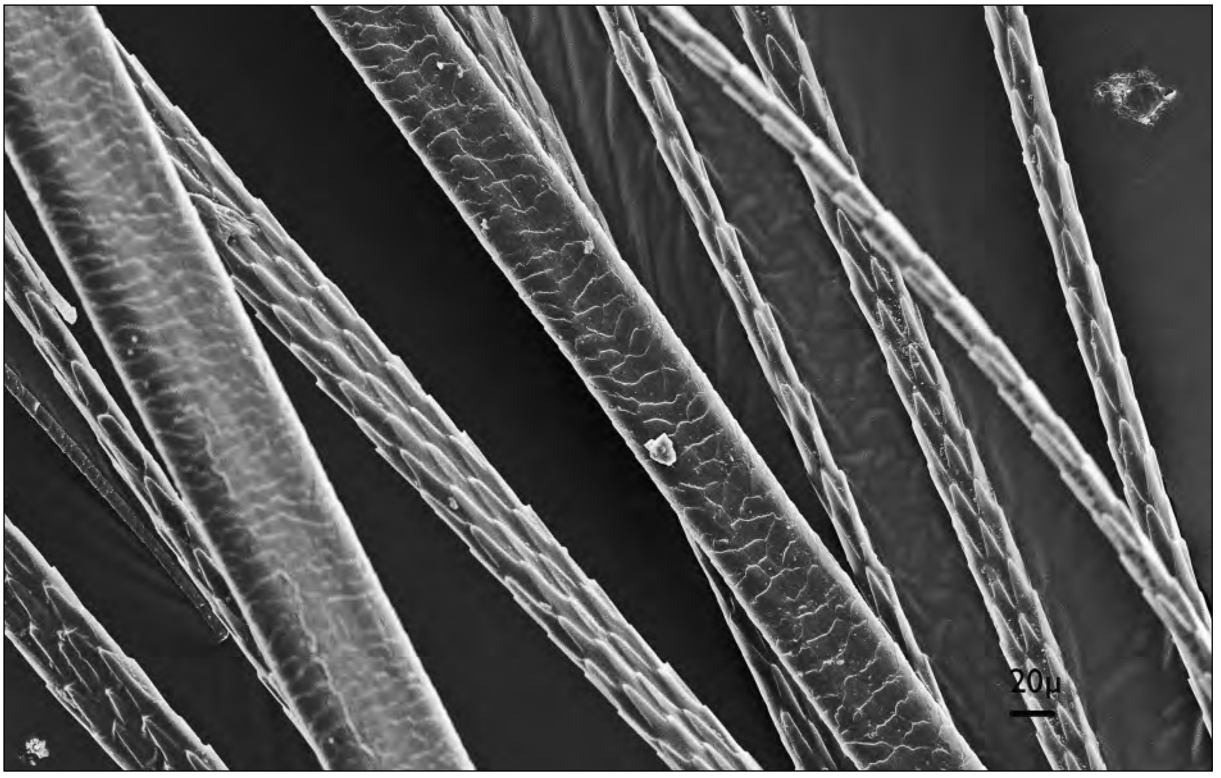

Fig. 206: Sable fibres, modern

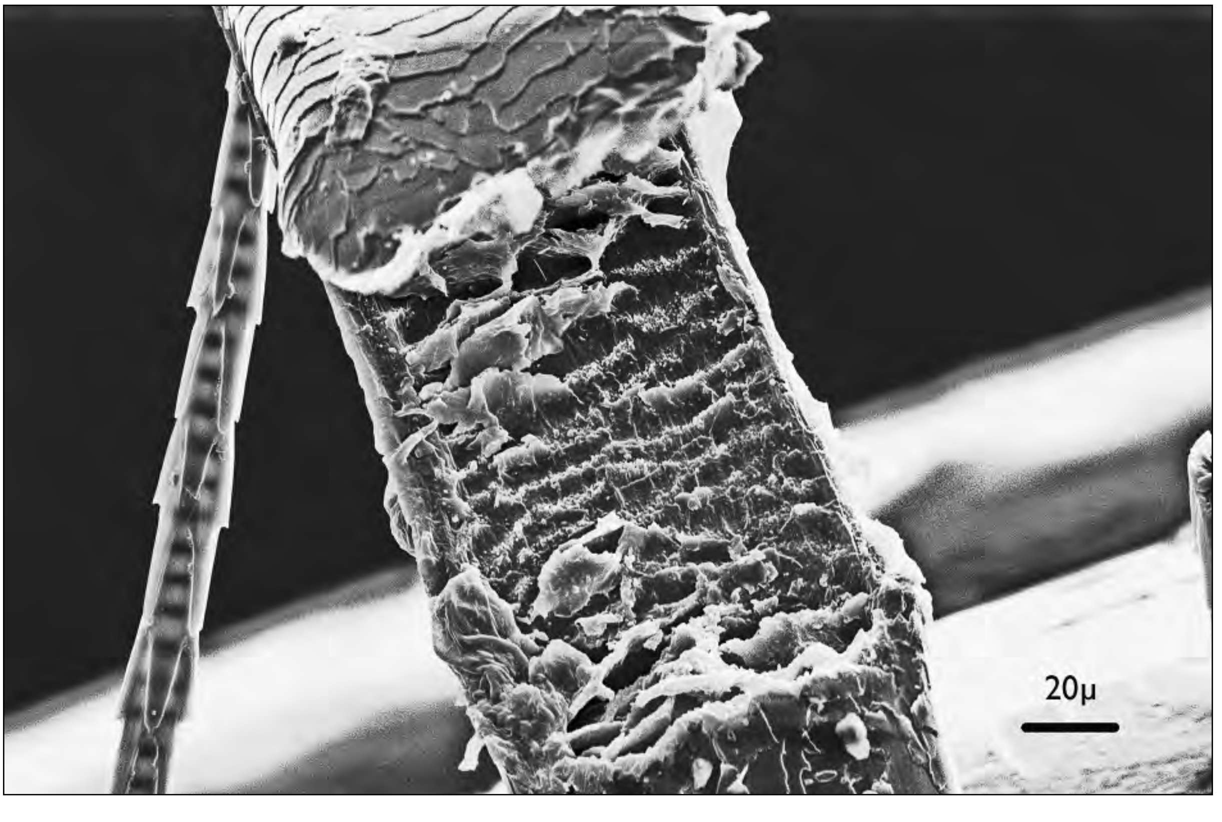

Fig. 207. Sable fibre showing multiserial medulla, modern

4.5.19 Stoat, Ermine *(Mustela erminea L.)*

4.5.19.1 Habitat

Biotopes with bushes, rocks, water, but also cultivated land, seldom in buildings.

4.5.19.2 History

Greeks named the ermine "white rat", and until the 17th century it was also known as *"rat d'Arménie"*. By the 4th century the ermine became the regalia of the Christian kings as well as those in the higher functions of the church – cardinals, for instance, were known for their ermine clothing. By the Middle Ages ermine pelt had become a distinction of nobility as well as in heraldry. Edward III (14th c.) declared ermine as the king's pelt and it remains today an important part of the ceremonial robes of the British monarchy (and other monarchs) (Davey 1895, 12ff.). The pure white and black of the pelt were symbolic of chastity and good conscience, being used for the coats of royalty even in place of more precious pelts (Franke – Kroll, 1976, 18). Most of the ermines were sold from Novgorod through the Hanse towns (Lübeck, Riga, Thalinn) (Delort 1978, 135). The little black tip, which remains with the fur even as it changes in winter, has been recognizably depicted as a clear sign for the ermine pelt. If was also given a specific design in heraldry with white spots in a black field, black spots on a gold field or gold spots on a black field (Phoenix 2010, 197). In Renaissance art, the ermine was given special significance. In the famous portrait of Cecilia Gallerani by Leonardo da Vinci (c. 1490), the pregnant Cecilia is carrying a living ermine, the symbol for her lover Ludovico Sforza who was in the "Order of the Ermine" and therefore also known as *"l'Ermellino"*. Furthermore, the white ermine is connected to pregnancy and childbirth; this is linked to the Ovidian story of the transformation of Galanthis into a weasel, and to Hercules' birth. People believed that weasels were conceived through the ear and gave birth through the mouth – a miraculous birth – and therefore a talisman for pregnant women and depicted in many ways during the 15th/16th c. (Musacchio 2001).

4.5.19.3 Fibre properties

The fibres become white in winter but only in cold regions. If the climate is not cold enough (e.g. GB), the ermine will stay brown all year (stoat). The black tip of the tail remains black in all seasons. Stoat and weasel can be determined by the length of fibre only (Tóth 2002, 245). Fine fibre 10–15µ, primary hairs 40–60µ (*Fig. 208*).

4.5.19.4 Archaeology

see. ch. 4.5.13

4.5.20 Least weasel *(Mustela nivalis L.)*

4.5.20.1 Habitat

Open land with bushes or hedges, woodland, also in buildings in wintertime.

4.5.20.2 History

In Medieval England the weasel (*"lettice"*) was, according to the accounts of Richard II or Edward III, imported from the Baltic and cheaper than ermine (Hayward 2014, "lettice"). The least weasel was cheaper than ermine, but more expensive than miniver.

4.5.20.3 Fibre properties

Similar but smaller than ermine, fibre dm. 10–20μ for the fine fibres, 40–60μ for primary hairs. The pelt is white in winter in cold climates but the tail remains black-tipped throughout the four seasons (*Figs 209* and *210*).

4.5.20.4 Archaeology

Much organic material has been found in the Iron-Age tumulus of Eberdingen-Hochdorf (D). Textiles, but also skins, have been documented which belong to a very rich "princely" grave dated around 550 BC. Fibres found under the body were probably part of a mattress. The hairs have been determined as *Mustela nivalis* or *Martes sp.* (Körber-Grohne 1988a, 81).

4.5.21 Europ. mink *(Mustela lutreola)*

4.5.21.1 Habitat

Today extinct in most of Europe with some remaining in Northeast Europe; semi-aquatic at rivers and lakes; needing woodlands and bushes for hiding.

4.5.21.2 History

The European mink has been one of the most prized of skins. It has been imported predominantly from the Baltic (Delort 1978, 119). Today, it is one of the most endangered species (Maran – Henttonen 1995).

4.5.21.3 Fibre properties

Dark pelt, fine fibre 10–20μ, primary hairs 40–60μ. See also *Table 4*.

4.5.21.4 Archaeology

see. ch. 4.5.13. In the salt-mine of Dürrnberg b. Hallein (A) a fragment of a mink fur has been found. It had been stripped off the animal, and two legs are still visible (Stöllner 2002, Taf. 395, 2506).

4.5.22 European otter *(Lutra lutra L.)*

4.5.22.1 Habitat

Semiaquatic mammal, lives at rivers (especially main tributaries), lakes, bogs and the seashore up to 1800m.

4.5.22.2 History

There is evidence of use in Prehistory found on otter pelts with skinning marks. In Tybrind Vig (DK), a Mesolithic settlement in Denmark, the skinning marks on adult animals are visible from the skull down to the pubis. The otter does not molt like other animals and so could have been hunted at any time of the year (Trolle 2013, 461f.). Herodotus reports about the *Budinoi*, nomadic people living near the Skythians north of the Black Sea at the river Tanais (Don), who are hunting otters (ἐνύδριες) and beavers. The furs are sewn as fringe on their skin garments (Hdt. Hist. IV,109). Charlemagne wore the Frankish garment which, in winter, meant a garment of otter or marten on his chest (Einhard, Vita Caroli magni, 23: *"… et ex pellibus lutrinis vel murinis thorace confecto umeros ac pectus hieme muniebat…"*). Saint Boniface sent otter skins to England for a special garment to be made (*gunna)*, a design probably originating from Saxony (Schier 1951, 24f.): *"gunnam breve nostro more consutam, unnam de pellibus lutrarum factam frateritati vetrae misi"*.

In the Middle Ages the otter, more frequently than the beaver, was widely used for its skin in Europe (Franke – Kroll 1976, 69f.; Delort 1978, 115). Medieval depictions show otter, rather than beaver, hunted by the nobility, otter being more difficult to catch and therefore a more interesting prey. At courts the hunting took place with the "otter-spike" (Dieberger 2003). During Early Modern history until the 1st World War, otter skins were valued most highly on the fur market. By the 20th century the otter was completely extinct in certain areas, such as in Switzerland. Special fishing laws in which the state paid out for each hunted otter (!) was one reason for this. Another contributing and devastating reason had to do with the massive environmental changes to their natural habitats caused by river rerouting (e.g. canal constructions, hydropower installations) and the accompanying water pollution from discharged chemicals (www.prolutra.ch).

4.5.22.3 Fibre properties

Like all semiaquatic animals, the otter is protected not by fat but by a dense fur. The otter tops all animals in hair density with 70 000 fibres/cm^2 it's thickness remaining the same throughout the year. The ratio of primary hairs to secondary fibres is very low, with few primary hairs being in otter fur (Kuhn *et al.* 2010). The fine fibres show a very specific form and scale construction with an interlocking pattern that resembles a zipper (Kuhn – Meyer 2010). They are not medullated, in contrast to the *Mustelidae* and identification of otter hair is clearly determined through the fine fibres. The ratio length of these long scales in narrow petal form to the width is about 40:7 (X/Y-Feret of the fine fibre = 0.17), with no such relation in the *mustelidae* being so extreme (*Figs 211* and *212*).

According to Keller (Keller 1981, 809), otters have petals with a rounded end which can be quite problematic for clarification compared to other mustelids such as *M. nivalis* or *M. erminea*.

4.5.22.4 Archaeology

In grave 41 of Saint Denis/Paris (F), an otter skin could be documented. It had been determined as fox in a previous publication (see ch. 4.5.2.4), however new analysis revealed otter skin (Rast-Eicher in press, Saint Denis), (*Fig. 213*). The function is not clear but it could have been a lining in a garment or a purse. A similar trimming of otter fibre was found in an Early Medieval context on a hat woven in 2/2 twill in grave 21 of Sutton Hoo (GB) (Crowfoot 1983). In grave 1 of Sutton Hoo (GB), an otter skin was found at the feet of the deceased. Mineralized otter fibres covered arrowheads in a man's grave at Baar-Früebergstrasse (CH) (*Figs 214* and *215*). It was identified at first as mustelid, but the ratio length to width of the scales of the fine fibres would make otter very probable (Rast-Eicher 2010, Figs 132, 133). A possible otter skin comes from Derrykeighan (Ireland) – an almost complete skin cape – which was determined in the 19th c. as otter (Wincott Heckett 2012, 436).

4.5.23 (Wild) cat *(Felis silvestris)*

4.5.23.1 Habitat

There are three subspecies of *F. silvestris*, *F. silvestris silvestris* (European wildcat), *F. silvestris lybica (Near Eastern wild cat) and F. silvestris ornata* (Middle East and Central Asia). The domestic cat is a subspecies of *F. silvestris catus*. The European wildcat lives in forests, alpine woods, rocky regions.

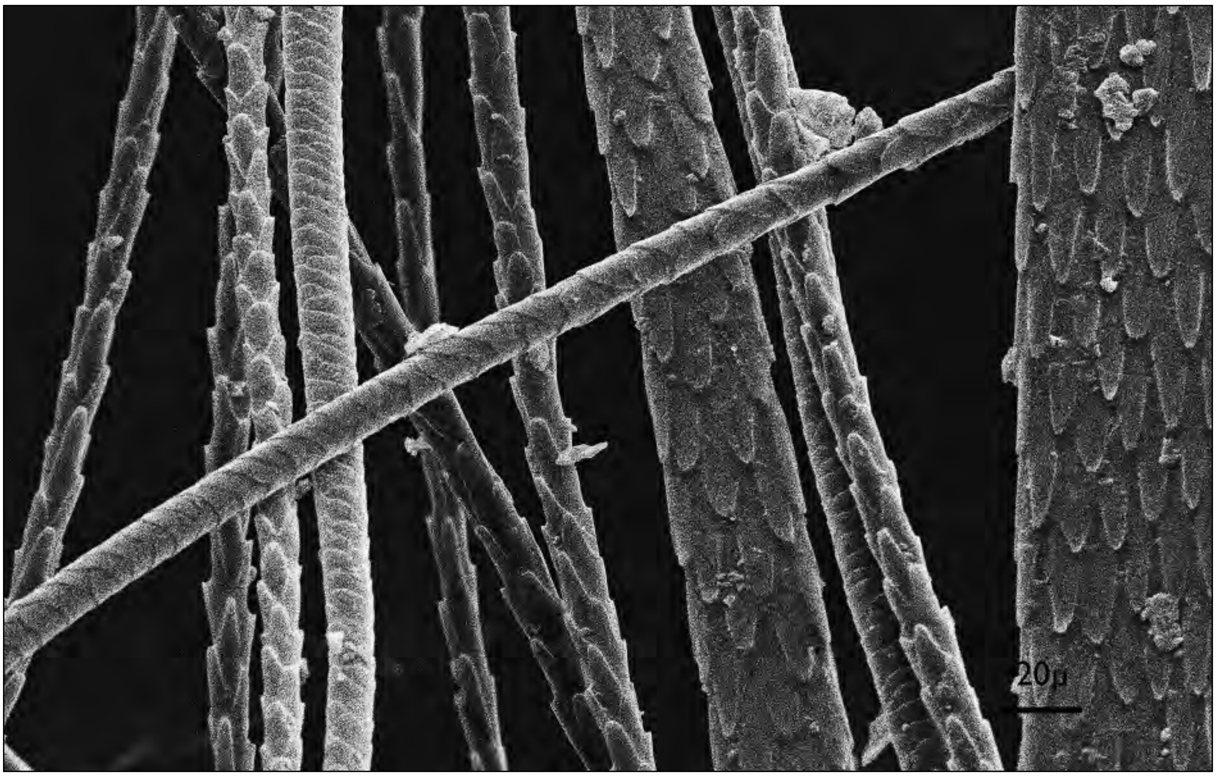

Fig. 208. Ermine fibres, modern

Fig. 209. Least weasel fibres, modern

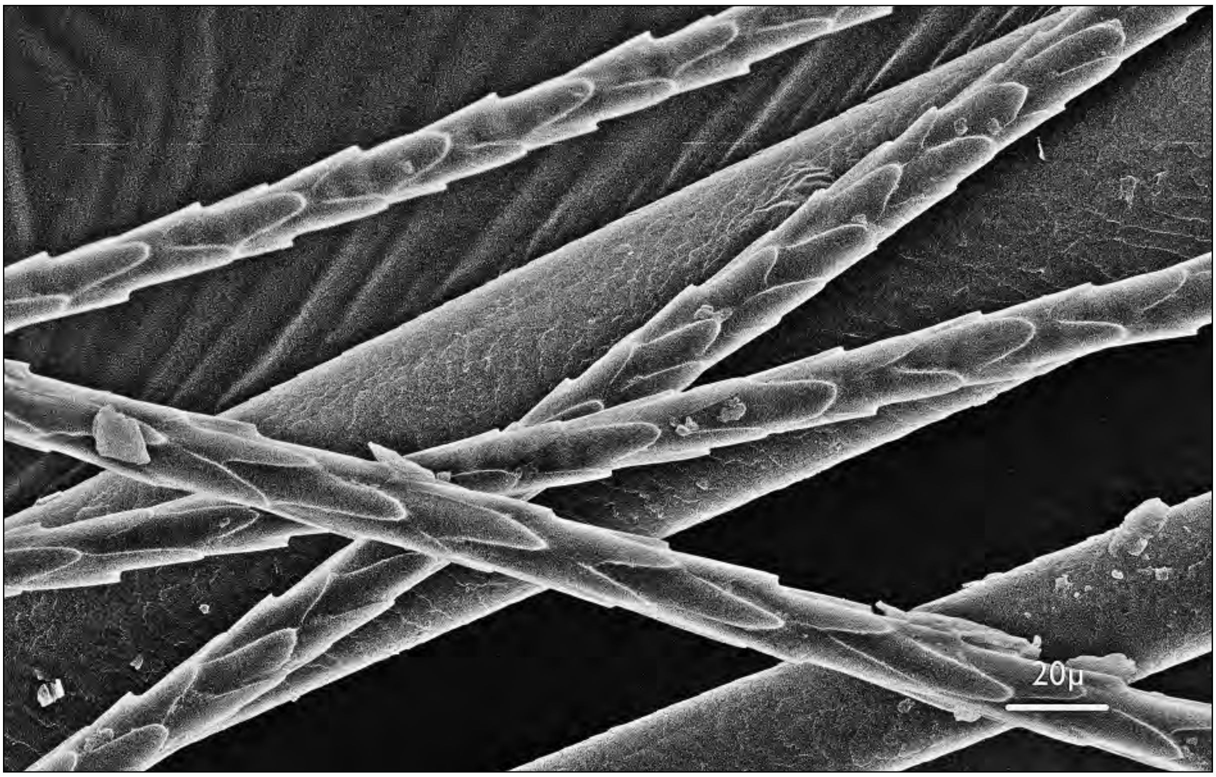

Fig. 210. Least weasel fibres, modern

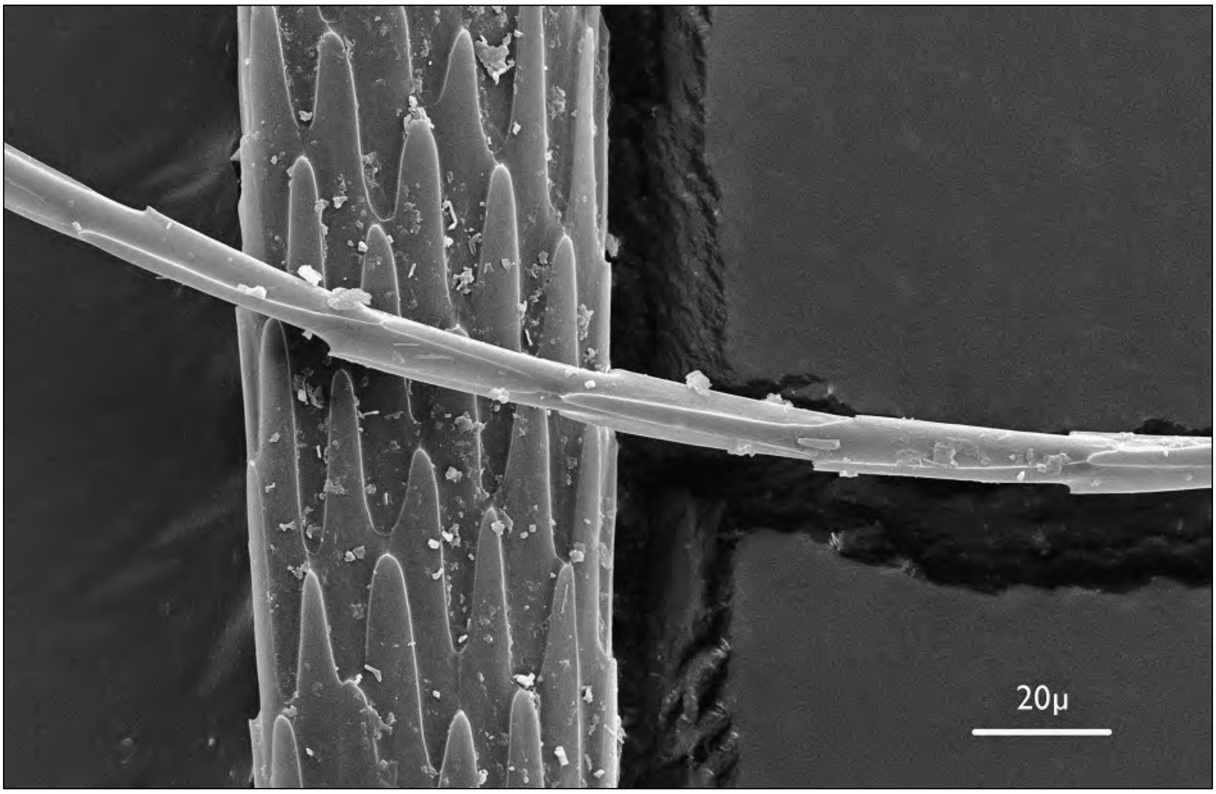

Fig. 211. Otter fibres, modern

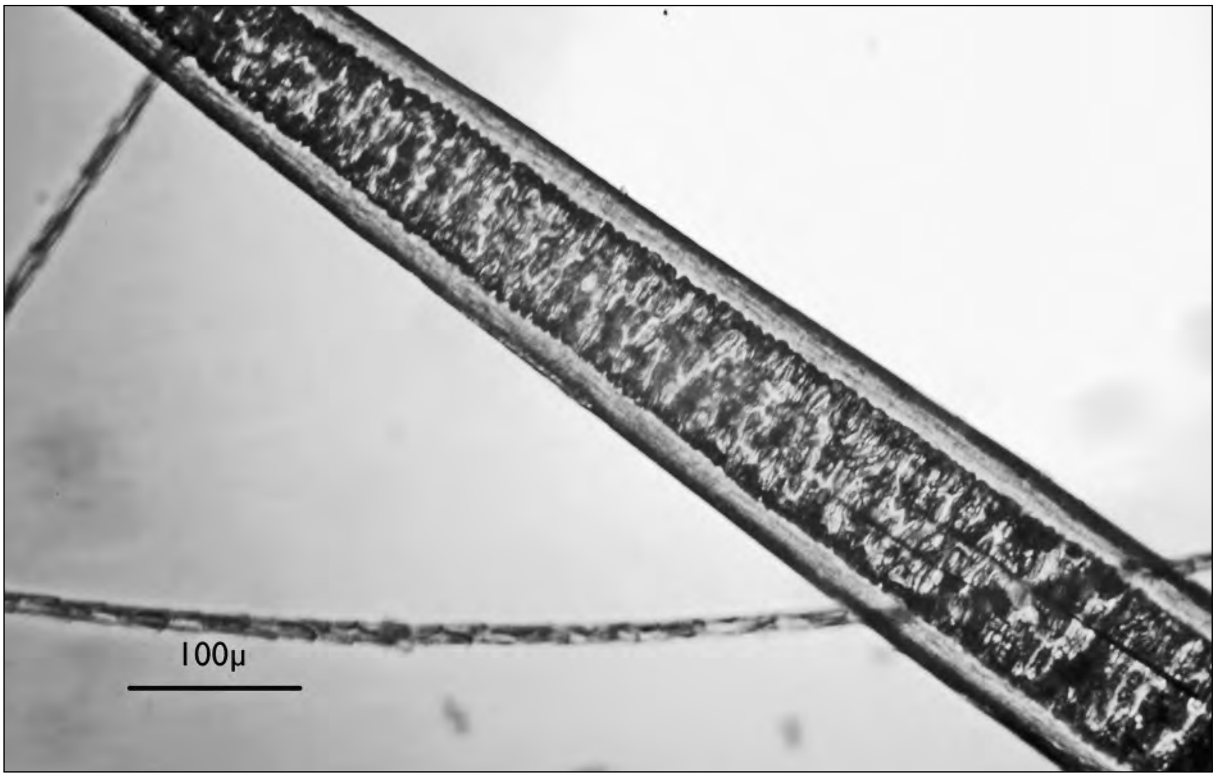

Fig. 212. Otter primary hairs and fine fibres seen with the light microscope, modern

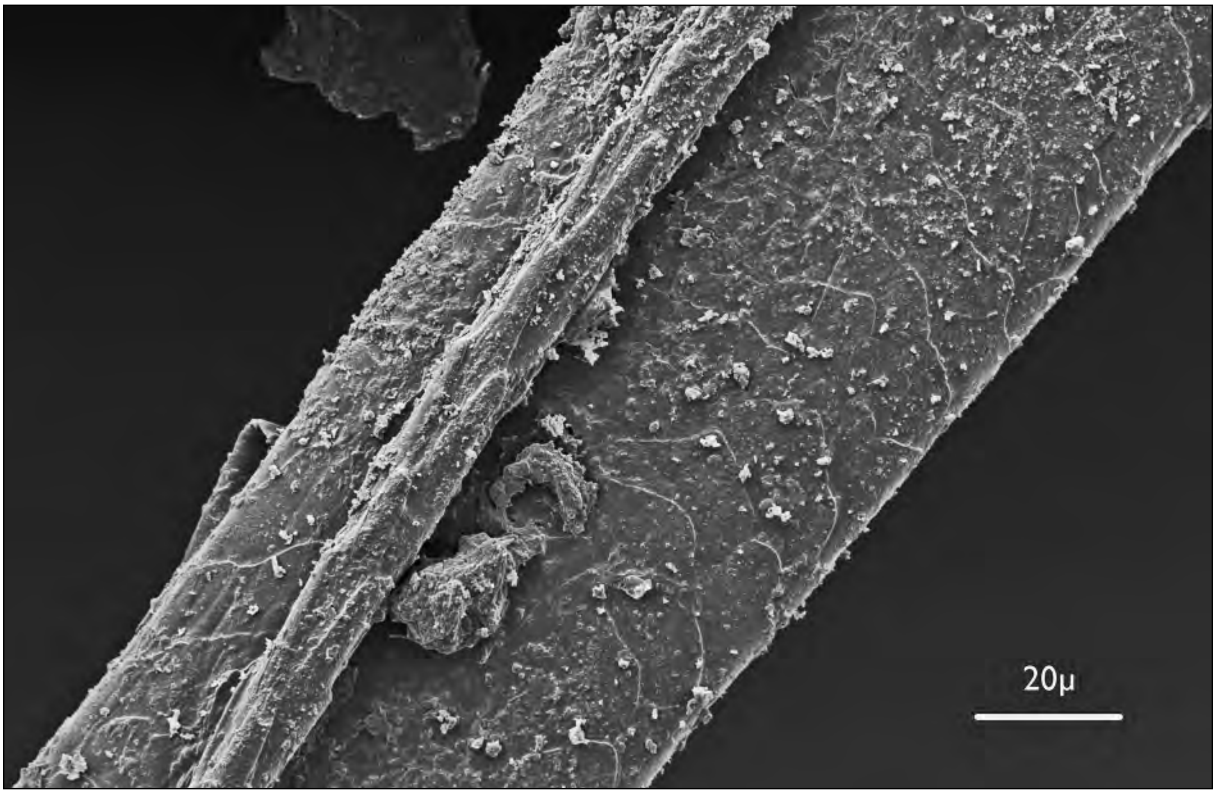

Fig. 213. Otter fibres, 6th c. grave, Saint Denis/Paris (F)

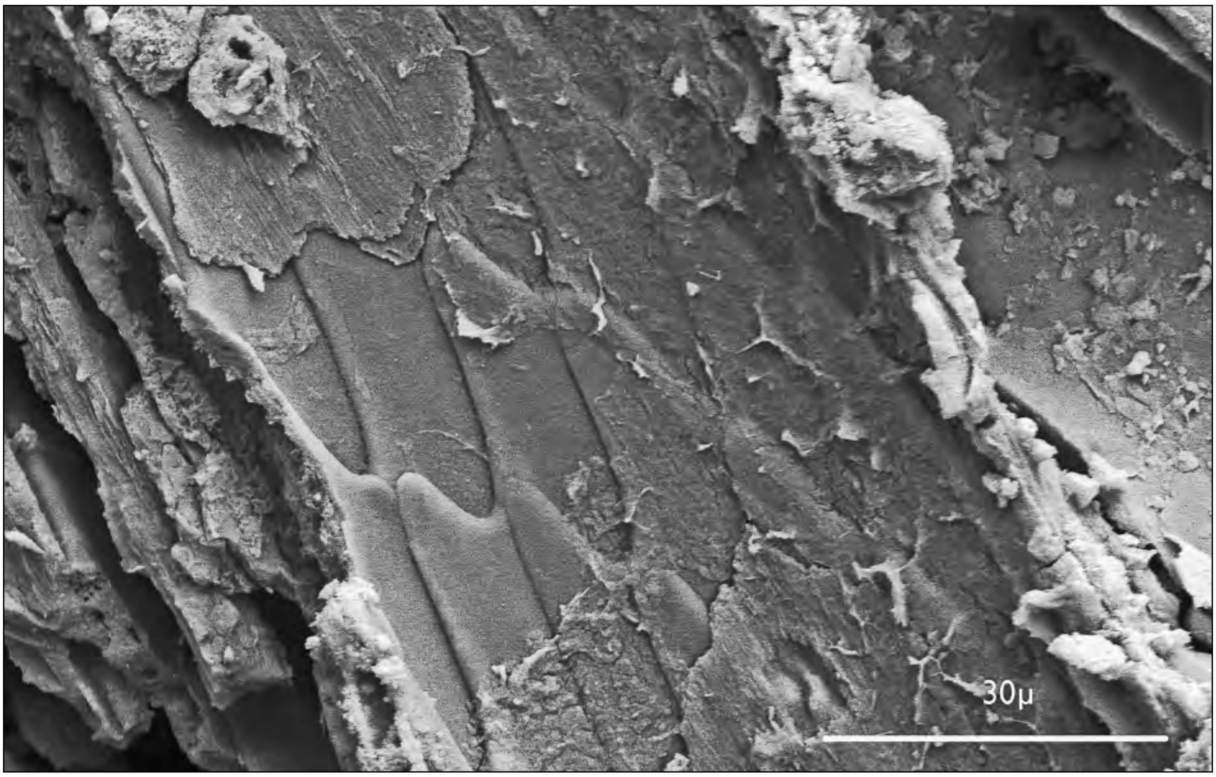

Fig. 214. Otter primary fibre, metal replaced, Baar-Früebergstrasse (CH)

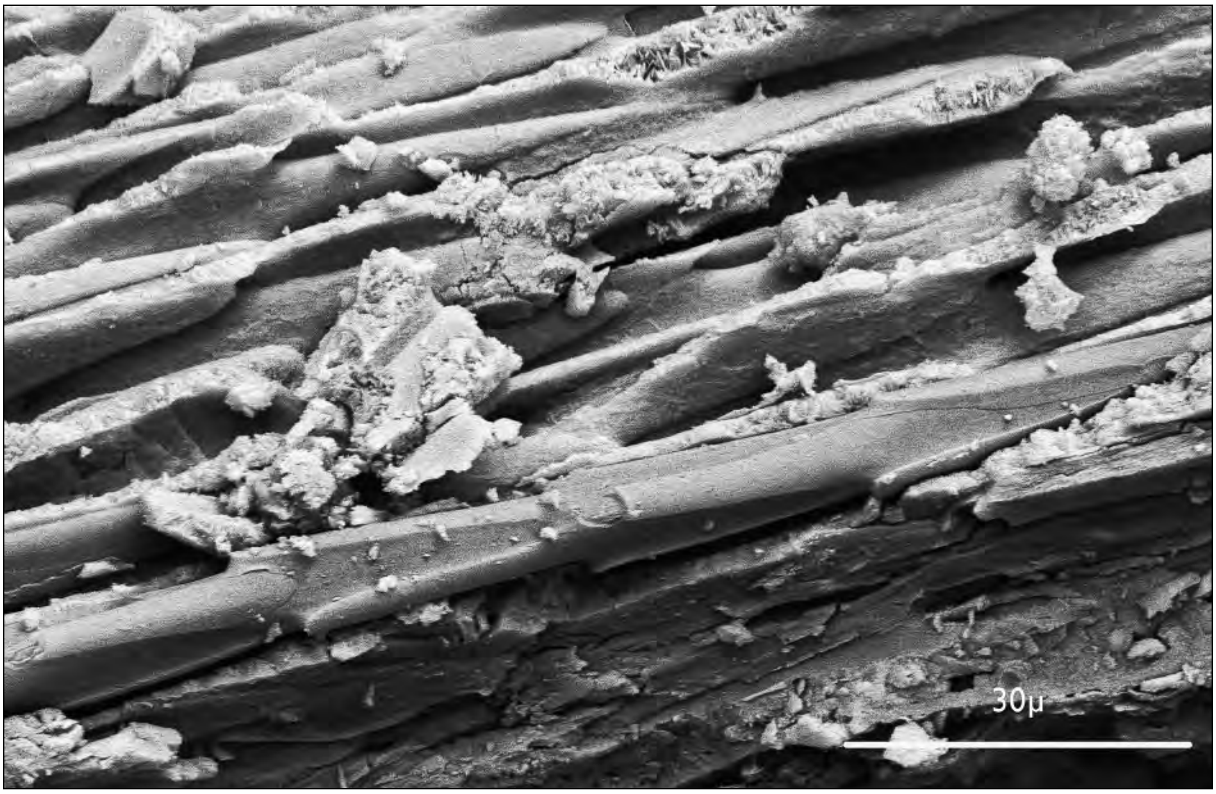

Fig. 215. Fine fibres of otter fur, metal replaced, 7th c. grave, Baar-Früebergstrasse (CH)

4.5.23.2 History

Bone finds from prehistoric settlements in Europe are rare. Those that are found often show cutting marks and it is thought that cats were probably eaten (SCHMITZBERGER 2009, 53). Assemblages dated to the Ertebølle Culture in Denmark have been found with comparably numerous amounts of fur bearing animals, especially wild cats – the exploitation of fur bearing animals is thought to have been part of the Ertebølle economy (CHARLES 1997, 268; TROLLE 2013, 462f.).

The domestication of cats took place in the Fertile Crescent. A new find of the species was found close to a human grave in Cyprus dating to 9500 BP. This might well show that cats were companions along with the rise in agriculture, one idea being that the accompanying assemblage of grain stores attracted mice (VIGNE *et al.* 2004; DRISCOLL *et al.* 2009). Each wild species represents a subspecies of *F. silvestris*. The Near Eastern wildcat is genetically the closest group to the domesticated cat (DRISCOLL *et al.* 2007). According to DNA results, few true wildcats remain, which may well be as a result of strong hybridization with domesticated cats and more genetic diversity in these regions (RANDI *et al.* 2001). Morphological changes did not occur in the same way as with other animals after domestication, this because cats were not bred for specific tasks as dogs were (for hunting, guarding, household pets). The breeds are differentiated mainly by pelt color rather than, say, chromosome count. Finding the differences between wild and domesticated cats is, therefore, difficult (ZEUNER 1963, 395ff.).

In Greek mythology, Artemis fled to Egypt and transformed herself into a cat in order to escape the serpent Typhon; Typhon was caught by Zeus under the volcano Ethna (SAX 2001, 59). In Ancient Egypt, cats became associated with gods (nocturnal, hunter) and were venerated and mummified in large quantities during the Late Kingdom and until the Roman Period. Furthermore, it was forbidden to kill a cat. DNA analyses of mummies proved them to be of Near Eastern derivation KURUSHIMA *et al.* 2012). In Bronze Age Mycenae, a depiction of cats on a gold plate has been found on the Attic relief of Poulopoulos (480 BC). Except for a few finds from the Late Celtic Period north of the Alps, the domesticated cat was supposed to have been brought by the Romans to Northern Europe (BENECKE 1994, 145ff.). In Irish Celtic history, clans were named after animals, one being called after the "Wild Cat" (Clan Chatain) (Carmina Gedelica V, 289). There was no negative symbolism inferred in these references to the cat (BIRKHAN 1997, 881). In Early Medieval, and especially Medieval, Europe cats became the companions of witches (black cat) and the symbol for evil (ZEUNER 1963, 396). They were, furthermore, an important food source (*"Dachhasen"*; STEUER 2000, 334) and their skins were used for leather (BLASCHITZ 1999). In the Middle Ages, the import of cat skins to England via Ipswich (1303) was high and they were traded by the dozens (*catti sylvestres)*. The term *cattus* or *cattinae pelles* includes both the wild and domesticated cat (HAYWARD 2014 "cat fur"). The furs of black cats were used by the Polish Jews as ornament for their caps (Davey 1895, 91). In the Early Modern and Modern Period cat pelts lined coats (*"Mudelhauben"*; BLASCHITZ 1999). After World War I cat pelts were also used for winter clothing (FRANKE – KROLL 1976, 110). Until recent times they were said to protect against rheumatism and were sold in pharmacies. Act no. 1523/2007 of the EU now forbids the importation of cat (and dog) skins.

4.5.23.3 Fibre properties

The fine fibres of wild cats generally have a dm. of 15–25µ, primary hairs of 60µ (*Figs 216* and *217*). See *Table 4.*

4.5.23.4 Archaeology

Skin found in the Oseberg ship burial (N) is believed to be cat skin (CHRISTENSEN *et al.* 1993, 254f.).

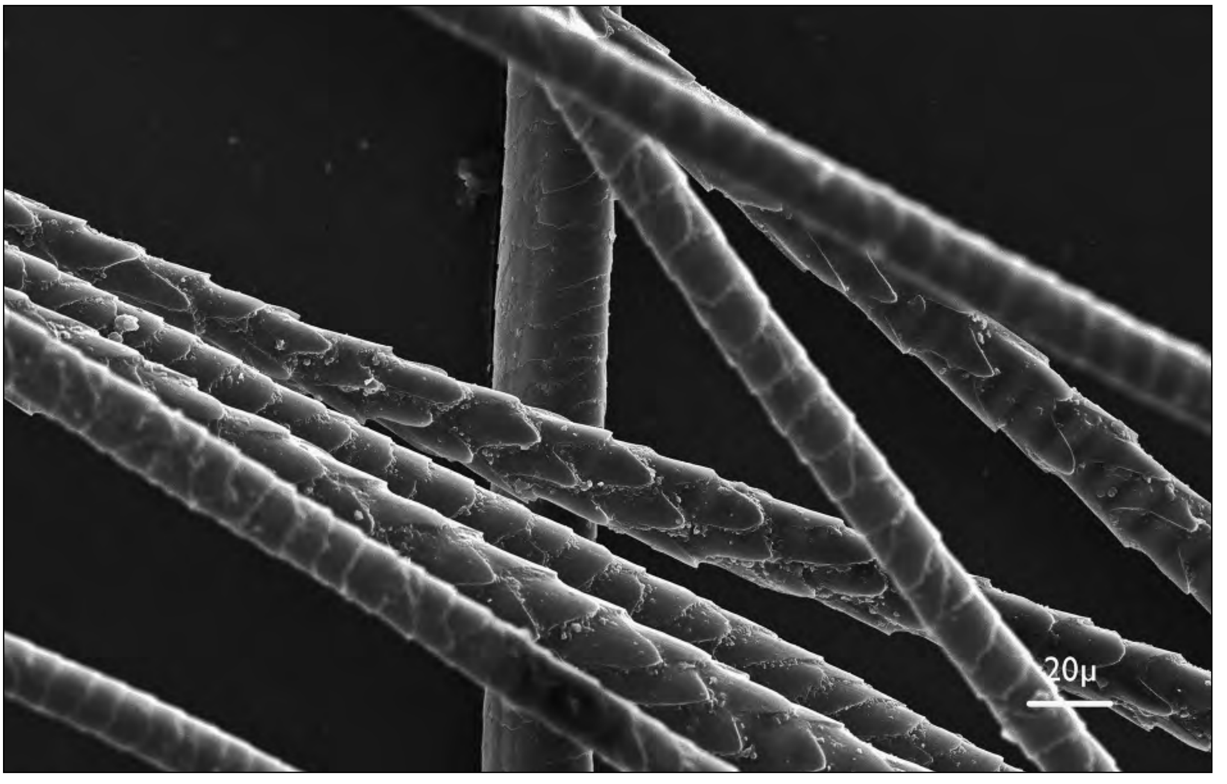

Fig. 216. European wild cat fibres, modern

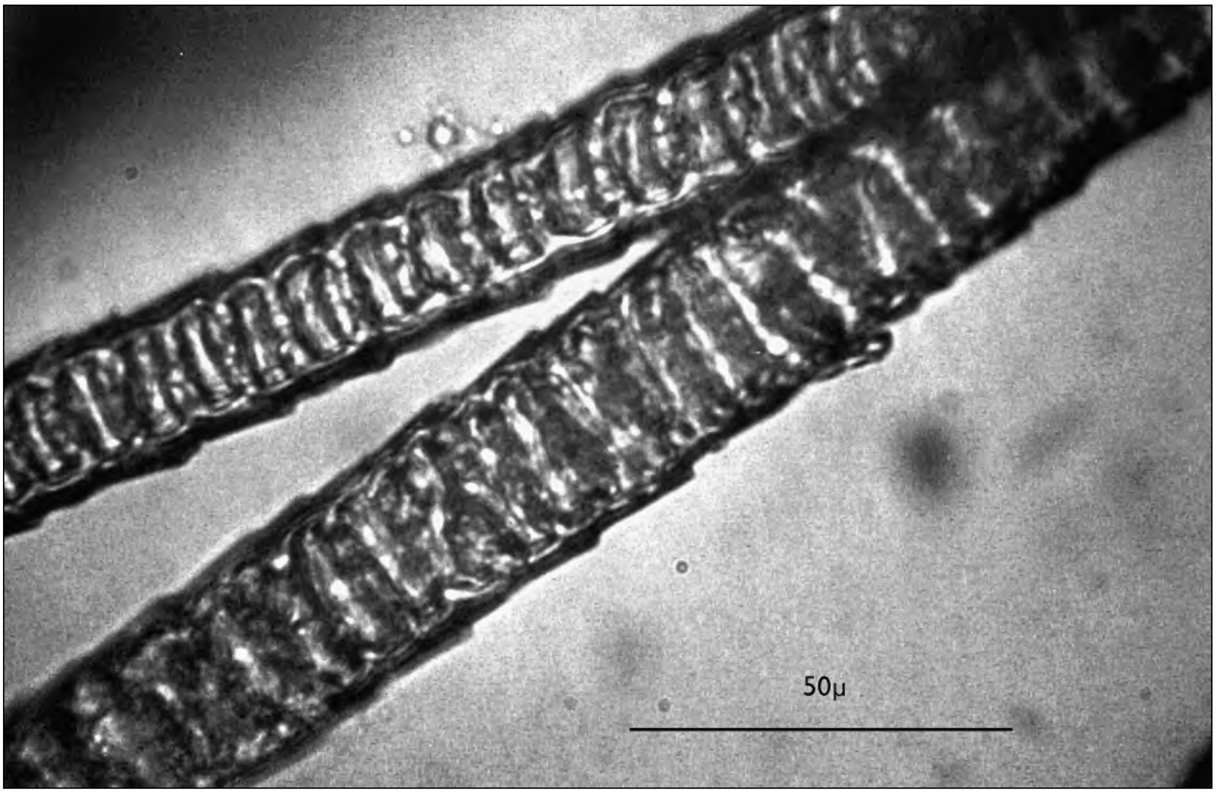

Fig. 217. European wild cat fibres, seen with the light microscope, modern

4.5.24 Lynx *(Lynx lynx)*

4.5.24.1 Habitat

Northern and Central Europe in forests and alpine regions.

4.5.24.2 History

From a prehistoric context, lynx are quite rare. In the Neolithic settlements of Twann (CH) or Auvernier (CH), bones have been found, the animal very probably having been used for skins (Stämpfli 1976).

In Greek mythology, Lynceus took part in the expedition of the Argonauts and was able to see through wood. The Celtic god *Lug* was a synonym for the lynx and a symbol for clear-sightedness. The strings of harps were made from lynx gut and therefore divine (Halna-Klein 1995, 125). Ancient writers, such as Theophrastus, reported that lynx urine was transformed into precious stones (Theophr. lap. 28), a story repeated until the Middle Ages. Even Hildegard von Bingen listed *De Ligurio* in the stone chapter (Hildegarde de Bingen, Physica, 9, col. 1262–1263; see Riha 2012). The ancients also wrote of wolf lookalikes having the skin of a leopard and even classified among the sphinx (Plin. nat. 30,48; Isid. Orig. 2,20). Ancient recorders copied one another, none of them obviously having observed a lynx firsthand. During the Middle Ages they were then classified among the cats (Halna-Klein 1995). The hunting of lynx was also at this time part of the feudal hunt (depicted e.g. in the *Livre de chasse* by Gaston Phoebus (Phoebus 1387). Until the 16th century, grey lynx was imported from Russia. Known by the Russian elites, this subspecies was not otherwise recognized in Western Europe. Other lynx were subsequently imported from Spain or Dalmatia (Delort 1978, 156, 173).

By the 19th century the lynx was extinct throughout most of Europe. In the second half of the 20th century it was reintroduced. Hunters do not especially appreciate them except for the fact that they do not create as many problems as do wolves and bears. But in Norway between the years 1845 and 1980, prizes were offered by the state for the killing of lynxes. Currently there are only about 300 lynxes remaining in Norway (http://www.rovdata.no/Gaupe/Bestandsstatus.aspx).

4.5.24.3 Fibre properties

Fine fibres (dm. 10–20µ) with curly underhair, circular cornet-like scales and uniserial ladder-type medulla. Intermediate hairs 30–60µ, primary hairs 60–100µ with amorphous medulla with large spaces (*Figs 218* to *220*). This latter type is the same for *canidae* and for badger fibres (Keller 1981). The scale pattern shows horizontal lines and is rippled in the upper part. The lynx from Siberia are nearly white. Winter pelts from northern animals were of a better quality and brought the highest prices.

Lynx can be difficult to differentiate from mustelids or wild cat (see *Table 4*). With wild cat, only the primary hair fibres are different, with secondary hairs being the same (Keller 1981, 813). Only the *Lynx lynx* has primary hairs that can be differentiated from the others (Keller 1981, 813). The petal pattern of the shaft is absent, in the base there is a mosaic/mosaic wave, and in the margins of the medulla at the thickest part it is fringed or scalloped (Tóth 2002).

4.5.24.4 Archaeology

Up to now, no finds.

4.5.25 Lion *(Panthera leo)*

4.5.25.1 Habitat

Former habitat was in (North)Africa, Anatolia and Southeast Europe; now in Africa south of the Sahara.

4.5.25.2 History

During the Bronze and Iron Ages lions were still living in Southeastern Europe. In the Roman Period, according to Pliny the Elder, they dwelt between the Achelous and Nestus rivers in Western Greece (Plin. nat. 8,17). Until the mid 19th century they could be found in the southern part of Turkey (Kasparek 1986; Ninov 1999).

The Babylonian goddess Ishtar, goddess of war, is depicted standing on a lion. Cybele, the Syrien "mother-goddess" harnessed lions to her chariot (Sax 2001, 174). The lions carved on the Bronze Age gate of Mycenae (Greece) have an apotropaic significance. They guard the gate. Also depicted on daggers of the time, they were also thought to be the hunting animals of kings, and associated generally with royalty. Later, in the Iron Age, they were held to the same high degree for the Persian kings. The lion is associated with the goddesses Hera and Athena, to the gods Apollo (sun god of eastern origin) and Dionysus, and as objects associated with the hero Heracles (Cancik – Schneider 2014, Lion). It is with these attributes in mind that the warrior depicted on the famous Greek "François-Vase" by the Kleitias painter wears a lion skin.

By 186 BC lions were fighting in Roman arenas (Liv. 39,22). L. Sulla in 92 BC exhibited a hundred lions with manes for the circus in Rome. Caesar later exhibited four hundred of the animals (Plin. nat. 8,20; Sen. De ira 2,31,6). Sueton tells us that Nero had a lion who was trained to attack in the arena (Suet. Nero, 53). Trade in lion skins is known from the 15th century (Delort 1978, 193). Lions, however, were not always hunted – Pliny the Elder reports on a lion breeder and tamer named Hanno from Carthago (Plin. nat. 8,55). Marcus Antonius harnessed lions to pull a chariot (Plin. nat. 8,21,4). In the Middle Ages lion skins were obviously worn and considered very prestigious. William Shakespeare's King John to Lady Constance: "Thou wear a lion hide! Do it for shame, and hang a calf's skin on those recreant limbs." (King John, Act 3, Scene 1).

Felid bones (lions and tigers) found together with the bones of horses were discovered in Istanbul (Turkey) and are dated to the Byzantine period. This suggests that the horses may have been butchered to feed the cats (Onar *et al.* 2012). In the 19th century, when lions still roamed the Atlas mountains (Morocco), skins were on the market (Delort 1978, 169). A safari lion hunt, even in our modern day, is still considered by some to be the highest of achievements, a triumph over the king of animals.

The Sphinx, a mythical creature in Ancient Egyptian and later in Greek and Roman art, was a creature half lion and half man that served to guard the royal tombs. In the Christian era, the apostle Marcus is often depicted with a lion. These creatures have been an important subject throughout the history of art and are most often shown in hunting scenes or in battles to the death against the strongest animals. They have been depicted not only in paintings, statuary and carvings but also on textiles, as with the famous byzantine silk, the so-called "Samson-silk" (Chur, VAM London, Berlin, Sens; Desrosiers 2004, 209).

4.5.25.3 Fibre properties

Lion hair is made up of coarse fibres (dm. 80–120µ) without underwool. It is not ideal for use as a pelt, but it has been employed in the manufacture of carpets (Franke – Kroll 1976, 69f.). The medulla is finely granulated, with fine lines of gas and pikes on the side; the medulla fills 3/4 of the fibre width. The scales are horizontal lines in the basal part, then diamond petals, becoming narrower and finely rippled and as well as larger towards the tip (Lochte 1938, 147f).

4.5.25.4 Archaeology

Up to now, no finds.

4.5.26 Leopard *(Panthera pardus)*

4.5.26.1 Habitat

In former times in Anatolia, Morocco and Sinai, today in the Sub-Sahara and Southern Asia. The snow leopard (*Uncia uncia*) lived in Africa, Anatolia, Middle Asia up to 4000m.

4.5.26.2 History

Leopards were spread throughout Europe during the last Ice Age. Finds of bones in caves and paintings show the characteristic dots of the fur (Chauvet cave, dated to the Aurignacien, ca. 33'000 BC), proving the connection to humans of the time (Diedrich 2013). Leopard skins have certainly been highly praised since ancient times. Bones and animal seals found in Late Neolithic Çatal Höyük (Turkey) may be an early indication of the hunting of a special animal by an elite in a period that approached the Bronze Age (Türkcan 2007; Galik *et al.* 2013). The seals appear in level V; humans (gods?) wearing garments with leopard-like spots are found in level III (Hodder 2011, plate 20 & Fig. 91). Leopard reliefs were fixed on walls. In Pharaonic Egypt, leopard skin formed part of priestly dress (Vogelsang-Eastwood 1999, 104; see also ch. 4.5.26.4). In Greece, the hunting of leopards has been connected to rituals for the goddess Artemis. Dionysus is depicted wearing a leopard skin. The Romans imported the animals themselves for arena games. The Leopard is also connected to Argos, Hera's watchman with a thousand eyes, the story being that after his death his eyes were passed onto the peacock's feathers. A special energy is given to the leopard as a guard animal. When ancient Troy was sacked, for example, Antenor's house was saved because Odysseus had put a leopard skin at the front door (Strab. Geogr. 13,1,53; Strabo refers to Sophocles). Menelaus wore a leopard's skin before the battle (Hom. Il. 3,16).

In the Middle Ages, leopards were tamed and kept as pets. The Medici (Florence/I), for instance, kept them for distribution as gifts (Delort 1978, 170).

4.5.26.3 Fibre properties

Fibre dm. 70–110µ, fine fibres about dm. 10–25µ. The scale pattern of the primary hairs is made up of horizontal lines in the basal part that get narrower and rippled towards the tip; diamond petals in the basal part of the fine fibres, then long petals. The medulla (about 3/4 of width) has fine disks and tooth-like pikes at the side (Lochte 1938, 130f.) (*Figs 221* and *222*).

4.5.26.4 Archaeology

In Tutankhamun's grave, a leopard's skin has been documented: "Leopard skin folded up anyhow with head underneath." Robes were interfolded with the leopard's skin. (http://www.griffith.ox.ac.uk/gri/carter/044q.html)

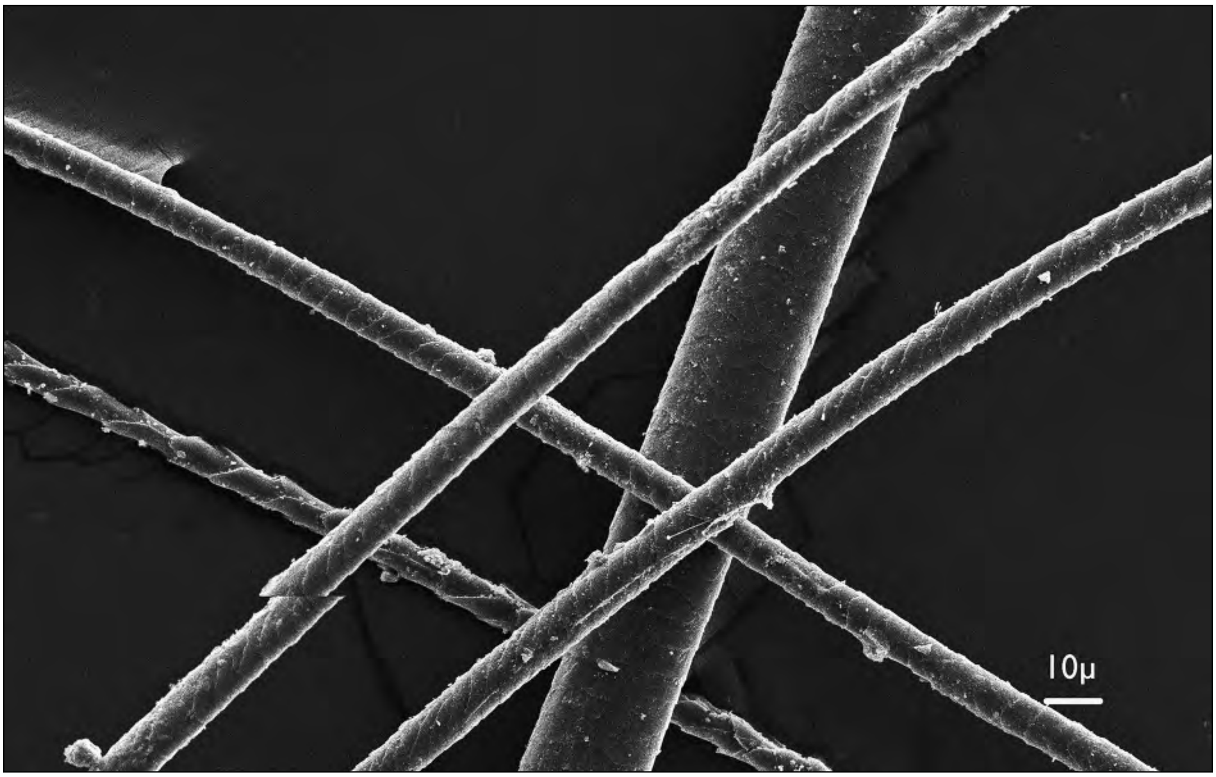

Fig. 218. Lynx fibres, modern

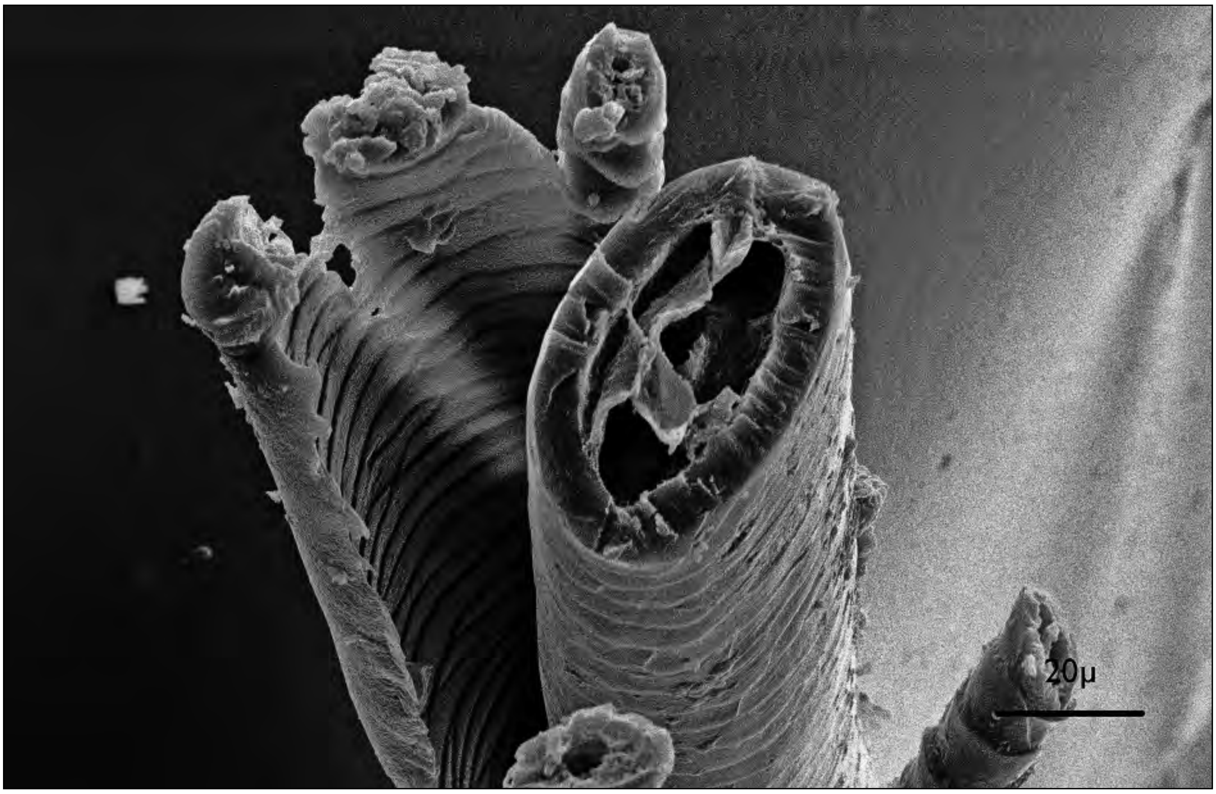

Fig. 219. Lynx fibres, cross-section, modern

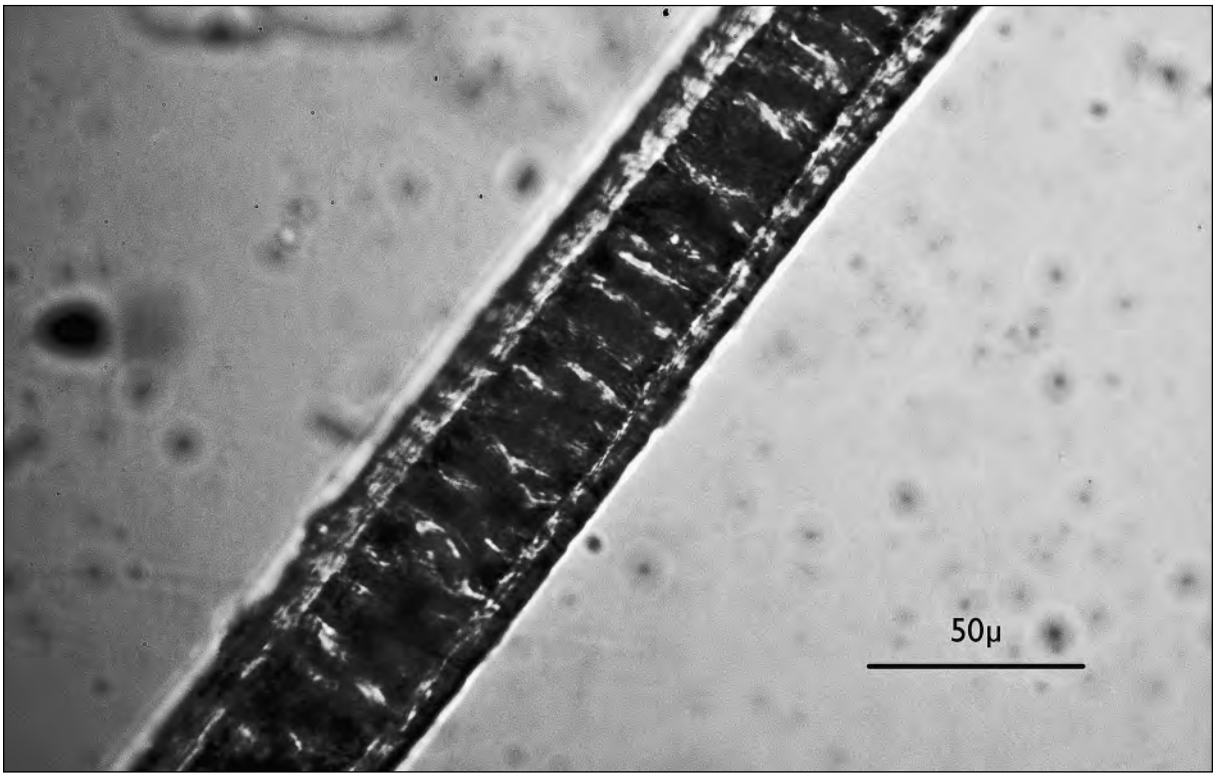

Fig. 220. Lynx primary hair, seen with the light microscope, modern

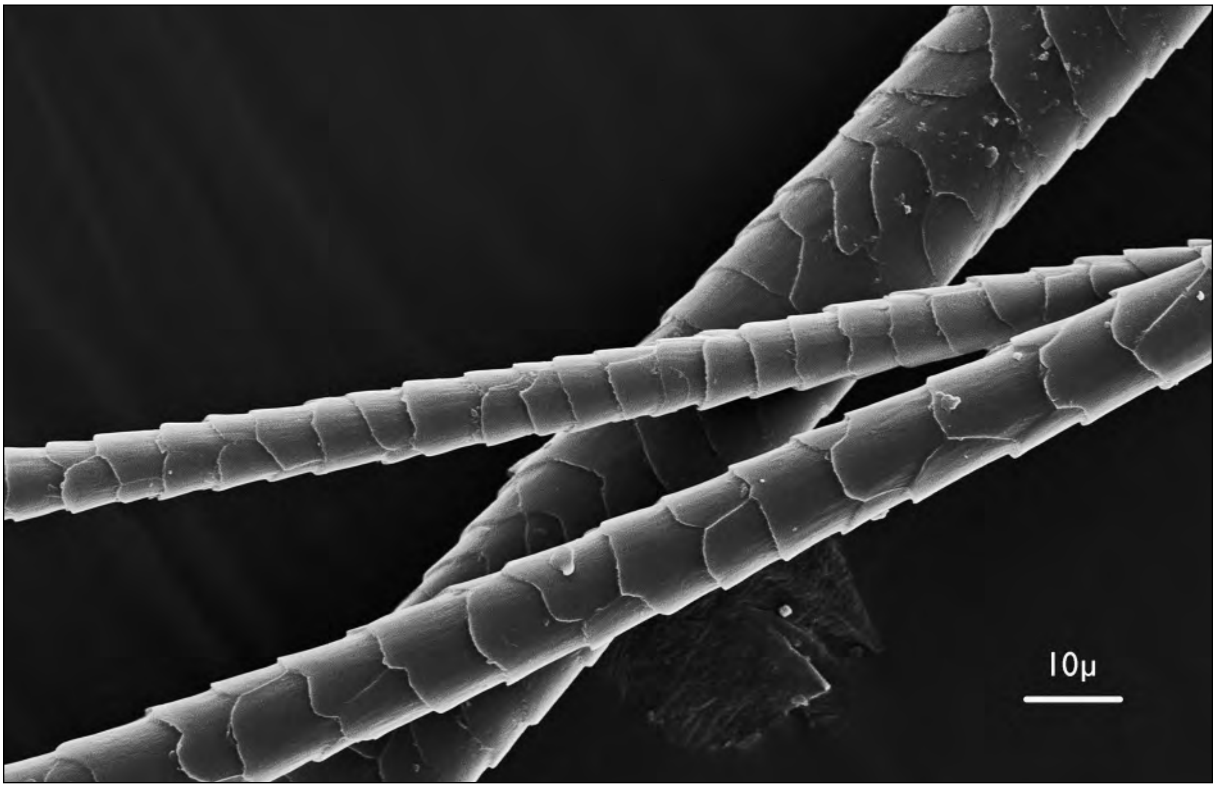

Fig. 221. Leopard fibres, modern

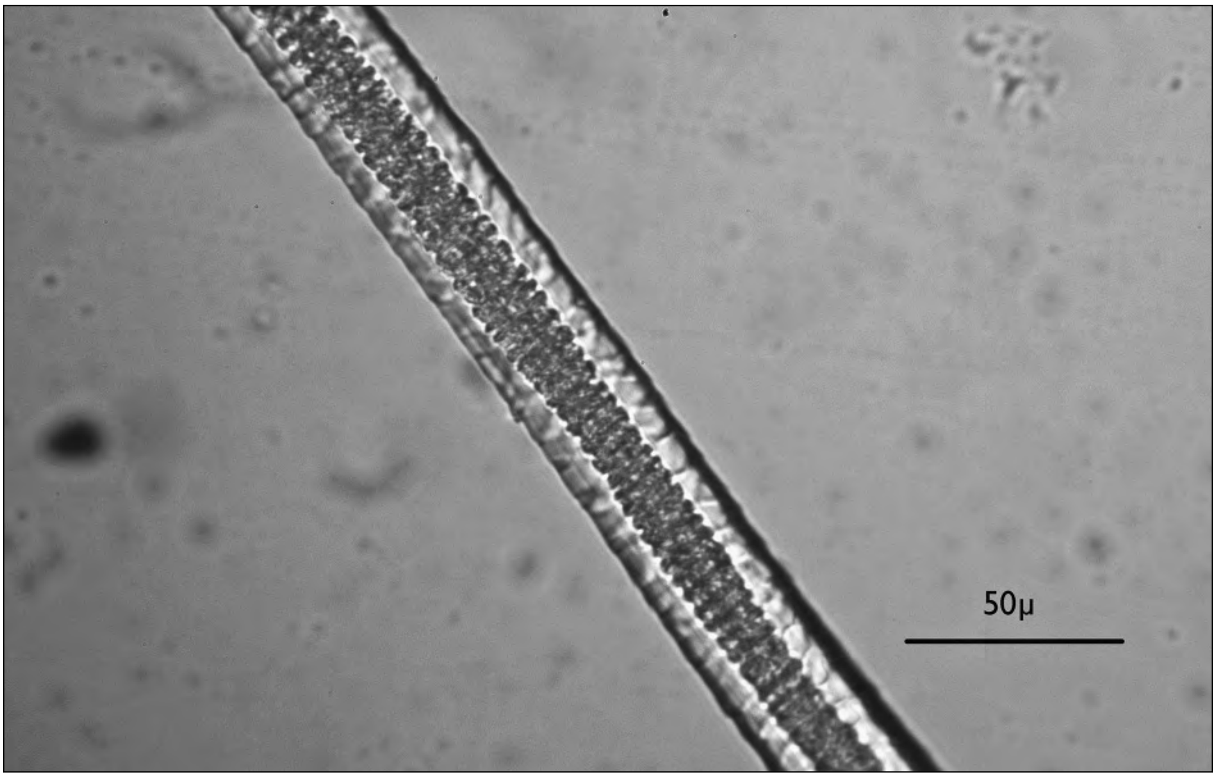

Fig. 222. Leopard fibre seen with the light microscope, modern

4.6 Elephantidae

4.6.1 Woolly mammoth *(Mammuthus primigenius)*

4.6.1.1 Habitat

Extinct. Lived in the arid tundra during the Ice Age.

4.6.1.2 History

The mammoth became extinct 6000 years ago, and is related to the Asian steppe elephant. An age of global warming and pressure from being hunted probably contributed to the extinction of the species (Sedvick 2008).

4.6.1.3 Fibre properties

The mammoth had three types of fibres: long, dark, wiry single bristles; coarse primary hairs (brown, much finer than bristles, 10–13 cm long, with irregular crenate scale margins) and thick underfur (soft reddish). The modern elephant doesn't have such an underwool, indeed, there is scarcely any hair at all (Valente 1983) (see *Fig. 223*).

4.6.1.4 Archaeology

Many mammoth fossils have been found (e.g. Furrer *et al.* 2007) but it has only been in the last several years that several frozen skeletons have melted out of the permafrost in Siberia. Most remarkably some have been mammoth babies (Valente 1983). Frozen mammoth were known already in the 17th c. and frozen carcasses had already been excavated by Europeans in 1728. The first fully documented specimen was discovered in 1799 by Ossip Schumachov, a Siberian hunter near the delta of the Lena River. (en.wikipedia.org/wiki/Woolly_mammoth). A substantial state of preservation occurs when an organic material is subjected to a quick and consistent freezing. As with the mammoths that have been frozen for millennia under the Siberian tundra, their fibres of skin and hair have been preserved in a nearly fresh state. Found as such on Bolshoi Liakhovski Island, Yakutia, Siberia (RU) in 2007, an example of a well-preserved mammoth skin is shown here. Dated to the Pleistocene Era, its state of preservation is extremely good (ownership NHM Vienna, *Fig. 223*). The underwool seen on the skin fragment of the NHM Vienna find created a very dense and curdled layer.

4.7 Perissodactyla

4.7.1 Introduction Equidae

The tracking of the domestication of the horse is not a simple process. The typical archaeozoological approach of studying bones, for example, has shown to be difficult in some cases with the definition of “domesticated” not being proven from an examination of bones alone. Smaller specimens could mean a reduction in size due to domestication but could as well be due to a simple variation in species. DNA studies have revealed a complicated evolution towards domestication. Here are the main results:

- During the Paleolithic, species tolerant of the cold climate of the era lived in mainland areas of Europe and were hunted for meat. As conditions warmed horses were pushed towards the less populated steppes or grasslands of Europe and Asia. There are few bones to be found in Europe compared with other animals, even those deriving from Middle and Late Neolithic times (Bendrey 2012, 140ff.).
- In Spain, a particular species of horse survived the Ice Age (Seco-Morais *et al.* 2007).
- Wild horses were still widespread in Central Europe during late Neolithic. Amounts of horse bones from the 3rd millennium increase as well as variability of sizes. Benecke surmises that there were different horse species that were domesticated (Benecke 1994, 64ff.; Schmitzberger 2009, 88). Horses appear to have fewer physiological changes as a result of domestication than other animals (Clutton-Brock 1989, 81).
- Domesticated horses have a different chromosome count than their wild ancestors: Ferus 2N=66, E. Caballus 2N=64. The domestication of the horse occurred during the Eneolithic Period with further DNA variation validating the domestication of mares; Haplo groupings suggest that one herd may have come up in Iberia (Achilli *et al.* 2012).
- By the Bronze Age most of the wild horse population had probably disappeared from Europe (Benecke 1999, 71).
- On Sardinia, there were no domesticated horses during the Bronze Age but it has been attested to during the Punic Period (Vigne 1999).
- The domestication of the donkey occurred at a later time than the horse. They were brought by the Romans to places north of the Alps (extensively under Emperor Augustus).

- Genetic studies show a great diversity in lineage. In Iberia and near the Caspian Sea there were important cross-breedings leading to the formation of particular European breeds (Bendrey 2012, 148).
- Other finds can be attributed to the study of wild and domesticated horses, such as in the handing down of knowledge about the taming of wild horses. An example would be an ancient method still in practice by the Indians of North America (Levine 2005; Schmitzberger 2009, 91) and e.g. in Kazachstan (Ståhlberg – Svanberg 2011, 361).

In an archaeological context, fibre analysis is quite complex. The horse is one of the species from which the medulla has to be seen in the fibres. Otherwise there is only the scale pattern to be studie which can be misinterpreted as cattle or even human hair (fine rippled scales). The differentiation between donkey and horse is also very difficult to make out (see ch. 4.7.3).

4.7.2 Przewalski Horse *(Equus ferus przewalski)*

4.7.2.1 Habitat

Originally from Mongolia.

4.7.2.2 History

The Przewalski horse is the last truly wild species of horse in that it is a purebred not descended from any breed of domesticated horse. It was brought to Europe in the 19th century by a Russian expedition lead by N. M. Przewalski. Wild herds of the species were extinct by the 1960's. However, with captive purebred populations held in various parts of Europe and Asia, the Przewalski horse was re-introduced to its native habitat in Mongolia and survives today (Levine 2006; Ståhlberg – Svanberg 2011, 361f.). The Przewalski horse is considered a sister taxon of wild ancestors of domestic horses, this mainly due to differences in chromosome number (Kavar – Dovč 2008; Bendrey 2012). The haplogroup to which the Przewalski horse is included, is only one of eighteen found in recent DNA analyses of horses; it is distinct from the haplogroups of domesticated horses (Achilli *et al.* 2012). Due to the difference in chromosome numbers, the Przewalski horse cannot be interbred with *E. caballus*.

Pelts of young animals were traded (Franke – Kroll 1976, 307). The Tarpan (Equus ferus ferus) is a feral horse from the Middle Asian Steppes and is considered a "cousin" of the Przewalski horse. It is one of only a small group of feral horses – or free roaming horses of domesticated ancestry – which has been found in the world (Ståhlberg – Svanberg 2011, 361).

4.7.2.3 Fibre properties

Fine fibre dm. 10–15µ, primary hairs 40–60µ, the medulla contains discs which appear as though filled with an amorphous/granulated mass, the discs themselves separated by flat spaces; the SEM picture with the view into the fibre makes clear that the discs are flat and the walls of the discs full of little round holes, as seen also in the cross-sectional view. The fine fibres show cornet-like scales, the coarse hairs horizontal lines with smooth or rippled edges, with medium spaces. See also ch. 4.7.3. (*Figs 224* to *227*).

4.7.2.4 Archaeology

see ch. 4.7.3.4

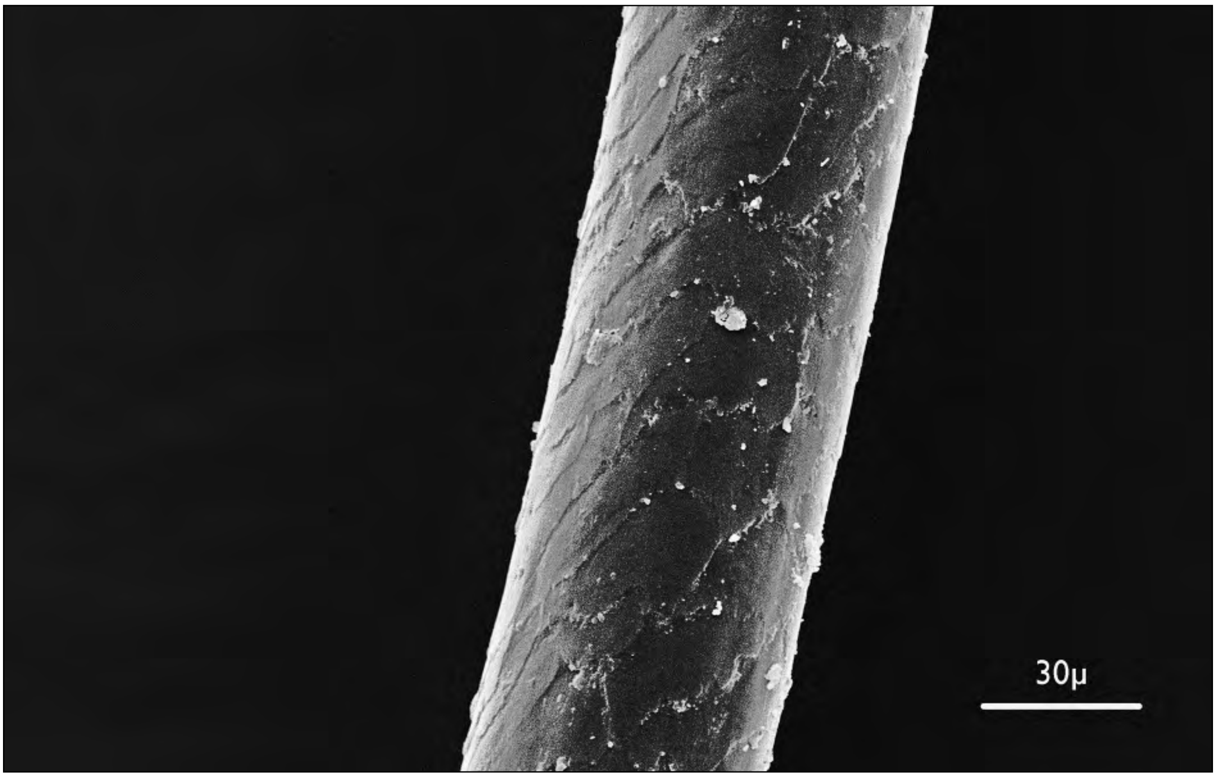

Fig. 223. Mammuthus primigenius fibre, NHM Vienna

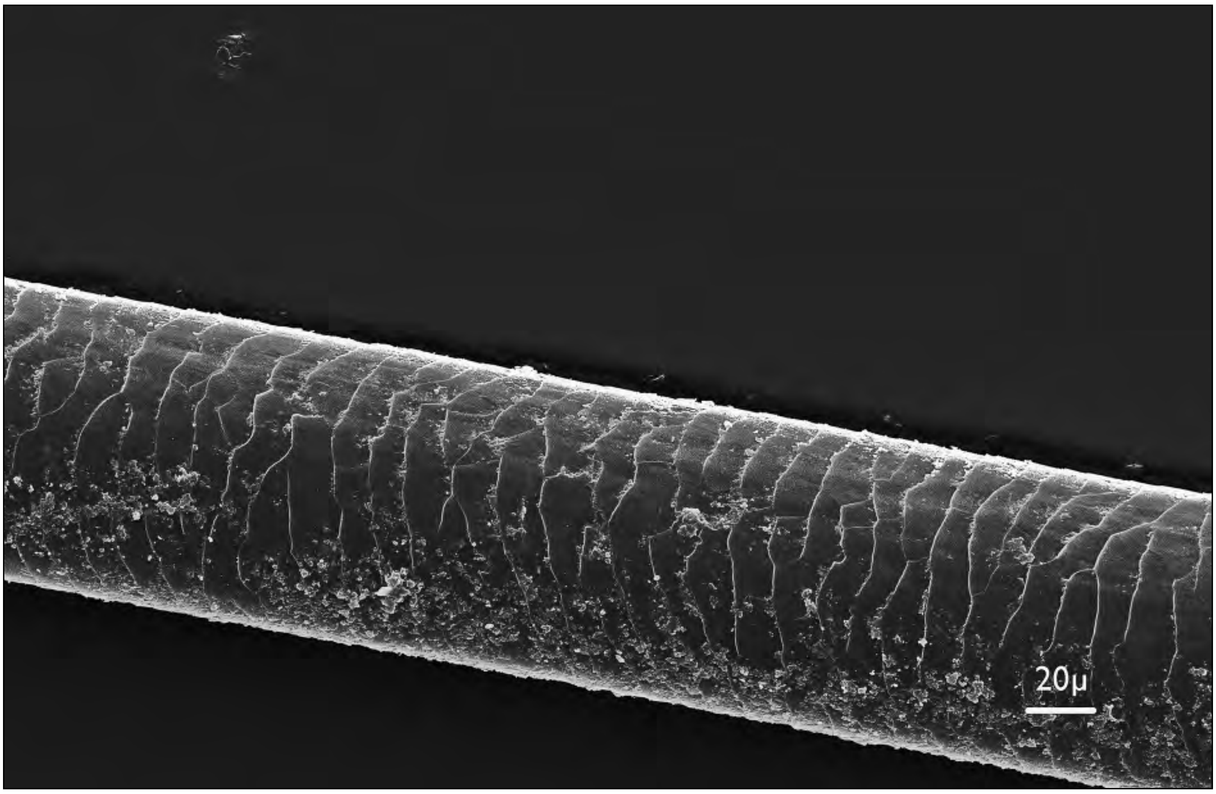

Fig. 224. Fibre of the Przewalski horse, modern

Fig. 225. Fine fibre of the Przewalski horse, modern

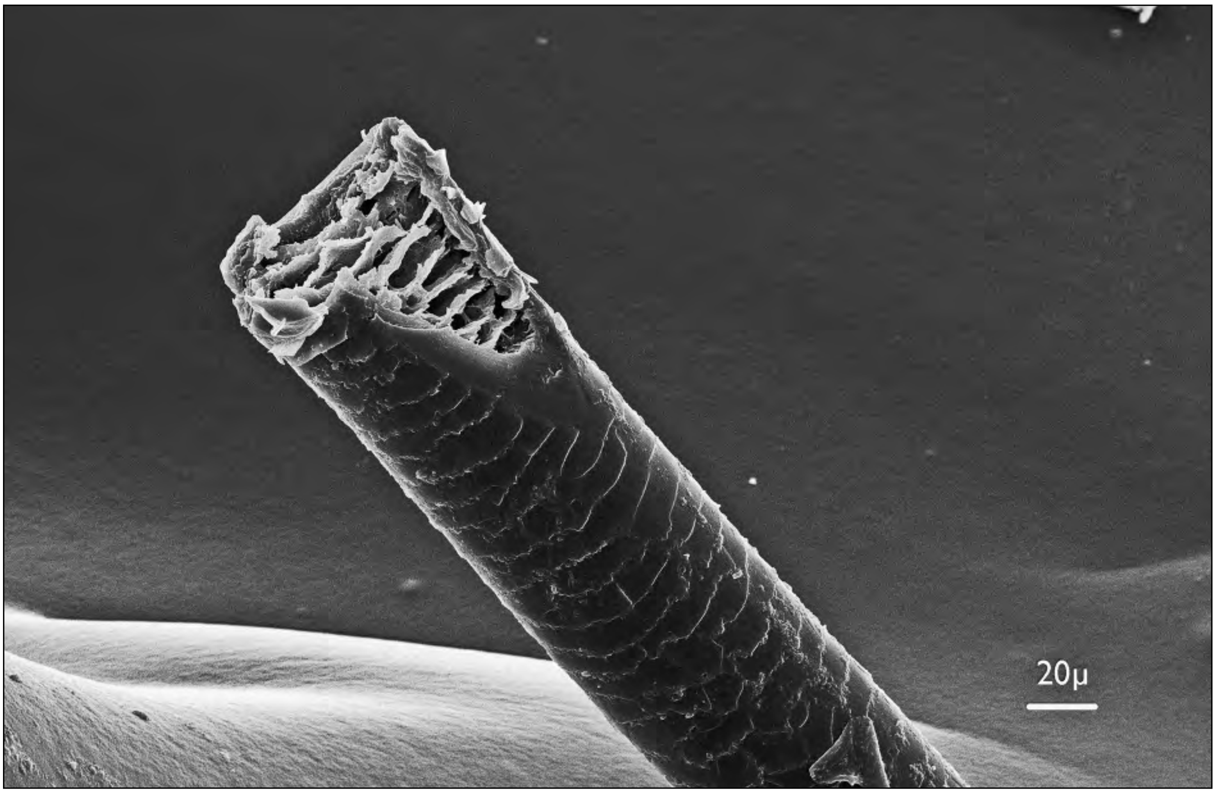

Fig. 226. Fibre of the Przewalski horse, medulla with large flat spaces, modern

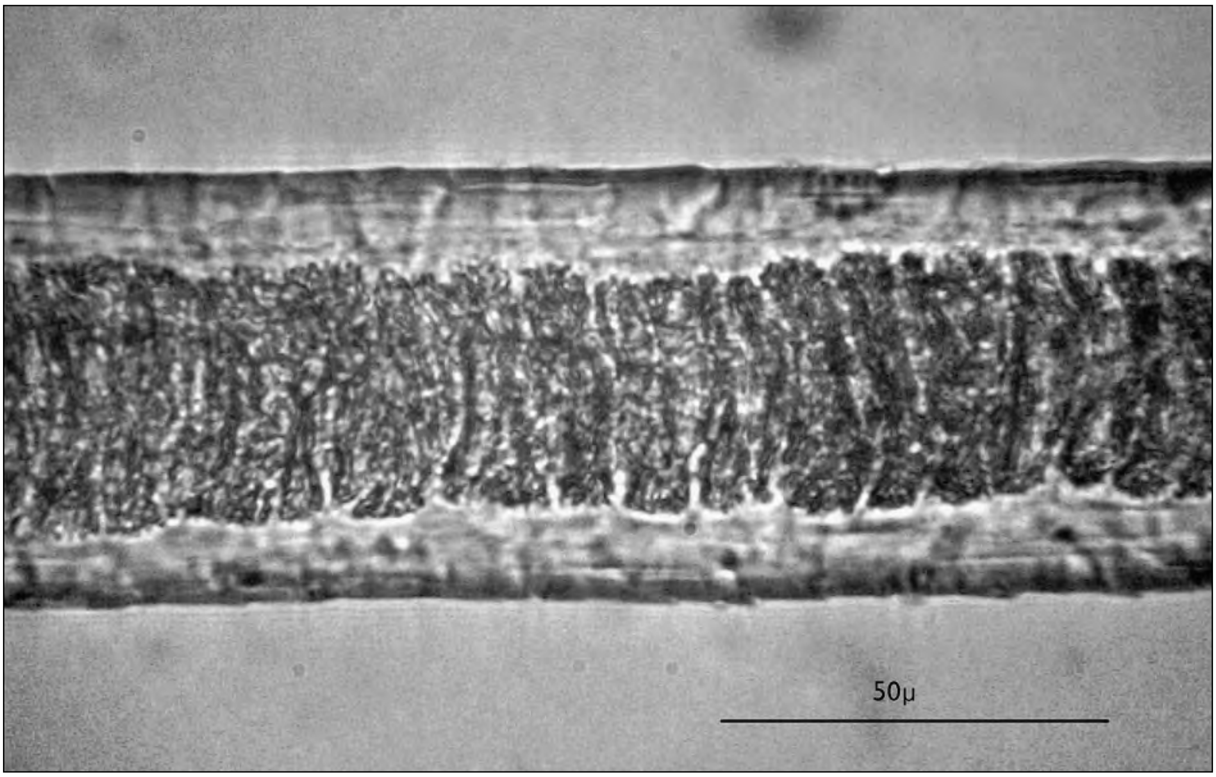

Fig. 227. Fibre of the Przewalski horse, seen with the light microscope, modern

4.7.3 Horse *(Equus ferus caballus)*

4.7.3.1 History

Prehistory

During the last glacial maximum, wild horses were dispersed over large areas but survived mainly within two geographical fields, southern Ukraine/Turkestan and the Iberian Peninsula. In the latter sphere, however, north of the Pyrenees, horses did indeed become extinct during the Mesolithic Period. Modern domestic herds show much diversity in the haplogroups. Low heterogeneity in Y-male chromosomes show that breeding occurred involving fewer males than females. Domestication began in the Late Neolithic Period, the result being that many haplogroups are well dispersed throughout Eurasia. In particular, one group – Haplogroup L – is found more frequently in Europe than further to the east and is linked to the Iberian horse (Achilli *et al.* 2012). In Kazakhstan, domesticated horses have been known (and ridden) since the mid-fourth Millennium BC. They reached Europe at a later time (Outram *et al.* 2009). In the Middle Volga region in very early times (4800–4600 BC), horses were included as part of funeral rites (Anthony 2007, 460). Just how late exactly is a topic of much discussion as there are few finds and object interpretation is weak. Levine suggests that the riding of horses came before they were put to other uses (Levine 2005). However, the fact that tamed horses could be ridden without a bit or saddlery makes for a lack of evidence and the study of equine domestication more difficult. One encouraging approach has been the paleopathological study of horse vertebrae and evidence of the animal having been ridden (Levine *et al.* 2005). An early find of the Badener Culture (c. 3000 BC) has been interpreted as early domesticated horse, related to the large Copper Age horses of Hungary (Schmitzberger 2009, 91). More often, domestication is attributed to the 3rd millennium BC. when the expansion and quick diffusion of earlier domestication developments from the East was brought to Europe by the Bell Beaker Culture (Bendrey 2012, 129f.). But in Sardinia and the like, there are no domesticated horses or asses until the Punic Period (Iron Age) (Vigne 1999).

The earliest chariots appear in the Sinthasha Culture, 2100 BC in Middle Asia, north of the Black Sea, and arrive later in the Near East (Anthony 2007, 462). In ancient Mesopotamia, horses were not used by the Sumerians, nor were they mentioned in the Chagar Bazar/Syria tablets (c. 1800 BC) or in the list of Hammurabi (1750 BC) (Zeuner 1963, 318ff.). In Bronze Age Mycenaean graves (1600 BC), 2-wheeled chariots are depicted with horses having hanging manes (i.e. domesticated horses). In Tutankhamun's grave a harness and a chariot point to a small type of horse of 1.28m (Littauer 1968, 28). As described by Homer, the Greeks are not riding horses but using them to pull chariots, even for races (e.g. Hom. Il. 11,699). In these races, four-horse chariots ran twelve times around the hippodrome, or a distance of nine miles (Hom. Il. 33,326ff.). In Bronze Age Scandinavia, chariots drawn by two horses are depicted on rock carvings (Kristiansen – Larsson 2005, 180-191). The famous 'Chariot of the Sun' found in Trundholm, DK displays a horse pulling a 4-wheeled sun chariot carriage upon which a sun disc is mounted (National Museum Copenhagen; dated to Nordic Bronze Age, c. 1400). The horse fundamentally changed modes of transportation and warfare. In Greek mythology, the horse is one of the few animals born from a god: Bellephoron is the offspring of Poseidon, the "horse-tamer", and Demeter (Pind. O. 13,70; Lucan. Phars. 19). But the most famous horse is certainly the "Trojan Horse", a wooden structure in the shape of a horse brought as an "offering" but secretly holding within it enemy soldiers who later were able to infiltrate and devastate the town.

Iron Age/Roman Period

Assurbanipal (686–626 BC), the last king of the Assyrians, had draught horses with bridles, reins and bits (Zeuner 1963, 318ff.). Horse racing was introduced at the 33rd Olympiad of 648 BC. Herodotus writes about the Scythians importing large horses. The Persians by this time have as well developed a very strong cavalry (Clutton-Brock 1989, 88; Hdt. 9,17). Later, Xenophon published a treatise on horsemanship in which he explains how to buy a horse and how horse and man should become acquainted to gain confidence in one another (Xen. equ.mag.). He explains how to mount a horse correctly (there were no stirrups in ancient Greece), and how to protect and ride the animal in battle. Other documents – such as the *Hippiatrika* – were written by various authors between the 5th and 4th centuries BC and on through the late Antique Period. They report about the health of the horse, veterinary visits and deceased animals (Schäffer 1985). Certainly the most famous horse of the Iron Age was Alexander the Great's *Bucephalus*.

In Central Europe, in the younger Iron Age (La Tène Culture), the large horse of the Hallstatt Culture was replaced by the smaller pony (H. 125 cm). Confirmed by DNA-analyses, there is the appearance of newly bred haplotypes. This may have been due to a new wave of domestication efforts during the Iron Age (Bendrey 2012, 149). The earliest saddles at that time appear north of the Alps (Quast 1993, 443). The Gallic goddess Epona is depicted riding a horse (Birkhan 1997, 714). Horses were buried to accompany elite persons especially in cultures from Eastern Europe (e.g. Skythians!) (Coleman 1998; Jerem 1998). The same practice has been identified as being carried out during the Roman Period and the Early Middle Ages (see below).

The Romans brought a larger equine species to the northern Alps (H. 140–160 cm) (Pucher 2010) and bred mules as draught animal for use in pulling heavy loads (Johnstone 2008). It is clear that the ancient Romans were breeding horses for specific uses. Columella (1st c. AD) describes three types of horse: 1) a noble stock for sacred games and the circus; 2) a stock to breed mules; 3) a common breed (Col. 6,27). The Roman postal service, the *cursus publicus,* functioned using horses, mules and oxen. In the *Codex Theodosianus*, load limitations were decreed (Cod. Theod. 8,5,17). It is also during the Roman Period that the first horseshoes of metal were used north of the Alps (e.g. Eschenz, TG/CH; Müller-Lhotska 1984, 174).

The stirrup was invented by the Chinese and first appeared in Europe in the Early Middle Ages with the Goths in AD 477 (Clutton-Brock 1989, 89). A new bow was also introduced at this time, shorter in construction to be more easily carried on horseback but also with a further reach than the usual bow. The Goths used these instruments together with a larger breed of horse to great advantage in battle, a knowledge that quickly spread to Western Europe (Benecke 1994, 173; 213).

Middle Ages

By the Early Middle Ages, the horse had become culturally more important. In Western Europe horse burials from this time provide verification of their ritual importance, e.g. Sutton Hoo (GB), Vendel and Valsgärde or Birka (S), Oseberg (N). This was especially true in both the Germanic and Eastern European cultures of the day (Martin 1976, 129ff.; Sikora 2003/2004; Cross 2011). Early Medieval graves have the added evidence of spurs, bits and long-bladed swords of an elite warrior that would have ridden a horse into battle. Fibulae of the same period made in the form of a horse were worn by women (6th century) and may have functioned as a form of protection for the person who wore it.

During the first centuries AD, Germanic riders altered tradition by taking up the saddle as the Romans before them had done (although stirrups were not introduced until the 9th century). Sources describe that horses were to be readied for the ride to Valhalla (or heaven). Horses were therefore buried with their saddles (Quast 1993). Horse burials were especially important to the Early Medieval people of the Avars (Eastern Europe) and the riders of the Byzantine emperors (Onar *et al.* 2012); individual burials, partly separated from the human graves were dug (Bede 2014). In the Carolingian manual *"Capitulare de Villis"*, horse breeding takes an important place (Capitulare de villis, c. 13–15). These animals were so valued, that anyone who would dare steal a horse (or a cow, or destroy a weaver's hut) was put to death as punishment: *"Si quis caballum furaverit aut bovem, aut screonam effregerit, capitali sententia puniatur, vel vitam suam pretio redimat."* (Lex Frisonum, De pace Faidosi, 3). The nailed horse shoe, the neck yoke and breast harness became more common in the second half of the first Millennium AD (Northern Europe and Poland) and were in general use by the 11th century. The oldest image of a neck yoke is visible on depictions of the Apocalypse of Trier (early 9th century). Yokes of similar construction have been found in 10th century archaeological layering in Novgorod (RU) (Benecke 1994, 213; Hall 2005). These developments which brought the presence of horse and cavalry to the fight had a great impact on strategies of warfare.

In the 13th century horses were bred to become ever larger and sturdier, often with heights of over 150 cm and an ability to carry heavy armour. Monasteries became important breeding grounds for horses, and nomenclature for specific breeds came into being (Müller-Lhotska 1984, 267; Benecke 1994, 224). Farms in England were replacing oxen with the more powerful breeds of horse as beasts of burden (Hall 2005). Horse riding became symbolic of hierarchy in the Late Middle Ages: the King would mostly likely ride a white horse, for example, while other members of the royal family or important persons would be mounted on a large battle horse with appropriate decorations or blankets of different colors (Mérindol 1992b).

Early Modern

By the 15^{th} and 16^{th} centuries horses became more and more essential to the service of warfare. Private breeders sold the animals at regional markets (Müller Lhotska 1984, 308f.). Up until the end of World War I, modern society was very much dependent upon the horse. Packhorses were used to transport goods as well as passengers, especially in the Alpine regions. They pulled stagecoaches, worked underground in mines and hauled machinery (thus the term "horse power" which came into being) (Hall 2005). Possession of a horse was costly, even into the mid- 20^{th} century. Today hundreds of breeds are recognized, each for a specific function or appearance with most being part of an historical or geographical tradition. Some breeds are descendants of an ancient wild lineage, such as the Dülmen pony in Germany (Hall 2005).

Horse hairs are still used for brush bristles and for high quality mattress stuffing, and for violin bows.

4.7.3.2 Fibre properties

Horse fibres from the body fur are round to oval with a dm. of 60µ to over 100µ, tail hair between 80–280µ and mane hair being a bit finer (*Fig. 228*). An important characteristic is the distribution of pigment in the hair which is close to the epidermis. The medulla contains flat gas spaces and in the spaces small structures (*Figs 229* and *230*). The scales in horsehair are horizontal and smooth in the basal part, becoming more rippled and narrower towards the tip. It appears very similar to human hair (Lochte 1938, 241). The hairs of the tail remain solid in wet conditions making them useful for such things as fishing lines of varying degrees of strength. Their scale pattern is fine rippled (*Fig. 231*). The distance between scale margins of the mane hair is longer than tail hair, the medulla small (*Figs 232* and *233*).

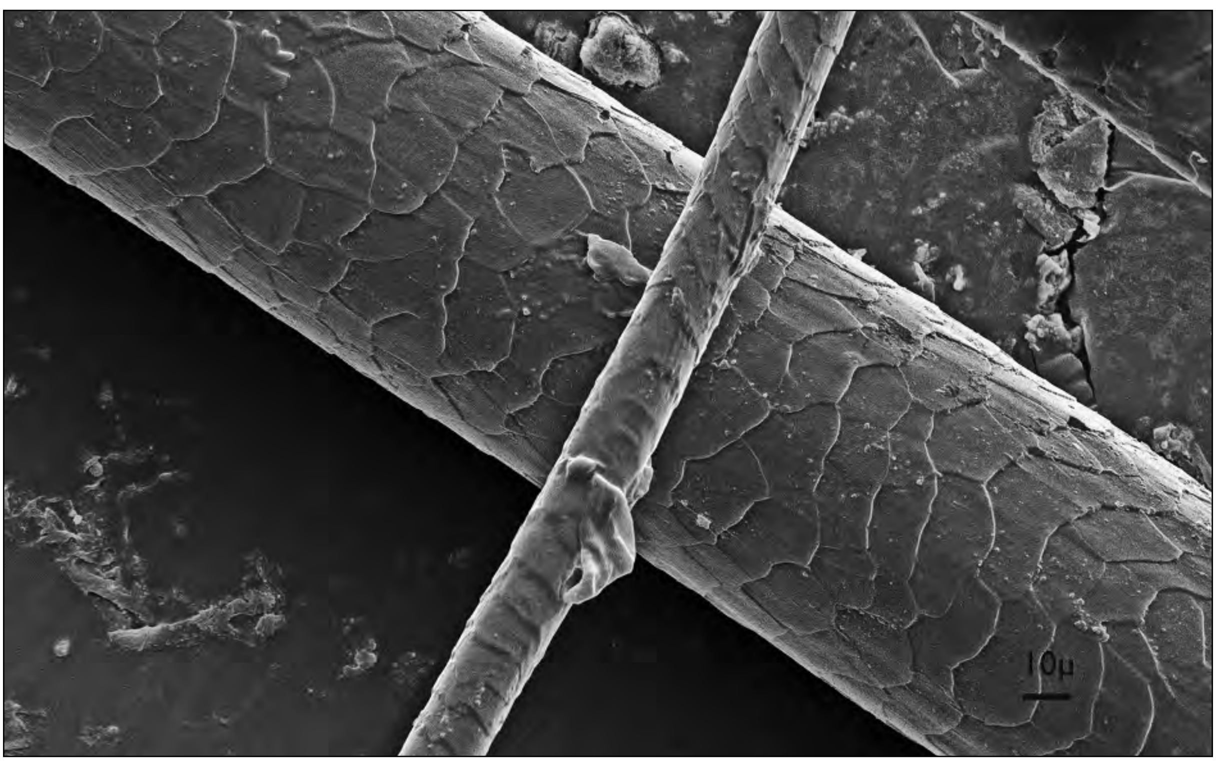

Fig. 228. Fibres of Island pony, body hair, modern

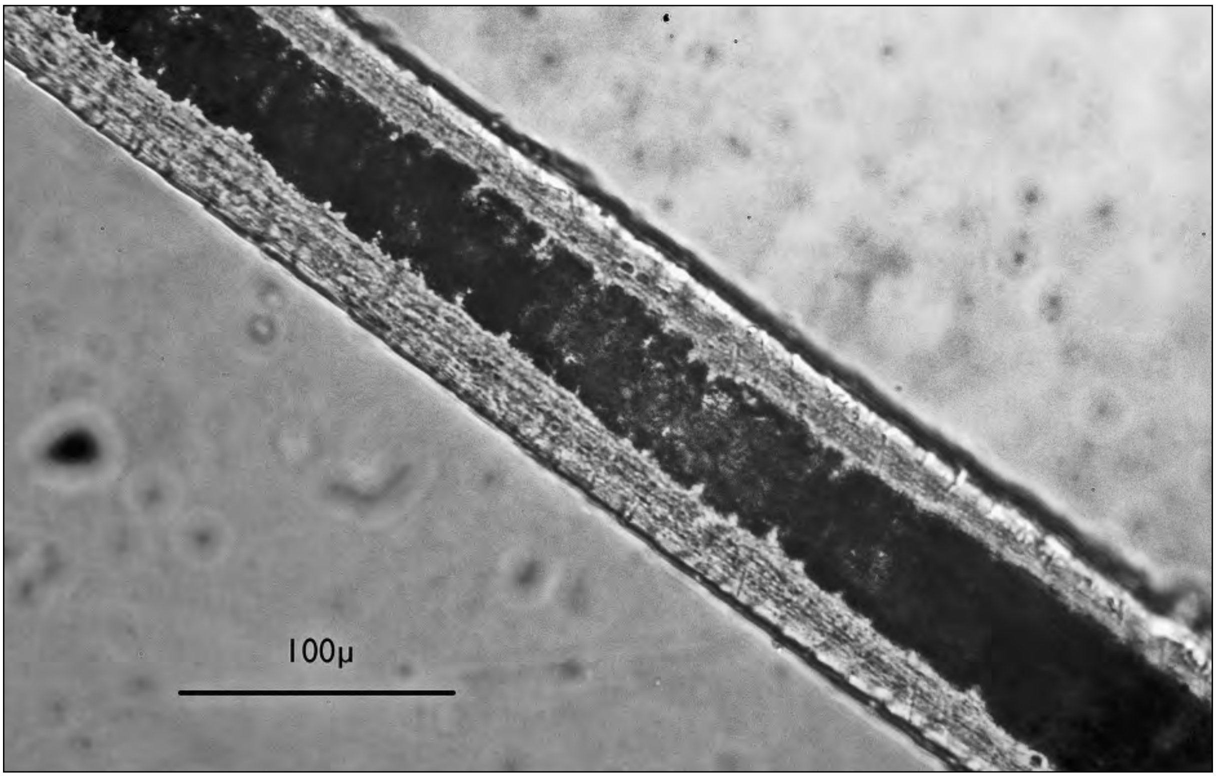

Fig. 229. Horse fibre, body hair, Haflinger, modern

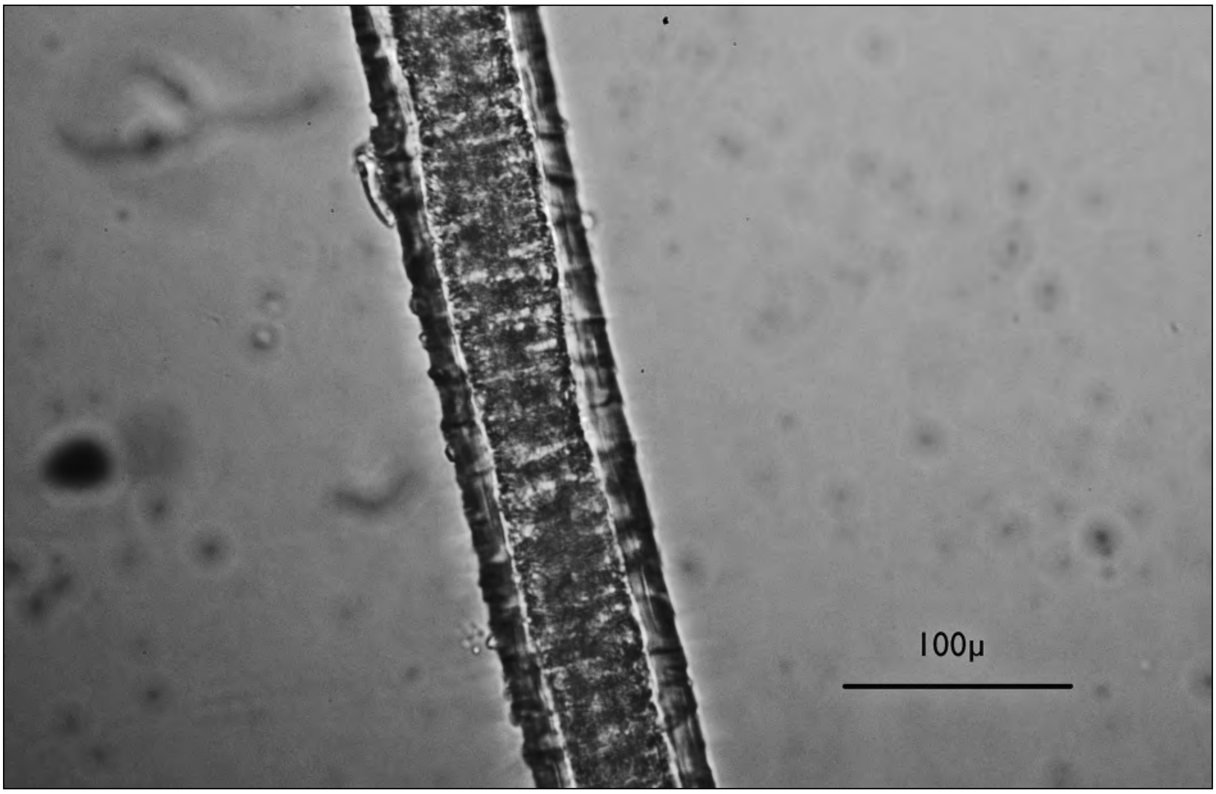

Fig. 230. Horse fibre, body hair, modern

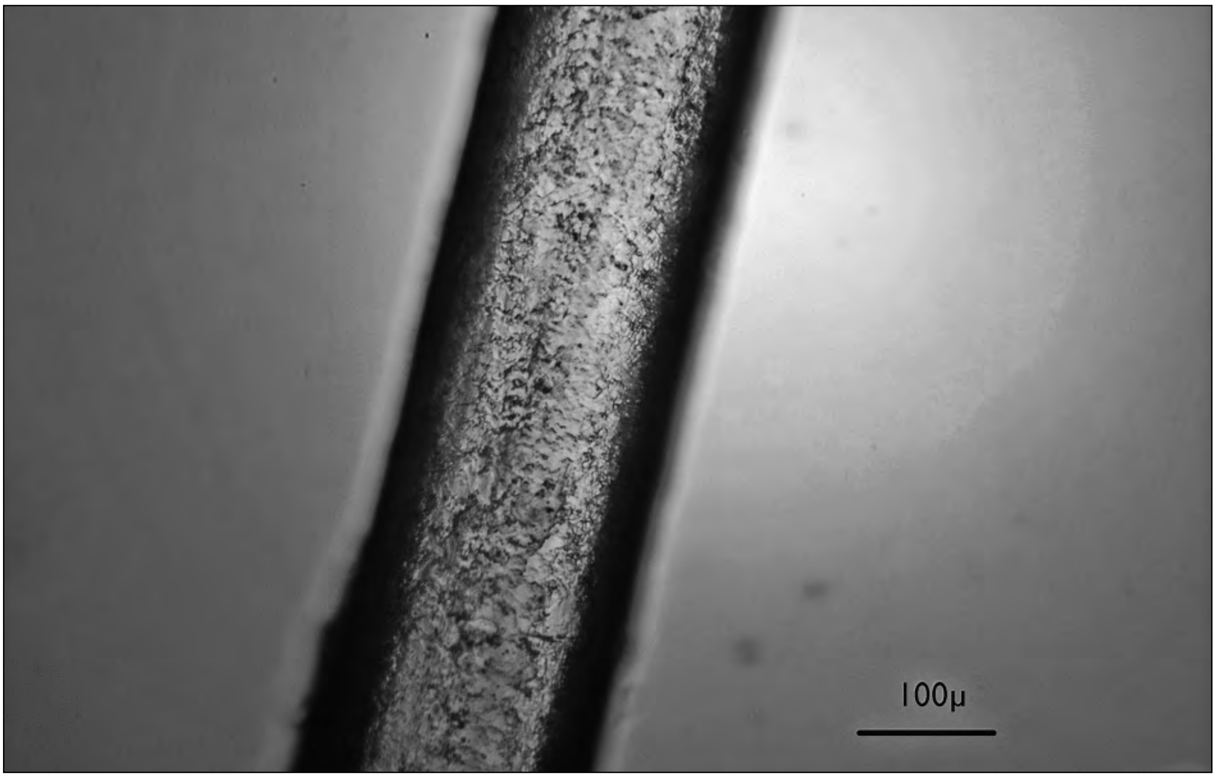

Fig. 231. Horse tail hair, Haflinger, modern

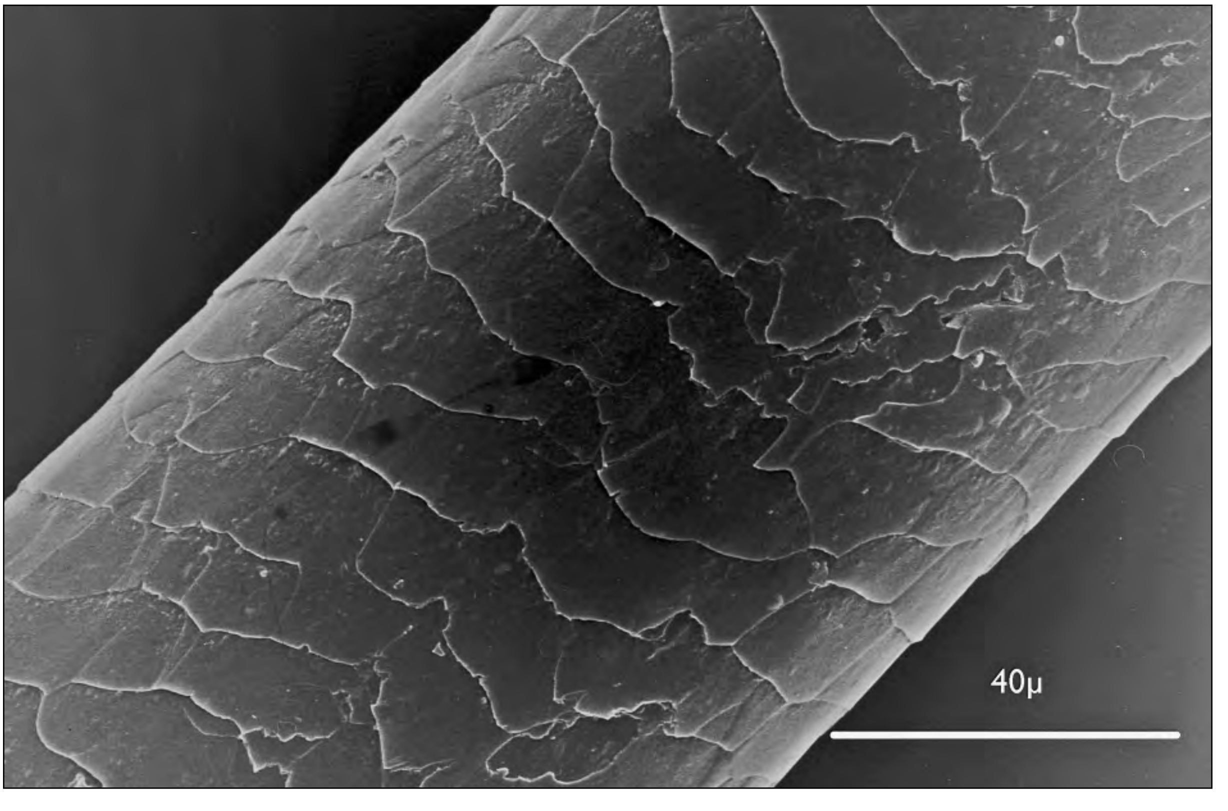

Fig. 232. Horse mane hair, Haflinger, modern

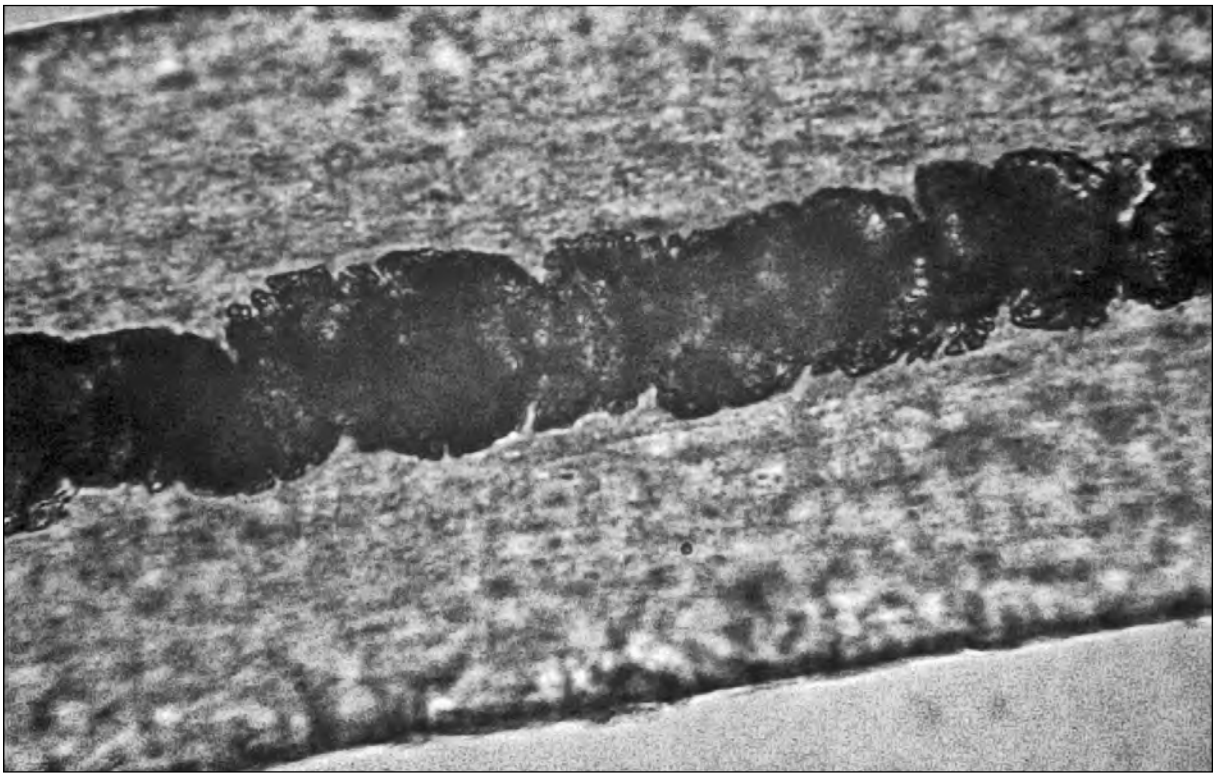

Fig. 233. Horse mane hair, Haflinger, with small medulla, modern

4.7.3.3 Archaeology

Horse hair has been found in a variety of contexts – as garment material, as string or in decorative bands. A Late Bronze Age hoard found in Cromagh (Ireland), held a fine horsehair textile woven in broken twill (this together with metal objects). Neatly braided tassels form the ends of the band. Elizabeth Heckett has interpreted this as possibly ornamentation in the outfitting of a horse, such as those depicted on a Assyrian relief of a royal hunt in Nimrud (Wincott Heckett 1998; 2012). At the same time, hair nets made of horse hair were worn in Denmark (e.g. Skrydstrup; Broholm – Hald 1940, 20). In the Iron Age tumulus of Eberdingen-Hochdorf (D), a string of 2mm diameter is made of horse hair and found tied to a fishhook (Körber-Grohne 1985, 115; 1988a, Fig. 6 and 7). Similar strings for small hooks or even harpoon cords have been used until very recent times in Northern Europe. The length of the fibres together with its strength under wet conditions, has made it an ideal material for such uses (see fibre properties).

A decoration has been documented on a Late Iron Age bronze disk found at a gravesite in Sion-Sous le Scex (CH). Mèches of mane or tail hairs have been sewn on what was probably leather (now gone), the leather having been fixed (glued?) onto the bronze substrate (*Fig. 234*) (Curdy *et al.* 2009, 59f.).

In a 10th century textile from Bogstown (Ireland), horse hair has been found on the surface of the cloth which may be evidence that the object was used as riding material, say as a saddle cloth (Wincott Heckett 2004). Of interest from a textile specialist's point of view is the use of horse hair as a weft thread on tablet-woven bands. One technique is a covering weft pattern made of horse hair, keeping the hair as a straight, shiny fibre. Such bands, functionally wrist and ankle band trimmings or decorating the lower hem of a tunic, have been found in several Scandinavian burials of the Migration Period, e.g. Högom (S) and Evebø-Eide (N) and seem to be a Scandinavian production (Nockert 1991, 91f.). They were part of an elite person's garment. The making of these bands has been found to be very time-consuming and a fabrication of a set of bands for the Högom costume would take a full year of work (Sundström 1996). Horse hairs have also been used for very fine hidden weft threads. One item has been recorded in the salt mines of the Dürrnberg b. Hallein (A) and is dated to the Late Iron Age (Early La Tène Period) (Grömer – Stöllner 2009). A double hair is clearly visible entering the band on the side with the scales being plainly recognizable (*Fig. 235*). Another band (cuffs) with horse hair weft is known from the Migration Period grave yard of Snape (GB) (Crowfoot 1996, 20; Walton Rogers 2007, 183). From the Medieval Period quite similar ribbons of horse hair appear in Latvia. Here, they were part of the headdress (Žeiere 2010).

4.7.4 African ass *(Equus africanus)* and Asiatic wild ass *(Equus hemionus)*

4.7.4.1 Habitat

African wild ass in Nubia; Asiatic wild ass in the Near East.

4.7.4.2 History

E. africanus is the wild ancestor of the donkey (Clutton-Brock 1989, 80ff.). Adapted to dry climates (it can digest much coarser food than horses) the donkey and its domestication was important for land-based transportation in arid zones and for mobile pastoralism. The early history of Egypt is closely linked to the domesticated donkey. The earliest found remains of a donkey date to the mid-5th century BC. Donkeys discovered in brick tombs in Abydos (Egypt) from the 1st dynasty (around 3000 BC) show the importance of this animal. Skeletal pathologies show their intense employment for pulling heavy loads (Rossel *et al.* 2008). The god Seth is ass-headed. Genetic studies show two distinct lineages. The Nubian wild ass is an ancestor of one haplogroup, but with a long line of interbreeding with wild asses. This means that the Abydos asses underwent very little size reduction and looked similar to their wild ancestors even 1000 years after the first domestication had taken place. A single branch of descendants (clade-2) may come from an extinct population, such as the Atlas wild ass (Rossel *et al.* 2008; Kimura *et al.* 2011). However, different species of wild asses are difficult to differentiate archaeozoologically as no ancient skeletons have been found (Rossel *et al.* 2008, 3716). In the Near East, the donkey was an important cult animal. It was as well a symbol of fertility in Egypt, Sumer, in old Hettite, as well as for the Semites and in the Iranian religion (Gamkrelidze 1998). In a Bronze Age grave in Israel (from about 1700–1500 BC), a donkey was found with a bit in its mouth (the first documented as such) and with a saddle-bag (Bar-Oz *et al.* 2013). In the Neolithic Era, in the southeastern part of Europe, the wild ass was the most hunted animal (Ninov 1999, 337). In Bronze Age Greece, the donkey became known as a domestic animal but was rarely mentioned in the ancient texts (Cancik – Schneider 2014, "donkey"). Early terminology for "donkey" arrives with the Indo-European languages, beginning with Greek (ὄνος) and followed by Latin (*asinus*) (Gamkrelidze 1998). Donkeys proliferated in Southeast Europe during the Phoenician expansion in Italy and with the Greek city foundations during the Iron Age. The population also grew during the Late Iron Age in Gaul, becoming even more numerous with the Romans in the northern Alps (Benecke 1994, 144f.). The Greeks associated asses with the Phrygians, their enemies (Sax 2001, 14). Socrates gave the opinion that those who live with too many pleasures will be reincarnated as an ass (Plat. Phaid. 80), which may pertain to the place of asses as losers in many tales (Sax 2001, 17). In the Roman Period, Pliny the Elder is familiar with both the Asian and African wild ass (Plin. nat. 8,16).

During the Roman Period, the donkey was an important pack animal, something documented by several authors of the time. And while sheep and goats needed a dog to protect them, asses were able to use their legs as defensive weapons (Varro, rust. 2,9,1). A donkey transported the Holy Family from Egypt and Jesus to Jerusalem lending to its reputation as a sign of majesty (Sax 2001, 17). Some stories reported that Nero's wife Poppaea bathed in donkey milk and put golden strings around the animal's feet (Plin. nat. 33,140; 28,183). In Diocletian's edict (c. 300 AD) there is a 64 kg weight limit on a donkey's charge (Lauffer 1971). In Palmyra (Syria), the unit of a charge was a *"gomos"* (*γόμος*), 96/97 kg (Pleket – Stroud 2014).

In the Near East, the Syrian or Asiatic wild ass (*E. Hemionus*) was most likely bred, becoming ubiquitous in the Near East (Dyson 1953, 666).

The first known breed of mule goes back to Prehistoric times with references by Homer and in the Bible (Hom. Il. 24,142; Gen. 36,24). Mules were important and used readily in ancient Rome as horses were still too small for the pulling of heavy loads (see ch. 4.7.3).

In the Middle-Ages during the Crusades, the first Mesopotamian depictions were brought to Europe of the ass playing a harp. Shakespeare uses such a picture as a symbol of the divine folly of love (Midsummer Night's Dream). In tales, asses were also often a symbol of wisdom and their excrement of gold (Sax 2001, 18).

Objects as diverse as garments (pants), drum skins and parchments were made with donkey skin and leather (Cancik – Schneider 2014, "donkey").

4.7.4.3 Fibre properties

Fibre dm. 30μ, broad medulla (4/5 width) with large air gaps and slightly spongy/amorphous insides, in the finer fibres as well, but partly interrupted. Donkey medulla is more compact and with fewer air gaps than horse. The fields are filled with an amorphous mass and could easily be confused with cattle. The scale pattern is the same as for horses (s. ch. 4.7.3) (*Figs 236* and *237*).

4.7.4.4 Archaeology

No finds recorded.

4.7.5 European wild ass *(E. hydruntinus)*

4.7.5.1 Habitat

Extinct in Europe since Late Neolithic Period (Schmitzberger 2009).

4.7.5.2 History

The European wild ass is the other equid of Southeast Europe, but there are fossil remains only. It lived in mild climates during the Holocene in western Mediterranean regions. It was already extinct by the end of the Neolithic Period, probably due to hunting and changes in climate. It has been found in Late Paleolithic context in Abruzzes and in the Mesolithic in Puglia (Wilkens 1999). They have a size similar to that of the wild ass (Clutton-Brock 1989, 80). Bones dated to the Neolithic have been found in linear pottery contexts, e.g. in Austria; it was the most hunted animal in the Köres-culture (Pucher 1991; Schmitzberger 2009).

4.7.5.3 Archaeology

No finds of fibres found in an archaeological context.

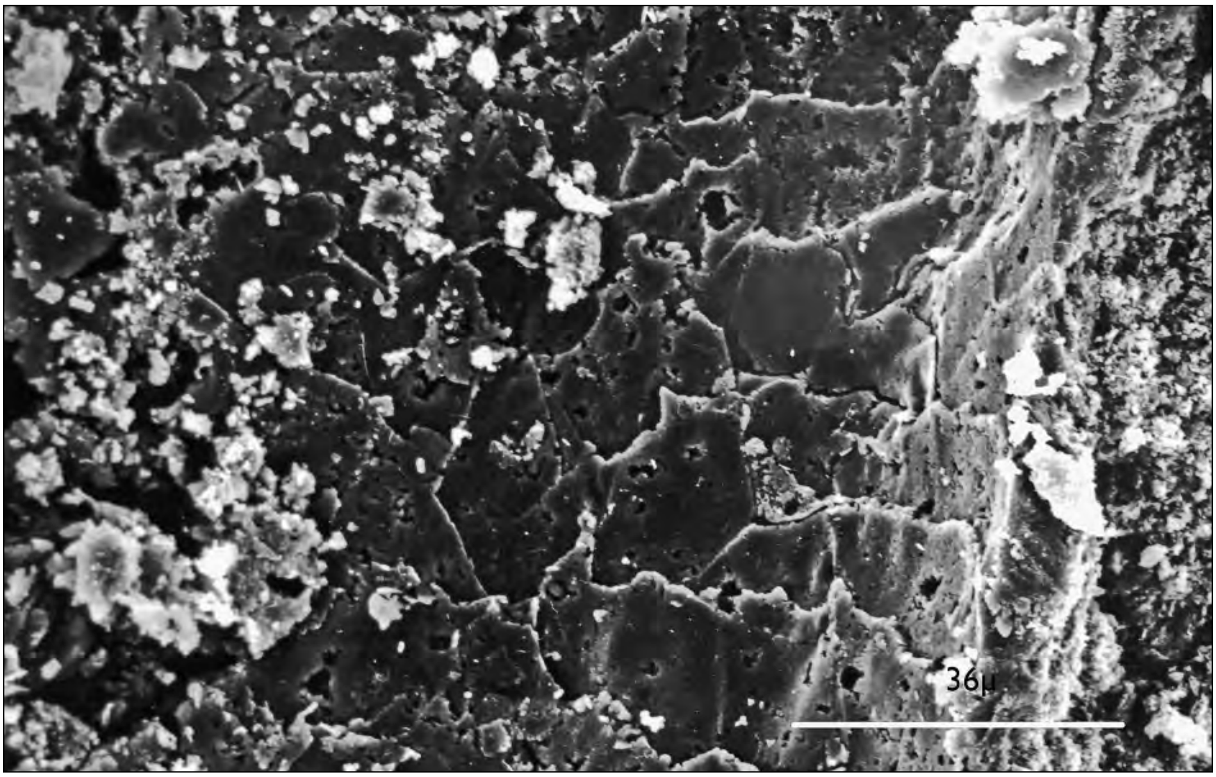

Fig. 234. Horse fibre, mineralized, Iron Age, Sion (CH)

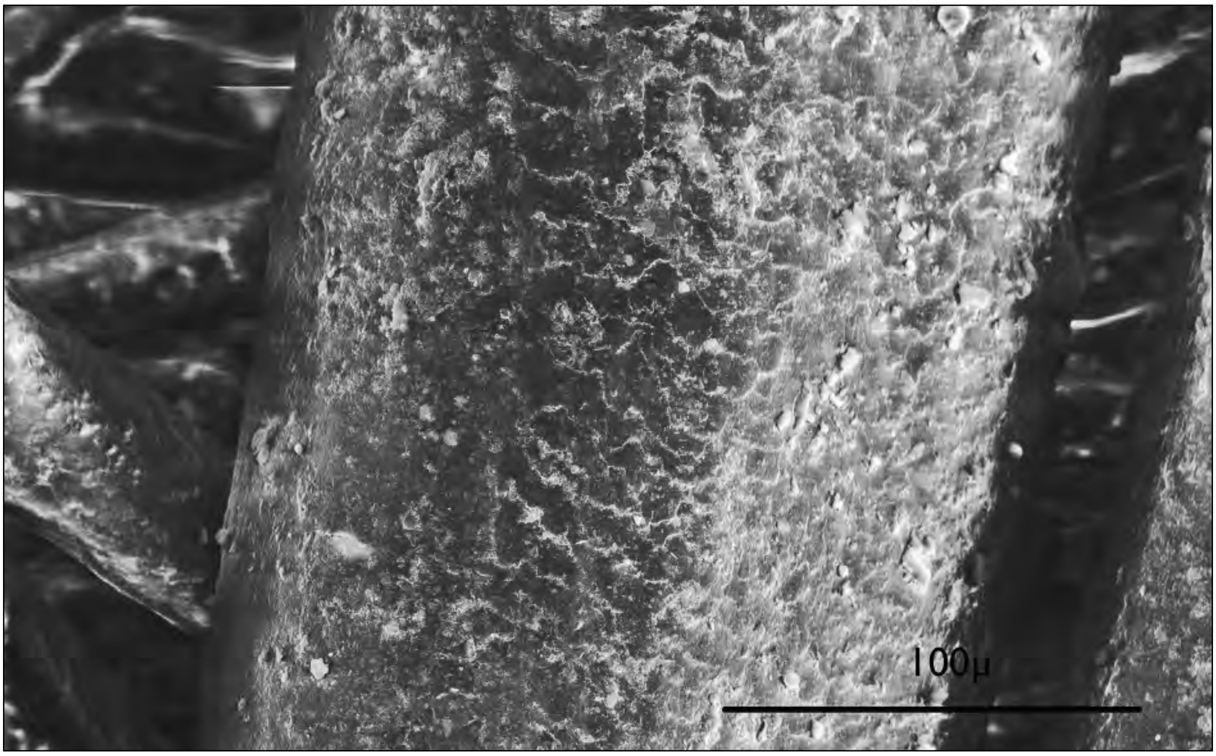

Fig. 235. Horse fibre, weft "thread " of tablet woven band, Dürrnberg (A)
Photo: Karina Grömer, NHM Vienna

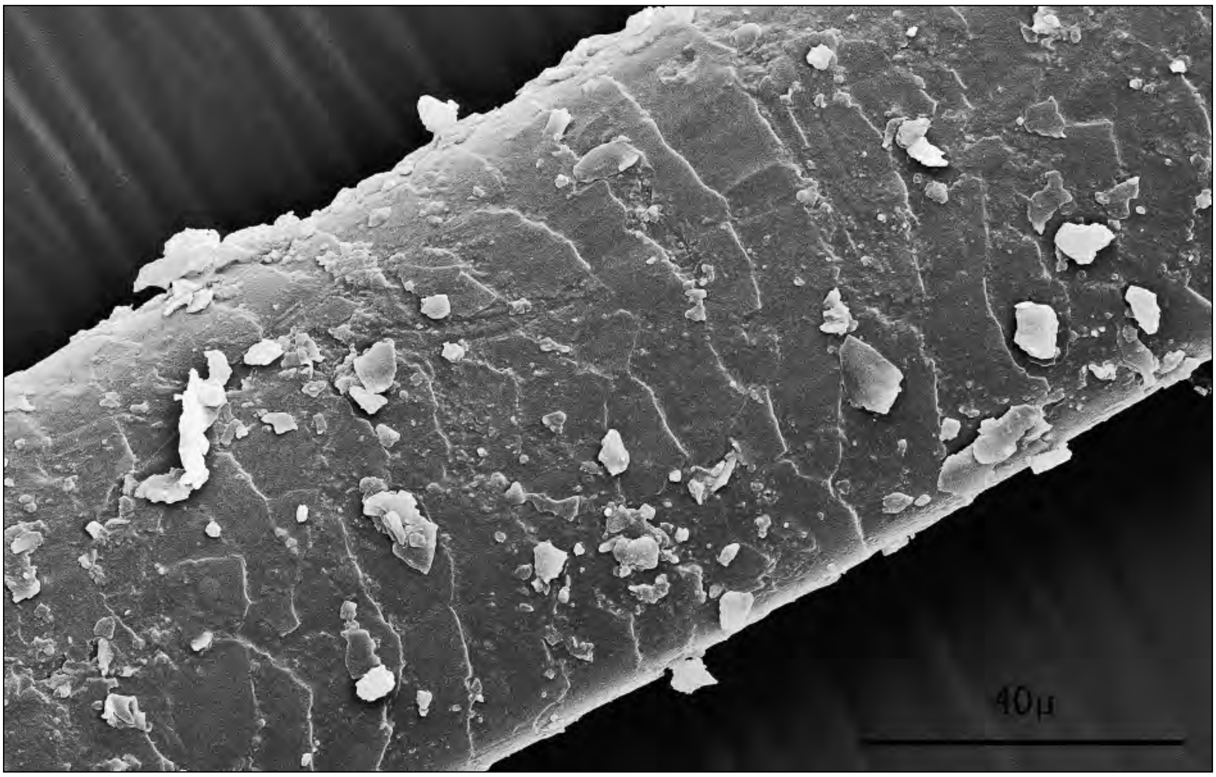

Fig. 236. Fibres of African ass, modern

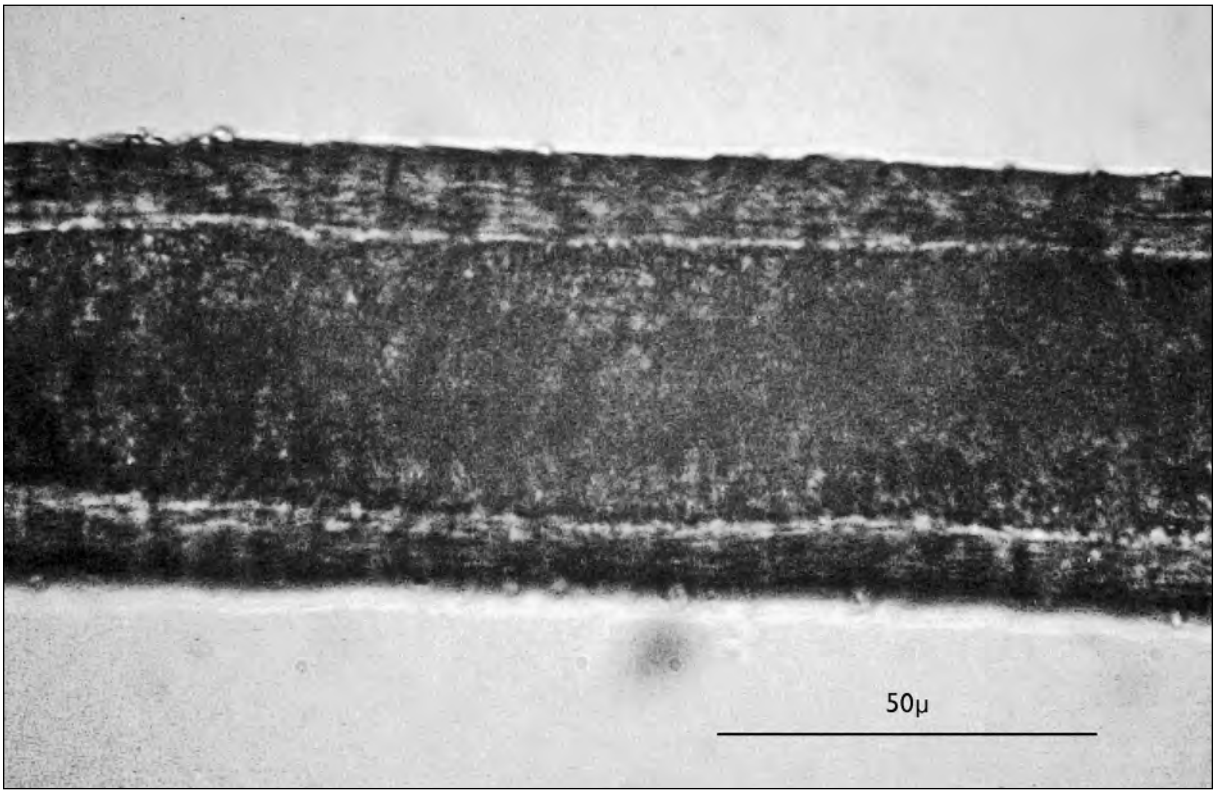

Fig. 237. Fibres of African ass, modern

4.8 Artiodactyla

4.8.1 Introduction to Camelidae

The Roman writer Pliny the Elder gives a good description of two camels:

"*Camels are found feeding in herds in the East. Of these there are two different kinds, those of Bactria and those of Arabia; the former kind having two humps on the back, and the latter only one; they have also another hump under the breast, by means of which they support themselves when reclining. Both of these species, like the ox, have no teeth in the upper jaw. They are all of them employed as beasts of burden, in carrying loads on the back, and they answer the purpose of cavalry in battle. Their speed is the same with that of the horse, but their power of holding out in this respect is proportioned in each to its natural strength: it will never go beyond its accustomed distance, nor will it receive more than its usual load. The camel has a natural antipathy to the horse. It can endure thirst for four days even, and when it has the opportunity of obtaining water, it drinks, as it were, both for past and future thirst, having first taken care to trouble the water by trampling in it; without doing which, it would find no pleasure in drinking. They live fifty years, some indeed as much as one hundred. These animals, too, are liable to fits of frenzy.*" (Plin. nat. 8,26).

4.8.2 Dromedar *(Camelus dromedarius)*

4.8.2.1 Habitat

The one-humped camel lives in Iran (endangered population), throughout the Near East, Arabia, Africa, less frequently in Asia. Some wild dromedaries live in Central Australia after having been introduced in the 19^{th} century.

4.8.2.2 History

One-humped camels are the best riding and transport animal in the desert and they are, indeed, used primarily for these purposes (see also ch. 4.8.3). Camels have been largely known since Prehistoric times in the Near East as riding or baggage animals and were domesticated in the Bronze Age. Abraham rides on a camel to Mesopotamia to find a bride for Isaac (Genesis 24-25). It's not sure if Ctesias' report concerns dromedars or camels (see below). They give wool, the amount per year depending upon the climate: in warm climates about 1-1.5 kg can be clipped (or pulled); in colder climates up to 5 kg. Today, dromedaries are used for the production of milk, wool, hair and hides (Harizi *et al.* 2007).

4.8.2.3 Fibre properties

The quality of dromedary fibre is considered one of the finest for textile use and it is chemically similar to sheep wool. There is an average of 17.7µ for the undercoat (14–28µ), 90µ for guard hair, 7–9 scales per 100µ. The medulla is sometimes interrupted. According to scale frequency, it is not possible to differentiate between fine dromedary and cashmere fibres (Harizi *et al.* 2007) (*Fig. 238*).

4.8.2.4 Archaeology

see ch. 4.8.3

4.8.3 Camel *(Camelus bactrianus)*

4.8.3.1 Habitat

The two-humped camel is bred in Eastern and Central Asia (Mongolia and Northern China) and can survive in extreme cold.

4.8.3.2 History

Herodotus reports that Persians had camels in the cavalry when they fought against the Lydians. Natural camel odor frightened the horses of the Lydians (Hdt. I, 80). Semiramis from Assyria had, according to Ctesias of Cnidos, 100 000 camels to fight against the Indian army (Diod. 2.1-28). Alexander the Great used 5000 Bactrian camels to carry away treasures (Zeuner 1964, 364; Clutton Brock 1989, 129). Ctesias of Cnidus reported, that the numerous camels were as large as the largest horses, and had wool comparable to the Milesian wool (Aelian. NA 17,34; Nichols 2008, 91). John the Baptist is usually depicted wearing a camel skin. The Romans brought camels to Western and Central Europe – bones have been found in Soisson, France and in Vindonissa, Switzerland, the Swiss bones being either camel or dromedar (Deschler-Erb – Akeret 2011, 22f.). Camel fur is double-coated, with the fine fibres being used for warm garments (reported in written sources of the Near East) and the coarse fibres for tents or bags.

Camel fibres are known for keeping in the warmth. The use of the fine camel hair is similar to the one of cashmere. During the Second World War special underwear was produced to protect pilots against the cold during active as well as inactive periods (Haigh 1949, 806). Today, camel hair is used for woven textiles, knitted objects and as filling in covers. Because of the growth of the finest fibres along with follicle inactivity, it is important to comb the camels (and dromedaries) with care so as to maximize the amount of fibres that can be collected (Ansari-Renani *et al.* 2010). The Bactrian camel has more of an abundance of wool with a capacity for 5–12 kg per year. In 20th c. industry, 1% of sheep wool was added to the fine camel wool to make the fabric more firm and to help the garment keep its shape (Haigh 1949, 797).

4.8.3.3 Fibre properties

The long haired camel – the "camel hair" of today from the Bactrian camel – is raised in Mongolia. These animals produce a fleece with both fine and short fibres which are medullated, have a diameter of 9–40µ and coarse fibres of up to 120µ (v. Bergen – Krauss 1942). Fibre quality depends upon the climate circumstances two months prior to moulting, with harvesting being done during the moulting period. The scales of the fine fibres show a diagonal to the axis, the coarse fibres with fine rippled waves (Vineis *et al.* 2011). Guard hairs are of a dimension up to 120µ (Ansari-Renani *et al.* 2010; Hofer 2000, 292). The fibres are pigmented (brown!) (*Figs 239–241*).

The medulla is amorphous, similar to cattle, but the diagonal scales especially of the fine fibres are an important clue for the differentiation. Camel hair of about 20–25µ shows a large medulla – larger than wool in such dimensions.

4.8.3.4 Archaeology

Many finds from the Near East have been made of camel hair. Fibre measurements of skin fragments show clearly the double-coated nature of the camel (Batcheller 2005). At present, few textiles made of camel wool have come out of Europe. One case, though, has been reported by Boyer and Vial to be from the antique port of Marseille (F; Boyer – Vial 1982). Many wool textiles are not closely analyzed, unfortunately, so that those made from camel hair and dated from the Roman period may not have been spotted. Camel is more important when dealing with Central Asian textiles.

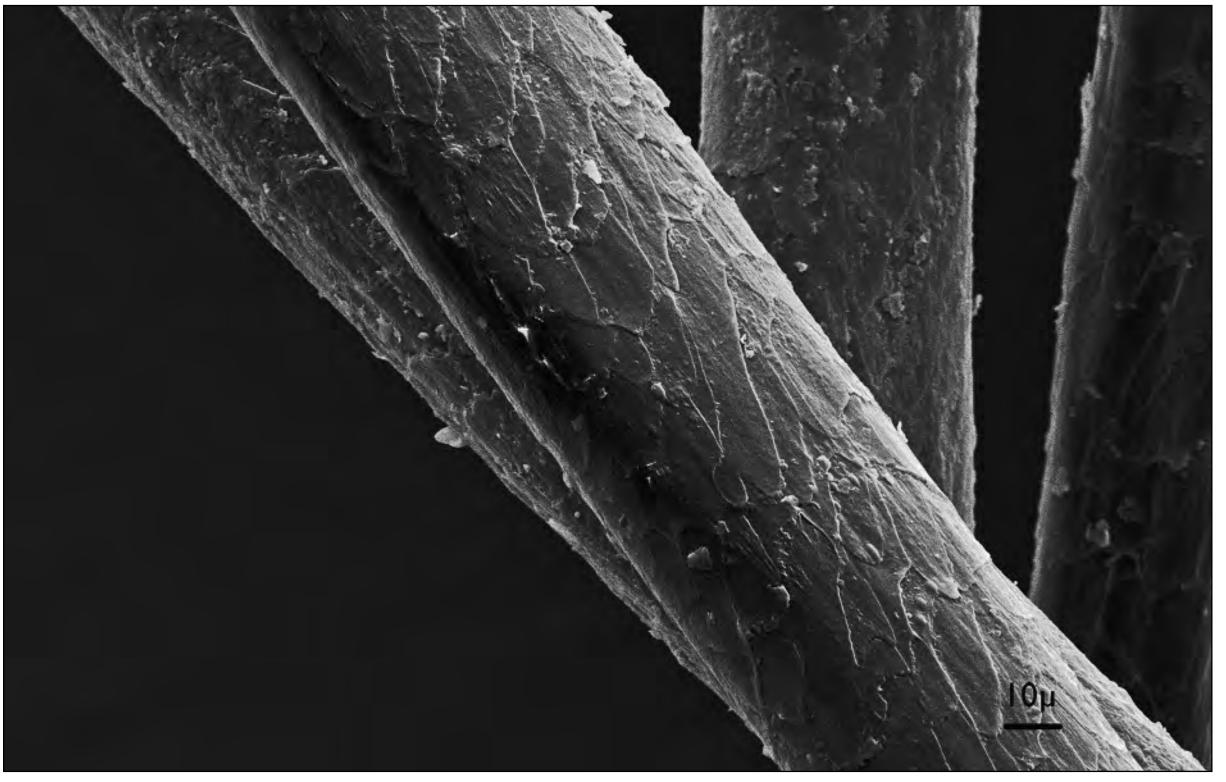

Fig. 238. Dromedar fibres, modern

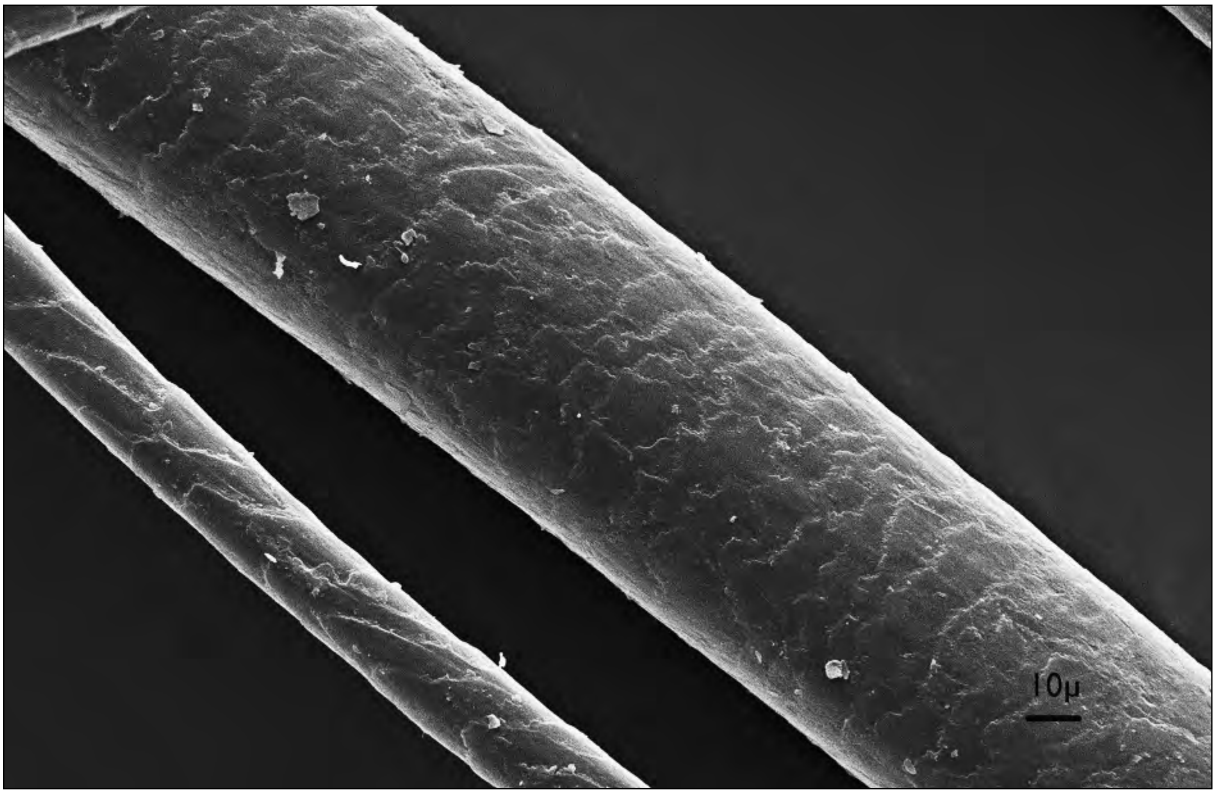

Fig. 239. Camel fibres, modern

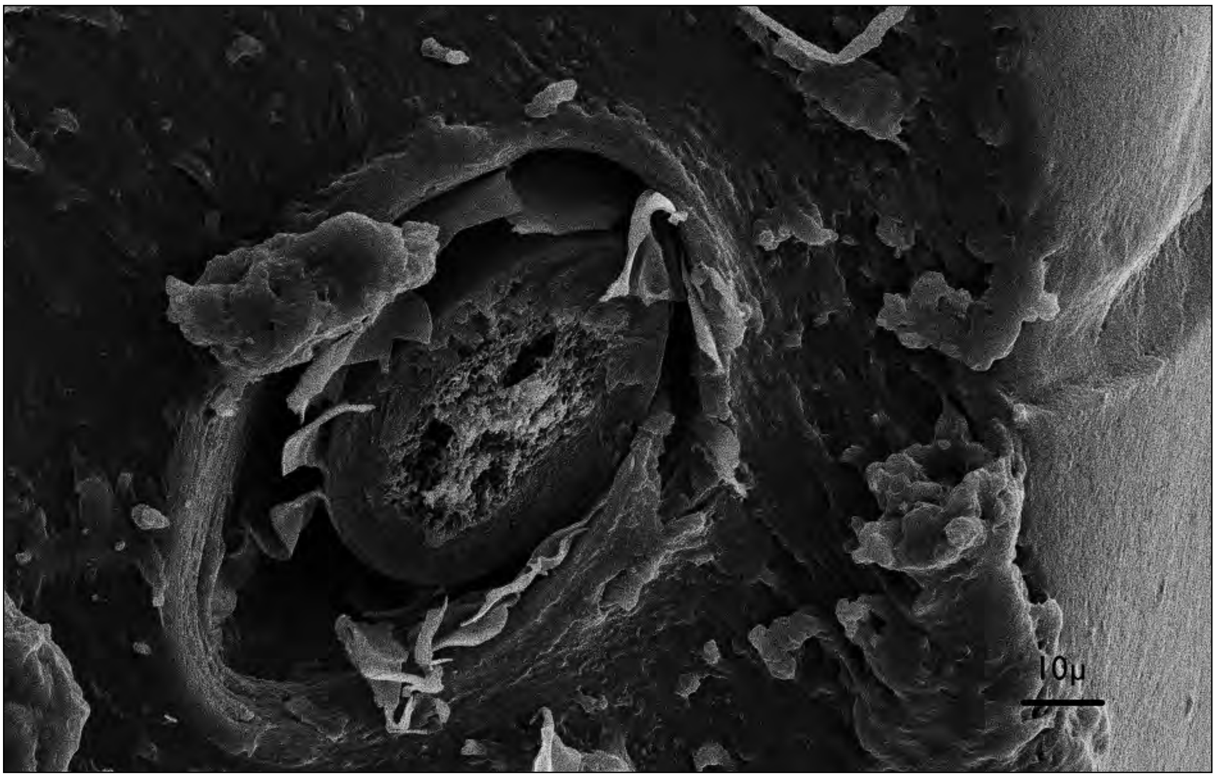

Fig. 240. Camel fibre, cross-section with amorphous large medulla, modern

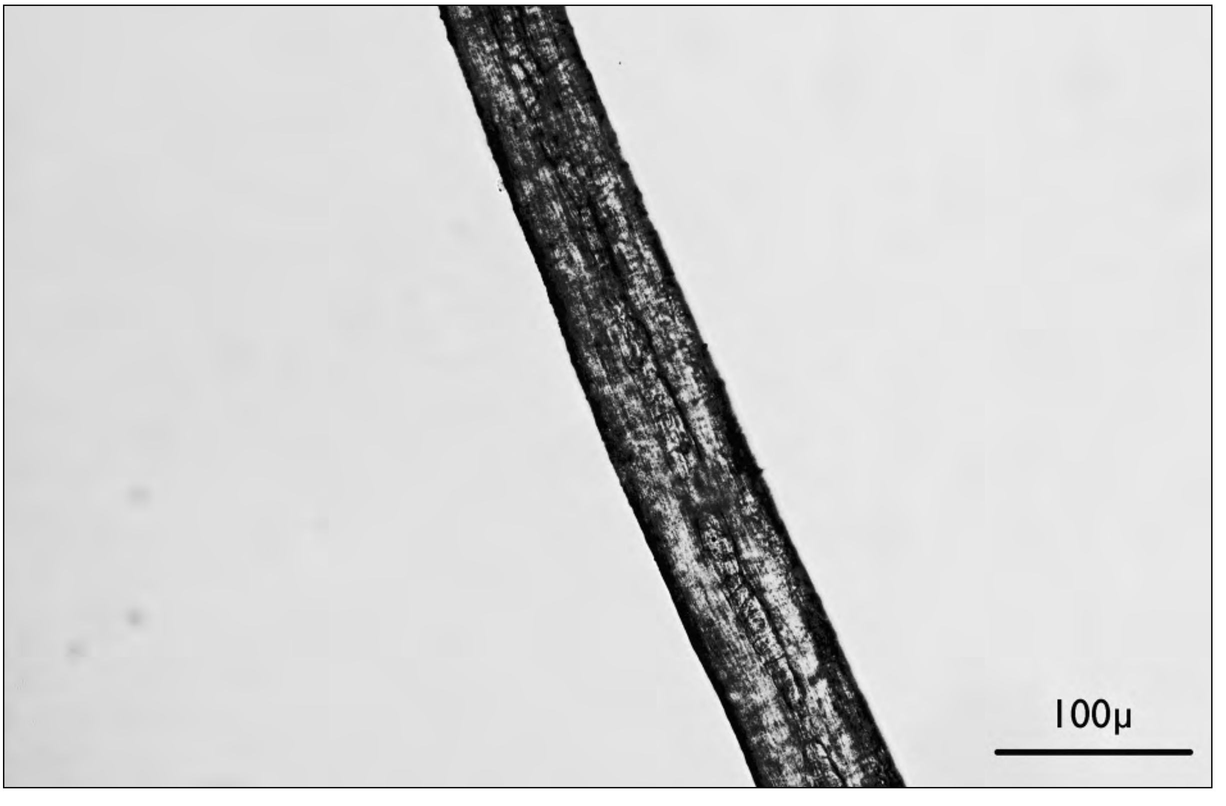

Fig. 241. Camel fibre, fine fibre with small medulla, modern

4.8.4 Wild boar *(Sus scrofa)*

4.8.4.1 Habitat

In forests, spread through all Europe and Asia.

4.8.4.2 History (incl. domesticated pig)

According to DNA-analysis, the *Suidae* have been domesticated in various places and independently from one another in areas of the Near East and Asia. In the Near East it came about sometime after the domestication of goats and sheep around 7300 BC (Giuffra *et al.* 2000; Wuketits 2011; Jing – Flad 2002; Larson *et al.* 2005). Domesticated pigs have evolved to be of smaller stature than their wild ancestor (Benecke 1994, 48). In Europe in about 4000 BC, however, domesticated pigs were interbred with wild boar while foraging in the forest so that they became larger in size (Pucher 2010). DNA analyses have confirmed that these European pigs are closer to the European wild boar than to the Near Eastern (smaller) wild boar (Schmitzberger 2009, 58; Zeder 2008; Haile 2010).

Different species are known all over the world, from very small S*us salvanius* in the Himalayas to the big *Hylochoerus meinertzhgeni* in East-/West-Africa. And in Europe – from the Pyrennees to Russia – lives the wild boar *Sus scrofa scrofa.*

Suidae were an important livestock species throughout history as they may have been used as working animals in addition to being a source of food. During the Neolithic Period they were employed for "ploughing" the ground (Schibler 2008, 387) and in later periods for finding truffles or even engaged as hunting companions. In Hallstatt (A) salted and air-dried bacon was produced in the Iron Age salt mines (Pucher 2008). During the Late Latène Period (2nd half of first century BC) very small pigs were known, for example, in Manching (D); Zeuner 1963, 268). Pig breeding was well-known during the Roman Period and the practice became very important and regulated during Medieval Times (s. *Lex salica*). The Romans enjoyed eating ham, most favoring that made by the Gauls and imported to Rome (Varro rust. 2,9). In the Early Medieval Period, pigs became more abundant in Northern Europe, continuing to be the phenotype of the wild boar. In the Middle Ages, pig became more important for meat and fat than in former periods (Benecke 1994, 55ff.). In the 19th century new breeds were the beginnings of the modern pig with a variety of species developing since then. Today, pork meat has a large place in the market.

Pigs are known in Greek mythology as an animal with powerful forces that can only be fought by the heroes (*Phaia and the wild boars of Caledonia*). The Celtic word for a boar, *torkos (torc, twrch)*, can also mean a "wild" or brave warrior. The Christian perception is one of the "wild beast" depicted in the Early Medieval Period (Wamers 2008, 46f.). In Norse mythology it is known as a symbol of fertility (*Gallinborsti*), as in the *lex Salica* where the ritual sacrifices of pigs are mentioned (Quast 1997, 436). The saints Blasius and Antonius of Egypt have the pig as their hallmark. Today, pigs can be found as a symbol of good luck, e.g. the term "piggy bank".

Pig bristles – from wild boars to domesticated pigs – are very elastic and have been incorporated for use in brushes and paintbrushes. They've been used in upholstery and even as an elegant addition blended with wool yarns (v. Bergen – Krauss 1942, 19).

In 1857 Edouard-Léon Scott de Martinville invented the "phonautograph", the first instrument to record airborne sounds capable of being played back. It consisted of a horn which collected the sound and a swine bristle which inscribed the sound on a black-coated cylinder as a visual image (Scott de Martinville, re-edited 2010, 9).

4.8.4.3 Fibre properties

The fibres are thick with dm. 200–400µ. The scales are finely rippled with narrow margins (*Fig. 242*). According to Newman, there is a difference between horsehair and pig bristle because of pigment in pig bristle being more concentrated at the center of the hairs than pigment in horsehair. However, there is no pigment to be found in the epidermis or scale section (see ch. 4.7.3; Newman 1952).

4.8.4.4 Archaeology

No archaeological finds recorded.

4.8.5 Reindeer *(Rangifer tarandus)*

4.8.5.1 Habitat

Lives in the northern hemisphere, is well adapted to snow.

4.8.5.2 History

During the last glacial period in Europe, reindeer existed over a wide area in the whole of Europe but retreated to the north after that. As fossil remains show, it was part of the mammoth fauna of the southern part of the North Sea (Glimmerveen *et al.* 2006). In Early Prehistory herding was more in practice than domesticated use. As the bones of both domesticated and wild reindeer are quite similar it is often difficult to differentiate the two. The first proofs of riding the animals, however, are more clear and are dated to the 1st century AD from China (Clutton-Brock 1989, 133f.). In the Middle Ages there is a genetic change among domesticated reindeer (Bjørnstad *et al.* 2012). A reindeer cult went from the areas around the Atlantic Ocean up to Lapland. In Northern Europe, or Lapland, today they are used for riding, as pack animals, in sleigh pulling and even for milking (Zeuner 1963, 112ff.). The Sami Culture, for example, lived in a hunter-gatherer economy until the 16th century but events at the beginning of the 17th century caused a movement towards a more nomadic pastoralism, something which stayed with them up until the 20th century (Lundmark 2007). As concerns pelts, younger animals are more favorable than more mature ones. At market a variety of qualities are differentiated: newborn animals with flat hair (L. 1 cm) vs. milk calves (fine, silky hair) vs. grass eaters (Franke – Kroll 1976, 248f.). They have been used as sleeping bags for Arctic and Antarctic explorers.

4.8.5.3 Fibre properties

Coarse and long upper hair, 120–200µ, very fine underwool, about 20µ. The scales show a net-like pattern with a distinct three-dimensional form of the scales, making reindeer distinguishable from elk or red deer although very similar to roe deer (*Fig. 243*). The net-like medulla fills nearly all the fibre and has an excellent insulating properties (*Fig. 244*).

4.8.5.4 Archaeology

In Medieval textiles from Greenland many tuffs of reindeer were found showing that hides were probably worn (Østergård 2009[2], 120f.).

4.8.6 Roe deer (Capreolus capreolus)

4.8.6.1 Habitat

The roe deer is wide spread and not restricted to a specific ecological zone.

4.8.6.2 History

During the Neolithic Period the roe deer was larger than it is today (SCHMITZBERGER 2009, 68). It was locally used for the pelt and especially so for sick persons with pressure sores (i.e. bedsores) for its restorative qualities (CUBAEUS 1911). In the Middle Ages, roe deer skin was an important material for book binding (see chapter 4.8.7).

4.8.6.3 Fibre properties

Primary hairs dm. 120–150µ, with a net-like scale pattern, similar to reindeer but with finer scale edges. Summer hair shows horizontally fine ripples towards the tip. There are fine lines between scale edges noted by Keller (KELLER 1981). Net-like medulla fills the full space of the fibre with the cells having 4-6 edges and those at the tips of the winter hairs with a granulated filling (LOCHTE 1938, 268). Underwool is with horizontal scales, smooth edges and a dm. 15–30µ. Generally, the epidermis is coarser than for the red deer, and the root a more pronounced wine-glass shape (LOCHTE 1938, 268) (*Figs 245* to *247*).

4.8.6.4 Archaeology

Roe deer has been found in Damendorf , northern Germany, as skin for a coat (MÜLLER 2001; SCHLABOW 1937, 17). Another coat, from Refstrup Hovegaard (DK) (250-540 AD) has been documented as being deer skin (EBBESEN 2009, 42). Danish pre-Roman skin garments have been made of deer as well (MANNERING *et al.* 2012, 105).

4.8.7 Red deer *(Cervus elaphus)*

4.8.7.1 Habitat

Woodlands, also mountain areas.

4.8.7.2 History

Red deer inhabited a wide area in Western Europe (SCHMITZBERGER 2009, 37). During the Neolithic Period deer were an important meat supply. Bone and antler remains from lake dwellings (CH) show an increase in the hunting of these animals because of climate deterioration (37^{th} c. BC). This lead to a reduction of the population and shortages of antlers for use as the sleeves of stone axes. During the Corded Ware Culture, red deer were less important for the food supply but rather hunted for skins (HÜSTER-PLOGMAN – SCHIBLER *et al.* 1997, 342ff.). Deer from Neolithic times were larger than today's deer (WILKENS 1999, 146). According to Homer, the bones were used for the mouth-pieces of musical instruments and the skins for blankets (HOM. OD. 13,436). Cervidae, as part of the deer family, were transported around the Mediterrannean even in Prehistoric times (BECKER 1999, 102). In the Celtic and Germanic Periods, *Cernunnos* was depicted on many objects as the god with deer antler. Found, for example, on the Gundestrup Cauldron (National Museum Copenhagen) he is the god of prosperity, due perhaps to the yearly renewal of the antler. A *Cernunnos*-cult with dances and masks was still in vogue during the Early Middle Ages (BIRKHAN 1997, 695ff.). The Romans also kept deer in parks (COL. 9,1). An Early Medieval law code, the *Lex Alemannorum*, elicits a fine if a deer with foot strings is stolen (LEX ALEMANNORUM 23/24). This would indicate that deer were kept in captivity. They might also have been used to attract other deer during hunting (MARTIN 1976, 134; POPLIN 1996). Late Antique and Early Medieval finds have exhibited deer with bridles (e.g. Nogent-sur-Seine, France). A Late Iron Age inhumated deer (Villeneuve-Renneville) was found to have a bridle in its mouth confirming the notion of deer in captivity (POPLIN 1996; MARTIN 1976, 133f.). In stories, carts used by the Goths were pulled by deer (BIRKHAN 1997, 703). Deer were also a sacrificial animal for Diana (POPLIN 1996). In Nordic mythology (Edda), four stags eat from the tree of life (Yggdrasill) and may represent the four elements, the four seasons or the four winds (www.northvegr.org). In the Early Medieval grave (mound 2) of Sutton Hoo (GB) a stag is decorating the top of an object which may be a scepter (Carver 2007, 27f.). In the Early Medieval grave yard of Schleitheim-Hebsack (CH), slices of the antler burr were cut and worn as dangling amulets at the girdle (Burzler *et al.* 2002, Taf. 79). Deer are important as a symbol of fertility – in Christian belief it was the symbol of the resurrection bearing the soul of the baptized person (Psalm 42.2). Saints report having seen a deer with a crucifix between its antlers (St. Hubert, St. Eustachius), a subject also depicted in art work. In Celtic mythology deer lead to the Other World (Sax 2001, 145).

In the Middle Ages deer skin is especially important in the binding of books, an example being reported by Charlemagne in connection with the forest of Saint Denis/Paris (F) and the supply of deer skins (red deer and roe deer) for the books of the monastery (Dasler 2004, 17).

4.8.7.3 Fibre properties

Primary hairs measure up to 200µ, medium fibres 60–80µ, fine underhair (highly crimped) 15–30µ, the scale pattern is an irregular wave mosaic pattern, the medulla is net-like for the larger fibres, filling 3/4 to 4/5 of the width, continuous amorphous for the fine fibres. The coarse fibres can be confused with the kemp fibres of primitive sheep. Fine fibres are medullated (unlike sheep) and the distance of the scales (for fine fibres) is less than that for sheep wool (Woods *et al.* 2011). (*Figs 248–250*)

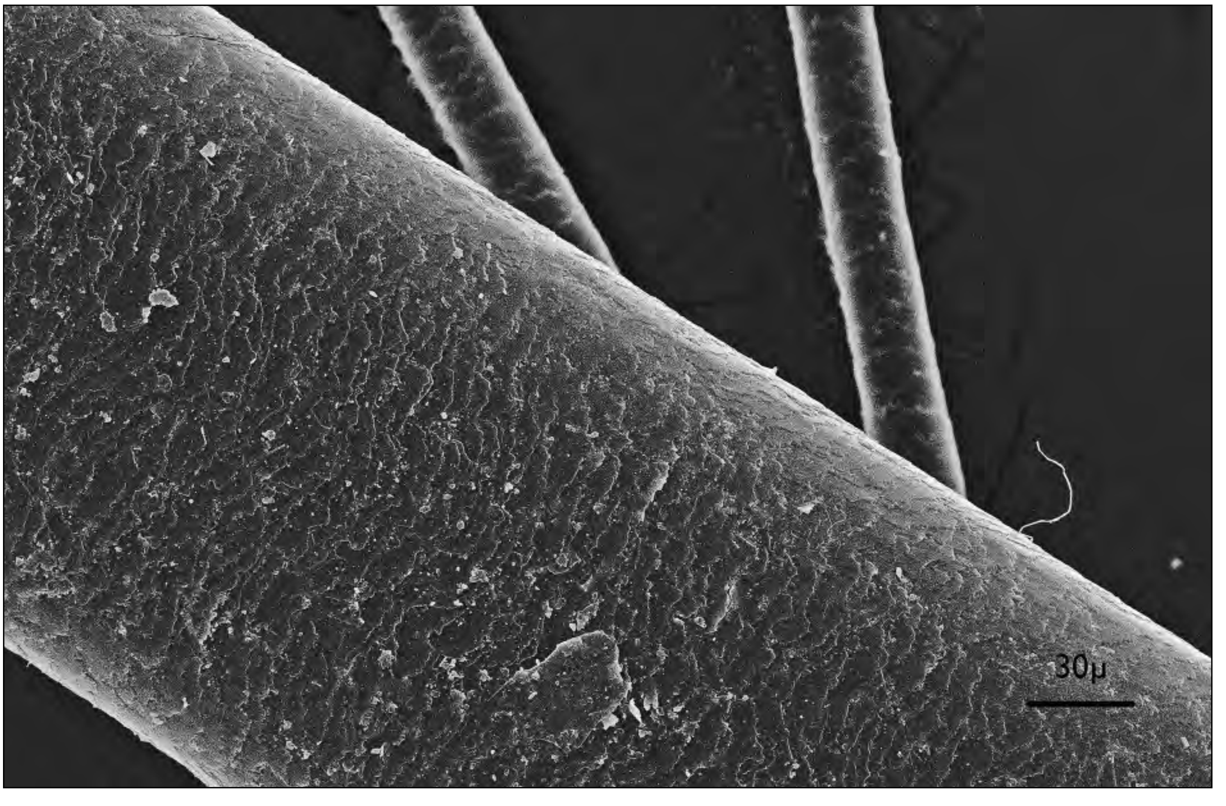

Fig. 242. Wild boar fibres, modern

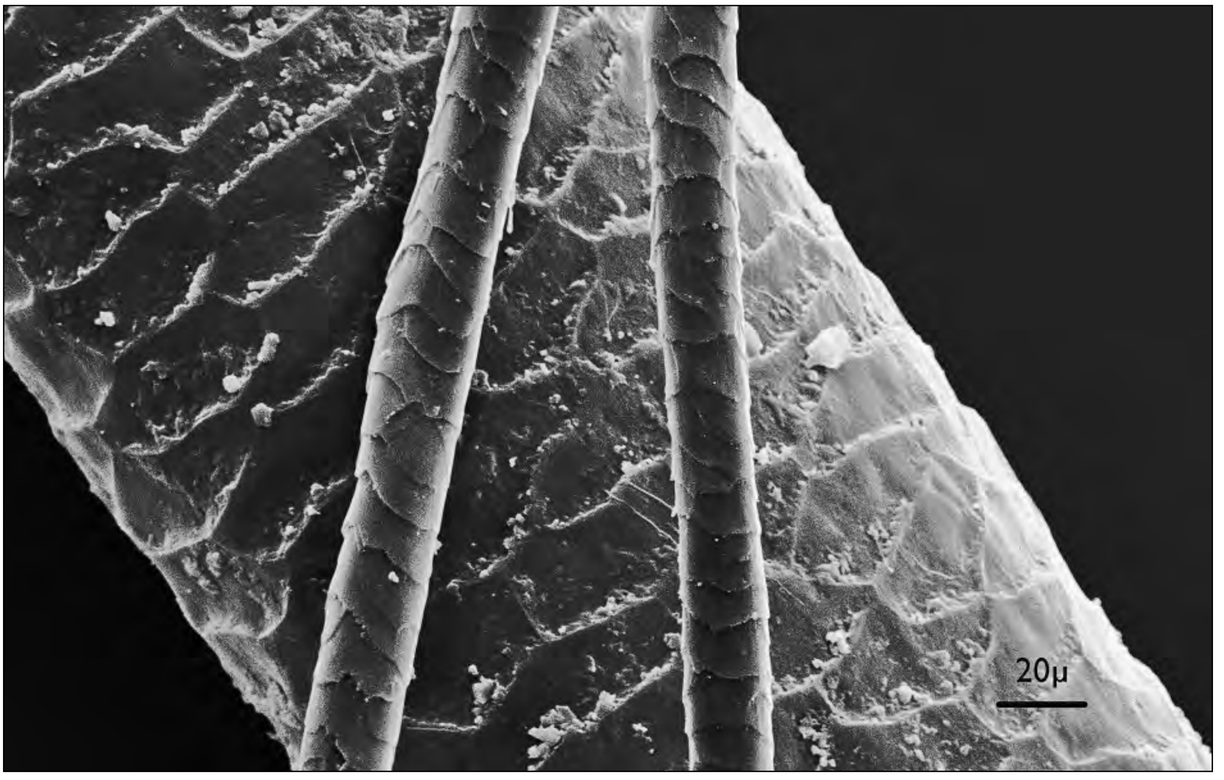

Fig. 243. Reindeer fibres, modern

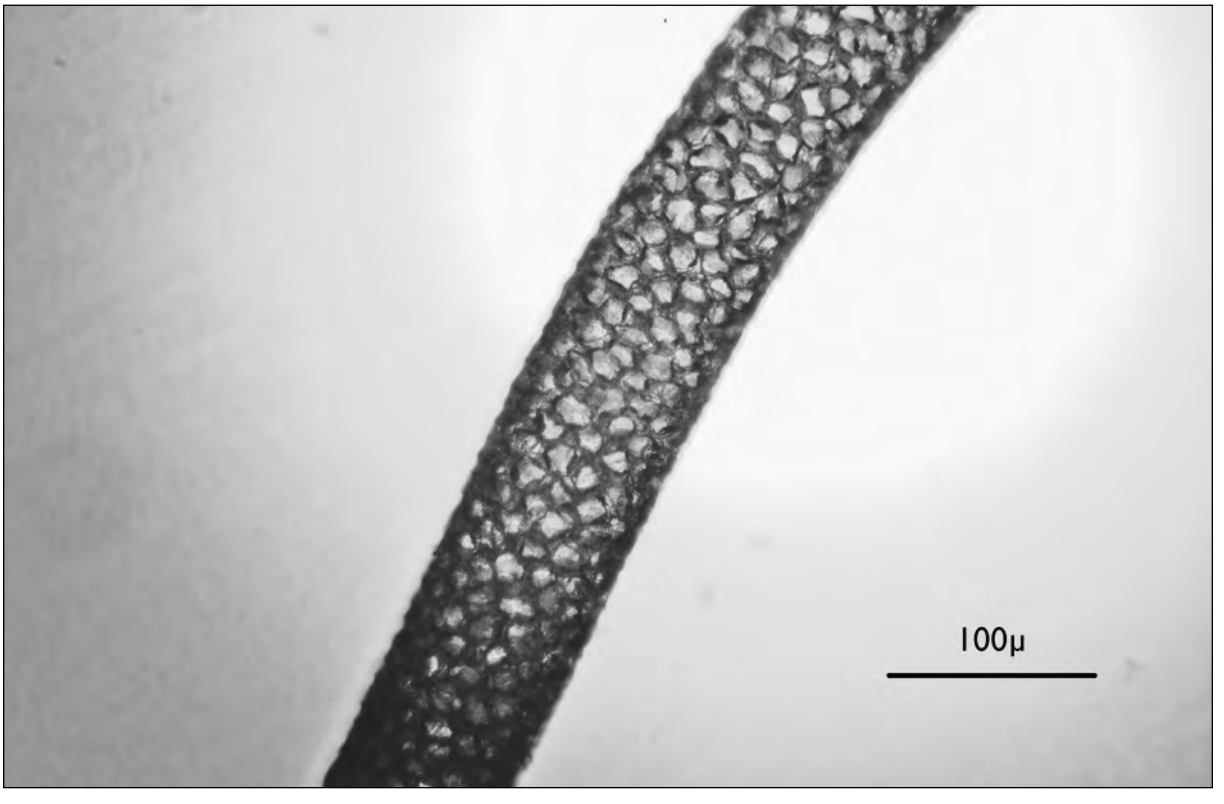

Fig. 244. Reindeer fibres, seen by light microscopy, modern

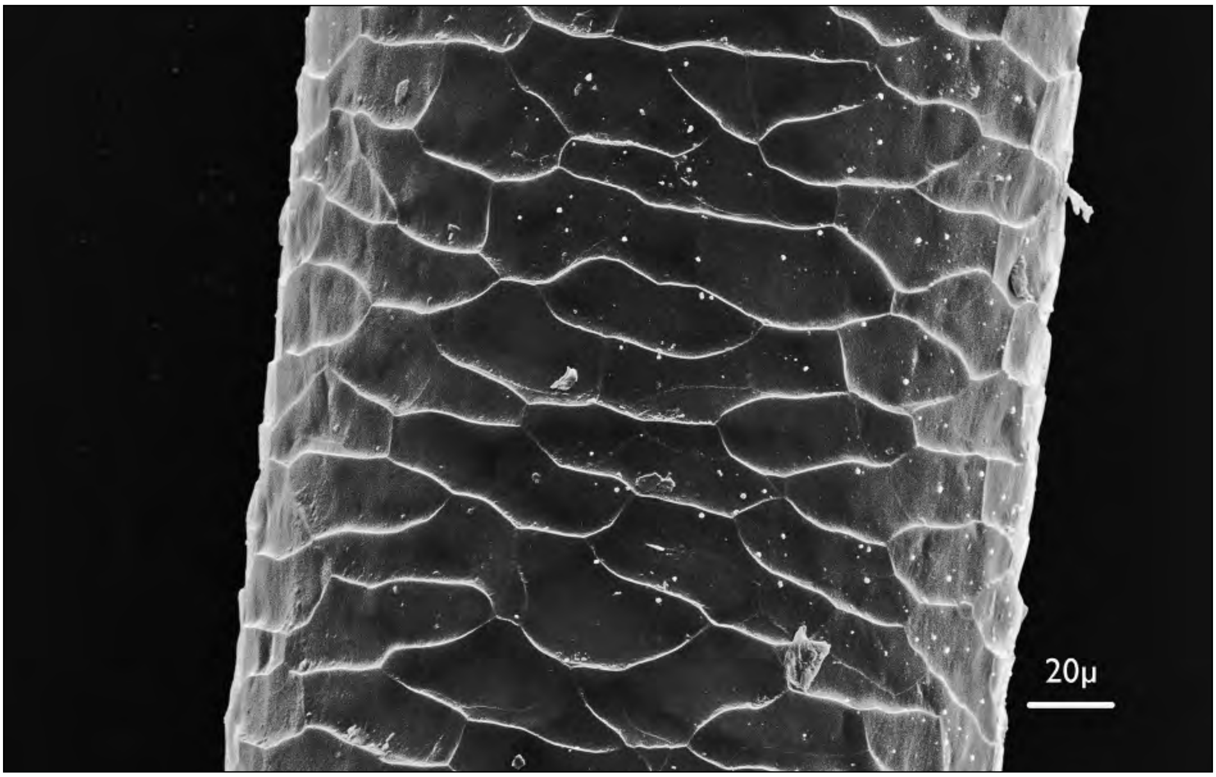

Fig. 245. Roe deer fibres, modern

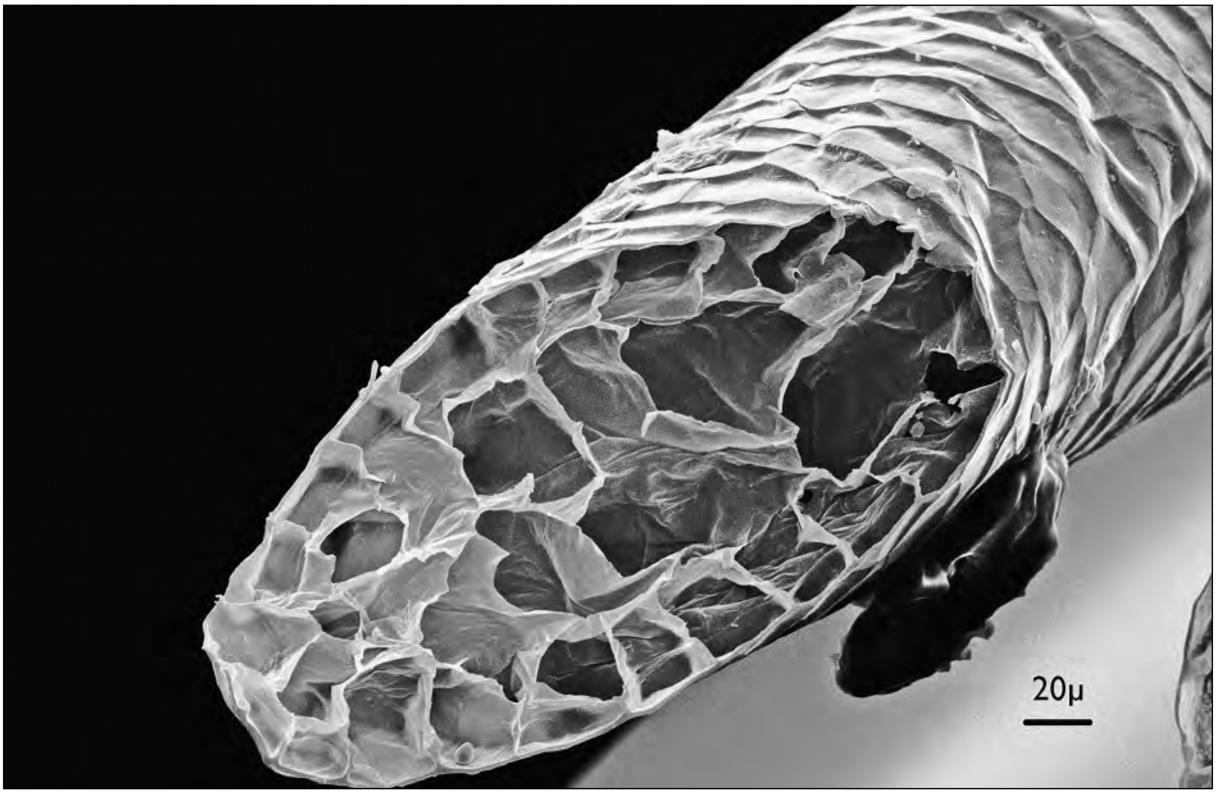

Fig. 246. Roe deer fibres, cross-section, modern

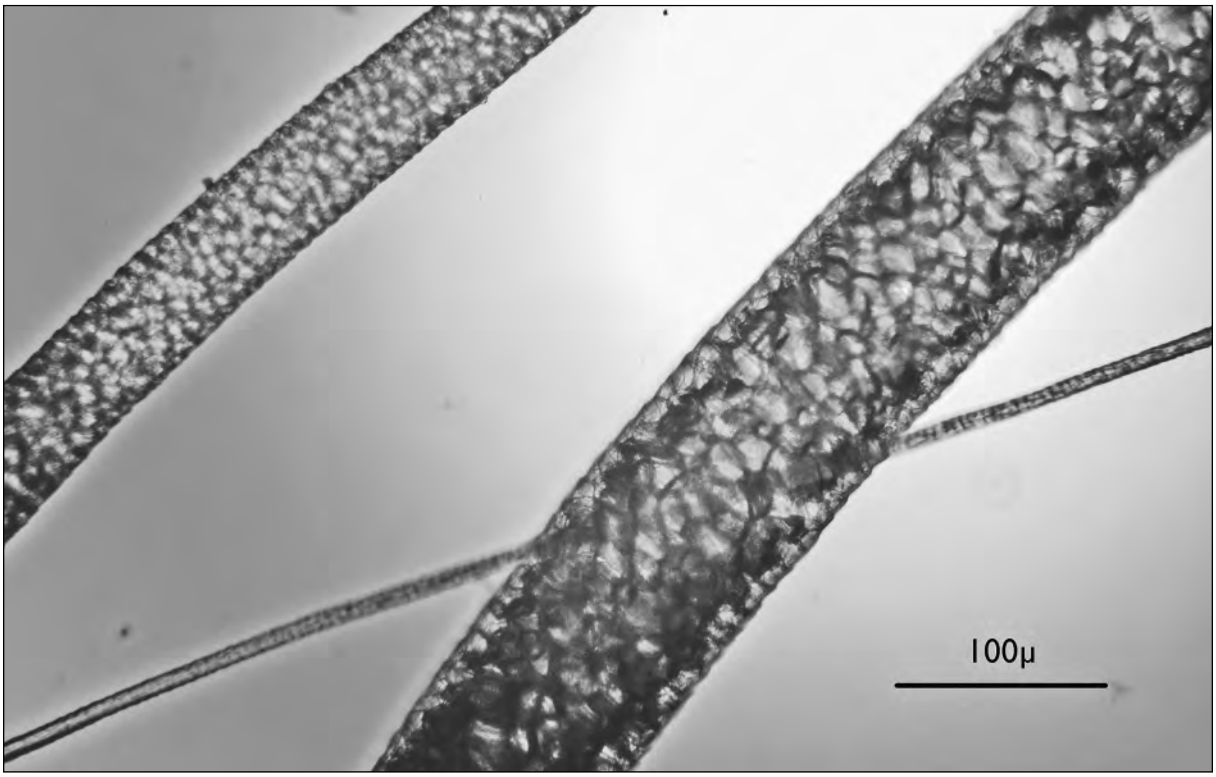

Fig. 247. Roe deer fibres, by light microscopy, modern

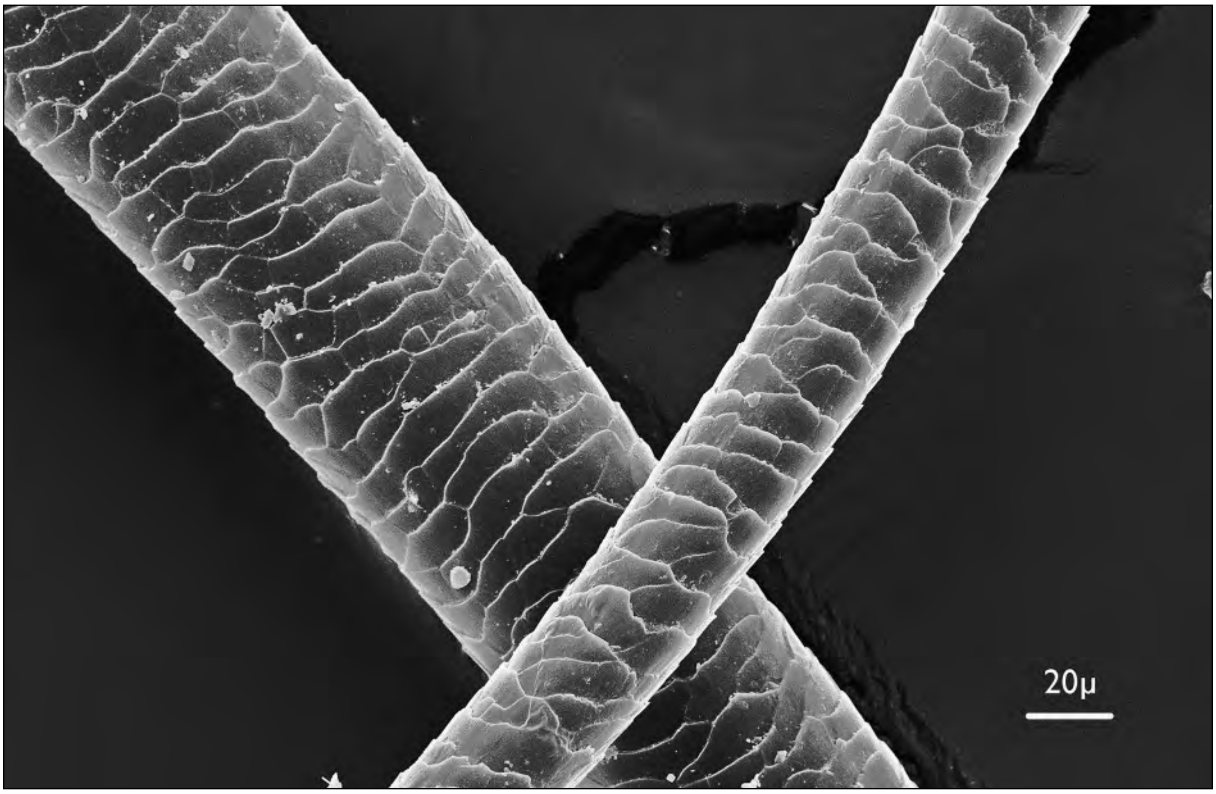

Fig. 248. Red deer fibres, modern

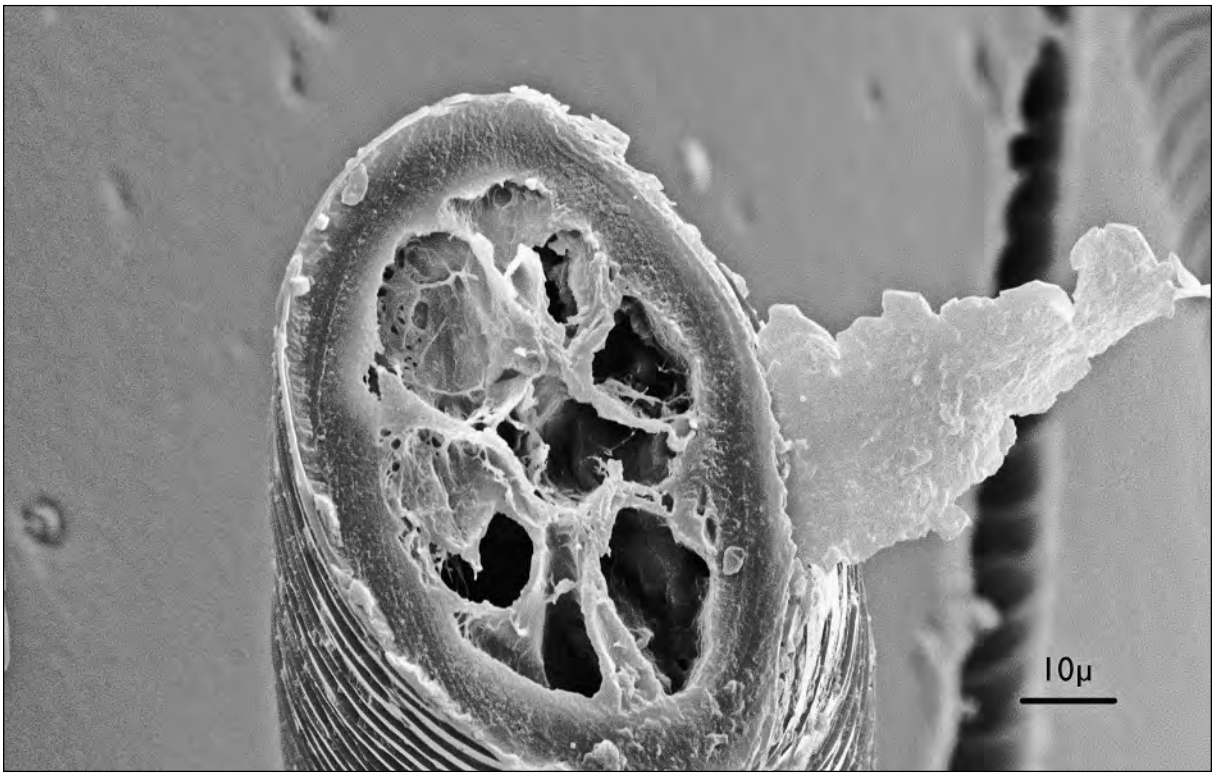

Fig. 249. Red deer fibres, cross-section, modern

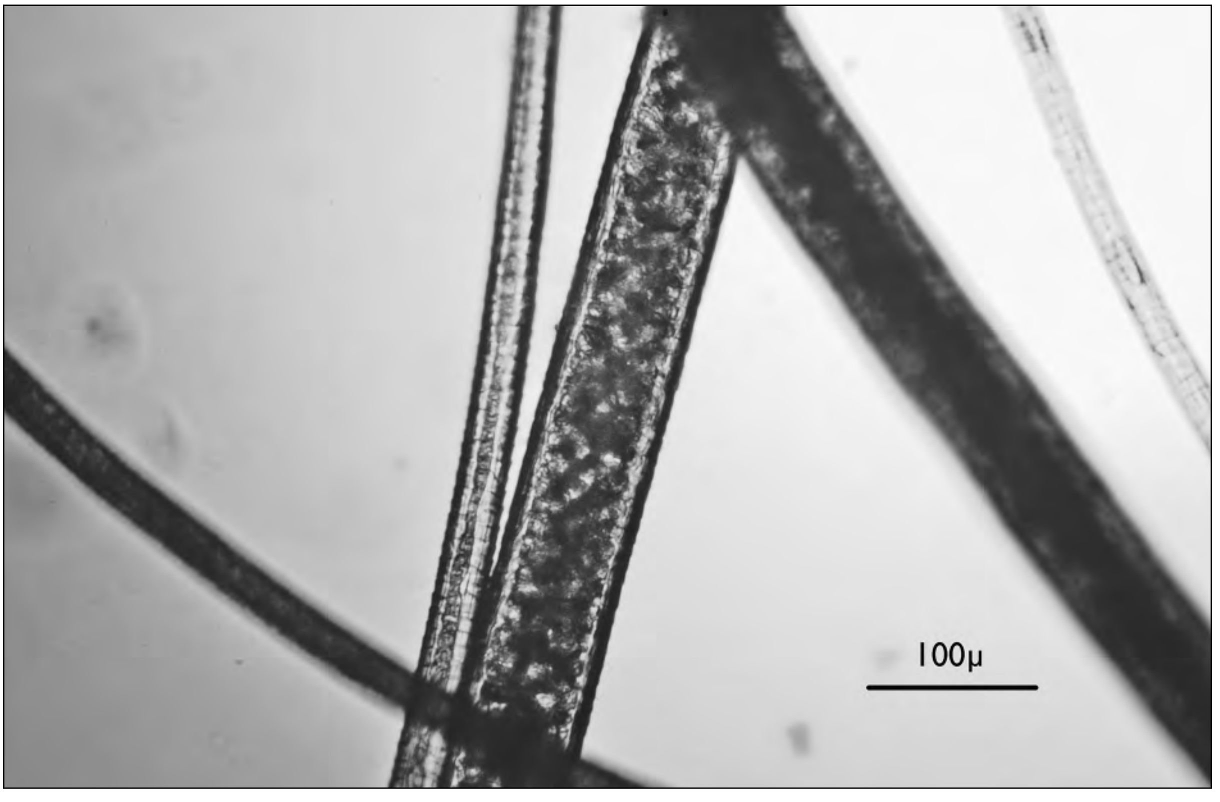

Fig. 250. Red deer medium and fibre by light microscopy, modern

4.8.7.4 Archaeology

Several Neolithic samples from “Ötzi’s” clothing have been determined as red deer using mass spectrometry of the keratins: his coat, leggings and shoes confirm former microscopic identifications (HOLLEMEYER *et al.* 2012). A deer skin garment has been found in Gallagh (EI) and is dated by C14 to between the 6th-2nd centuries BC. A cape in a rectangular shape has been found in Denmark, in Søgaards Mose, and this is made of deer skin (HALD 1980, 34). In the Anglo-Saxon cemetery of Snape (GB), mineralized deer skin has been reported (CAMERON – FELL 1996, Fig. 3.9).

4.8.8 Fallow deer *(Dama dama)*

4.8.8.1 Habitat

Originally from the Mediterranean, open forest, grassland.

4.8.8.2 History

The fallow deer survived the glacial periods of Southern Europe and may have been introduced to western Europe via the Greek island of Rhodes. The skeleton (bones broken for marrow) dating to the Eem interglacial have been found in Hollerup/DK. They are one of the earliest evidence of man in Denmark (MØHL 1955). Written evidence (linear B, means *dama* or *elaphus*) and representation in art from the Mycenaean and Minoan Cultures show they were well known during the Bronze Age (YANNOULI – TRANTALIDOU 1999, 254). The fallow deer was sacred to the Hettite god, then to Diana of Ephesos (ZEUNER 1963, 430f.). They were easy to keep in captivity and adapted well to northern climates. The Romans sacrificed deer to the hunting goddess Artemis. In the Middle Ages fallow deer were kept in enclosures for the aristocracy. They were introduced by the Normans to England in the 11th century (DOBNEY – HARWOOD 1999, 382ff.).

4.8.8.3 Fibre properties

The primary hairs are oval with a dm. of 90–120µ, guard hairs up to 300µ with a tile-like scale pattern and the scales being grooved at the surface. Towards the root, the scales become finely rippled. The medulla is net-like as with all the deer. The fine fibres have a dm. of 10–20µ and a cornet-like scale pattern (LOCHTE 1938, 274).

4.8.8.4 Archaeology

There are no finds known.

4.8.9 Elk *(Alces alces)*

4.8.9.1 Habitat

Elk live in Northern Europe, Scandinavia, Russia, The Baltics, Poland and The Ukraine in forests and marshland.

4.8.9.2 History

Elk has been hunted ever since the Mesolithic in Scandinavia (AARIS-SØRENSEN 1988). During the Neolithic Period and the Bronze Age the elk was present in Europe but was not important to the food economy. A Late Iron Age depiction shows the milking of Elks – the animal was probably tamed but not domesticated (BENECKE 1994, 360; BILLER 2013). The Romans knew the elk (PLIN. NAT. 8,16) and hunted it e.g. in Augst (CH) (SCHMITZBERGER 2009; HÜSTER-PLOGMANN – SCHIBLER 1997, 99f.). It lived in Switzerland until the 12th c. AD. Some Early Medieval finds of elk antler may point to a sacred animal or to a Christian symbol such as the red deer. In the north of Europe, elks are used as draught animals (Zeuner 1963, 425ff.). Benecke describes the use of elks also as "new domestication", and according to written sources riding was sometimes practiced in the 17th c. in Scandinavia, Siberia (Benecke, 1994, 360). The Swedish King Carl XI. made his courriers ride on elks (Zeuner 1963, 425ff).

4.8.9.3 Fibre properties

Primary hairs are very large, up to 400µ, with underhairs about 20µ. The scales are mosaic-like, flatter than the roe deer and similar to the red deer, but the fibres are much larger. The medulla is net-like as with all *cervidae* (*Fig. 251*).

4.8.9.4 Archaeology

Within the salt mines of Hallstatt (A), finds revealed some separate large fibres without skin which proved to be elk fibres (unpublished analysis Rast-Eicher, NHM). In 2015, from the salt mine of the Dürrnberg (A) elk fibres could be determined as well (unpublished analysis Rast-Eicher, DB3680) (*Fig. 252*).

4.8.10 Aurochs, Wild cattle *(Bos primigenius)*

4.8.10.1 Habitat

Aurochs became became extinct in Poland in 1627. It lived in forests (deciduous and mixed) but also liked open land. They were not found to exist 60° north or 30° south of these areas but more frequently found in Karpates and the plains of Hungary, more so than the red deer (Clutton-Brock 1989, 63; Weniger 1999; Schmitzberger 2009, 69).

4.8.10.2 History

Herds of wild cattle existed before the Early Preboreal (dating 9600-9200 BC cal.; Benecke 2002). Bulls were black, cows red. Prehistoric cave paintings reveal the anatomy of the animal (Chaix – Arbogast 2010). They were hunted, but there was no domestication of the European wild cattle *Bos primigenius*. In the Linear Pottery Culture, domesticated cattle were imported to Europe and were at first not much interbred with the indigenous wild herds. DNA analyses have revealed a hybridization in Northern Europe (Tresset – Vigne 2007). Both were used – the domesticated cattle and the hunted wild cattle (Benecke 1994, 48ff.; Bollongino *et al.* 2008). Bone remains of wild cattle, especially jung animals, in lake dwellings show a clear diminishing of the breed towards the end of the Neolithic Period (beginning 3rd mill. BC; Hüster-Plogmann – Schibler 1997, 100; Hüster-Plogmann *et al.* 1999). The archaeozoological differentiation between wild and domesticated cow is often difficult to identify (Wilkens 1999). Ancient authors report on herds of wild cattle in the Eastern Mediterranean and in Western Europe (Plin. nat. 8,16; Varro Rust. 2,1,5; Caes. Gall. 6,28; Vergil Aen. 3, 531–533.). Skins were always highly valued and traded. Tacitus wrote about the northern Germanic people (Friesen) using the skins of wild cattle (Tac. An. 4,72). Several projects were started in the 1920's – such as the TaurOs Project – to recreate a breed similar to the ancient Aurochs and based upon different ancient European breeds (http://www.stichtingtaurus.nl) (Aurochs 1994).

4.8.10.3 Fibre properties

See domesticated cattle, ch. 4.8.11.

4.8.10.4 Archaeology

M.L. Ryder has published work on the fibres from a Neolithic wild cattle found in Pultusk (PO). The fibres were found on the leg bone of a 13th century Aurochs, which could be determined archaeozoologically. There are fine and coarse fibres, and the diameters are – according to fibre measurements – finer than domestic cattle. The range given for the Polish animal is 18–60, 70, 72µ. Other skin finds with similar ranges are interpreted as wild cattle, such as a Neolithic skin and from the Orkney Islands (GB) (Ryder 1984).

4.8.11 Domesticated cattle *(Bos primigenius)*

4.8.11.1 History

The aurochs (Bos primigenius) is the wild ancestor of the domestic cattle. There are two mitochondrial haplogroups and therefore probably two domestication events, one in the Fertile Crescent 8800–8300 BC (Bos taurus), and one in India (Bos indicus; Taberlet *et al.* 2008). The earliest evidence of domesticated cattle comes from Çatal Höyük (Turkey) around 6200 BC; these cattle were probably difficult to milk as they were still partly wild (Clutton-Brock 1989, 66). Sherratt's idea of using first the primary products (meat, hide and bone) and only several millennia later the secondary products (milk, wool and traction) (Sherratt 1983) has been questioned (Greenfield 2010). Lipid analyses, however, show that milk was already in use during the Younger Neolithic in Arbon-Bleiche 3/CH (Spangenberg *et al.* 2008). Domesticated cattle came in a slow wave to the European coasts, but there was a quite rapid movement of haplotype T3 (without mix with aurochs), T1 and T2 which came by the Eastern Balkan route (Zeder 2008; Taberlets *et al.* 2008). In the Alps, the domestication of cattle began in the 5th mill. BC. At lake dwellings, domesticated cattle made up a small part of the food supply (up to 10%), but this changed during the Corded Ware Culture in the 3rd mill. BC (60%–80%). In this last period, cattle (oxen) began to be used for ploughing. Small traces of the use of their horns are also evident from this time (Hüster-Plogmann – Schibler 1997, 55; Schmitzberger 2009, 96ff.). Cattle or oxen (castrated males) were heavy draught animals. Cattle used for ploughing eventually became essential to farming. It is with this in mind that the Greek author Hesiod (8th c. BC) remarked in his "Works and Days" to first obtain a house, afterwards a wife and then an ox for ploughing (Hes. op. 405). Slaughtering patterns of cattle show a mixed strategy of use for both ploughing/traction and meat supply (Isaakidou 2006).

Milk fats have been found from the late 4th mill. BC in ceramic from Arbon-Bleiche (CH) (Spangenberg *et al.* 2006; Spangenberg 2008). In the Bronze Age, a new breed of cattle came up that was smaller (110–120cm high) but may have had more milk than earlier breeds (Benecke 1999, 64; Pucher 2010). Celtic and Germanic people were able to digest milk products but the Romans were not (Pucher 2010). Like sheep, cattle were very important to early economies being used as payment for goods as well as to pay fines (*pecunia*, lat. money, derives from *pecus* or cattle). In Ancient Greece cattle was very important economically as well as religiously. The bull stands for power and wealth and is a reference of value. Homer reports on the value of a prize being a large kettle/recipient to be put on the fire which would cost twelve cattle; a few lines later he reports that a woman would bring four cattle (Hom. Il. 23,703; 23,705). He also talks about shields being covered with bull hide (Hom. Il. 12, 429). Xenophon advises carrying the largest hunting nets in a bag of calf-skin (Xen. Kyn. II).

The story of Zeus and Europa was that they were the parents of Minos of Crete who took power as a foreigner; Minos then became the step-father of the Minotaur who had been fathered by Poseidon's bull. It was from this legend that the Minoan games came into being using jumps over bulls as part of the competition. Irish sagas call for the bull of Ulster and the jumping over dark bulls. Caesar gives the name *Donnotaurus* to a Helvetic Celt (Caes. Gall. 7,65), which corresponds to *Donn Tarbh*, the Ulster bull (Birkhan 1997, 704f.). Germanic people (Frisian) sold cattle to the Romans (Brogan 1936). The Romans made brushes of tail hairs to clean their clothes (Mart. 14,71). In Ireland skins were used as shrouds, an Early Irish shroud being called a *geimen* and related to the word *gemen* = hide (Wincott Heckett 2012, 431).

In the Late Medieval Period a change of diet took place in England within two centuries, from rye bread, cheese and small amounts of fish and meat to wheat bread, beef and ale (Dyer 1988).

When, in the Early Modern Period, horse breeding led to larger and heavier breeds which could be employed as draught animals, oxen became more of a source of food than beasts of burden (Quinn 1993, 149). The invention of the horse collar and the traction harness in the Middle Ages was another step toward their use as draught animals in place of oxen and cows (the mass production of milk from cows had not yet been invented.) The lumbering ox, no longer preferred for pulling the plough became in Shakespeare's plays the symbol of stupidity (Moore 1961). Before the 18th c. cattle breeding was not recognized as an important farm product. From the Late Middle Ages to the Early Modern Period, the sizes of cattle went through changes. Old breeds of the 19th century have been genetically linked to older cattle types. Modern animal husbandry has endangered the genetic resources of the ancient breeds (Taberlet *et al.* 2008).

In terms of food, the word "beef" is used rather than "cow" and this derives from the old French *"buef"* used by the Medieval Norman rulers (http://www.etymonline.com/index.php?term=beef).

Mythology from the Ancient world shows how important cattle were. Bulls were generally a symbol of power and cows are the providers of milk. In Norse mythology, the cow *Andhumbla* created the world from melting frost. The giant Ymir was fed with rivers of milk. She formed Buru, the ancestor of the gods, with her tongue. Similarly, Hathor is the Egyptian goddess of love, music and fertility and is depicted as a cow. Apollo became the god of music after Hermes had stolen his cows, killing two of them and making strings for his lyre with the guts. Apollo left him the cows but received the lyre (Sax 2001, 48f.). In Christian art, the apostle St. Luke is shown with an ox.

4.8.11.2 Fibre properties

Domestication led to thicker coats of primary hair. Even so, in the Middle Ages before domestication had really taken hold, the double coats of the cattle with fine underhair with a course upper hair were still a natural phenomenon (Ryder 1984).

Fibre diameter was 40–80μ, fine fibres around 20μ and often without medulla. The scales are horizontal and wavy in the basal part with narrower margins and rippled edges further up. The latter look very similar to human hair (*Fig. 253*).

The differentiation between cattle and goat, which is difficult to decipher when having just scales to work with, can only be reliably made together with the pattern of the medulla. Cattle medulla is amorph granulated, and medulla differs as well with the cattle from *cervidae* (Keller 1981) (*Fig. 254*).

4.8.11.3 Archaeology

Cattle is certainly one of the most important skin used by man. Neolithic cattle skin has been found in "Ötzi's" clothing and items such as the shoe sole, the upper part of the quiver, the girdle bag and the leather straps. Analyses have been done by mass spectrometry and confirmed partly from previous analyses by microscopy (Hollemeyer *et al.* 2012).

In the Bronze Age in Denmark, the oak log coffins of the deceased were placed on a cowhide (Gram 1891; Thomsen 1929; Broholm – Hald 1935). These are Bronze Age skins from the oak coffins confirmed by recent re-analysis of several cattle skins (Ørsted Brandt *et al.* 2014). Samples have been taken that show the granulated/amorphous structure of the medulla on the inner wall of the fibre epidermis, even if the medulla is broken away (see *Fig. 43*). Several Iron Age skin garments from DK are made from cattle skins (Gleba – Mannering 2012; Ørsted Brandt *et al.* 2014). In the Early Medieval grave yard of Dielsdorf (CH) the scabbards usually consist of a layering of skin-wood-leather. In grave 57, the skin has been proven to be cattle. The material is mineralized, and the scales are well visible in the negative, which is rare. The medulla has been preserved in some casts and is very well visible Rast-Eicher – Dielsdorf, in prep. (*Fig. 255*). An other cattle fur has been documented in Matran (CH) (*Fig. 256*) (Mauvilly *et al.* 2011). Medieval caulking in Northern Europe has been made – contrary to Mediterranean caulking – with some animal fibres seeming to have been made of cattle hair (e.g. Haderslev (DK) (Möller-Wiering 2004).

4.8.12 Europ. Bison *(Bison bonasus)*

4.8.12.1 Habitat

Subalpine, kollin-montane, living in forests and rare in the EU (American bison prefer open grassland).

4.8.12.2 History

Bison are the largest mammals in Europe. It became extinct in France by the Middle Ages, as well as in Central Europe by about 1500 and in Poland after World War I. The exception are a few animals held in captivity (Daleszczyk – Bunevich 2009).

Bison have been depicted in cave art from the Prehistoric Period (e.g. Lascaux/F; Chauvet/F; Altamira/E).

Pliny the Elder's report on the *B. bonasus* in Paeonia describes the animal as having a mane like a horse but with bent horns and otherwise with the characteristics of a bull (Plin. nat. 8,16).

In Early Modern Times, the Polish King and the Russian Tsar are known to have protected the bison herd living in the Białowieża forest. Bison were kept in enclosures as early as the 16^{th} century. In Mecklenburg in the 17^{th}-18^{th} century, for example, there were unsuccessful efforts to free them. Ironically, it was the captive herd that probably saved the species (www.wisentprojekt.de). The Russian bison population was too small to survive and was subsequently cross-bred with both the Polish and the American bison (Pryde 1986, 360). Bison bred in captivity are listed in the "European Bison Pedigree Book". The genetic pool continues to be small and coordination between breeders is an effort to strengthen it. Most of the free living populations are in Latvia, Poland, Russia, Slovakia and Ukraine. Bison have recently been re-introduced to the island of Bornholm (DK).

4.8.12.3 Fibre properties

Primary hairs have a dm. of 50–100µ, the underwool 20–40µ, and is partly medullated. The medulla is granulated in a similar way to cattle medulla and the scales are a rippled to irregular wave. It would not be possible to distinguish it from cattle (*Figs 257* and *258*).

4.8.12.4 Archaeology

In Greenland (DK), a hook (cord tightener or buckle) with an S-plied cord of bison hair has been found (Østergård 2009, 121; Fig. 87).

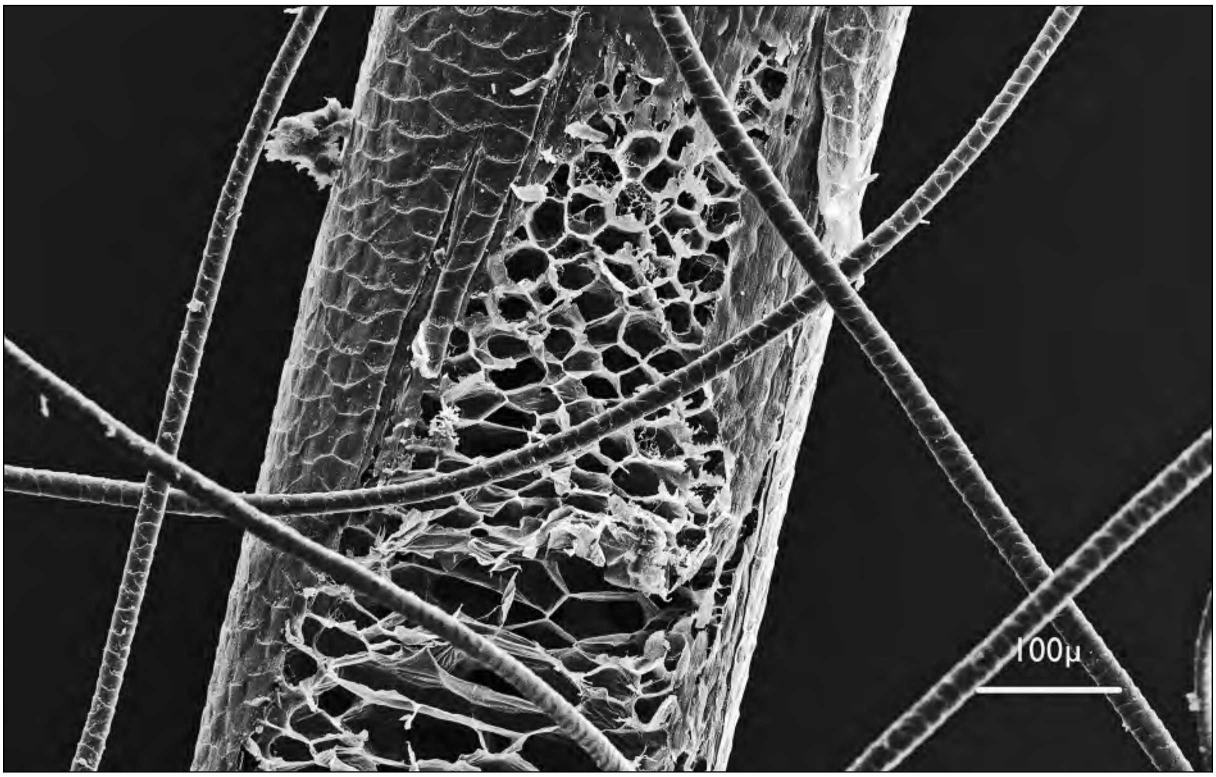

Fig. 251. Elk fibres, modern

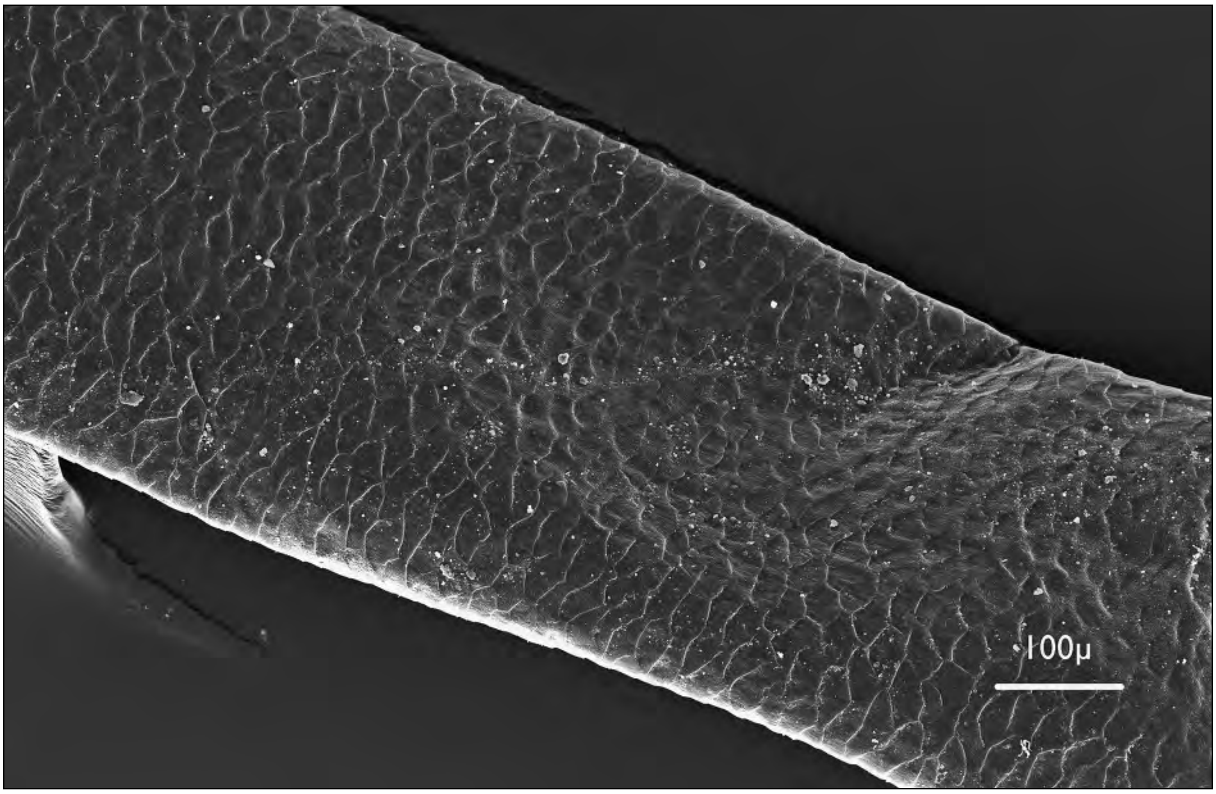

Fig. 252. Elk fibre, salt-mine of Hallstatt (A)

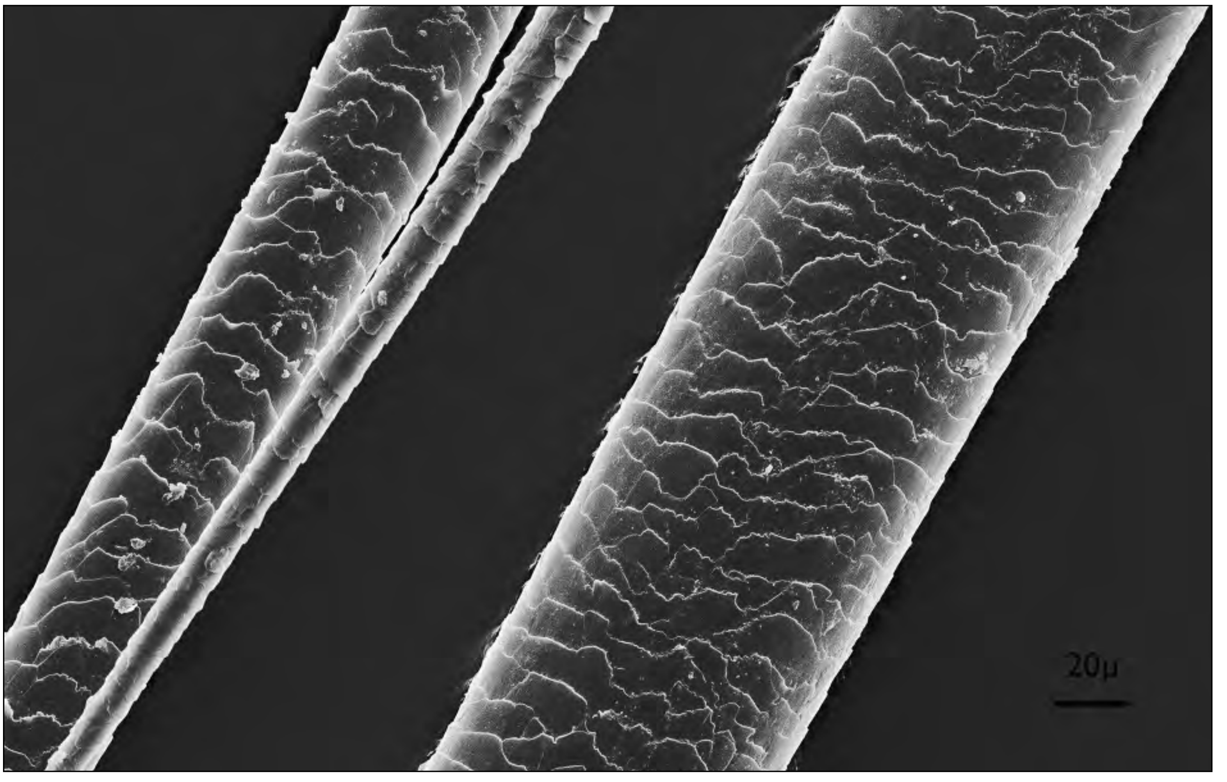

Fig. 253. Cattle fibres, modern

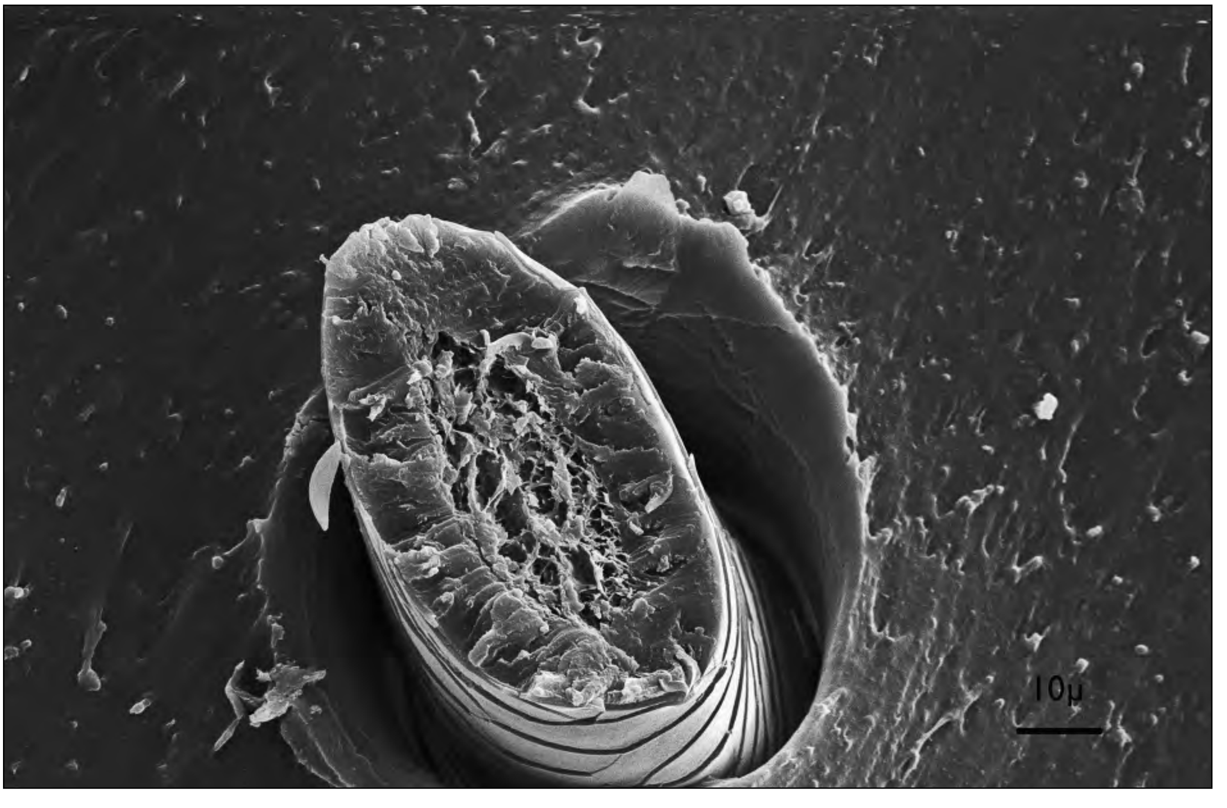

Fig. 254. Cattle fibres, cross-section, modern

Fig. 255. Cattle fibres, Early Medieval grave, Early Middle-Ages, Dielsdorf (CH).
The negative imprint of the scales is visible, as well the amorphous medulla in the fibre cast

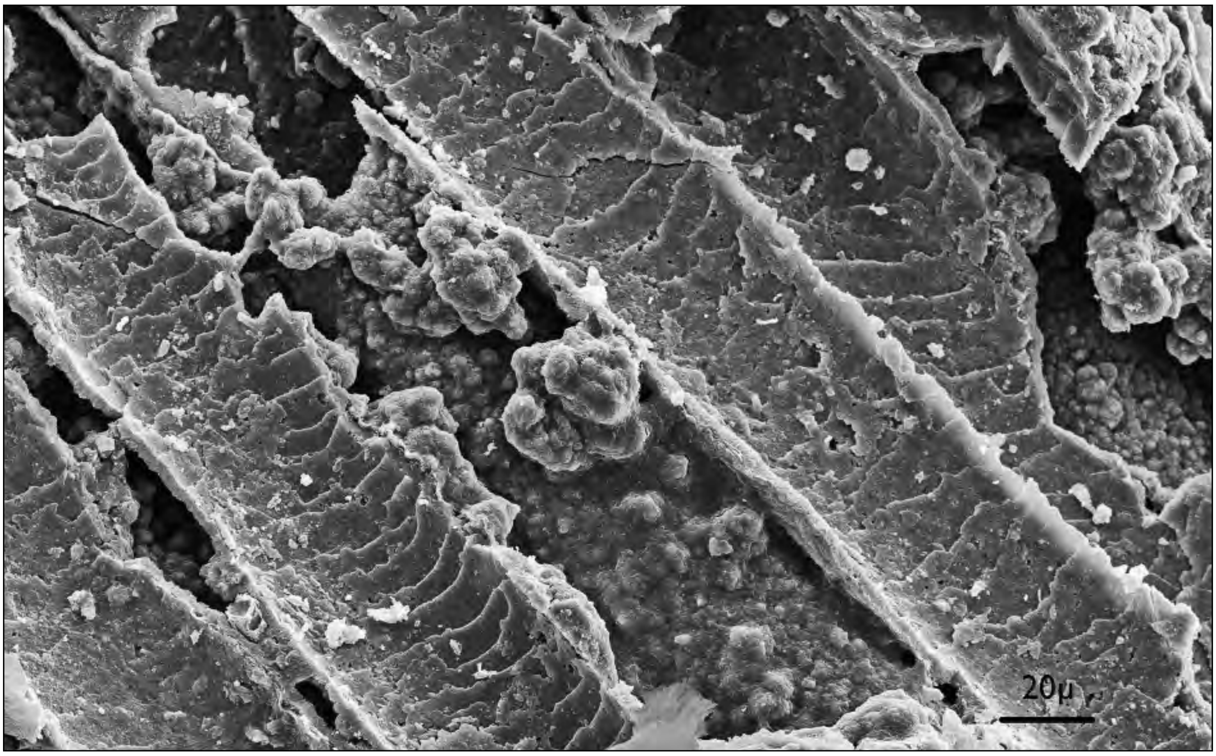

Fig. 256. Cattle fibres, mineralized, scales visible as fibre cast, some remains of amorphous medulla, Iron Age, Matran (CH)

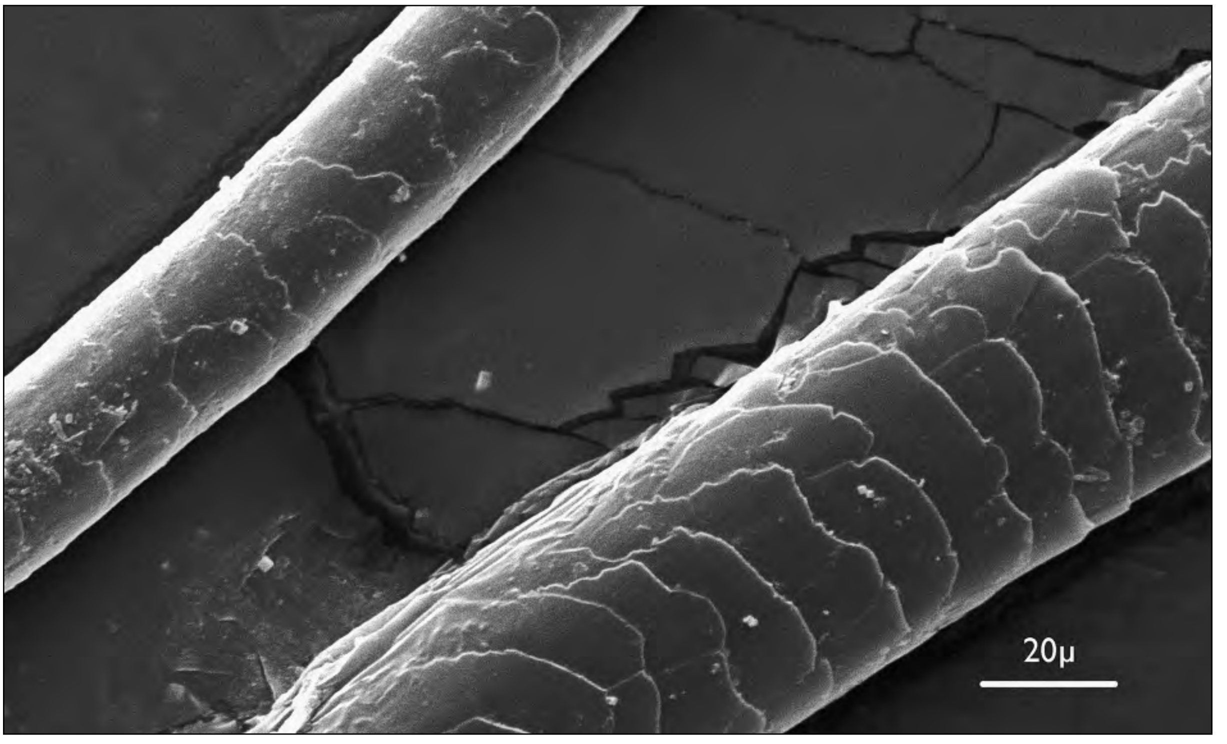

Fig. 257. Bison fibres, modern

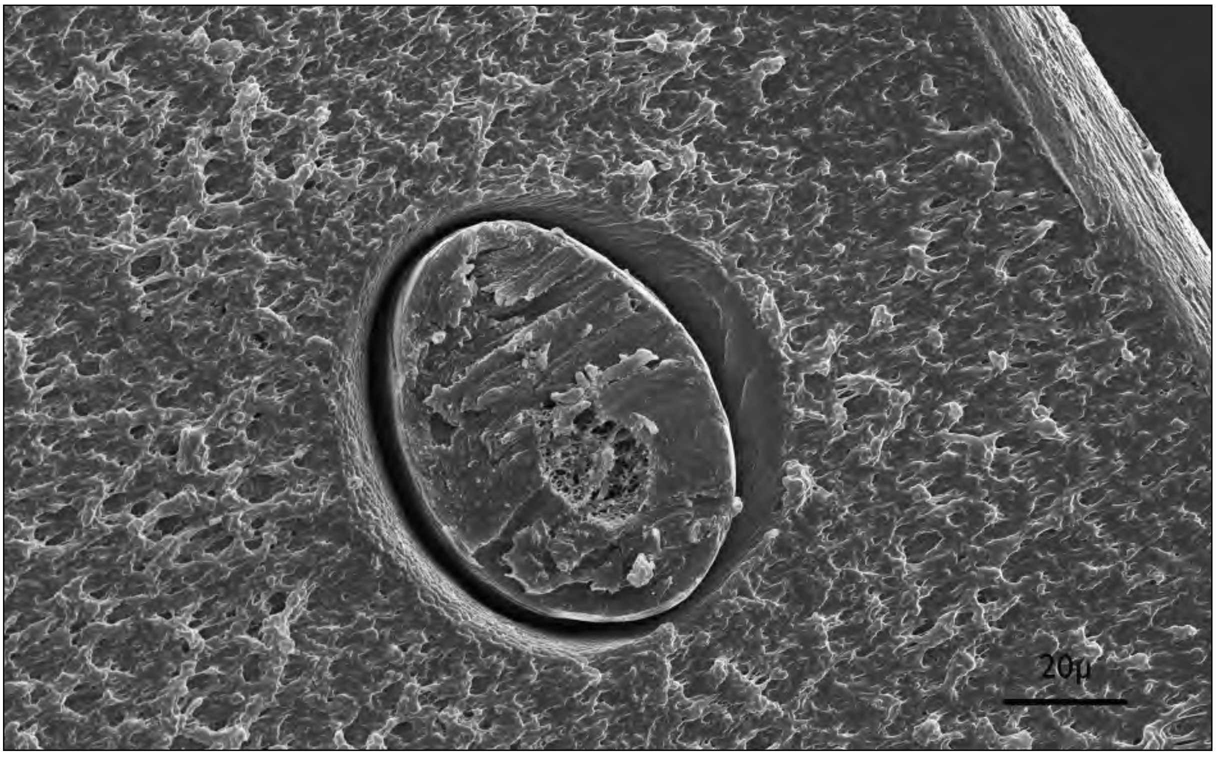

Fig. 258. Bison fibres, cross-section, modern

4.8.13 Introduction to goats: differentiation capra/ovis

Goats and sheep were the first ruminants to be domesticated and are among the most important to the economic development of mankind. Neither have wild ancestors in Europe, but they have various related species in Europe such as Ibex and Chamoix (Tresset – Vigne 2007; Shackleton – Lovari 1997; Zeder 2008). The bones and fine fibres of the sheep and goat species are difficult to differentiate which has led to a wealth of industrial research and publications on the determination of these fibres (Wortmann – Phan 1999; Robson 2000). The ability to decipher bone remains of either has also proven to be problematic with only the rare find clearly indicating one species or the other. Even the categories of "sheep" versus "goat" can be misleading as the two animals have been handled and bred for very different purposes yet may be confused when identified. Sheep were most importantly employed for the wool they provided while goats were selected for milk and leather. Sheep wool interwoven with pure cashmere grades made for imitation cashmere shawls, a well-known and long standing invention of artifice.

Today, products are often mislabeled (Phan/Wortmann wrote of 15% of analyzed garments being so). Sheep wool (even from old rags), camel wool and other fibres have been recorded as "true cashmere" (Phan – Wortmann 2007). The differentiation of these fine fibres has clearly been an important and long standing topic for the textile industry. Until the 1980's light microscopy was the singular approach for fine fibre analysis (Leeder 1998, 42). With the introduction of the scanning electron microscope (SEM), surface analysis of fine wools and cashmeres became a more precise art. In industry, differentiation is made possible by measuring the scale height (below 0.5µ for goats) and the number of scales per length (100µ); for sheep that would be between 10–12 scales, for cashmere 6–7 and mohair 4–6 (Wortmann – Wortmann 2000; Vineis *et al.* 2011). These measurements have been catalogued as averages. The use of DNA analysis along with computer assisted automatic scale measuring or protein analysis are, to date, the most advanced developments to be used in industry for fibre identification (Phan – Wortmann 2007). These also facilitate finding the differences. Modern day fibres will pose difficulties for the accurate measurement of scale dimensions because of damage commonly caused by chemical treatments. Archaeological material, however, is the more difficult to analyze due to poor states of preservation. The minimum amount of fibres necessary for the count/measure may have shrunk or are not preserved enough in other ways to enable observation and evaluation of scale height; reliable measuring of scale dimensions is hampered. Scale heights in the fibres of prehistoric sheep and goats, interestingly, don't seem to have great differences (see mouflon and goats, see *Figs 275, 280*). In the experience of this author, single large fibres in a thread are the most important to observe for fibre determination, this either by the type of medulla or by scale pattern of the large fibre if using the SEM. If this is not the case, differentiation may well be very difficult. As soon as there are coarse fibres, however, differentiation can be quite clear. Fibre measurements will help as well. Personal experience has shown that in well preserved textiles and felts from the Later Iron Age on, sheep underwool with an average of about 13–15 micron is nearly never present but is normal for cashmere fibres. It is also important to note that goat fibres did not change morphology from wild to domesticated breeds (De Marinis – Asprea 2006). Goat fibres have been and remain an important commodity and there are a great variety of domesticated breeds. Of these, two more types – the Cretian wild goat and the Western Caucasian tur – have been added to the record books.

4.8.14 Ibex *(Capra ibex)*

4.8.14.1 Habitat

Mountain areas, Alps or Pyrenees, mostly above 1500 meters altitude.

4.8.14.2 History

Ibex and goats have the same number of chromosomes (60) (Clutton Brock 1989, 57). Genetically the Alpine ibex is close to *Capra pyrenaica* (Kazanskaya *et al.* 2007). Ibex skins have been used for warmth and protection from rain (Delort 1978, 133). The "Iceman" (or "Ötzi") might well have been hunting ibex as he had with him a bone of the species of ibex that was indigenous to the Central Alps (Schmitzberger 2009, 78), and for the fact that his last meal seems to have been ibex meat (Rollo *et al.* 2002). Ibex had been used for food apparently, and no furs were found in the clothing. The quiver, first thought to be made from ibex skin, turned out to be made from cow hide (Hollemeyer *et al.* 2012).

4.8.14.3 Fibre properties

Primary hairs 80–100µ, fine fibres 15–20µ, the scale pattern with horizontal lines and medium margins; the medulla of the primary hairs show distinct slices unlike chamois according to Keller (Keller 1981) and spikes like other goats (*Figs 259* and *260*). This was visible in medium fibres, but can be seen in other wild goats as well (see *Fig. 261*). However, ibex is difficult to differentiate from other goats.

4.8.14.4 Archaeology

A cap made of ibex and dated from the Younger Iron Age has been found in the Dürrnberg (A) salt-mine (Stöllner 1999, 155, no 150).

4.8.15 Cretan wild goat *(Capra aegagrus cretica)*

4.8.15.1 Habitat

Sub-species of the domesticated goat from Crete as well as from several islands in the Mediterranean (Montecristo, Antimilos, Youra) (Horwitz – Bar-Gal 2006, 125).

4.8.15.2 History

Wild goats were not endemic to Crete but were introduced after domestication. They resemble the wild Bezoar goat but are a bit smaller in size. The earliest well-dated bones that have been found on Crete (Knossos) date to the 7th millennium BC.. There is a marked increase in the amount of finds coming from the 6th millennium BC. (Horwitz – Bar-Gal 2006, 125). During the Minoan period, goats were depicted pulling chariots (Zeuner 1963, 144).

4.8.15.3 Fibre properties

Fine unmedullated fibres dm.15–20µ with cornet-like scales; medium fibres about 40µ with more horizontal scales and smooth margins; coarse fibres 60–100µ with horizontal, finely rippled scales. As with other goat species, the medulla of the coarser hairs makes up 4/5 of the fibre width. This goat shows especially similar traits to the kemp fibres of sheep (*Fig. 261*). The similarity of this species to the wild mouflon (see *Fig. 280*) has been discussed by De Marinis and Asprea (De Marinis – Asprea 2006). The spikes seen on the side of the medulla which are typical for goats are not, however, very well visible for this particular breed (*Fig. 262*).

4.8.15.4 Archaeology

No finds determined.

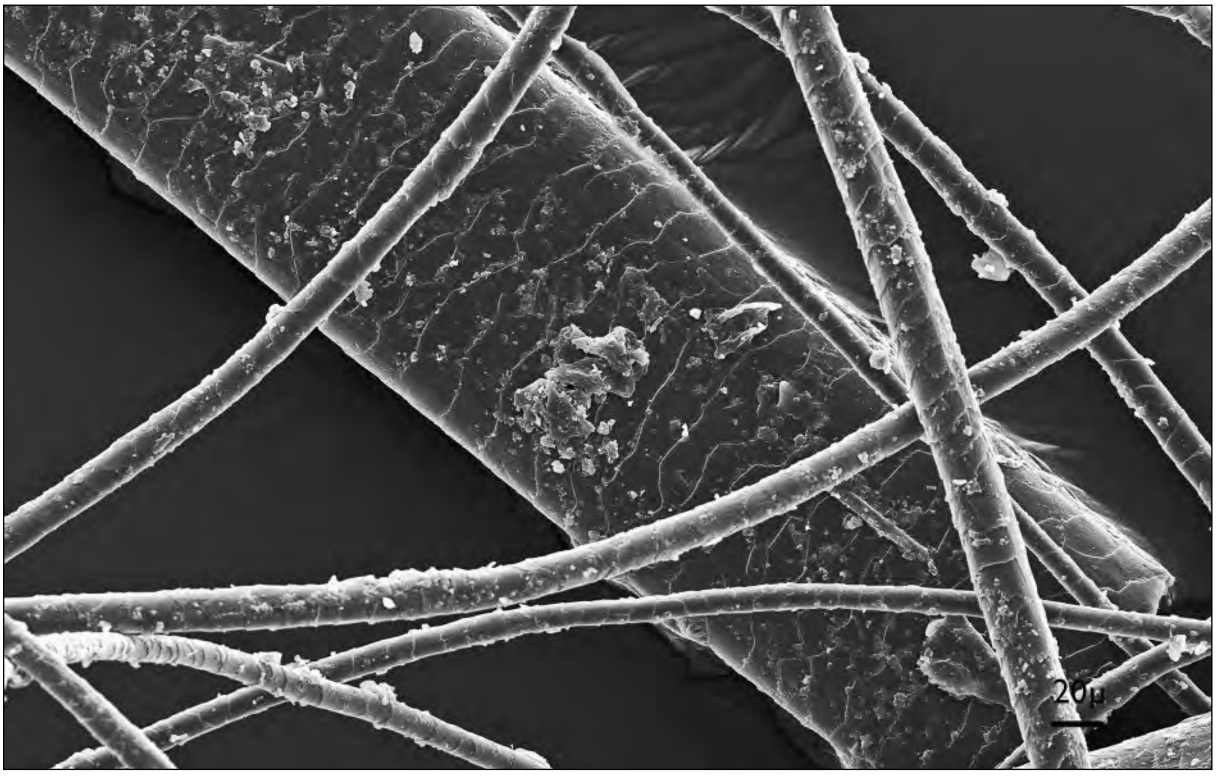

Fig. 259. Ibex fibres, modern

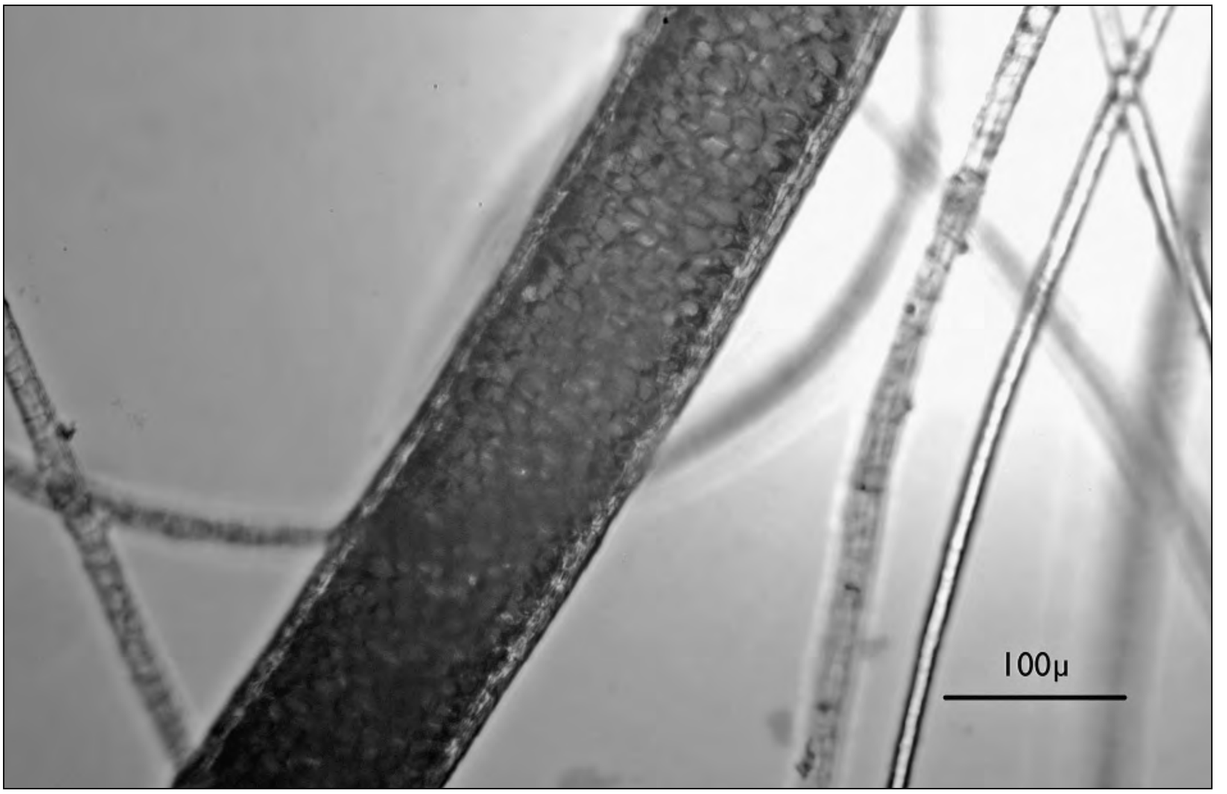

Fig. 260. Ibex fibres by light microscope, modern

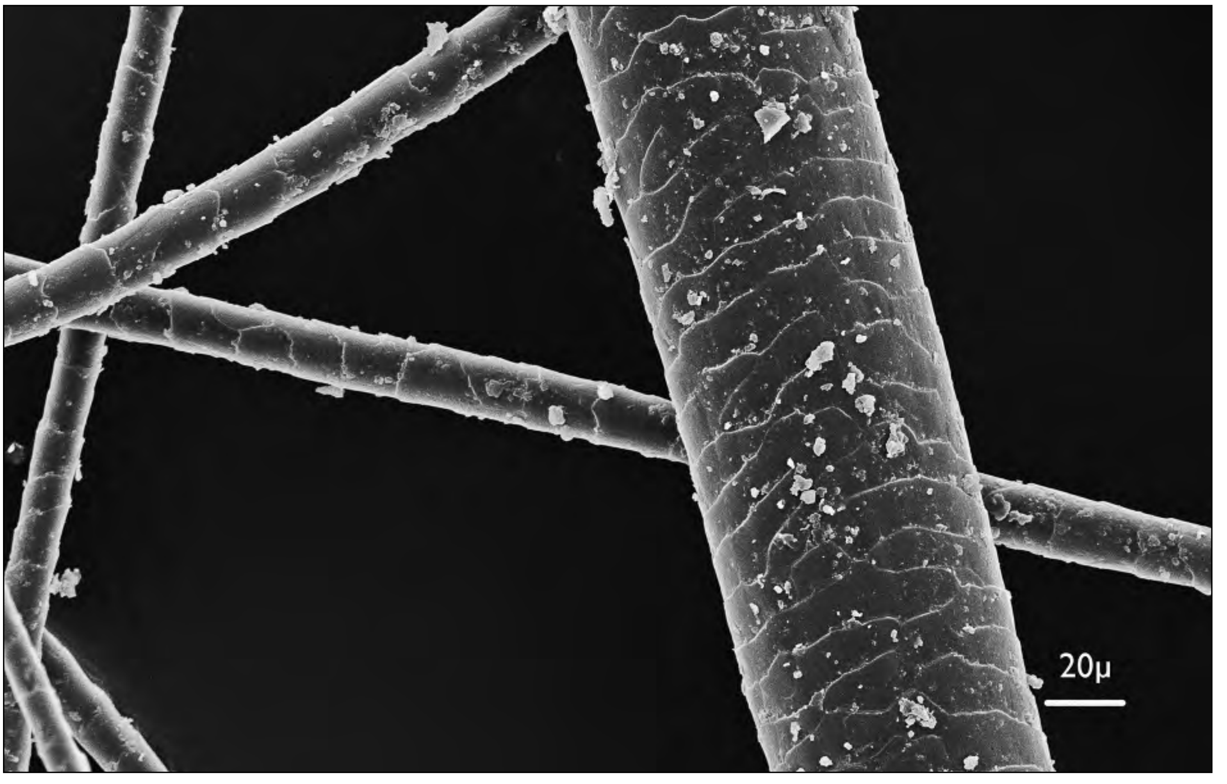

Fig. 261. Cretan wild goat fibres, modern

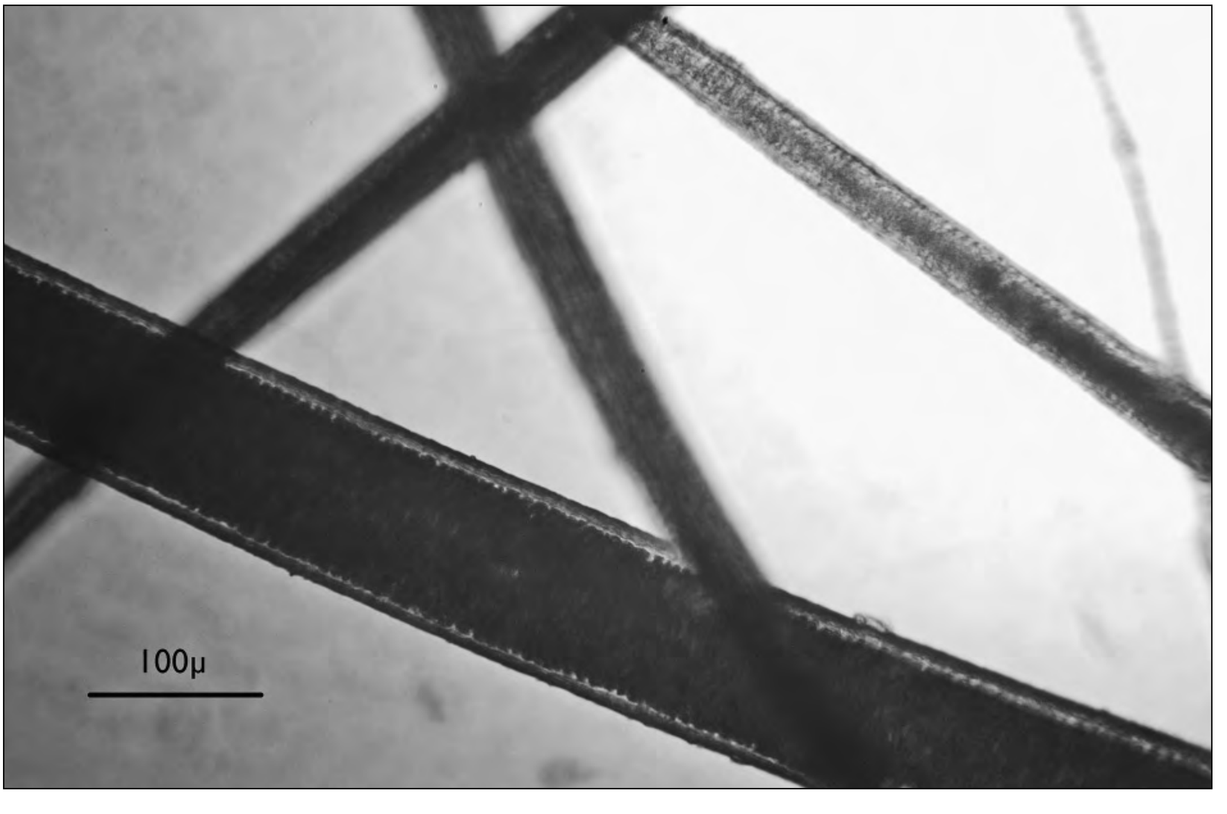

Fig. 262. Cretan wild goat fibres, seen with the light microscope, modern

4.8.16 West Caucasian Tur *(Capra caucasica)*

4.8.16.1 Habitat

West Caucasus.

4.8.16.2 History

Genetically, the Cucasian Tur is linked to the goat, *Capra aegagrus* (Kazanskaya *et al.* 2007).

4.8.16.3 Fibre properties

Fine fibres dm.15–20µ with cornet-like scale pattern, coarse fibres up to 140µ with horizontal scales and narrow, rippled margins.

4.8.16.4 Archaeology

No finds determined in Europe.

4.8.17 Domestic goat *(Capra aegagrus hircus)*

4.8.17.1 Habitat

With the exception of the ibex, goats were not endemic to Europe. Their habitat was in the Caucasus, Middle East, Near East, Anatolia, Armenia.

4.8.17.2 History

Goats were of the first animals to be domesticated, around 8500–7900 BC. Neither sheep nor goats were endemic to Central Europe but the takeoff of domestication did begin with the Bezoar goat, c. *aegagus* during the Neolithic Period. The ancient Neolithic goats of Southern France show evidence of a highly specialized pastoralism (Helmer *et al.* 2005). It is already during the Neolithic Period that there is a concentrated gene flow within five mtDNA haplogroups (Taberlet *et al.* 2008). In Asıklı Hüyük, Anatolia (mid 9th–8th c. BC), there is some plant cultivation with a few animal species but certain confirmation of proto domestic caprine (Pearsen *et al.* 2007). By the Neolithic (PPNB), goats had been brought to Europe and the Mediterranean Islands (Vigne 1988b; Zeder 2008). The animals are represented by six domestic lineages (Zeder 2008). Most of the Corsican goats, living partly as feral goats again, remained genetically stable (Hughes *et al.* 2012). And while they have, in fact, been local to this area since the 6th millennium BC they were only recognized as a breed a few years ago (Dubeuf – Boyazoglu 2009)! In Neolithic settlements such as Arbon-Bleiche (CH) there were, according to the size of the horns, obviously very large goats (Deschler-Erb – Marti-Grädel 2004, 177).

Goats have the same amount of chromosomes as Capra ibex (N=60). While domestic goats did not go as far north as sheep (Clutton-Brock 1989, 57), they are found in the Alps and frequently share space with the ibex. Goats have been important for milk and cheese throughout history and can live on land unsuitable for farming or housing. They are kept in flocks together with sheep. A large-scale DNA analysis of goats the world over and has revealed six haplogroups, with haplogroup A being the dominant and containing 90% of the samples (Naderi *et al.* 2007; Zeder 2008).

Until modern times, milk production remained mainly a subsistence product for small-scale economies rather than an item of trade. On the other hand, fibre production (mohair and cashmere) were brought to global markets and controlled by international standards (Dubeuf – Boyazoglu 2009). In the Middle Ages goat skin was very important for the construction of parchments and thus book production. It is a thin and very solid leather, used also for drum skins (Benecke 1994, 212). Over a long period of time, from the ancient societies to early modern ones, goat breeding was an important enterprise essential to societal livelihood. This changed only by the 19th c., when social structure began to focus more towards large towns, specialized farming and fibre production (Boyazoglu *et al.* 2005). Today, some breeds are used to produce milk, meat and fibres, these being well defined for a large-scale agricultural system. Still others are maintained as they once were, to yield these same products on a much smaller scale for local use and being not well defined (Dubeuf – Boyazoglu 2009). With the exception of Greece, goat breeding has declined since the 1st World War. But with the 1960's milk production rose again and has remained at a steady level (e.g. for goat cheese in France, the Netherlands and Norway). Goats are now equated with positive changes to farming and organic production, not least by their habit of eating bushes and hard plants (Boyazoglu *et al.* 2005).

According to ancient text, goats were important for milk but as well for ropes and textiles (e.g. Cic., Verr. I: goat hair for ropes and sacs). Columella gives advice about keeping a hornless male as a way to prevent it becoming too dangerous for handling (Col. 7,6,4). The goat played an important part in rural economy until modern times, its products being available to poor people (e.g. Euripides, Cyclops, 63,: *"…a slave in exile, dressed in this wretched goat-skin cloak and deprived of your friendship."*).

Their skins were used for clothing, parchments and water bottles. Male goats – preferably black according to Columella – were shorn (Col. 7,6,2) and their coats used for a variety of things. Rope from goat material was used for nautical purposes as the coarse fibres do not rot easily; it is for the same reason that sailors throughout the past have worn textiles of goat hair. In an additional case, Varro lists the use of such rope for military engines, incorporating the long hair of the Cilician goat (Varro rust. 2,11,2). Cloth for sacks or tents or even as rubdown material for horses are mentioned in the Old Testament. Such textiles were 30 cubits long and 13.5 cubits wide (about 13.5m x 1.8m) (Ex. 26, 7–13). Goat skins were used for sailor's clothing (oilskins) until the advent of modern water-repellant materials (Ingstad-Trætteberg 1999). Textiles in modern times, as a continuation of tradition, incorporate goat fibres, the fine underwool being harvested by combing (Frölich *et al.* 1929, 138).

Goats were sacred in ancient societies. The Egyptian god Osiris appears at times as a goat. They were sacred within the realm of the Sumarian and Babylonian gods Marduk and Ningirsu, and Zeus was fed with the milk of the goat Amalthea (Boyazoglu 2005). In Germanic mythology, the goat Heiðrún stands on the roof of Walhalla, gives beer ("Met") instead of milk and eats the leaves of the sacred tree Yggdrasil (Edda, Grimnismál 35; Gylfaginning 39). In another context, that of Judeo-Christian symbolism, goats even became a parable for evil (this as opposed to the sheep lamb which became a symbol of Christ).

4.8.17.3 Fibre properties

Goat fleeces consist of fine and coarse fibres. Fine fibres have dm. of 15–25µ, primary hairs dm. 40–80µ, and higher. The scale pattern of fine fibres is very similar to that of sheep scales but is less thick (below 0.5µ). The primary hairs are finely rippled, with thin scales and the lines of the scales are often in the fibre axe. The underwool maintains a shorter length than the primary hairs (unlike mouflon); hair growth takes place in a simple cycle, growing in summer and being inactive during winter (Ryder 1966). The scale pattern of the primary hairs is similar to the ones for horses and cattle which is why the medulla structure is important in determining the fibre (*Fig. 265*). Fine fibres are not usually medullated. Coarse hairs show a large medulla, so large, that the fibre will collapse to an oval or reniform fibre. The medulla contains small disks and scalloped ends or pikes (*Fig. 266*). Very often the medulla is highly pigmented and the structure not well visible. This medulla type is quite different from coarse sheep hair medulla. Furthermore, it creates a disk-like structure in mineralized fibres visible when they are breaking up. The disk shows an angle which is open towards the fibre root (Lochte 1938, 246).

Besides scale thickness, the difference to sheep is the different scale pattern of the primary hairs (see *Fig. 281*).

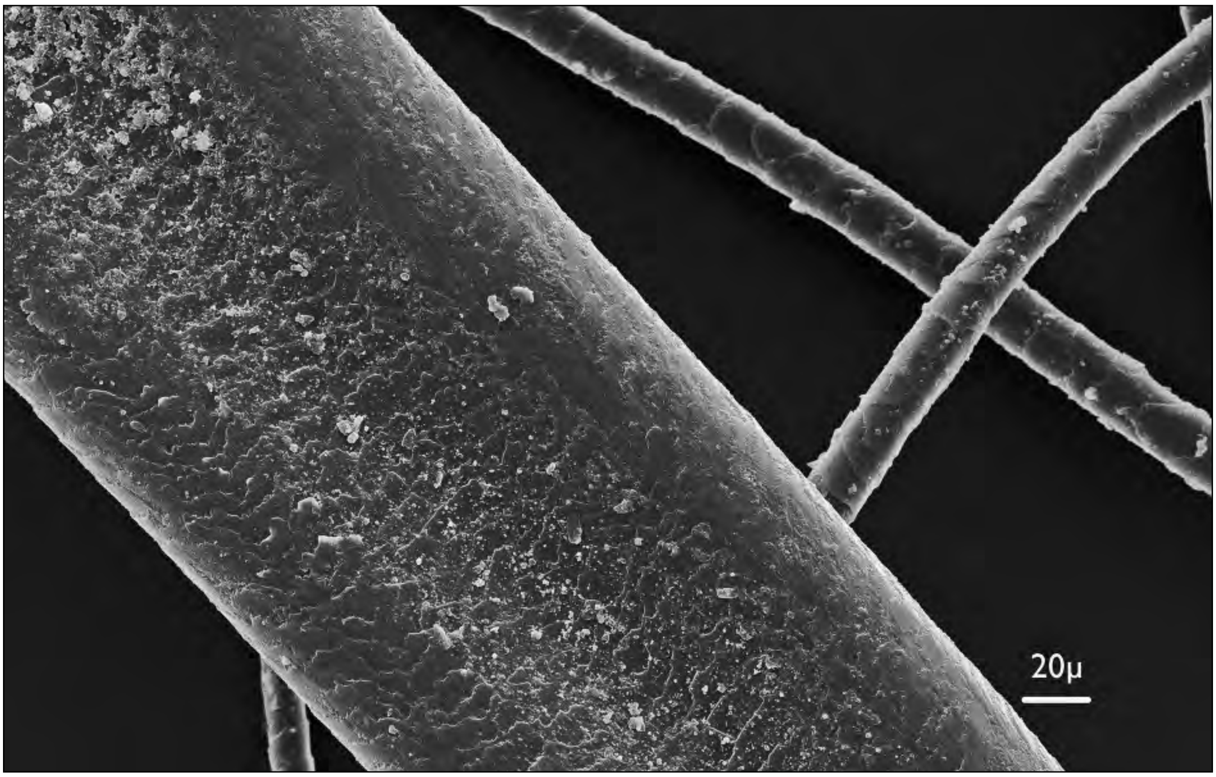

Fig. 263. West Caucasian Tur, modern

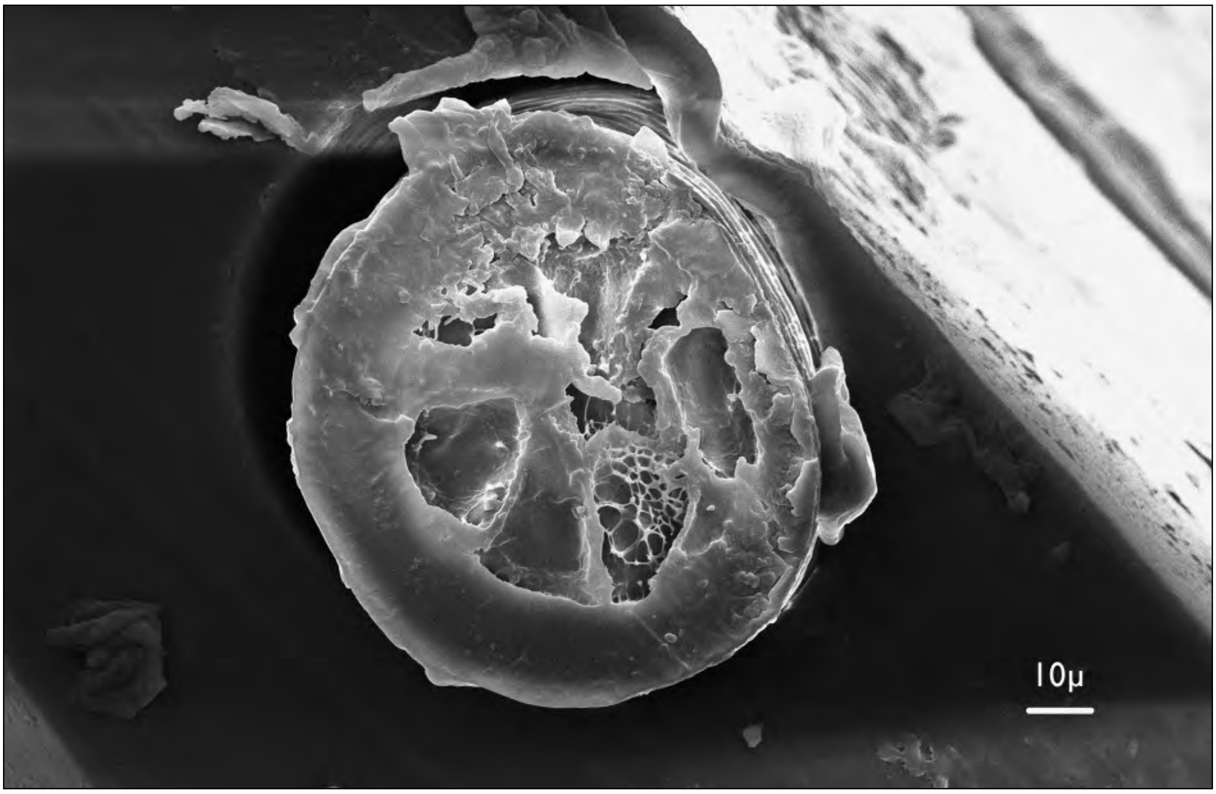

Fig. 264. West Caucasian Tur, cross-section, modern

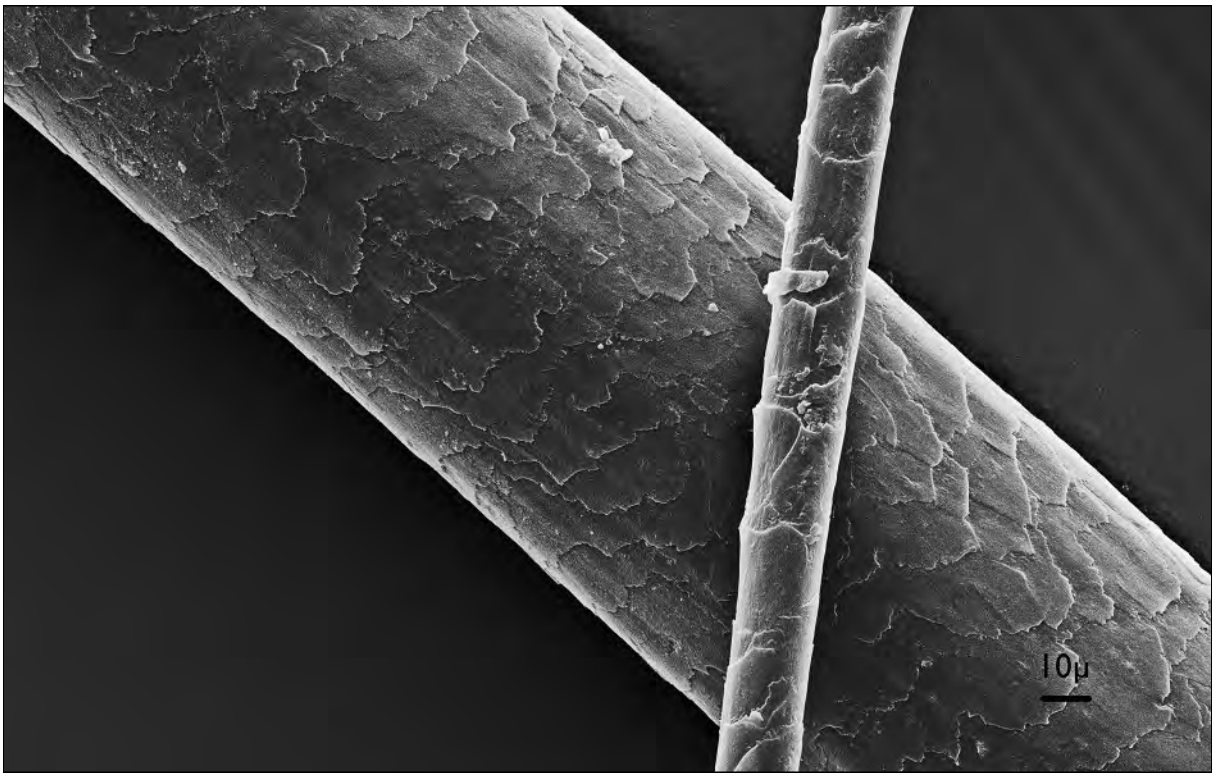

Fig. 265. Goat fibres, modern

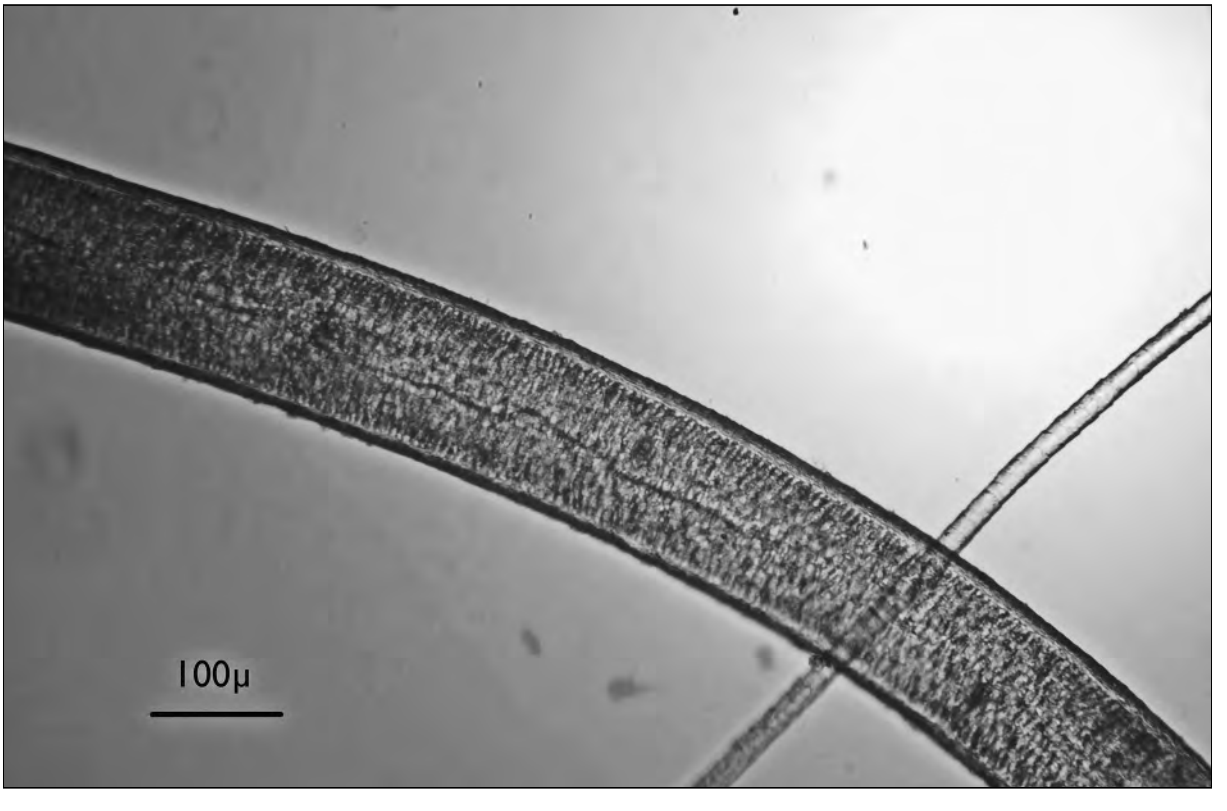

Fig. 266. Goat fibres by light microscopy, modern

4.8.17.4 Archaeology

There are in Europe remains of goat skins that date to the Neolithic Period. One is the skin of the domestic goat *Capra hircus* which was found in the Iceman's ("Ötzi") clothing in the coat, the loin cloth and the leggings (Hollemeyer et *al.* 2012). Another Neolithic garment also found in a glacier area, has been documented from Lenk-Schnidejoch (CH) (*Fig. 267*). It is a nearly complete, very well preserved left leg of a pair of trousers made from the goat skin *Capra hircus*. It is from a haplogroup (B1) which is not frequently found in Europe but more of an Asian type, showing that this haplogroup came into Europe at a much earlier time than previously thought and perhaps reflecting the large-scale movement of people (Schlumbaum *et al.* 2010).

In the salt mines of Hallstatt (A), goat fibres have been documented in several objects (Ryder 1992). The fibres are so well preserved that the medulla can be clearly recognized; SEM pictures add the scale pattern (*Figs 268* and *269*).

Coarse cloth used mostly for sacks and saddlebags have been found in archaeological excavations, especially in the Near East and in Egypt as with Ancient Roman goods (Batcheller 2001). Similar items are still in use today (Crocker Jones 1989).

Medieval finds such as a cloth from London (GB) show the use of goat material in merchandizing but also for such things as corpse wrappings (Crowfoot *et al.* 2001). Similar textiles have been found in Winchester, Oxford (GB) or Lund (S).

4.8.18 Mohair *(Capra hircus aegagrus)*

4.8.18.1 Habitat

Anatolia, dry climate, long hairs, does not like cold and wet climate.

4.8.18.2 History

The Angora goat (or mohair goat), which produces the lustrous wool known as Mohair, is a species of the same type as most other domesticated goats including that of cashmere (*Capra hircus laniger*). Mohair is still one of the most luxurious of known fibres (Vineis *et al.* 2008). It was first bred in Turkey, but South Africa has since taken up most of the production (Leeder *et al.* 1998).

The Angora goat is believed to have originated from the Himalayas. Frölich reports that these goats were known by the Venetians by 1380 (Frölich *et al.* 1929, 134). In 1550 a Dutchman discovered this goat in Turkey. Some goats were noted to have been sent to Charles V, the Holy Roman Emperor of the 16^{th} century. Turkey maintained a monopoly for processing until the 19^{th} century, with exports of raw fibres being forbidden until that time (Hunter – Hunter 2002). As the 19^{th} century began to unfold Mohair came exclusively from Turkey. In 1838, for example, few goats were imported to South Africa. By 1912, however, a large portion of the production had been taken over by that country. Today, Mohair is produced in South Africa, the USA (Texas), Turkey, Argentina and Australia. Quality ranges from the fine kid mohair, which are under 24µ, to the coarser adult fibres of about 40µ. In the 1920's upholstery for car interiors was made from mohair (Haigh 1946). It remains today the best quality ingredient for upholstery including the fact that it is antistatic.

4.8.18.3 Fibre properties

Unique to the Angora goat (Mohair) that is produced from this animal are the same diameters of the primary and secondary hairs – they are equivalent with medium dm. of about 40µ (*Figs 270* and *271*). Young animals have the finest fibres (“kid mohair”). Becoming coarser with age, the wool of animals older than 7 years is no longer used (Frölich *et al.* 1929, 135). The Angora goat does not molt which means that the hairs grow continuously. As it is one of the best quality fibres known it has very good dye properties and is antistatic. It does not matt together as felt – scales in mohair wool are less prominent and in a narrower range than in sheep wool so that the fibres are less apt to felt (Leeder 1998). The fibres have a low crimp, about 4 bows per 10 cm and only the coarser quality fibres are medullated (Hofer 2000, 283). Mohair fibres have about 5 scales per 100µ (compared with sheep wool having 10-12 and cashmere 6-7). The scale length ranges from 18–22µ, thickness is less than 0.6µ (Wortmann – Wortmann 2000; Vineis *et al.* 2011).

4.8.18.4 Archaeology

Among the textiles from the Oseberg (N) ship burial, a very fine lozenge twill with 60 threads per centimeter has been determined as mohair fibre (Ingstad 2006, 188; Rosenqvist 2006, 173).

Differentiation between sheep and goat (see ch. 4.8.13) is difficult but finding the differences between cashmere and mohair presents an even more difficult situation. With scale measurements (amount per 100µ), specific identification may be possible.

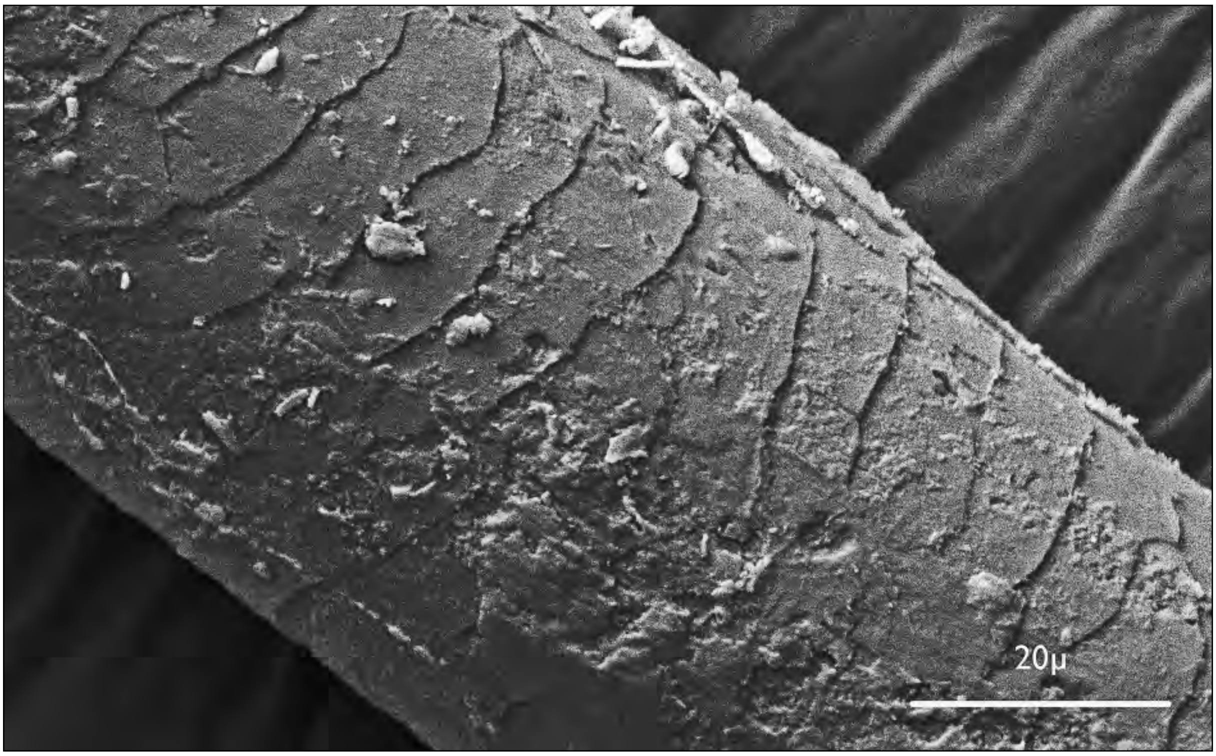

Fig. 267. Goat fibres, glacier find, Neolithic, Lenk-Schnidejoch (CH)

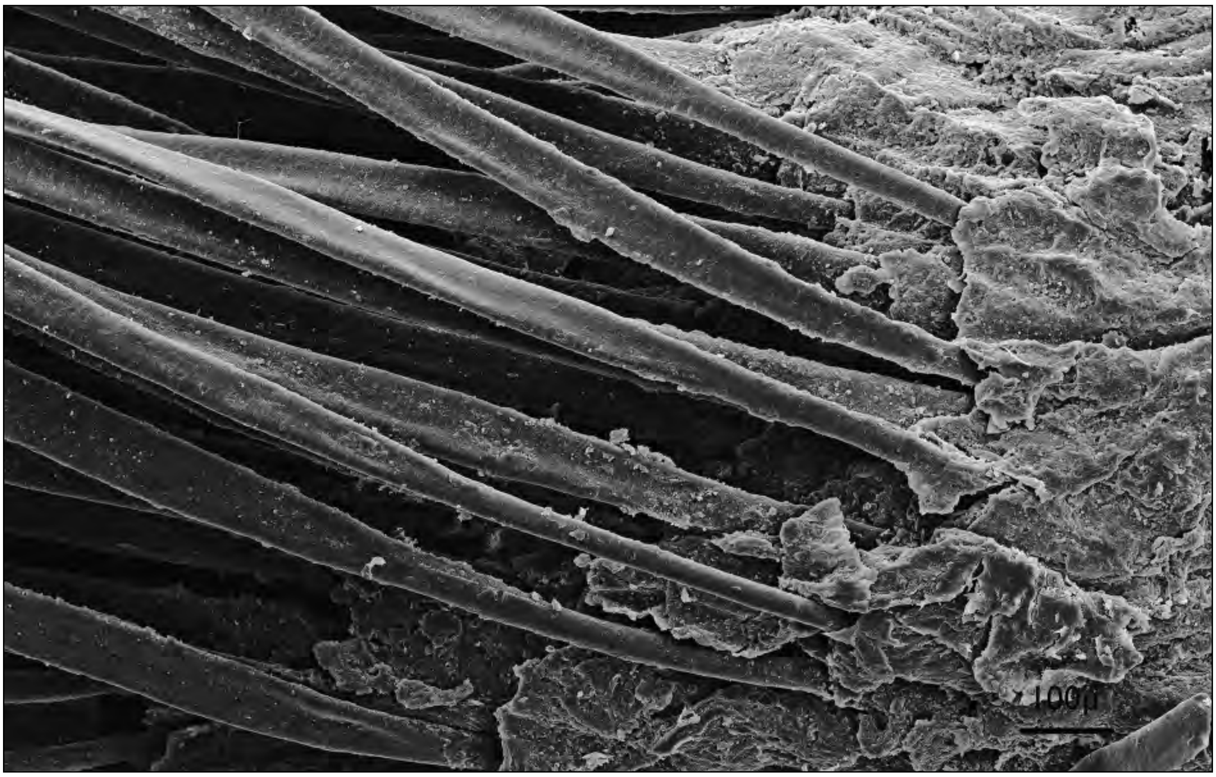

Fig. 268. Goat fibres, part with follicles, found in the salt-mines in Hallstatt (A)

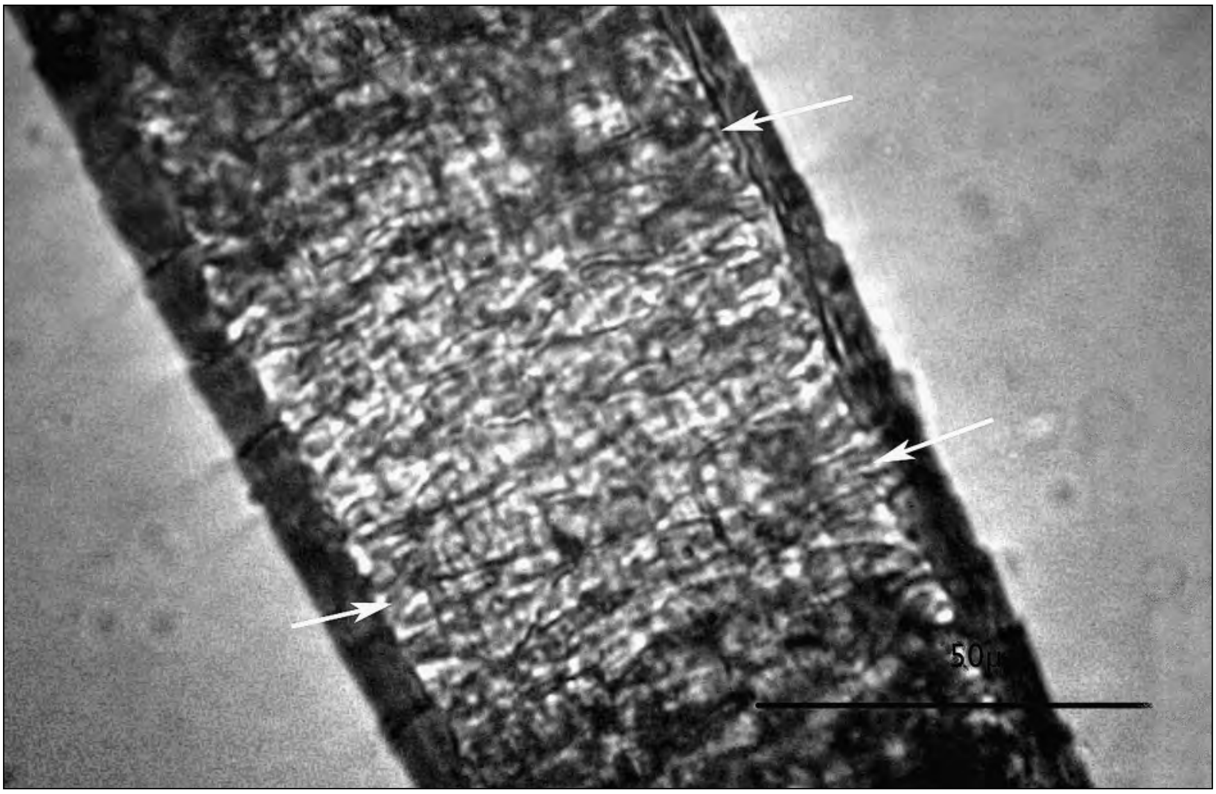

Fig. 269. Goat fibres, found in the salt-mines in Hallstatt (A) same as Fig. 268 seen with the light microscope

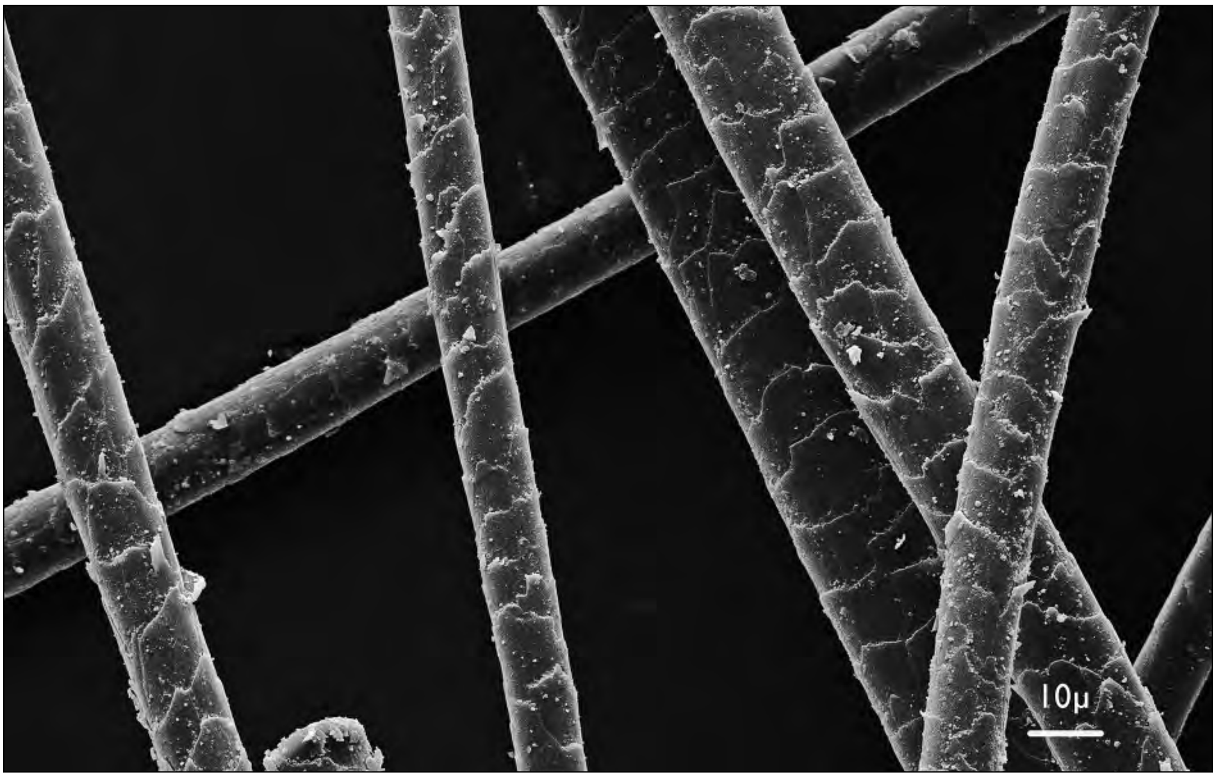

Fig. 270. Mohair fibres, Turkey, modern

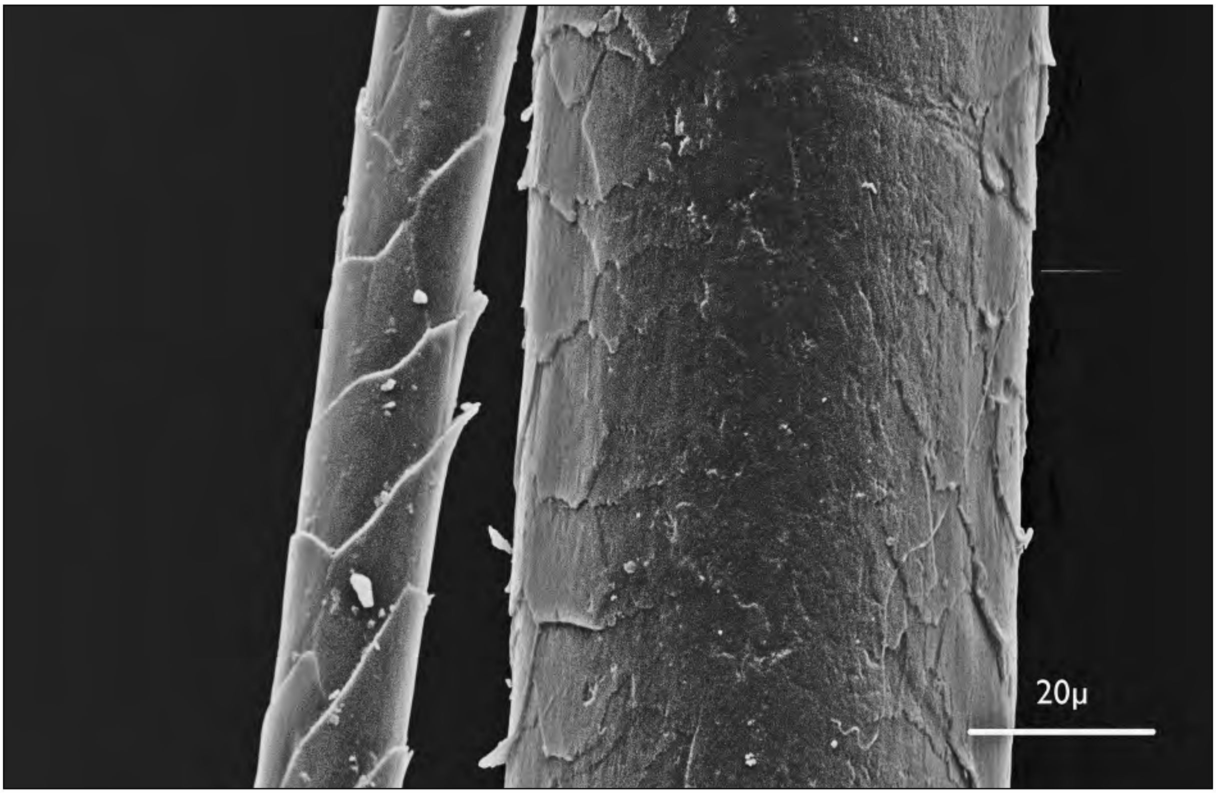

Fig. 271. Mohair fibres, Mongolia, modern

4.8.19 Cashmere goat *(Capra hircus laniger)*

4.8.19.1 Habitat

Originally from the Himalayas and Pamir, the country known as Kashmir, now domesticated in Persia, Anatolia, China.

4.8.19.2 History

Cashmere goats consist of about 20 breeds. Cashmere wool is produced today in China, Mongolia, Afghanistan and Iran (Vineis *et al.* 2008).

Aelian (or Aelianus Tacticus, Greek military writer from the 2nd century who lived in Rome) has written that Caspian goats were bright white, small in size, lacking horns, and snub-nosed. Were these cashmere goats? (Ael. NA. 17,34).

In 1664, the French doctor Bernier, along with Mogul Muhammed Aurangzeb Alamgir, travelled to Tibet and found a goat with very fine fibres. The wool from this goat was then used by the weavers for cashmere production. From 1650–1850 exclusive cashmere was imported by Scotland (Paisley). In the 19th century, cashmere shawls of special design were called Paisley shawls (Ryder 2001). Cheap knockoffs were subsequently made from printed cottons. In the beginning of the 19th century the wool industry brought goats, first to France and then to other European countries (http://www.ziegenlexikon.de/ch02s05s02.html). "Pashmina" is the Indian name for cashmere and has been used as a marketing trick to promote this "new" fibre (Ryder 2001).

Cashmere fibres are often manually combed out during molting rather than sheared. This method, however, does not assist in keeping the fibres parallel which would then make for easier processing. The industrial dehairing of cashmere became prominent in the 19th century by a Scottish industrialist and since the 1970's Asian industries have mastered this technique (Phan – Wortmann 2007).

4.8.19.3 Fibre properties

The cashmere fleece consists of primary hairs and a very fine, soft underwool. Down fibres grow from mid-summer to early winter by which time the follicle activity has declined (Vineis *et al.* 2011). The fine fibres are harvested by combing when the animal is molting. Coarse fibres will be removed during this process. The dimensions of fine fibres will be 13–25µ, primary hairs 65–85µ (*Figs 272–274*). The colder the climate, the finer the underwool. Cashmere has a flatter cuticle than sheep wool (see ch. 4.8.22) which results in a more lustrous fibre (*Fig. 275*). Kemp fibres are determined as having more than a 60% fibre width with medulla (Leeder 1998). The differentiation of scale height (mohair, as with other goat hair having scales of less than 0.5µ in height) helps to differentiate sheep wool from cashmere but does not differentiate from other speciality fibres (Wortmann – Arns 1988; Hunter – Hunter 2002, 84; Vineis *et al.* 2011). Among these are the Yangir and Shatoosh fibres (Tibetan antilope), which can be distinguished by scale pattern, scale height and scale density (according to Tonin *et al.*), while fibre diameter is overlapping (Tonin *et al.* 2002).

4.8.19.4 Archaeology

An Early Iron Age find has been documented from Lattes (F) in Southern France (Moulherat – Vial 2000). Lattes is not far from the 6th c. BC Greek colony which may explain why this special fibre has turned up there. There is partial pigmentation (i.e. it is not a white fibre). In the Syrian town of Palmyra, certain textiles have been identified to be cashmere mixed with silk (Schmidt-Colinet *et al.* 2000, cat. 490, Taf. 102e, f). A recent find in Cologne (D) dated to the 3rd c. AD, is a fine textile, woven in cashmere and wild silk and decorated with gold threads (Stauffer 2007).

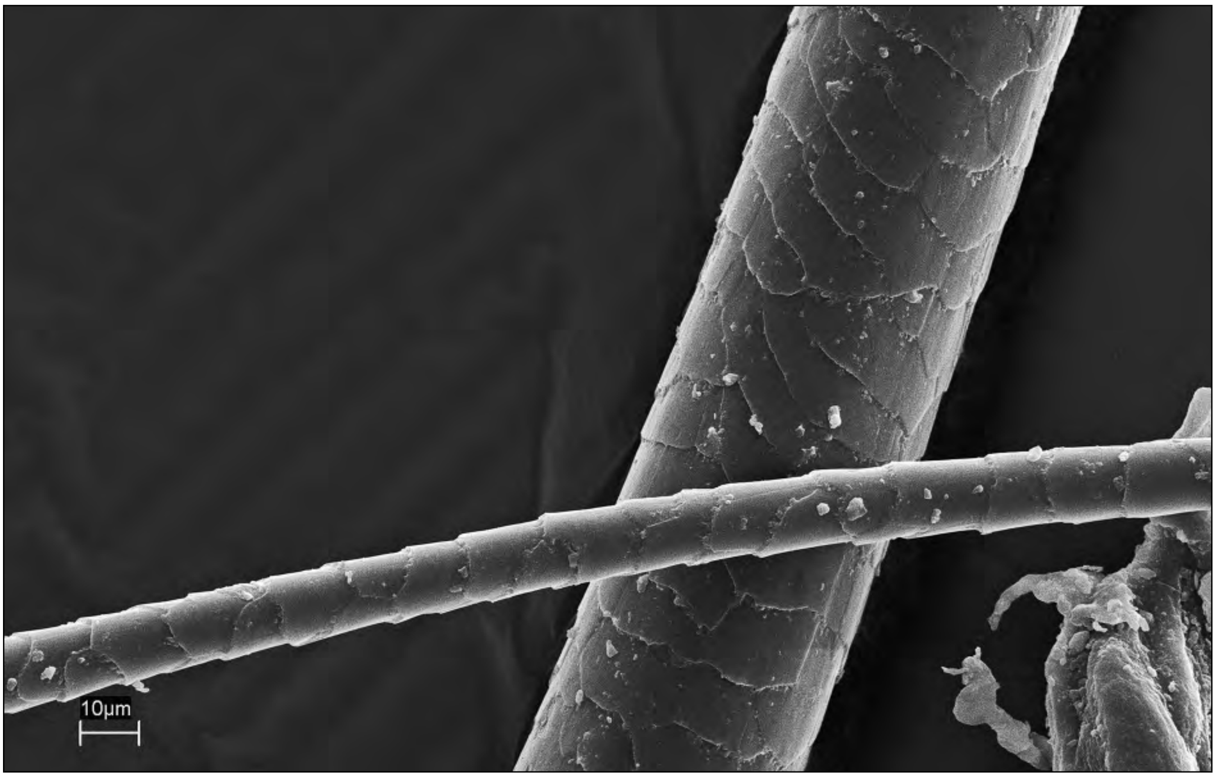

Fig. 272. Cashmere fibres, modern

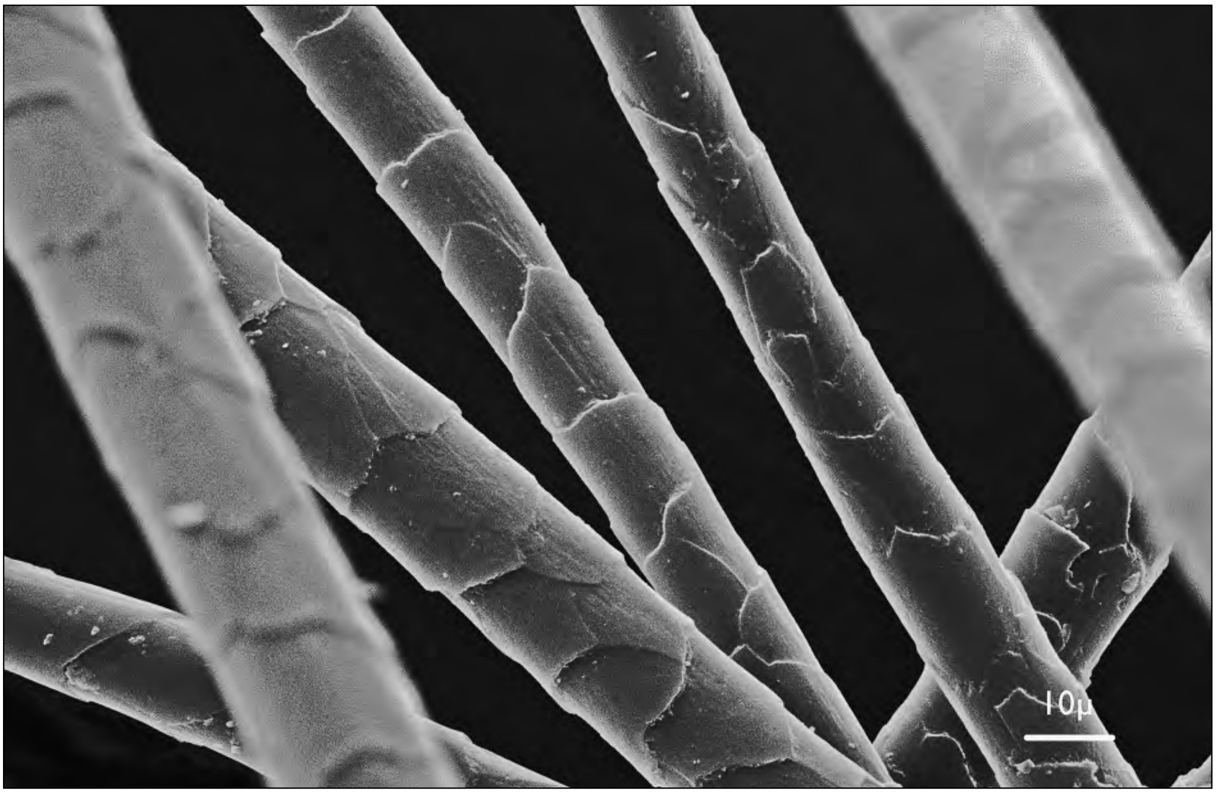

Fig. 273. Cashmere fibres, modern

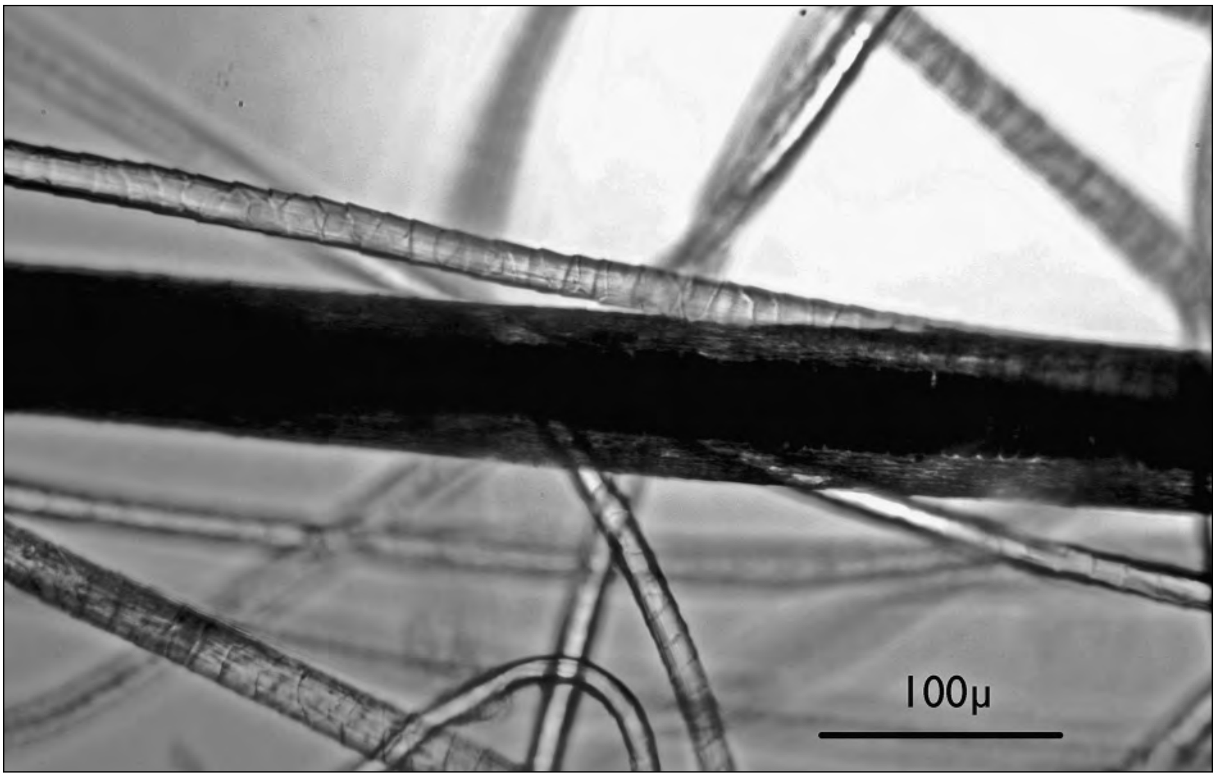

Fig. 274. Cashmere fibres seen with light microscope, modern

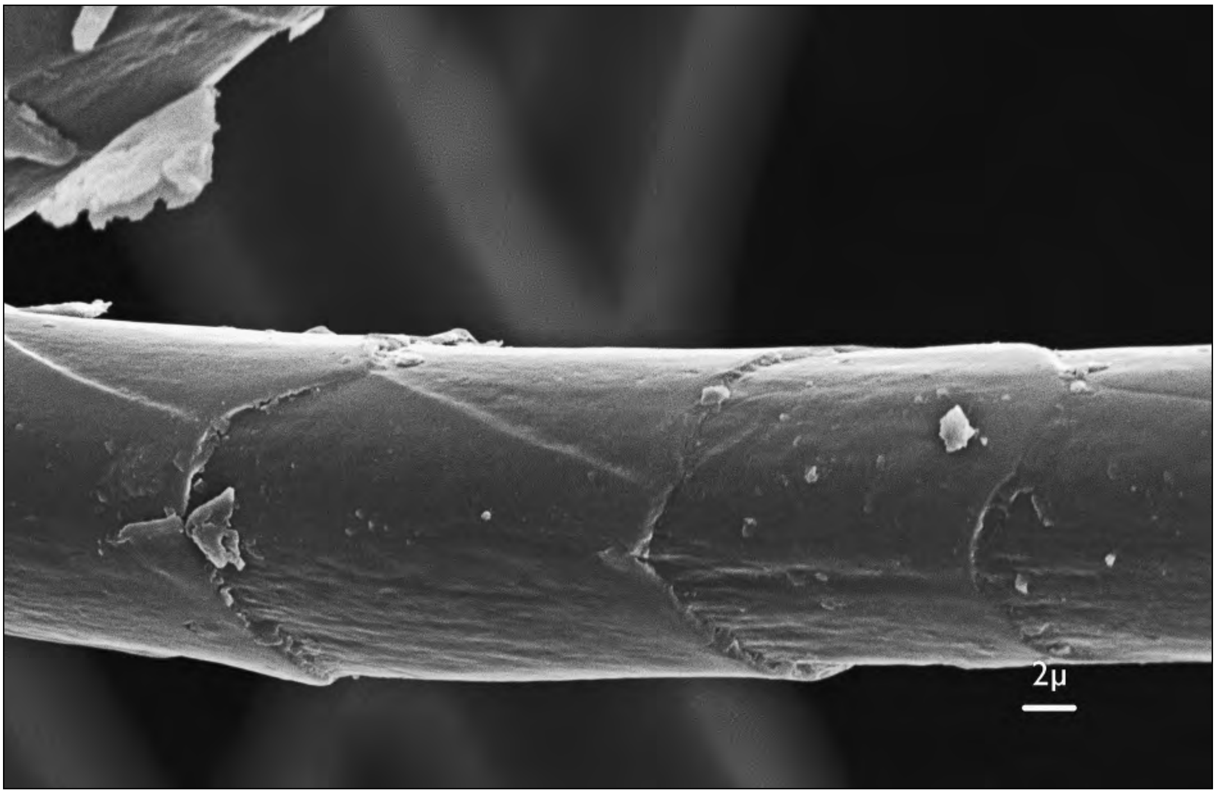

Fig. 275. Cashmere, fine fibres with thin scales, modern

4.8.20 Chamois *(Rupicapra rupicapra)*

4.8.20.1 Habitat

Found in mountain areas in Europe, chamois live at higher altitudes in summer, coming down below the forest line during winter.

4.8.20.2 History

Written sources report the use of chamois and ibex skins used to protect against cold temperatures and rain (Delort 1978, 133). In an archaeo zoologicial context, bone remains of sheep, goat and chamois are difficult to differentiate. The term "chamois-leather" (in German *"Samischleder"*) is used for a wash leather from sheepskin or lambskin from which the grain has been removed and which has been tanned by oxidation of fish oil (British standard BS 6715:1991).

4.8.20.3 Fibre properties

Fine fibres measure 15–20µ, primary hairs dm. 60–100µ. The scales are fine and rippled, with larger fibres being mosaic-like. The medulla is very large with a fine net-like structure (Lochte 1938, 259f) (*Figs 276* and *277*).

4.8.20.4 Archaeology

Chamois has been identified through mass spectrometry in "Ötzi's" clothing. There were parts of the coat and the quiver made from this skin (Hollemeyer *et al.* 2012).

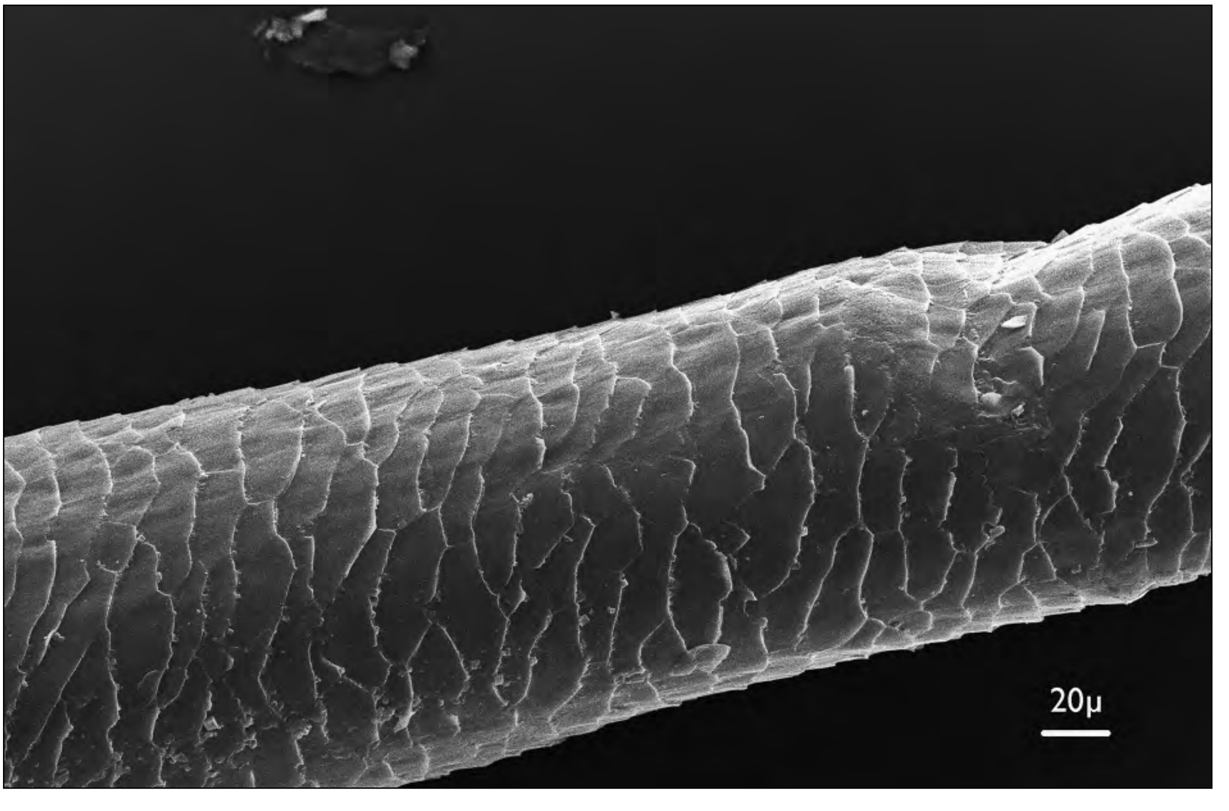

Fig. 276. Chamois fibres, modern

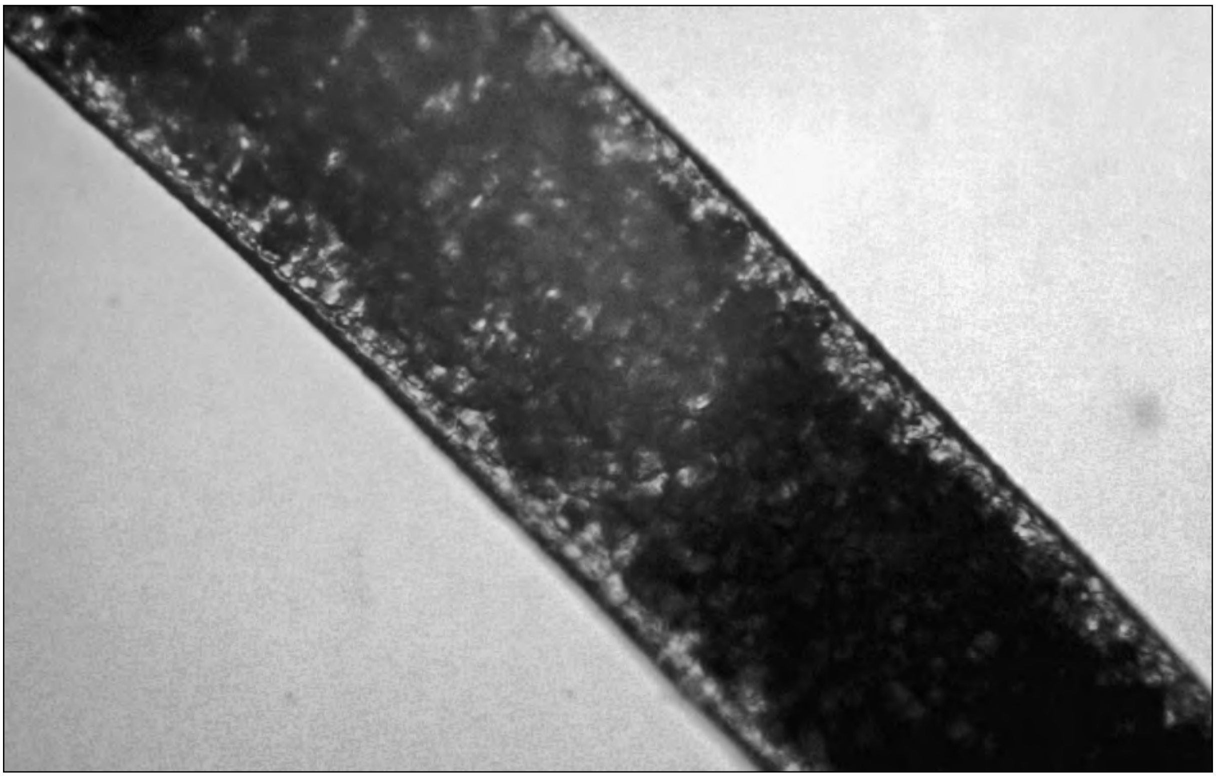

Fig. 277. Chamois fibres, seen by light microscope, modern

4.8.21 Mouflon *(Ovis orientalis musimon)*

4.8.21.1 Habitat

The origin lies in the Middel East, now living in mountain areas of Sardinia and Corsica.

4.8.21.2 History

The mouflon are a sub-species of *Ovis orientalis*. It is a short tailed sheep with a very hairy coat. There are not only morphological similarities but the number of diploid chromosomes is the same (2n=54), unlike other sheep, such as the Urial (2n=58) (Rezaei *et al.* 2010).

The mouflon is descended from to the first domesticated sheep brought to Europe but which became wild again. As there is no Pleistocene ancestor of sheep in Europe, these animals were probably brought to Europe from the Near East (Poplin 1979; Vigne 1999; Rezaei *et al.* 2010). The mouflon is a short-tailed sheep with a heavily haired coat. The Roman historian Plinius describes the mouflon as a "curious sheep of Corsica with a fleece like a goat" (Plin. nat. 8,75).

4.8.21.3 Fibre properties

The mouflon fleece has mainly two hair types: underwool and kemp. The fine underwool measures 7–19µ and kemp fibres can reach 150µ. Wool measurements show a typical graph reading, with a high peak at the smaller dimensions followed by many gaps and and then the larger diameters being demonstrated as single small peaks. Mouflon show the same fibre morphology as early sheep from the Bronze Age (here in ch. 4.8.22, *Figs 285* and *286*). Distinguishing them from goats also presents difficulties, this especially when there is an absence of kemp in the finds. The medulla of the mouflon is also similar to that of the coarse fibres of wild goat hair, the exception being that its medulla fills the hair completely leaving only a fine line for the cuticule (see *Capra aeg. cretica*, 4.8.15) (De Marinis – Asprea 2006). What does help to distinguish the mouflon from the others are the coarse fibres with mosaic-type scales that are typical for sheep. Also to take into account are the medulla that show multiseriate patterns for sheep versus disks for goats (see *Fig. 266*). Unfortunately, medulla structure may break away (see chapter 2, *Fig. 43* for cattle), or in the case of dark fibres the medulla can hardly be seen (*Figs 278–280*).

4.8.21.4 Archaeology

Current research has been able to locate DNA in the bones but not the hairs of the animal (Ørsted Brandt *et al.* 2011). General morphology has found to be very similar to sheep from the Neolithic Era (Vigne 1999). Hair morphology has similar results, which show that making a distinction between the mouflon and other domesticated primitive sheep (*o. orientalis aries*) is not possible.

4.8.22 Domestic sheep *(Ovis orientalis aries)*

4.8.22.1 History

Prehistory

The early history of domesticated sheep begins in the Near East in the 8th millennium BC. Until the 1990's, the reduction in the size of the animal was an important marker of domestication. It is a fact that herd management was already known in Iran around 9900 BP (Ganj Dare) and in Anatolia 10 400–9400 BP. Early colonists brought domesticated animals to Mediterranean Islands. On Cyprus sheep were not endemic but arrived there as early as 10 500–9000 BP, then brought only 3000 years later to Europe. The first imports to Europe are dated around 8000 BP, first to Southern Italy and then to France from between 7700 and 7600 BP (Zeder 2008; see "mouflon", chapter 4.8.21). There are four haplogroups of sheep: A, B, C, D. Representing 92% of sheep are the A and B haplogroups. The expansion of domesticated sheep begins 9000 years ago in the Near East with group A, and group B is considered the "Asian Sheep". Group C represents both the Caucasian and Asian types. The geographical origin of Group D is not clear (Tapio *et al.* 2006). At least one other independent domestication event must have happened in Asia (central/south-west Asia), and the woolly sheep may come from this part of the world and produce the second wave of domesticated sheep coming to Europe (Guo *et al.* 2005; Chen *et al.* 2006). Populations sharing the same provirus on the same genomic location are phylogenetically related. An analysis of sheep retrovirus has shown that mouflon and soay-northern breeds are linked as sheep but don't have the retrovirus R-18, this belonging only to the first wave of domesticated sheep coming to Europe (Chessa *et al.* 2009).

Evidence of domestication can be seen in morphological changes, such as hornless ewes, longer tails or curly fleeces. In Mesopotamia (Uruk, Jamdat Nasr period) by about 3000 BC two types of sheep are depicted, one a hairy sheep with screw horns and a short tail, another with a curly fleece (Clutton Brock 1989, 57ff.). The evolution from hairy to woolly is not measurable by examining the bones, but it can be detected by considering the slaughtering age and of course the wool measurements as found in textiles (see ch. 2.5.2). In the Neolithic settlement of Çatal Höyük (Anatolia/Turkey, 7400–6200 BC cal.), lamb burials point to a special meaning that (young) sheep were given for the deceased. It should be noted that until 2006 this was the only burial of its kind in the area (Russell – Düring 2006). By the first half of the 8th millennium BC herd management was practiced. Sheep were kept for meat and milk or at certain sites for lamb and milk. In the Chalcolithic, the changes in adult ewes and wethers become visible and is related to the production of wool (Arbuckle *et al.* 2009).

Early written sources from the Near East and the Minoan Culture (4th/3rd mill. BC) show how important sheep were during the Bronze Age (RYDER 1983, 133ff.). A wool economy organized by the ruling class had risen and this raw material became a most important trade good for metals such as copper and tin (MCCORRISTON 1997; DE GRAEF 2014). In Knossos (Crete) a change of slaughtering patterns (from the Neolithic) can be seen, with a "meat pattern" moving towards older ewes; a specialized wool economy is also evident, as sheep are slaughtered at a later age and kept for wool (ISAAKIDOU 2006).

During the Linear Pottery Culture (end 7th/first half 6th mill. BC), domesticated sheep were bred in Central Europe. The presence of milk lipids might also be proof that sheep were used for their milk during the late Neolithic in Central Europe (GREENFIELD 2010; SPANGENBERG *et al.* 2006). Neolithic sheep in Neolithic layers found in Twann (CH) (Cortaillod Culture, about 3800 BC) show a size of 56 to 66 cm; they are larger than sheep of the Linear Pottery culture in Germany (BENECKE 1994, 107). In the Late Neolithic the amount of sheep increased in numbers considerably, this development coinciding with more open landscape. Furthermore, in the 4th/3rd millennium BC, larger sheep reached Europe from the southeast and with them most probably the beginnings of the use of wool in that area (SCHMITZBERGER 2009, 81). Larger sheep were bred as well and slaughtering patterns changed in the Corded Ware Culture (first half 3rd mill BC) to a wool economy (SCHIBLER 2008, 387).

Unlike Mesopotamia, where cork screw horned sheep were most common, in Europe ammon horn sheep (a subspecies of argali wild sheep) were found. Recent strontium analyses from bones of a Polish site has revealed that in phase 1 and 2 (3800-3650 BC) sheep were local, but in phase 3-6 (3650–2700 BC) sheep were of a non-local provenance, suggesting an incoming of other sheep types (PIPES *et al.* 2014).

Bronze Age sheep were a bit larger than those from the Neolithic (BENECKE 1999, 65). The most ancient wools in Central and Northern Europe so far have been dated to the Late Neolithic Period. In the Early Bronze Age wool was used for textiles and for decorations (BENDER JØRGENSEN – RAST-EICHER 2015). A very important change comes with the first white wools, something that had been present in Europe since the Middle Bronze Age (GRÖMER *et al.* 2013, HallTex275; RAST-EICHER IN PRESS/CAMBRIDGE). Heredity is the most important factor in the development of white fleeced animals. White is a dominant color and was first bred from white belly sheep followed by piebald sheep (white on black). This was only by means of artificial selection (RYDER 1990). White wools made colored garments possible and when this became known the development of fancy designs quickly followed. In linguistic research the word for white wool comes up in the Iron Age only (SMITH *et al.* 1997), but textiles made of white wool were known before this (BENDER JØRGENSEN – RAST-EICHER 2015). Skins also seem to play a major role in garment manufacture (HALD 1980; RAST-EICHER 2008; MANNERING *et al.* 2012).

During the Iron Age, fleeces changed again; they are longer and crimped (RAST-EICHER 2013). Shearing instruments come about (north of the Alps) in Latène B only (from c. 350 BC), the earliest ones being found in the cemetery of Dürrnberg b. Hallein (A) (RAST-EICHER 2008, 156).

Ancient written sources show that sheep were very often named so as to simplify more complex associations. Plato, in what would appear to be a political statement, wrote that *"Kings ought to shear, not skin their sheep."* (PLAT. REP. 1,343b). Well chronicled in the ancient texts, clothing is given descriptive names such as the coats of sheep wool being named *"chlaina"* by Homer (e.g. HOM. OD. 4,50).

Roman and Early Medieval Period

In Central Europe, the influence of Roman sheep breeding, with textiles being made of fine wool, is evident as early as the Late Iron Age La Tène D (RAST-EICHER 2008, 150ff.). Regional differences were great but in general Roman breeds were larger than those from the Germanic. In Roman provinces hornless ewes were a majority (Benecke 1994, 169ff.). The "Golden Fleece" was still the ideal reference to quality (Horaz, C. 3,5,28: *aurea lana;* see also Rast-Eicher, in press/Cambridge). Pliny the Elder was aware in the 1st Century AD that from Spain and Corsica there came a curious animal known as the *"musimon"* which had a fleece like a goat (Plin. nat. 8,75).

The Romans used sheep and cattle as payment for wares and penalties. The earliest coins were decorated with a sheep's head (RE *"Schaf"*, 375). By the time of the Romans sheep breeding had resulted in differentiated breeds, with varying qualities and colors. There continued to be plucked sheep and these were the finest wools. Noted of these were the coats coming from the so-called 'Tarentine' sheep. The animals were covered with protective cloths and kept partially indoors in order to obtain the softest wool (Plin. nat. 8,73). Several authors refer to a special breed from the south of Spain – Martial tells that this wool (obviously raw wool, not clothing) from *Baetica* could be considered a nice a gift for a lover, as expensive as perfume (Mart. Epigram. 12,65)!

Columella (Col. 7, 2–4), in his book on agriculture, gives advice about sheep breeding saying that each land must obtain only the most appropriate type of sheep for the area with larger sheep best bred on flat land and smaller breeds in mountain regions. He enumerates on the most outstanding breeds as being Calabrina, Apulina, Milesian, Parma and Mutina with the best of these being the Tarentine sheep. He mentions in addition to this the breed from the Gauls (especially those from Altinum, a town near Venice) which he feels to be the highest quality of all. He states that at one time his uncle crossed North African sheep (colored) with Tarentine sheep for the purpose of producing fine colored wool. The first generation of these sheep had coarse fibres but progress was made to eventually produce a male sheep with soft and colorful wool. When purchasing a flock of white-fleeced sheep, Columella says, it is important to choose the whitest ram in order to breed purely white lambs (these offspring never being the possible outcome of a red or dark sire). He goes further to say that it is important for the ram not only to have a white fleece but also a light tongue; he has to be large and with a long tail.

Ewes are used for breeding between the ages of three and seven years. Tarentine sheep have the most elaborate care as, mentioned above, they must be kept covered and kept indoors at intervals to maintain the softness of their fleeces. Males are not used for breeding but rather slaughtered at only the age of two when the quality of their skin is best for selling.

Middle Ages

Sheep in the Middle Ages were as varied as they were in earlier times. The highest quality wools were known to be from Spain as with the Merino sheep which was created from the *lana merina* by Fernado of Castille in the 11th century (Cardon 1999, 33f.). Lambskin (*pellura; avortons)* was one of the lesser expensive skins and was used, for example, by the clergy. *Pampillon* was of a higher quality, a black skin originally from Pamplona (Spain). By the 14th century, *Budge* fetched a high price and was usually a black lambskin coming from both Southern Europe and North Africa. It was known as one of the higher quality lambskins and on a level to be sold to the higher classes only (Hayward 2014, "Lambskin"; "Budge"). Sheep or even just their skins were used as forms of payment, while the Scandinavian *vadmal* served as currency compared to fish (Schier 1950, 309). On the Faerør islands (N) payments were transacted in sheepskin until 1856 (Schier 1950, 304, 309)! *"Persina lambs"* (or the skins of newborn lambs also known as *astrakan* or *agnelli barbaresche)*, were brought by the Tartars to Novgorod (RU), then via Hanse to the merchants of Leipzig (D), who dressed and dyed them (Davey 1895, 86; Delort 1978, 82).

Wool was a main export good for England during the 13th–15th centuries and one of the factors that helped to establish the country as an economic power. The Woolsack, the seat of the Lord Chancellor, chairman of the House of Lords, commemorates this. Often produced in abbeys, wool was a prominent product sold to weavers in France, Flanders and Italy (Lucca, Florence) to be used for luxury clothing (BELL *et al.* 2014). The Medieval Italian wool industry of Florence was powerful and rich. In fact it was the wool weaver's guild that paid for most of the construction of the dome of Florence!

Medieval draperies also played an important role in the economy of the time (CARDON 1999). England and Flanders began producing worsted textiles, which are made with combed wool, and it can be stated that the industry was closely linked to newly emerging towns with free workers (VERHULST 1996).

Modern

The Merino sheep is the source for what is nowadays the most favored fine wool. M.L. Ryder gives a large overview in his book about the most important breeds in the world (RYDER 1983). All populations of Merino sheep known derive from the Spanish Merino. During the 18th century, when export restrictions were loosened, they were brought out of Spain to Germany and France where they were bred for meat only. The breeds ending up in Portugal and New Zealand, however, were selected for wool production (FRÖLICH *et al.* 1929, 413; DIEZ-TASCÓN *et al.* 2000). Closer to primitive sheep in stature than most other breeds, the Soay sheep and their short-tailed relatives still exist in various parts of Northern Europe (DÝRMUNDSSON – NIŻNIKOWSKI 2010). Landrace breeds such as the *"Pommerschen Landrasse"* or the *"Walliser Landschaf"* have varied fibre types and are often protected in a rare breeds category (e.g. Pro Specia rara, Switzerland).

Today, sheep produce about 1 kg of greasy wool annually (0.6kg of clean wool) from 1 hectare of pasture (POPESCU – WORTMANN 2010). In the 19th century specific breeds were developed to produce finer fibres, however, a counter effect of overbreeding this type was that the meat became inedible (FRÖLICH *et al.* 1929, 186). DNA analyses have revealed high gene flow among sheep breeds from Asia and Europe (MEADOWS *et al.* 2005).

Ancient breeds have become known for their strong resistence to modern diseases and interbreeding with more modern stock strengthens overall immunization strategies (TABERLET *et al.* 2008). The modern wool industry tried to change the specific property of felting fibres artificially to control the technique. Early attempts in the 1950's were with chlorinates which descaled the fibres and hindered felting but also lead to fibre damage. In recent years attempts to further control the process have been made through plasma treatment, a method that produces a thin protective layer over the scales (RIPPON – EVANS 2012). As a result new types of synthetically altered materials have been created to produce items ranging from underware to fashionable sportswear which are machine washable without risk of felting.

4.8.22.2 Fibre properties

Sheep fleece consists of different fibre types, at least coarse fibre (primary fibre) and underwool (secondary fibre). Sheep fibres have been transformed through domestication and breeding (MEYER *et al.* 2002; DE MARINIS – ASPREA 2006). There is not one dominant breed, instead a vast array and many facets of fibre types and morphology.

Primitive sheep have a hairy fleece with coarse upper fibers and fine underwool. The fine fibres range in dm. from 10–20µ and are not medullated; coarse fibres have dm. from 50–60µ; the brittle light kemp with dm. from 120–140µ. The latter have large medullae which fill the whole width and leave a thin epidermis – there is not much of a difference from goat hair. Bronze Age wool was molted; it was plucked and therefore roots and tips were visible (see chapter 2.3.1).

Iron Age fleece contains at least two fibre types, a long upper fibre and underwool. Interestingly, the underwool is no longer as fine as is found in the Bronze Age. Cross-sections show the cuticula to be quite large, their medulla more or less oval and with scales that can vary in form, such as with edged scales. From the Late Iron Age to the beginning of the Roman Period, fine fleeces show measurements comparable to modern Merino: a symmetrical curve with a mean diameter of around 20µ; no gaps on the graph; and no coarse fibres in the larger diameters. In cross-sections the epidermis is fine and the wool ideally is not medullated (see *Fig. 290*) (Rast-Eicher 2008c). During the Middle Ages this wool type was in use but until the Modern Period, landraces – if not too interbred with other sheep – show a type of bi-modal Iron Age fleece. Soay wools, which are said to be a remnant of Bronze Age wool type and of which DNA show a link to the European mouflon (Chessa *et al.* 2009), have proved to be mixed with modern sheep and it does not look like Bronze Age wool. Measurements show the underwool to be thicker in diameter than real Bronze Age wool and has crimp which has not been found in Bronze Age wool in Europe (Rast-Eicher 2013b). The best comparison has been found by the author with wool from Kyrgyzstan (*Fig. 281*).

Scales can show variations in pattern depending on the breed (Frölich *et al.* 1929, 79ff.). Coarse wool types can have edged scales (*Fig. 289*), such as from the Tavetsch sheep, a last remnant of a very old breed in Eastern Switzerland (one animal is in the Museum of Natural History (Naturmuseum) in Chur (CH) (*Fig. 282*). The Spälsau sheep from Norway, on the other hand, has very distinct scales which look a bit like the three-dimensional form of the reindeer scales among the deer types and could well have been ideal in keeping air better insulated in the fleece (*Fig. 283*).

4.8.22.3 Archaeology

Within the context of archaeological textiles, sheep wool is the most important fibre studied. Most excavated textiles that are of animal fibre are made of sheep wool. In observing hundreds of textiles, many factors can be detected in wool, something that is not possible when studying other animal fibres as single finds. The quality of the wool fibre, the host breed of sheep and methods of processing can all be ascertained. Sheep fleece took on changes with domestication. Coarse fibres of Bronze Age sheep or primitive breeds are comparable to mouflon in that they show a distinct net-like medulla, comparable to deer medulla but rounder cells (see ch. 4.8.17; *Fig. 284*). At this stage the medulla with round to oval cells of the coarse fibres can be differentiated from goat hair with disk-like cells, and an important criterion for archaeological material (see ch. 4.8.17). When kemp fibres have been eliminated by breeding in the course of forming denser wools, the coarse fibres have a broad cloisonné-like medulla and the fibre may still be oval from a large medulla. Depending on the state of preservation, the medulla is not always clearly visible under light microscopy. Sheepskin is also important to the study of prehistory. One of the oldest sheepskin articles documented in Europe is part of the garment of the Iceman ("Ötzi") and dated to 3300–3100 BC (Hollemeyer *et al.* 2012). Sheepskin has been used as lining for scabbards, for garments or garment linings, as protective mats for sleeping or as protective coverings. A skin of the Early Bronze Age was found on the back of the head decoration of the deceased (Cooper *et al.* 2010). Fibre scales are similar to the ones of the Karakul sheep (see *Fig. 281*; *Fig. 285*). The lining of a coat found in Skythian Pazyryk (Olon-Kurin 10 burial) was made from a hairy sheep with long fibres (up to 20 cm) and an underwool similar to Bronze Age fleece (Molodin *et al.* 2009). According to the authors, this could have been the result of interbreeding with the wild Argali sheep. The skins found in the salt-mines of Hallstatt also gave important results when compared to the textiles (Rast-Eicher 2013b).

Early Medieval garments (women's coats or men's kaftans) from Moščevaja Balka at the Black Sea, have been found to be either lined with sheep or lambskin or, for the richer garments, with squirrel (Ierusalimskaja 1996, 41).

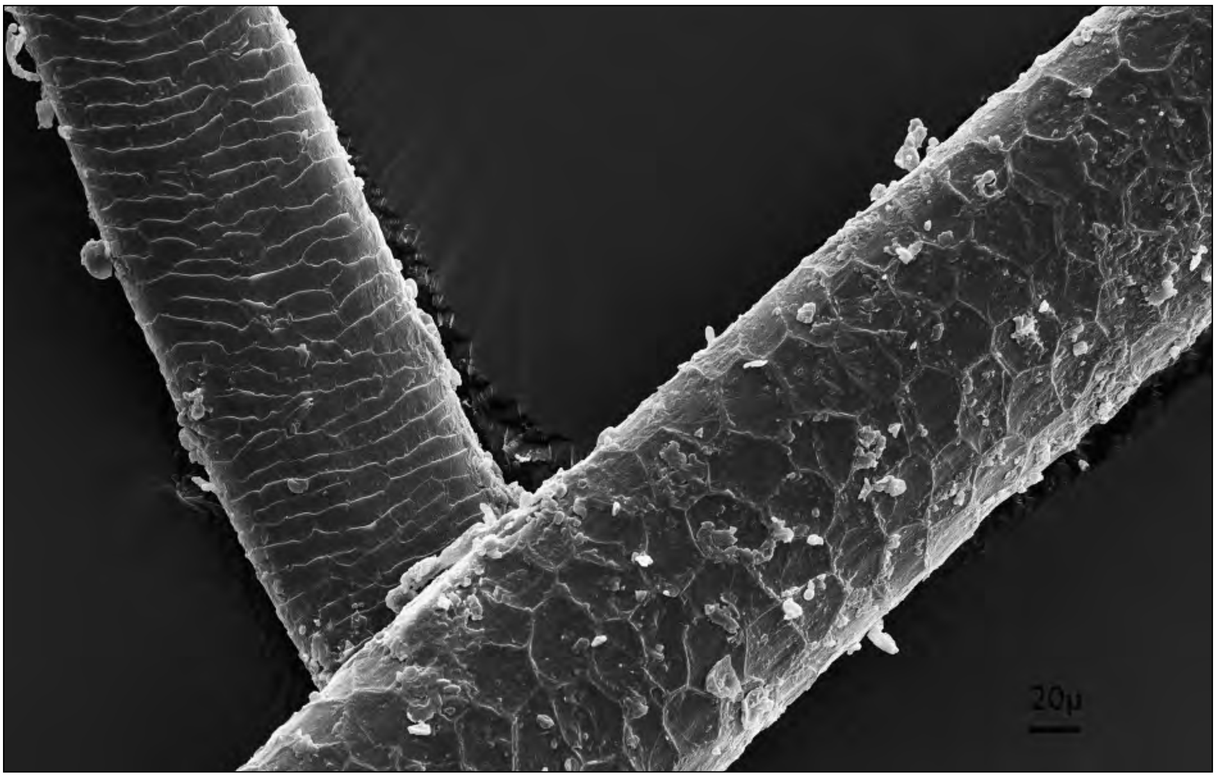

Fig. 278. Mouflon fibres, modern

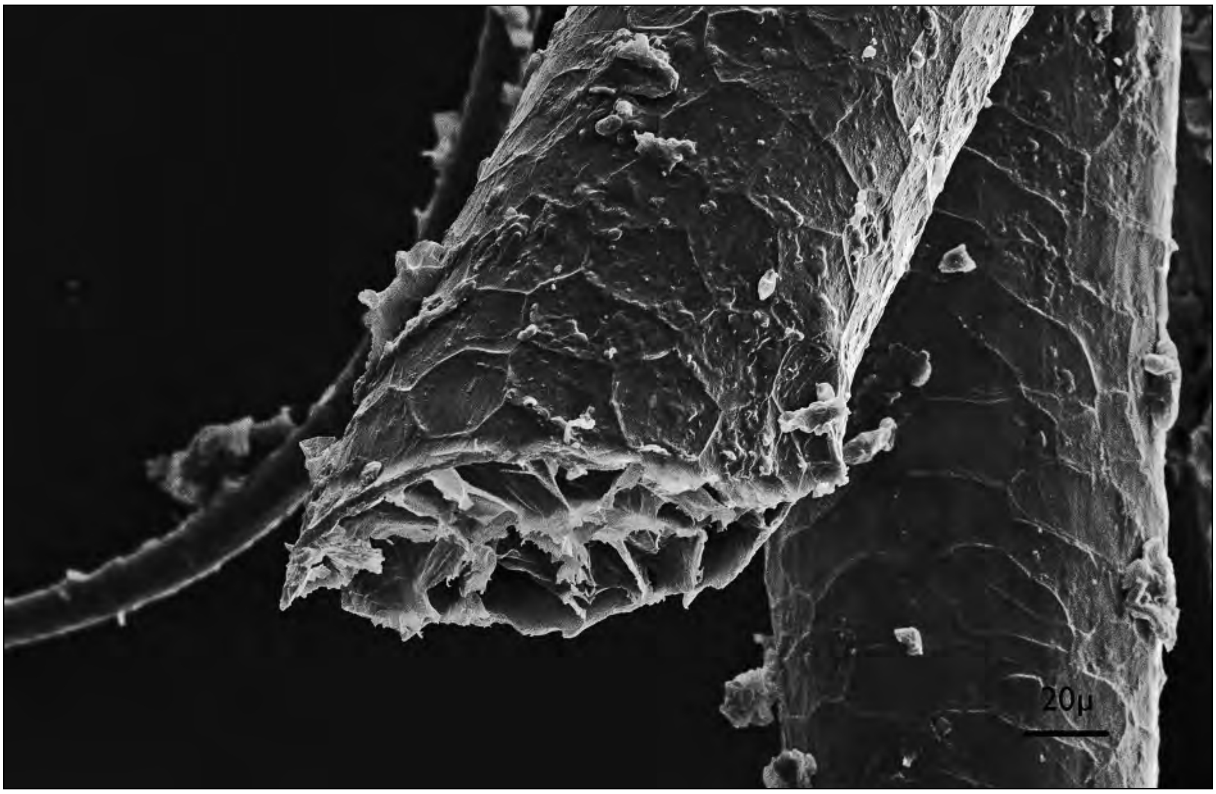

Fig. 279. Mouflon fibres with cross-section, modern

Fig. 280. Mouflon fibres, fine and coarse, modern

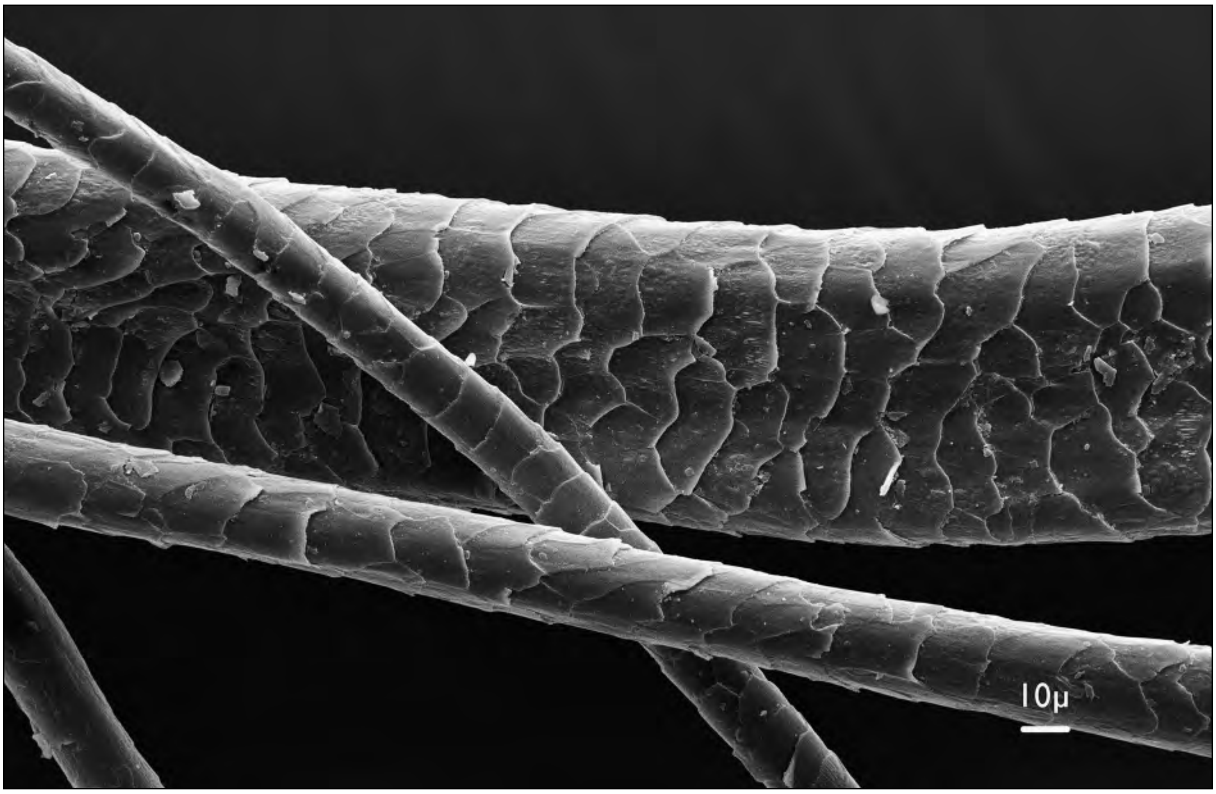

Fig. 281. Sheep fibres, Karakul sheep, modern

Fig. 282. Sheep fibres, Tavetsch sheep, modern

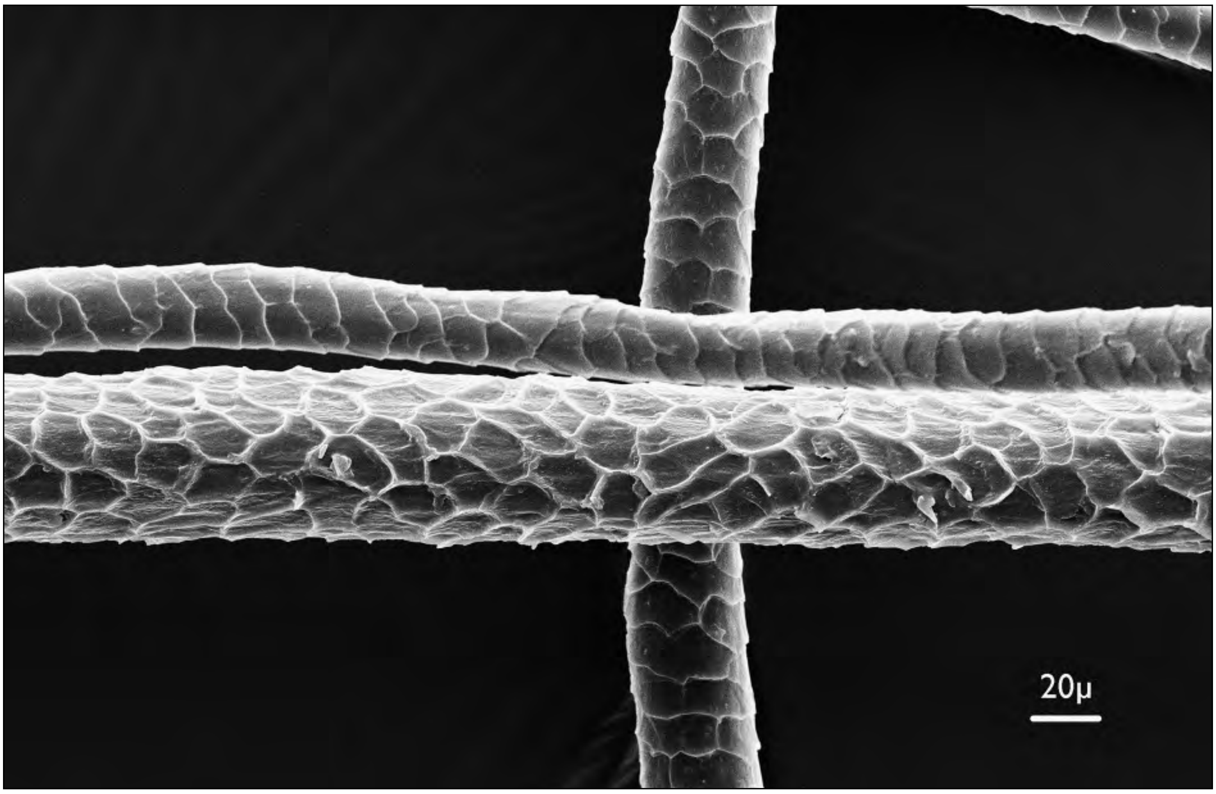

Fig. 283. Sheep fibres, Spälsau sheep, modern

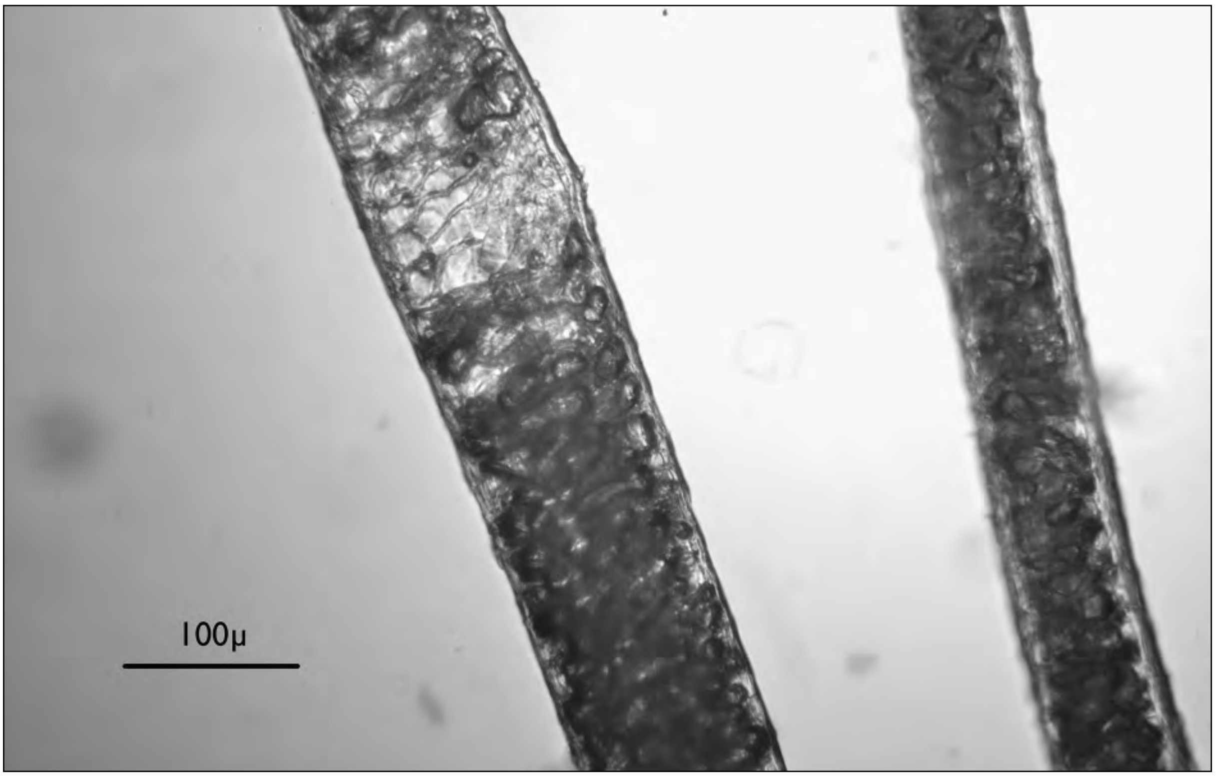

Fig. 284. Sheep fibres, primary hairs (kemp) with net-like medulla

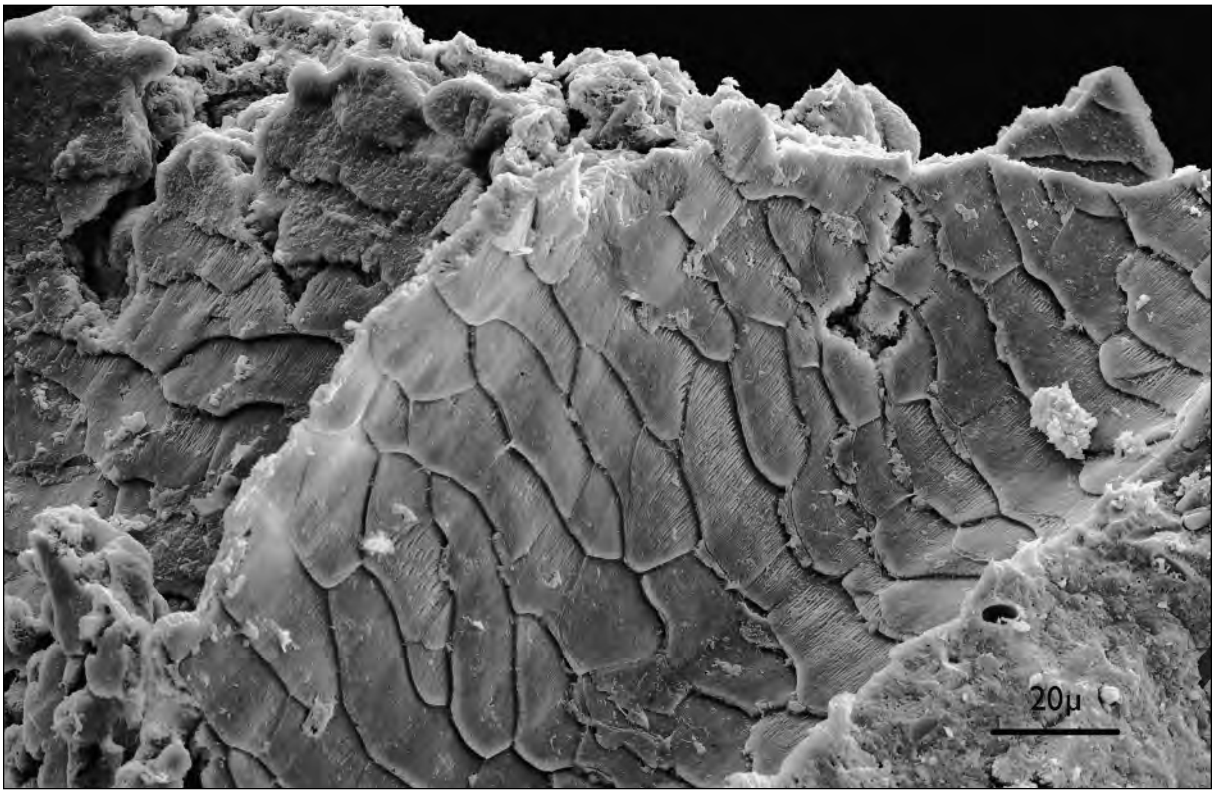

Fig. 285. Sheep fibres, Bronze Age skin from a Bronze Age grave in Spiez-Einigen (CH)

Wool quality will vary greatly according to the type of textile produced, this being true as early as the Bronze Age (Rast-Eicher 2013b; Rast-Eicher – Bender Jørgensen 2013). One of the oldest wool textiles found in Europe, dated to the Early Bronze Age ca. 1900 BC, was discovered in the glacier of Lenk-Schnidejoch (CH) (Rast-Eicher 2015). It is made with fine light underwool, mixed with some dark kemp fibres; the quality of this wool falls within the range of Bronze Age wools (*Fig. 286*). The kemp fibres show a large medulla (*Fig. 287*). The most important development during the Bronze Age is the formation of unpigmented – white – wool, this occurance being well documented for the Middle Bronze Age in Hallstatt (Grömer *et al.* 2013, HallTex275) (*Fig. 288*).

During the Iron Age, there are a variety of sheep breeds in Europe. Differentiation can be observed from the form of the scales which will often show edged scales and quite thick epidermises (*Fig. 289*). Tips and roots will confirm that sheep wool has been plucked (a typical practice during the Bronze and Iron Ages) (see ch. 2.3.1). A sample of Late Iron Age wool from Lausanne-Vidy (CH) shows a regular fine wool, round fibres and fine epidermis (*Fig. 290*; Rast-Eicher 2008c, 148). In the Iron Age, wool with crimp appears (see *Fig. 57*). It was only during the Middle Ages that a method to eliminate crimp was developed using warm combs. In the Early Medieval Period, fine wool was available for the more precious garments (*Fig. 291*) and coarse wool to produce tweed-like outer garments of a rougher quality.

Sheep wool was sorted and processed often to such an extent that it no longer resembled the original fleece. Special techniques, such as tablet weaving, required fine wool (see *Fig. 58*). Quality categories of fibres and textiles were formulated by taking wool measurements. Medieval finds will show these categories and are described in sources of the time (Cardon 1999).

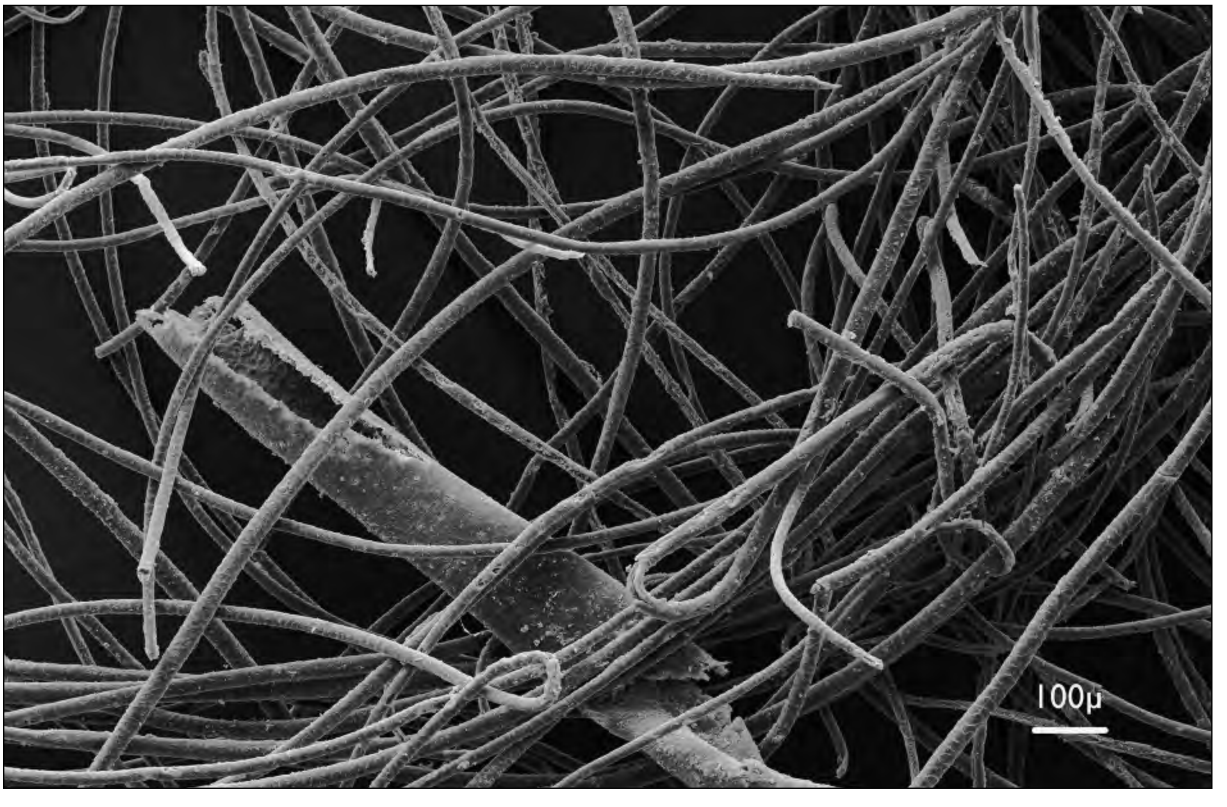

Fig. 286. Sheep fibres from an Early Bronze Age textile, the net-like medulla is visible in the kemp fibre, Lenk-Schnidejoch (CH)

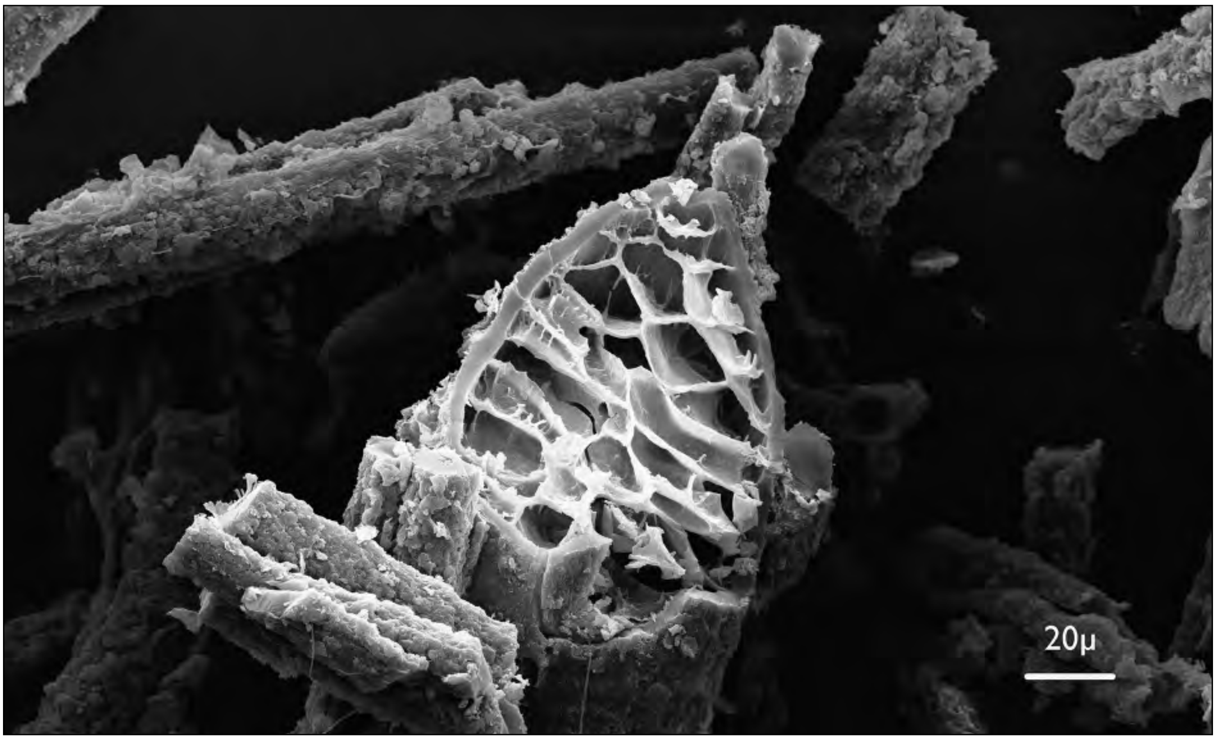

Fig. 287. Large net-like medulla, cross-section, Bronze Age, Schuby (D)

Fig. 288. Nearly unpigmented and dyed sheep wool, Bronze Age textile, Hallstatt (A)

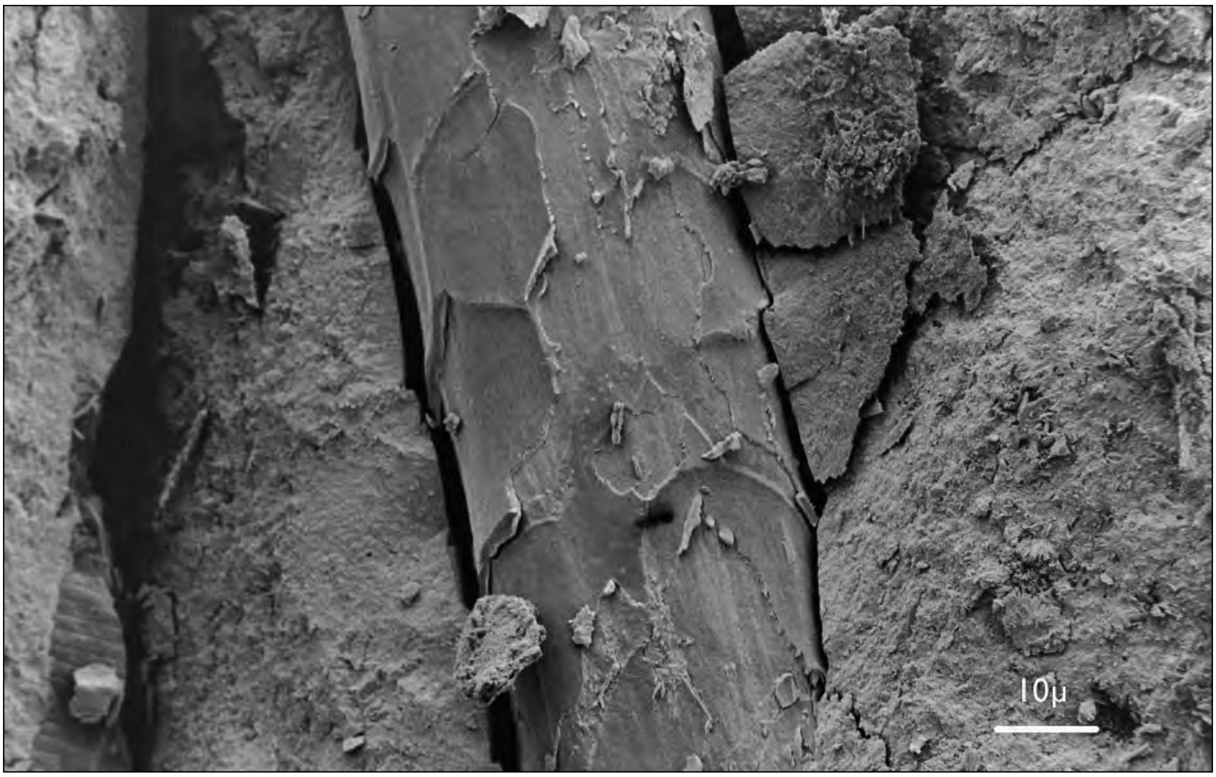

Fig. 289. Mineralized wool fibre with edged scales, La Tène B, Trun (CH)

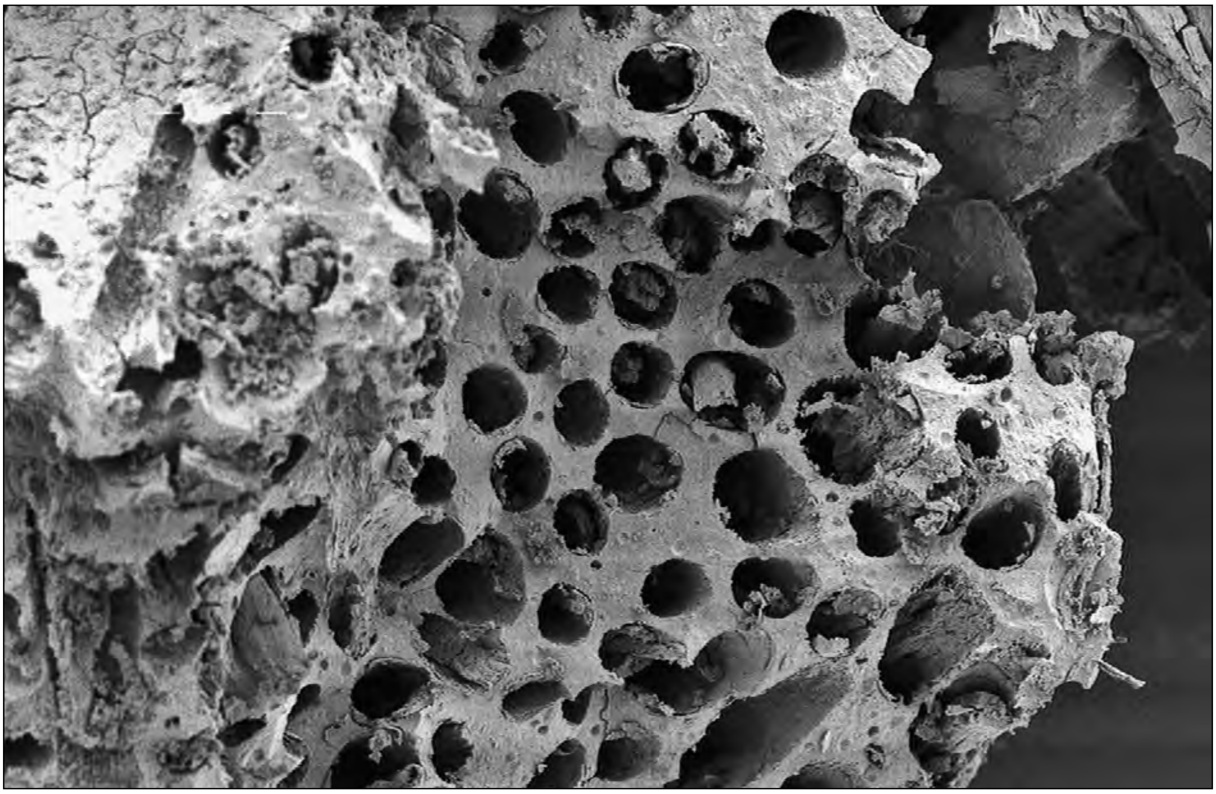

Fig. 290. Cross-section of a late Iron age thread, La Tène D, Lausanne-Vidy (CH)

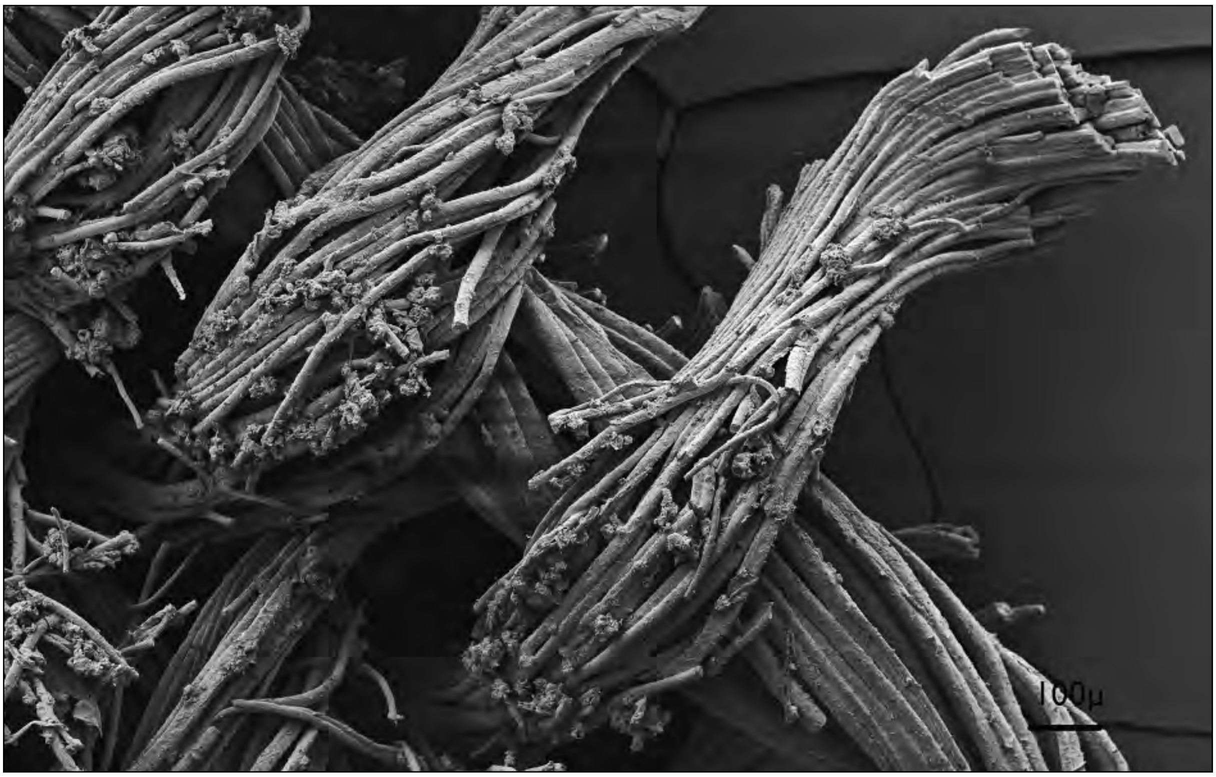

Fig. 291. Fine wool used for very fine threads, Early Medieval, Saint Denis/Paris (F)

4.9 Human hair

4.9.1 History

Human hair can of course be part of any archaeological site, especially with grave finds.

A person's hair style or color would have been part of the whole costume. Portraits of women from Ancient Rome are a good example of this important connection, with many even being dated according to the hair style of the day. Ancient Celtic men were famous for their colored hair and spiky style (Tac. Ger. 38). The knot of the *Suebi* (Germanic tribe) was considered the mark of a free man. Depicted in Roman art, this was found preserved in Oesterby Man (Schleswig-Holstein, D; Gebühr 2002).

Hair fashion is a relevant form of expression throughout all periods and regions, not only of the individual but of his era, tradition or ethnicity. Wigs have been known early: they were common in Pharaonic Egypt, and Roman women used wigs made of blonde hair (of captive Germanic women) (Ov. Am. 1,14,45-6; Bartman 2001). In the 17th and 18th centuries, hair was turned into high quality wigs known as *"Perüken"*. The hair was purchased from women in such places as Piemont (Italy), or more specifically from the remote village of Elva. The complex construction of these wigs required the use of a wood support (e.g. in Konstanz: Röber *et al.* 2008).

Human hair (even skin) has been cause for superstition, even in modern times. The soul, or life itself, was believed to exist within the hairs. Tales such as "The Devil and the Three Golden Hairs" or "Iron John" were authored by Grimm and are full with ancient beliefs and rituals (Grimm's fairy tales, online: en.wikipedia.org/wiki/Grimms%27_Fairy_Tales). In the Late Medieval Period, the skin and other body parts of someone who suffered a brutal death were believed to hold the life energy of the deceased. A piece of human skin that was worn as an amulet, for example, was found in its preserved state (now housed in a museum in Germany) (Germ. Nationalmuseum Nürnberg, Inv. TSb46; 15th c.).

In forensic science and anthropology human hair has been studied since the earliest days of microscopy (Seta *et al.* 1988 with references). From observation of physical states (e.g. crushed hairs, abnormalities) to elemental analysis, hairs can offer a wide range of evidence (Seta *et al.* 1988, 128ff.).

4.9.2 Fibre properties

Human hair has no underwool (there is no double coat as with sheep); fibre diameters for scalp hair will range from dm. of 50–90µ which vary according to hair type (smooth, wavy, kinky) as well as age and sex (e.g. Europeans 50–70µ, Chinese 65–90µ) (Seta *et al.* 1975; Seta *et al.* 1988, 68). Scalp hair color may vary on the same individual. Cross-sections will depend in general on racial factors (Western Europeans being oval for example) (Seta *et al.* 1988, 88). Body hairs will differ from hair found on the head. Pubic hairs, for example, are generally wiry and with an oval cross-section; beard hair will be coarse. Body hair fibre will usually show rippled and narrow margins on the scales (*Fig. 292*). The medulla is small and partly interrupted, or nearly not visible, the medulla index (dm medulla : dm hair) is for human hair less than 0.30 (*Fig. 293*). Again, there will be variants according to age, sex and provenance and there are, of course, important differences from animal hair.

4.9.3 Archaeology

In inhumations, well preserved hair and even elaborate coiffures have been found in Northern Europe in Bronze Age oak-log burials (Broholm – Hald 1940), in Pre-Roman Iron Age bog bodies (e.g. Fischer 2012, Hald 1980, Van der Sanden 1996), and in waterlogged burials of the Roman Iron Age in Northern Europe (Munksgaard 1974, 194–202).

Mineralized hairs have been found on interred bodies, most often if there has been exposure to earrings (*Fig. 294*). The Late Antique burials at St. Maximin in Trier have given evidence of beard hairs (Reifarth 2013, 18). Church graves from later times might contain well preserved hairs. One fine example is long hair that belonged to the Merovingian Queen Bathilde (Chelles/F) († 680) (Laporte – Boyer 1991). Another would be recently analyzed hairs from the Merovingian Queen Arnegundis († 580/81) (*Fig. 295*). An Early Modern find in a house from Oberägeri (CH) exposed three carefully packed hairs in a neatly folded piece of paper that had been deposited in a wall together with a small piece of silk (Rast-Eicher, unpublished report). Wiry and apparently pubic hairs, this may have been an effort to symbolically hold power over the person. It brings to mind the superstitious tale by Jeremias Gotthelf's in which the black spider (the devil) is enclosed in a wall to prevent evil (Gotthelf 1842).

Hairs were also used to braid objects such as chains or nets. A Medieval hair chain has been found in Greenland (Østergård 2009, 108). Wigs have been found in Early Modern graves, an example being an 18th century woman, buried in a church in Konstanz (D) found wearing a baroque-style wig in which the hairs were held together with fine wood strips (Röber *et al.* 2008). In the 19th century, ornaments made of human hair were popular in northern Europe (e.g. Vasstrom 1984).

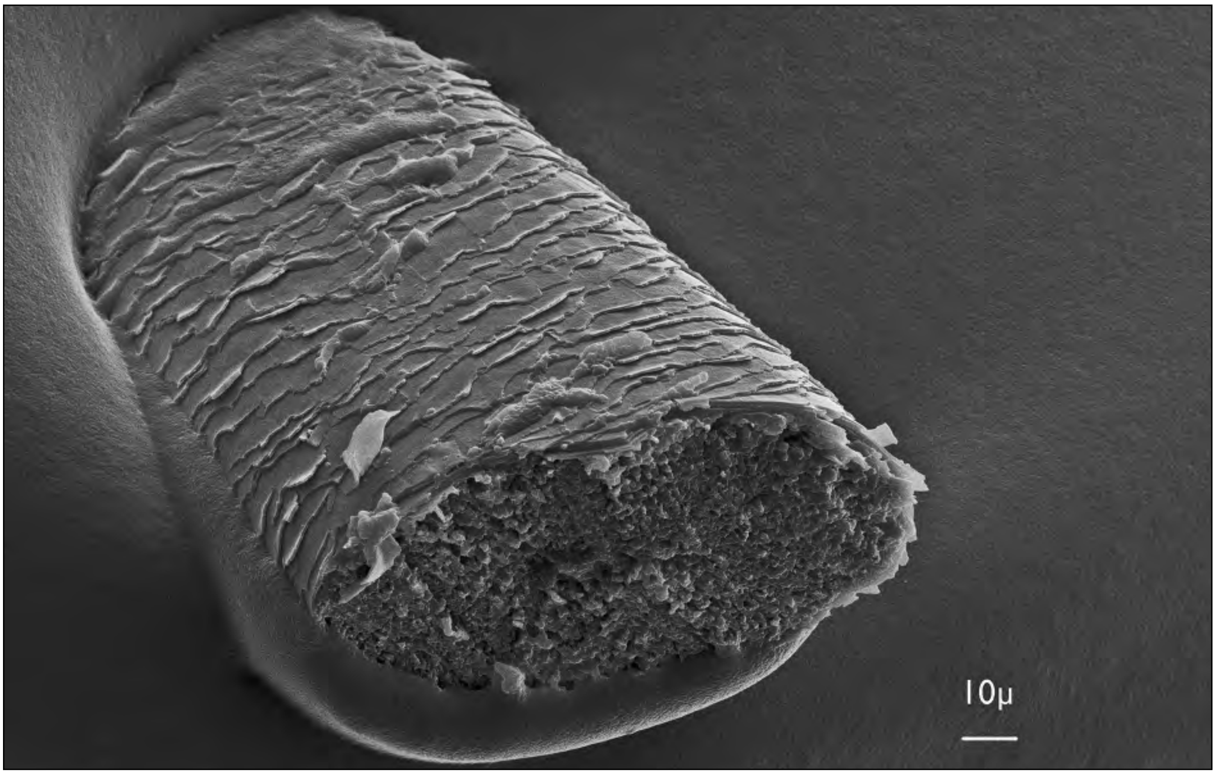

Fig. 292. Human hair, modern

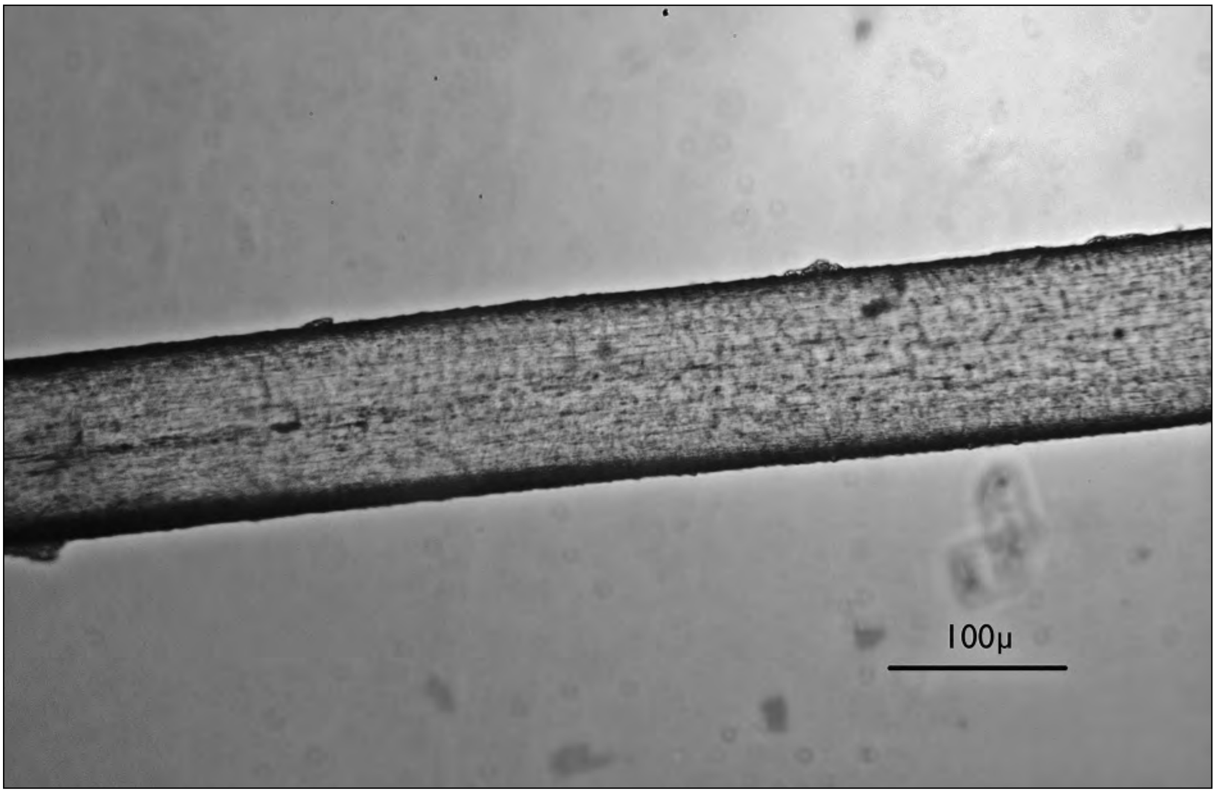

Fig. 293. Human hair, modern

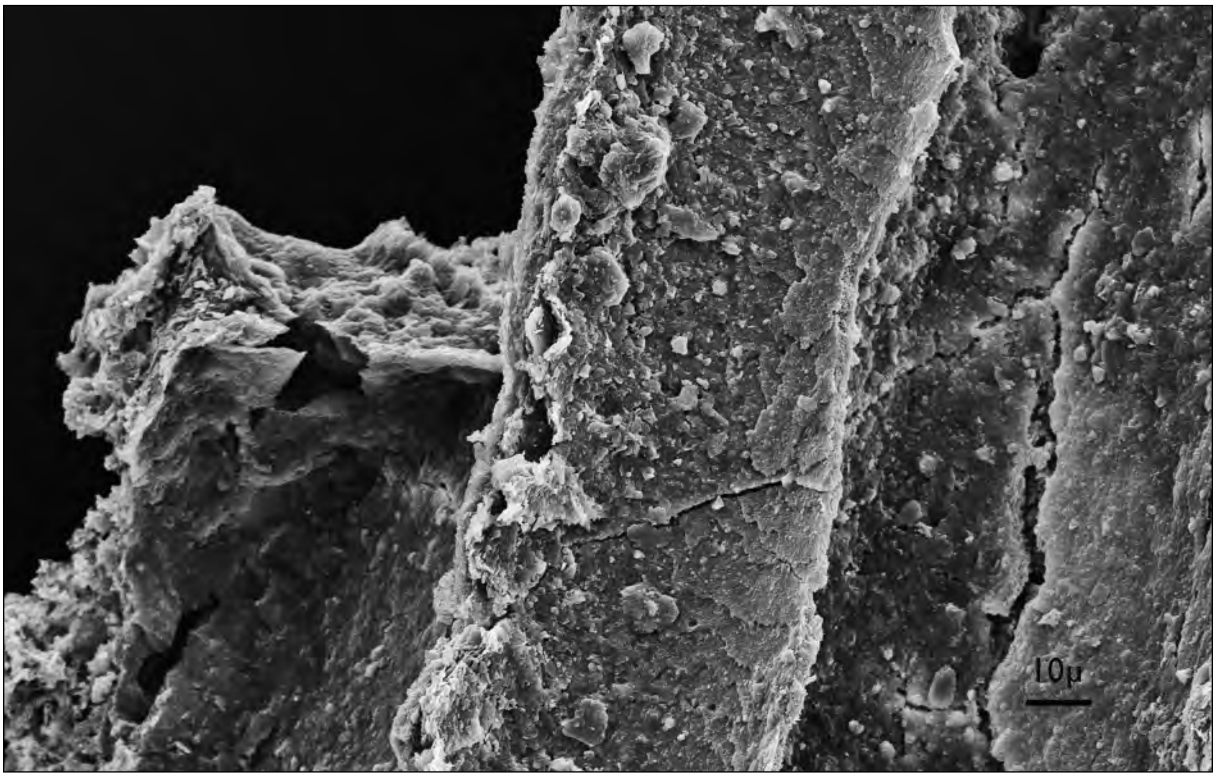

Fig. 294. Human hair mineralized on an ear ring, Early Medieval, Dielsdorf (CH)

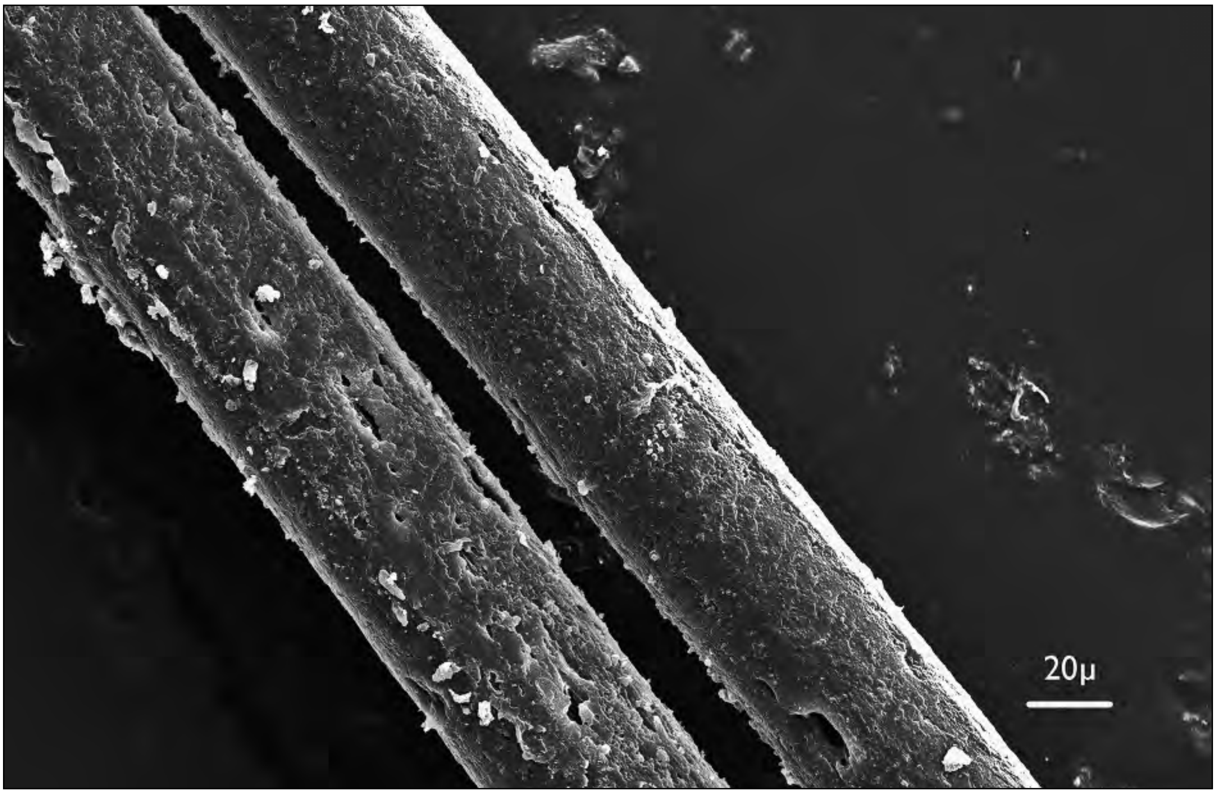

Fig. 295. Human hair, hair of Queen Arnegundis, Early Medieval, Saint Denis/Paris (F)

4.10 Silks

4.10.1 Introduction to silk

Silks are primarily classified as either *domesticated (Bombyx mori) or* wild (the so-called “tussah silks”). They are then identified as being either univoltine or bivoltine. The ability to determine silk fibres, more so than with other fibre types, is very much dependent upon their state of preservation. The most important criteria come from studying the cross-sections of the fibre as the outer most part is smooth and not well suited for observation. An initial look at silk under the stereo-microscope may well indicate if the fibre is reeled (domesticated/*Bombyx mori*) or wild (“tussah silks”). Threads of reeled silk will usually have little, if any, spin, something that is not necessarily inherent to its makeup as the fibre itself is endless. Spin would furthermore diminish its lustre. The threads consist of completely parallel or horizontal fibres. Wild silk, on the other hand, will often not consist of endless fibres. This is something that will depend upon the handling of the silk as it was taken from the abandoned cocoon as well as with its processing later on. *Bombyx* silk can be differentiated from the wild silks by its triangular cross-sections; the wild silks will be flattened or appear nearly rectangular in cross-sections (Nunome 1992). A third “silk” comes from the *Pinna nobilis,* a large mollusque of the Mediterranean (see chapter 4.10.3). The cross-sections of the latter are oval (see *Fig. 303*) and very distinct from the domesticated or wild silks.

Present research has shown that the early silks found in Europe are mostly of *Bombyx* silk, with very few wild silk specimens (see *Fig. 298*). Differentiating the wild silk species from one another is difficult. From an archaeological standpoint, this author believes it is not possible to do so through optical means alone. Silks have not yet been identified as having been present in Prehistoric Europe. Nearly all suggested “silks” (Good 2011) – Altrier, Hohmichele, Hochdorf, Chiusi and Kerameikos – have turned out to be other types of fibres (wool or vegetable fibre) (Bender Jørgensen 2013). It is still a mystery as to which type of silk Aristotle refers to when he writes of Pamphile from Cos as the first silk weaver (Aristot. Hist. An. 5,19). We can assume from writings from Antiquity, that one of the two silk species – *Saturnia pyro* or *Pachypasa otus* (Forbes 1930) – was known in Southeastern Europe. One hint given is that this silk had to be combed. Pliny wrote a passage about Pamphile and the silk that was first spun by her (Plin. nat. 11,26). Furthermore, it is also unknown if during early history *Bombyx* silk was reared in India as well.

Silks were not only used for quality garments. For example, in the Early Medieval Period the Alamannic people used silk textiles to bind head wounds (Lex Alemannorum 57, 7).

4.10.2 Wild silks (non-mulberry-silks)

4.10.2.1 Habitat

China, India, Africa – depending the species.

4.10.2.2 History

The earliest use of wild silk in Europe remains a mystery. The word *“serica”* found to indicate this material does not indicate if this was a domesticated form of silk or not. Aristotle wrote about Coan silk production and that the silk had to be combed. This is the method used in the case of wild silks where the caterpillar has escaped the cocoon and the remaining fibres are now only good if spun. Two species of Mediterranean silk worms could have been used: *Saturnia pyro* for brown silk, and *Pachypasa otus* for white silk (Forbes 1930). An interesting fact is Pliny the Elder mentioning the kind of food attractive to the two Mediterranean silk worm types – the oak and ash trees – but not eaten by the *Bombyx mori* species.

Table 5. Different non-mulberry silks (Peigler 1993; Chowdhury 2004)

Species	Diet	Color of fibre	Area
Bombyx mandarina	oak	yellow	originally China
Antheraea perenyi	oak (Quercus mongolica)	écru, tussah	China, now semidomesticated
Antheraea melitta Antheraea prolei	oak	tasar; brown	India
Antherea assama	Machilus bombyciny, Latsea polyantha	gold-yellow; Muga silk	Assam (India); now semidomesticated
Philosamia cynthia Philosamia ricini	Ricinus communis	varies in color; Eri-silk	Mainly North-East India; filaments discontinous; now domesticated
Attacus atlas	Ligustrum vulgare, Prunus laurocerasus	brown	China, Australia, Afrika Fagara silk
Pachypasa otus	pine, ash, cypress, oak	white	Mediterrenaen, SEEurope
Saturnia pyro	ash and others	brown	Mediterrenaen, SEEurope

The term "tussah" is derived from the Hindu *"tasar"*, is used primarily for *Saturnidae* silk and now for all wild silks (Liddiard 1982). According to Chinese texts, wild silk cocoons were collected and yarns were produced from the silks that came from them. This was especially true of the Chinese oak silk worm, *Antheraea pernyi*. During the Ming dynasty, five wild species of silkworm were used (Yangun *et al.* 2010). *Antheraea pernyi* originating from Southern China was already known during the Han and Wei dynasties (Arunkumar *et al.* 2006) and was by the 17th century farmed in this area as well (Liu *et al.* 2010).

Tussah is difficult to reel, with wet reeling and prior bleaching making the process easier. To produce even yarns, three half-reeled along with three new cocoons can be taken together. The best quality type is known as "pongee" silk (Liddiard 1982).

Based on new finds, the question of silk in the Indus valley has been discussed (Chowdbury 2004; Good *et al.* 2009). There is no silk from India that has yet been determined in Europe even though the ancient sea route between India and Egypt would certainly have made it possible to import the product, the latest by the Roman Period (Schiettecatte 2012). Wild silks, had to be spun (because of their makeup coming directly from the cocoon) and this limited their dye properties as well as compromising their luster. It also wouldn't have been white. These factors made it a less desirable product than the finest white silks called *Bombyx mori*. And when the samite weaves were introduced in the Mediterranean countries, their dense surface warps that gave high visibility to color called for color-friendly material.

4.10.2.3 Fibre properties

Tussah fibres are generally larger than *Bombyx* fibres and show a flatter cross-section. In the longitudinal view stripes can be visible which implies less filament length (*Tasar*: 700m, *Muga* and *Eri* 450m) (Kushal – Murugesh 2004) (*Figs 296* and *297*; *Table 5*). Tussah silks have less sericin than *Bombyx* silk. This makes it chemically slightly different from *Bombyx* silk and so it is more resistant to corrosive reactions from alkali. This is a precise advantage for the administration and fixing of some dyes (Indigo!) (Liddiard 1982). The color of the fibre will depend upon the nutrition that the larvae is receiving and many shades from yellow to green to brown are possible. *Bombyx* silk will need twice as much color for the dye bath as wool. Tussah silk will need even three times that due to the flatness of its fibres (Liddiard 1982). The Indian *Tasar*, *Muga* and *Eri* silks can be differentiated through amino analyses. Looking at cross-sections from *Tasar, Muga* and *Eri* silks one will see how problematic the determination of fibres will be. *Bombyx* silk is the finest fibre whereas *Tasar* and *Muga* are quite large (20–30µ) and flat in cross-sections, with flatter fibres only being in the inner layer of the cocoon. *Eri* silk shows a very similar triangular cross-section to that of *Bombyx mori* except for it being a bit larger in diameter (15–20µ). The longitudinal view of these fibres shows differences as well: the *Tasar* silk has a distinct longitudinal striation whereas the *Muga* and *Eri* silks do not (Kushal – Murugesh 2004). In an archaeological context, where color has mostly disappeared, differentiating *Eri* from *Bombyx* silks could prove to be very difficult.

4.10.2.4 Archaeology

Silks found in Europe are, with few exceptions, *Bombyx* silks. There are NO prehistoric silks north of the Alps (see discussion in Bender Jørgensen 2013)! Spun silks such as in the St. Paulinus silk in Trier (D) could be made of wild silks, but this has to be stated by an analysis (Wild 1984; Reifarth 2013, 87). Badly preserved wild silks would be very difficult to spot; flat fibres would be seen as badly preserved plant fibres. The rare tussah silks have been found in Germany, one of them in a Late Antique grave from St. Maximin in Trier (D; Reifarth 2013, Abb. 174/21; *Fig. 298*). Another has been documented in a sarcophagus near Cologne dated to the 3rd c. AD (Stauffer 2007). In church collections (relics) a few have been found, among them a non-woven silk made with the cocoon sheet (Vial 1985).

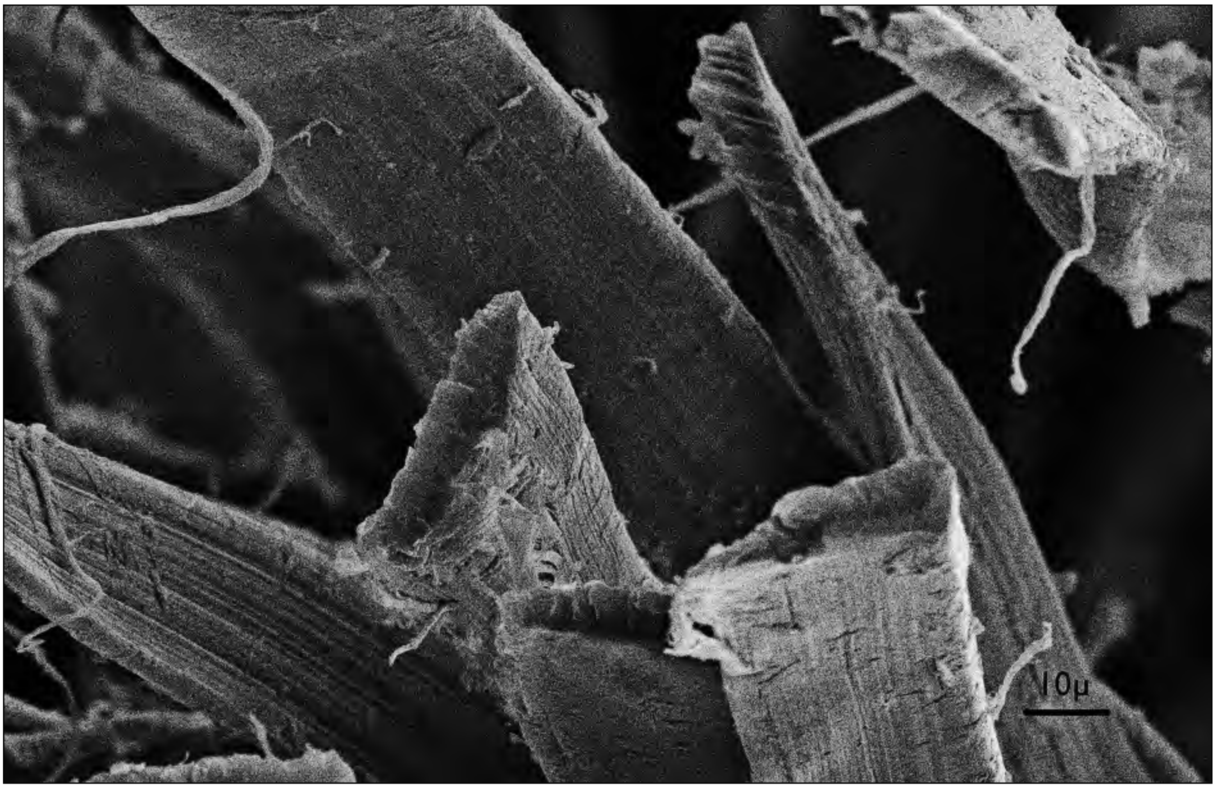

Fig. 296. Tussah silk, modern

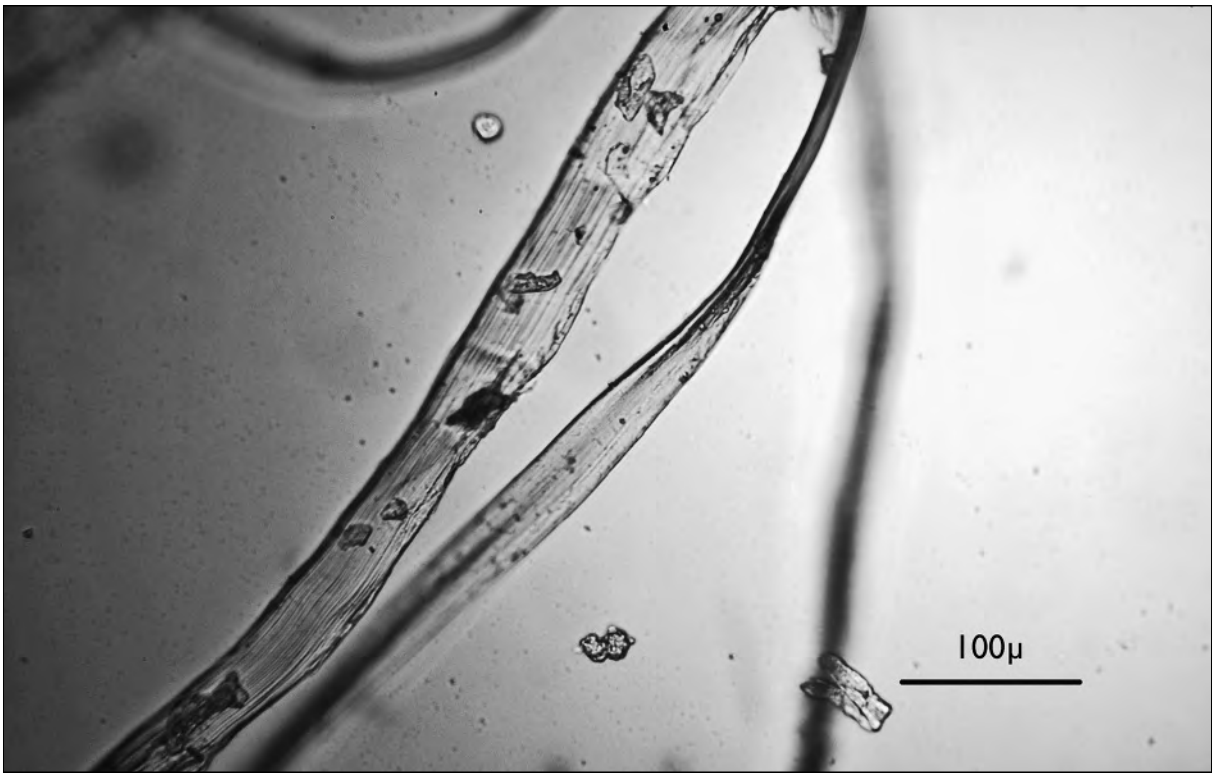

Fig. 297. Tussah silk, modern

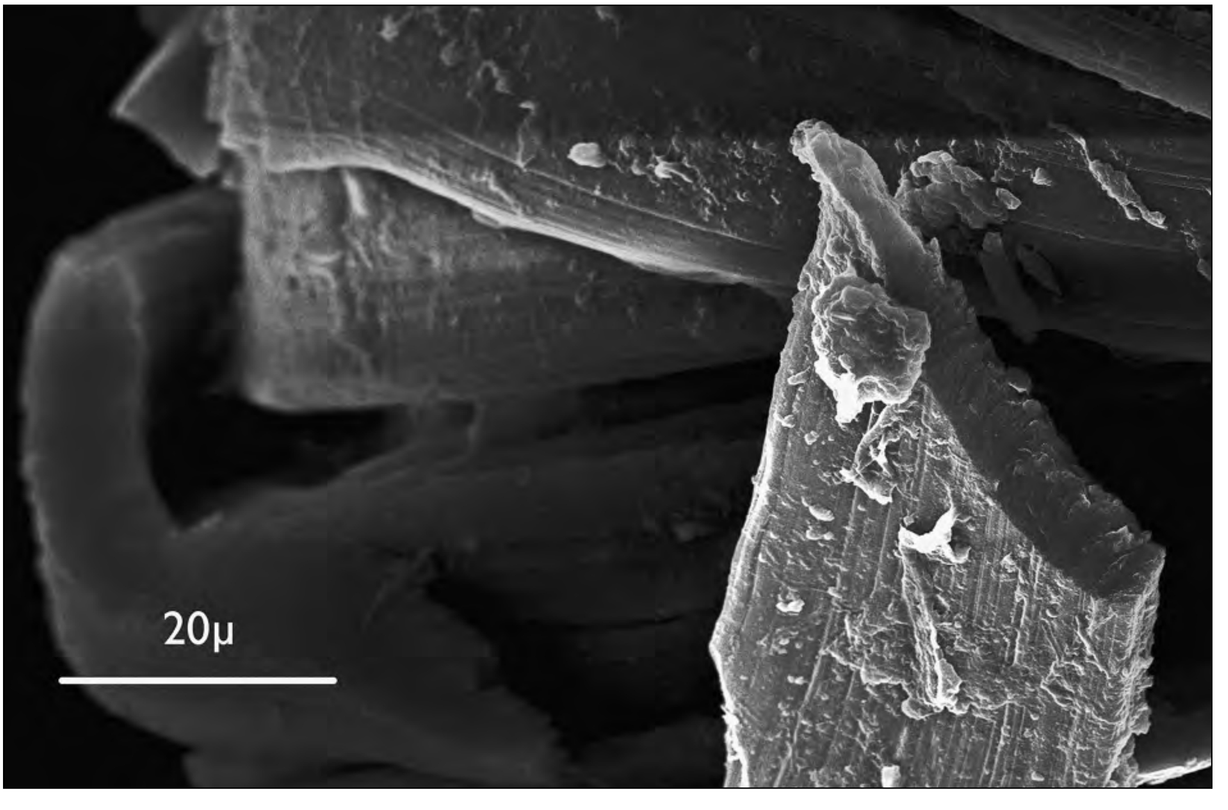

Fig. 298. Tussah silk, St. Maximin, Trier (D). Photo N. Reifarth

4.10.3 Domesticated Silk (mulberry silk) Bombyx mori

4.10.3.1 Habitat

Mulberry silk worms live where mulberry trees grow.

4.10.3.2 History

China: silk domestication and early finds

Silk was domesticated in Neolithic China. Recent DNA analyses point to a unique domestication event and the Chinese *Bombyx mandarina* as progenitor of *Bombyx mori* (Arunkumar *et al.* 2006; Xia *et al.* 2009). The wild *Bombyx mandarina* from China has the same amount of chromosomes as *Bombyx mori* and can cross-breed. The domesticated silkworm, however, cannot survive without human support. Early inscriptions dedicated to the "silkworm god" have been found on turtle shells (the oldest 4887 ±96 BC), cocoons found in the Shanxo province (dated to 5000–3000 BC) and a barrel with silk pupae (from 5400 BC), all of which point to a very early use of silk (He 2011). Already by the Xia dynasty (2070–1600 BC), female mulberry harvesters were appointed in the royal household (Hao 2012, 66). Early depictions on oracle bones show an early divination of silk (He 2011; Kuhn 2012, 67).

The story of how the first silk worms were carried beyond China is well known: a Chinese prince and princess were married in Kothan (today Northwestern China) and the princess carried silk worms hidden in her hair. Etienne de La Vaissière recently proposed a date for this kind of occurance which, according to early texts from a Buddhist monastery in Kothan, would be sometime between AD 280 and AD 310 (La Vaissière 2014).

Cocoons are thrown in hot water to kill the worm and soften the sericin so that the fibre can be reeled. Any remains of sericin still coating the silk fibres after this process are taken away with later washings of the yarns in warm soapy water (i.e. degumming).

The draw loom came about in China at the latest during the Han Period – it is described in a text dated AD 89–158 (Kuhn 2012, 56). An earlier find of silk textile dates to the Neolithic (ca. 2770–2500 BC) (Hao 2012, 72). By 1000 BC sericulture was fully developed. New analyses have shown that not only was the domesticated *Bombyx mori* used but the wild ancestor *Bombyx mandarina* as well (Liu *et al.* 2011).

The earliest looms were back-strap looms but by the 6th c. BC the horizontal treadle loom is documented to have been in use. By the 1st c. AD the draw-loom was invented (Kuhn 2012, 55f.). The early Chinese silks are characterized by the dominance of the warp, such as with the warp-faced compound tabby. Even imitations of western design by the Chinese weavers (patterns woven in the weft) were imitating the patterns originally woven in the warp. In the first half of the 8th c. AD Persian merchants had brought western designs and technology to China and weft-faced textiles appear. At the same time, Chinese weavers were also working in Baghdad (Kuhn 2012, 31).

Early silks in Europe

Many writers refer to the Procopius (500–565 AD) story of a monk bringing eggs of the mulberry silk worm in a walking stick from Serindia to Byzantium (Proc. De bell. Goth. 4, 17). Muthesius quotes from other texts as well, such as Theophanes of Byzantium (end 6th c.), that silk worms were probably imported from Syria to Byzantium. Chinese documents from the 3rd c. AD mention a place called *Ta-Chin*, where domesticated animals such as "mules, camels and mulberry worms" can be found and which was supposed to have been Syria (Muthesius 1993). Chinese reports about the Romans that they had a flourishing sericulture (Liu 1998, 74, note 1). Also in this report is a date given for the beginning of silk production in the West as being at least a hundred years earlier than that in Procopius's story.

Silk was known still earlier, in the Roman Empire. It was considered a luxury item and immoral as well for women and men to wear. Roman authors of the 1st c. do not seem to be educated in the details of silk production, although it didn't prevent some of the most famous people from those days from donning silk textiles. Already in the 1st c. BC Cleopatra is known to have worn a silk dress, and both Caligula and Ceasar possessed silk curtains (Dio. Cass. L. 59; L. 43). In lyrics (Horaz, Tibull) Coan garments are mentioned. Cos has repeatedly been argued as a place of Mediterranean silk production (e.g. Good 2011), although at present there is no solid evidence of this. A depiction of a silk butterfly has been found in Crete, dated to the Bronze Age (Panagiokatopulu *et al.* 1997).

In Antiquity, there was some astonishment about the Parthian silk flags made of silk (Flor. epit. 46,11). It is interesting that Pliny talks about feeding the silk worms with oak or ash (*quercus*, *fraxinus*) an indication that points to wild silk (Plin. nat. 11,27). Another important source is the *Periplus maris Erytraei* (Periplus). The worm from Hindustan is mentioned which would again indicate a native worm, although not *Bombyx mori* (Good 2009; Schiettecatte 2012).

By the 3rd c., silk became quite a normal product for the Romans and the ancient authors seem to know much more about the worms. Pausanias wrote about breeding the animals in houses (Paus. 6,26,6–7). Different dress qualities (half-silk, full silk tunics) are mentioned in Diocletian's price edict (AD 303) (Lauffer 1971). Damask silks of the 4th c. (Conthey/CH; St. Paulinus Trier/D) have spun warps and could therefore have been produced within the Roman Empire (Wild 1970, 12; Wild 1984). The *samite* weave which was developed in the Mediterranean, became the most important weave for patterned silks until the 14th c. (Desrosiers 2004). The Codex of Justinian (6th c.) makes clear that silk production is a state monopoly and that the silk textiles must be made in state workshops (*Gynaeceae*) (Cod. Iust.).

Isidor (of Seville) interestingly compares wild silk with Chinese silk, describing the differences whereas *Bombyx* is the silk from Cos and *serica* the one from the *Seres* (Chinese):

"Bombycina e bombyce vermiculo qui longissima ex se fila generat, quorum textura bombycinum dicitur; conficiturque in insula Coo. Apocalama. [14] Serica a serico dicta, vel quod eam Seres primi misurunt." (Isid. Orig. 19,28,13–14).

Silks have been found in the Early Medieval European elite graves, as with the Merovingian family at Saint Denis/Paris (F). Dated from the 6th c., the majority of the samit weaves have come from the Mediterranean; there are a few Sassanian silks and even Chinese silks with a distinctive pattern in the warp (Desrosiers – Rast-Eicher 2012; Desrosiers 2015a). Interesting is a remark made by Grégoire of Tours in his "History of the Francs" from the 6th c. AD. He states that a silk mantle brought from afar had been cut and made into another garment: *"De palla quod repotarent, protulit monachem nobilem, quae ei mafortem olosyricum, quem de parentibus detuli, muneris causa conceserit, et inde partem abscidisset, unde quod vellet et faceret…"* (Greg. Tur. Franc. 10,16). The garments had, obviously, to be fashioned in the local tradition and even expensive textiles were cut to adapt to local taste.

Silk Road, trade

The term "Silk Road" was invented in the 19th c. and it describes the very long trading route (ca. 6500 kilometres) from China to the Mediterranean Sea, via Central Asia and with a northern and a southern variant around the desert of the Taklamakan (Timmermann 1985, 192; Whitfield 2000, 1–26). There has been documentation of the silk trade since the 5th/6th c. BC. However, the people living in the Oasis of the Silk Road (especially in today's Xinjiang/China) were mostly based in the production of wool; the beginnings of silk production on the Silk Road (with the wild silks as well) is therefore difficult to find (Debaine-Francfort – Abduressul 2000). By 400 BC contacts to India were settled. Under the emperor Wu of the Han Dynasty (140–87 BC), there were Central Asian connections and the creation of an alliance against the Huns. The southern route from China to India was also explored (Haraprasad 1995). Nomadic tribes in Central Asia were trading their horses for silk (Liu 1998, 56). By the 1st century BC the Romans knew about and imported silk yet, as mentioned, they were not familiar with the processing techniques of this material. Several of the *sericarii* (silk dealers) are active in towns such as Palmyra (Syria) as well as in Rome (Ruffing 1999, 367; Finlayson 2002). The route over land was not the only connection between east and west; the sea route via India was also very important and as the finds from Berenike (port at Red Sea, Egypt) prove, they were used in Early Historical times linking Rome to Indonesia (see ch. 3.1.1; Wild – Wild 2014). Sailing was limited to certain wind constellations during the monsoon season, but it made a direct sailing route possible from India to Arabia without having to follow the coast (Stiles 1993, 156; Schiettecatte 2012). Multinational trade networks from the Red Sea to India were working up until the beginning of the 6th c. It was then that Ethiopian rulers began to take control, followed later by the Sassanians. One reason for this development could be traced to a type of ship that the Ethiopians possessed that was better suited to the conditions of the Indian Ocean (Christides 2013). Another reason could have been due to the closure of the land route due to the Roman-Parthian conflicts (Stiles 1993, 156). Trade was not only from east to west, but also from west to east: see chapter 3.1.1.2, "cotton". The Chinese imported from the Mediterranaen world as well, introducing to China silks woven in a weft-faced compound tabby and establishing this type of silk weaving to China (Liu 1998, 17f.).

Medieval silks

By the 10th c., Islamic and Byzantine silk production was equivalent (Muthesius 1963, 60). Byzantium had monopolized purple silk production but the Persians and Arabs were equally important traders (Liu 1998, 90). In the 11th c. an important step in weaving technology came about in the Near East with the development of a draw loom that enabled the production of the *lampas* weave. This loom type was brought to Southern Spain with the Arab conquest of that region (Desrosiers 2004, 23). Roger I. of Sicily, in the 12th c. brought silk weavers to Palermo and in turn Palermo became an important center of Medieval silk production. From Palermo, silk production was brought to Italy and Spain. The new Medieval centers were Lucca, Florence, Bologna, Genova and Venice. In the 14th/15th c. the weavers of Florence and Venice developed the velvets (Monnas 2008). From 1470, Tours (F) became a silk weaving town followed by Nîmes (F) and Avignon (F). In the Middle Ages silk became the cloth used for the sacred vestments of the church (Liu 1998, 89). The relics of saints were often wrapped in silk or put into silk bags and silks were stored in church treasuries (Liu 1998, 115).

By the 15th c., Lyon (F) was chosen as a center for the silk trade eventually developing into an important place for the production of silk as well. It was here that J.M. Jacquard invented the mechanized draw loom with perforated cards (1801). With the revocation of the edict of Nantes (1675) which protected the Protestants in Lyon, the Huguenots were forced to leave the country, bringing their silk weaving skills away from Lyon to Germany and England (Currie 2001). Today, Lyon continues to retain a few silk weaving firms that produce high quality textiles worked on the draw loom by hand.

4.10.3.3 Fibre properties

One cocoon contains up to 1000 meters of silk fibre. Reeled silk is the only fibre which can be used unspun. The silk fibroin is enclosed by silk gum and makes up about 1/4 to 1/3 of the cocoon. There is considerable loss of weight, then, when the fibre is degummed (about 25%). The fibres are 10–12µ in diameter and of triangular shape (*Figs 299* and *300*), with a protein amino acid sequence (Glišović – Vollrath 2010; Slootmaker – Müssig 2010, 316f.). Silk is not elastic and becomes less stable when wet. The transparent, triangular form and fibre diameter of *Bombyx* silk influences the dye properties of the fibre which means it needs twice as much dye as does wool, for example (Liddiard 1982, 396). Silk is a compact fibre and if it is badly preserved it will not show fibrils as wool would, but rather glass-like breaks (see ch. 2.2.3).

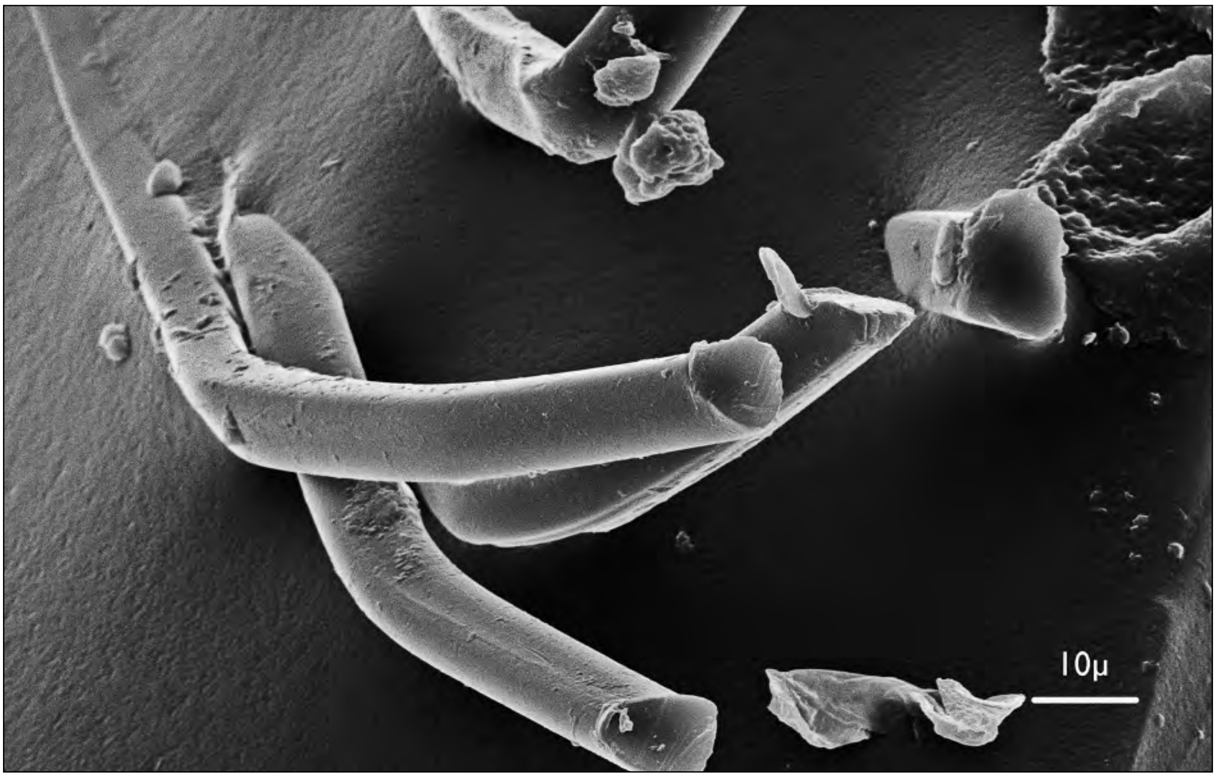

Fig. 299. Bombyx silk, modern

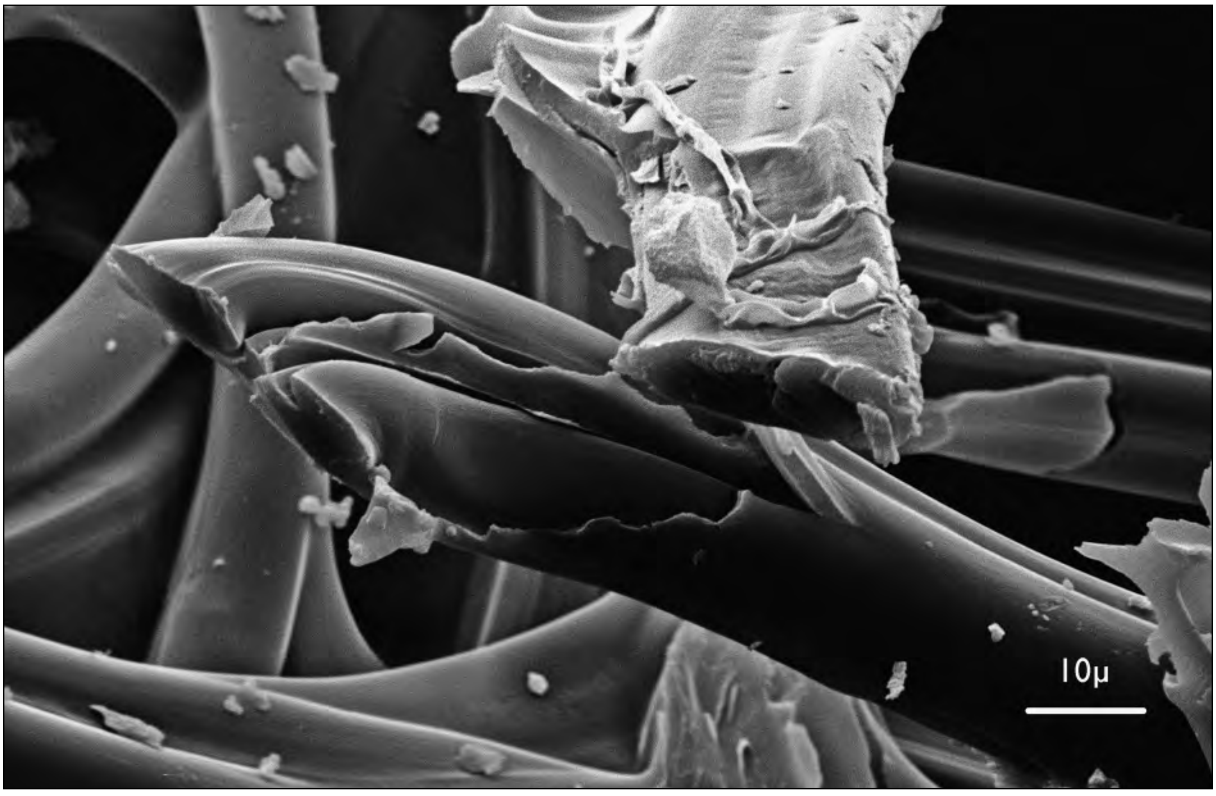

Fig. 300. Bombyx silk, undegummed, two filaments still hold by sericin, modern

4.10.3.4 Archaeology

There are innumerable silks, types having proliferated since the Medieval Period. Early silk finds have been discussed in depth (Bender Jørgensen 2013). So far, however, silk textiles dated earlier than the Roman Period have not yet been found in Europe. Many of the Early Medieval silks in Europe have been documented either in church contexts (reliquaries) or at older excavations where they have not been well dated. The exceptions to this, such as with the well documented graves of St. Maximin (Trier, D), Saint Denis/Paris (F) or Chelles (F), are therefore very important (Reifarth 2013; Desrosiers – Rast-Eicher 2012, Laporte – Boyer 1991). There are important differences to be found in processing methods which in turn lead to geographical attributions (for general discussion see Desrosiers 2015b). Among some of these Late Antique and Early Medieval silks are unspun or very slightly spun threads which are typical for *Bombyx* or reeled silk (*Fig. 301*; see *Fig. 71*); spun silk like the one from Unterhaching (D) (Nowak-Böck 2013, Fig. 34), is usually seen as being from Mediterranaen production. Lately, spun silk that hasn't been degummed has been found (see *Fig. 71*). Cross-sections of silk samples from Saint Denis/Paris (F) and Chelles (F) have revealed *Bombyx* silk which is mostly degummed (with a few double filaments only) (see *Fig. 74*). Silk that hasn't been degummed could suggest a Central Asian origin, however there are not enough examples at the present time to be sure of the provenance. Silks can also turn up in textiles that have undergone mineralization, as with the small samit fragment of Louviers (F) (Rast-Eicher 2008b, Fig. 65) (see *Fig. 35*) or the tabby from Unterhaching (D) with a sharp spun warp direction (Nowak-Böck 2013, Fig. 26 and 24). The cross-section from the Louvier piece shows well the triangular form of *Bombyx* silk. Not well preserved (and not mineralized) material from (Medieval) graves can be processed with an embedded cross-section and light microscopy to solve the question of the silk species (*Fig. 302*). The filament is not always well preserved, and a cross-section is needed to be sure (*Fig. 303*). In many church collections where textiles are found in graves or from relics, there is a clear picture of Medieval silk weaving (e.g. Sens/F; Chur/CH; Bamberg/D; Maastricht/NL). Silks of extraordinary quality have been found in the graves of kings or queens. Such is true of the garments and cushions in lampas weave from the grave of Eleanor of England, Queen of Castile (d. 1214), in Las Huelgas near Burgos (E). Another example would be the silk garments decorated with gold thread from the grave of Rudolf I of Habsburg (d. 1307) in Prague (Otavsky – Wardwell 2011, with ref.). Early Modern material is usually quite well preserved and presents fewer problems for fibre determination.

4.10.4 Sea-silk *(Pinna nobilis)*

4.10.4.1 Habitat

Italy, Sardinia, Corsica, Bay of Smyrna/Istanbul, indian Ocean.

4.10.4.2 History

Mussels of the *Pinna nobilis* were harvested by tearing them, together with their long fibres, from their host rocks. The best fibres came from those animals embedded in the sandy soil, however, as exposure on open rock can cause the fibres to become hard and dark. For processing they were first washed and dried, then combed with a wide bone comb followed by a narrower one and with the finest threads being brought through an iron comb (Gilroy 1853, 182).

In Antiquity, large textiles could also be made from sea silk: *"Nec fuit satis tunicam pangere et serere, ni etiam piscari vestitum contigisset: nam et de mari vellera, quo mucosae lanusitatis plautiores conchae comant"* (Tert. De pallio, 3,6). Procopius discusses the *chlamys* as well (Proc. aed. 3,c.1). The oldest textile known (lost unfortunately during the Second World War) was from a 4th c. grave in Aquincum (H) (Wild 1970, 12). Pope Leo IV (790–855) ordered *"pinnikon"* in Sardinia, which could mean *Pinna, a* genus of the *pen shell*. Jewish, Persian and Arab writers from the Medieval Period mentioned the use of "sea wool". *"Byssus"* has often been translated as linen, silk or cotton with *"byssus"* as a term used for the fibres of the *Pinna nobilis* and which appears as well in the 15th century. It is not clear what term has been used for these fibres during Antiquity. *"Muschelseide"* in German is first written in a book of the 18th century (Rudolph 1766, quoted in Maeder 2008). He writes about a fibre from the mussel *Pinna nobilis* in Southern Italy (Palermo, Tarento) which was used for items such as caps, gloves or socks. The mussel, *Pinna nobilis,* adheres itself to rock with its long fibres. Archaeological finds do not so far follow as transparently as the descriptions of *byssus*. According to historical texts, *byssus* was mixed or plied with silk. The oldest and quite well preserved object we have which is made of *byssus* is a cap dated to the 14th c. and was discovered in Saint Denis/Paris (F). In the 19th c. even large textiles were made from *byssus*; embroidery and fancy *"pelliccia"* (fibres used and mounted as pelts) were admired (*drap de pinne marine*, *gilets en vigogne* et *pinne-marine*). Textiles such as these were often offered as diplomatic presents and as a result spread around the world (Maeder 2008). See also www.muschelseide.ch.

4.10.4.3 Fibre properties

The fibres have a golden-brown color, a diameter of 10–30µ and an elliptical cross-section (*Fig. 304*). This variation in width is unlike the silks that have more regular diameters. This cross-section shows how it differs from other silks which are either triangular (*Bombyx* silk) or in an elongated triangle (wild silks). It is important to acquire a cross-sectional view rather than a longitudinal one. The latter would invariably lead to a conclusion of wild silk if, as is often the case, some fibres appear quite flat or even with a longitudinal striation thus resembling tussah silk (*Fig. 305*).

4.10.4.4 Archaeology

To date, textiles made of *Pinna nobilis* found in an archaeological context are wishful thinking.

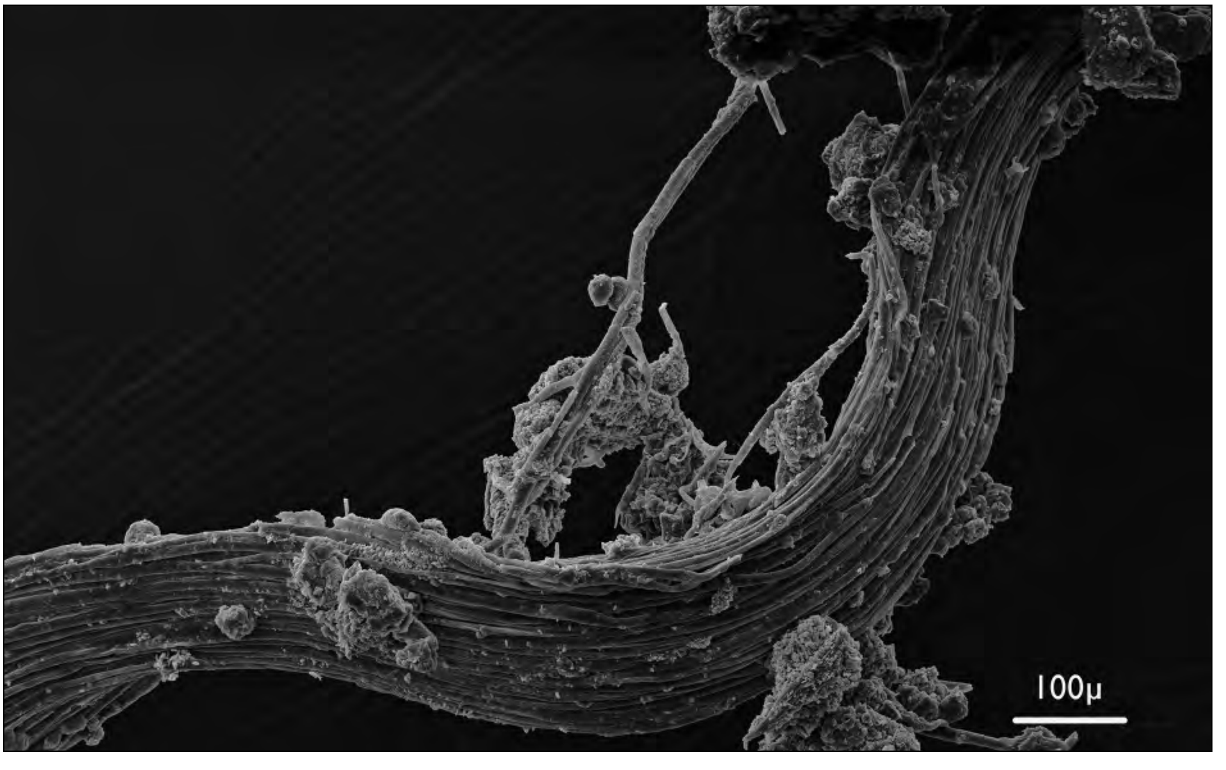

Fig. 301. Bombyx silk, 6th c., Saint Denis/Paris (F)

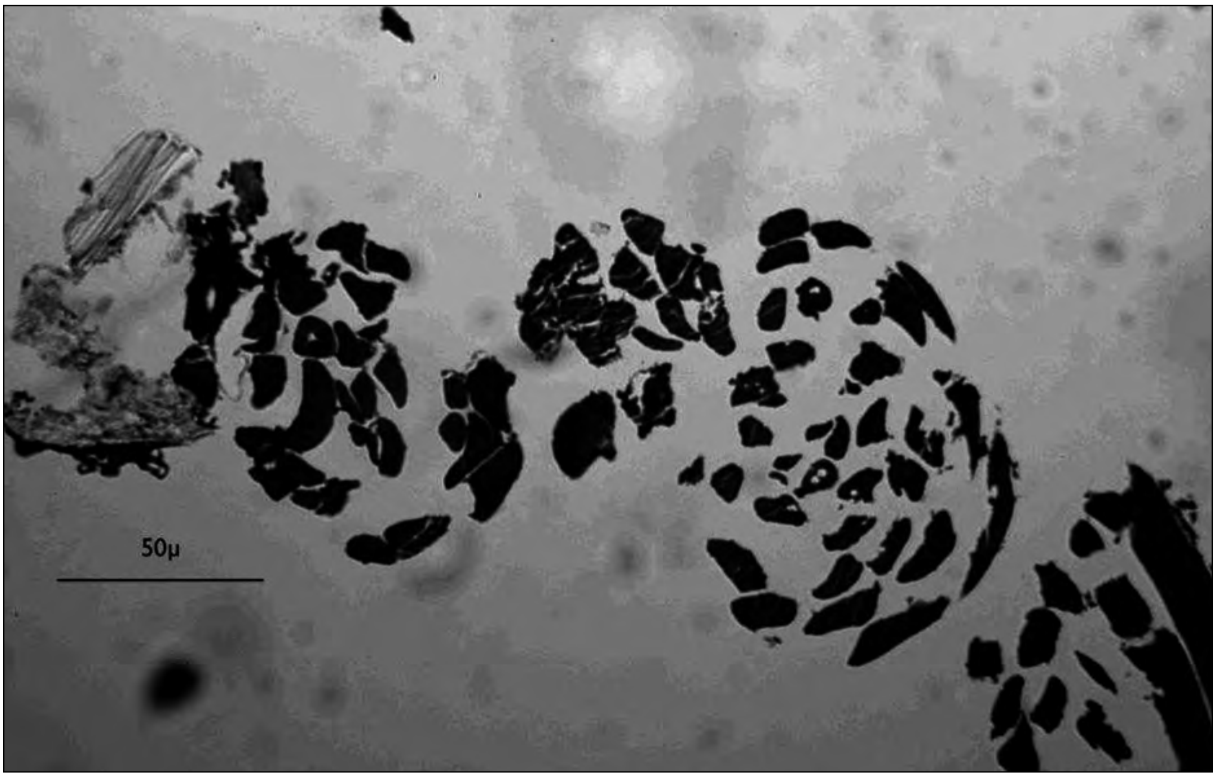

Fig. 302. Bombyx silk, embedded cross-section, Medieval, Prag (CZ)

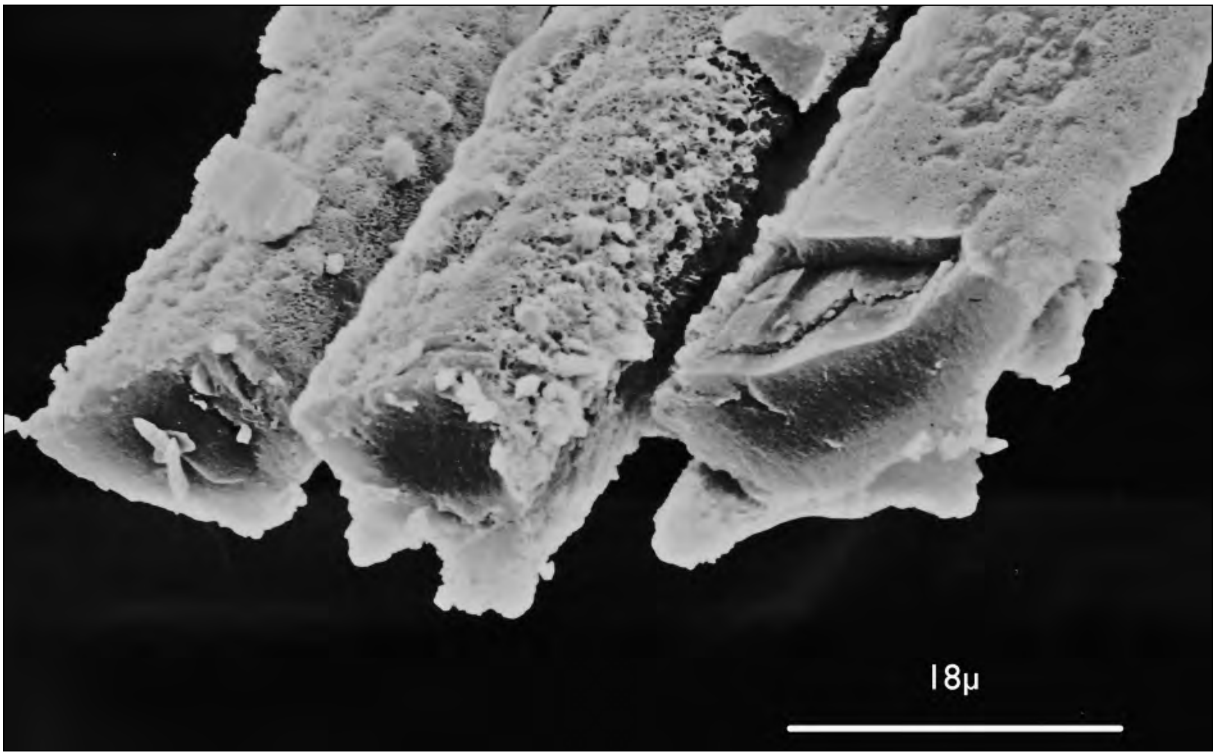

Fig. 303. Bombyx silk, longitudinal and cross-sectional view, Medieval, warp of a tablet-woven band mineralized on the back of a bronze decoration (mount), Morat/Murten (CH)

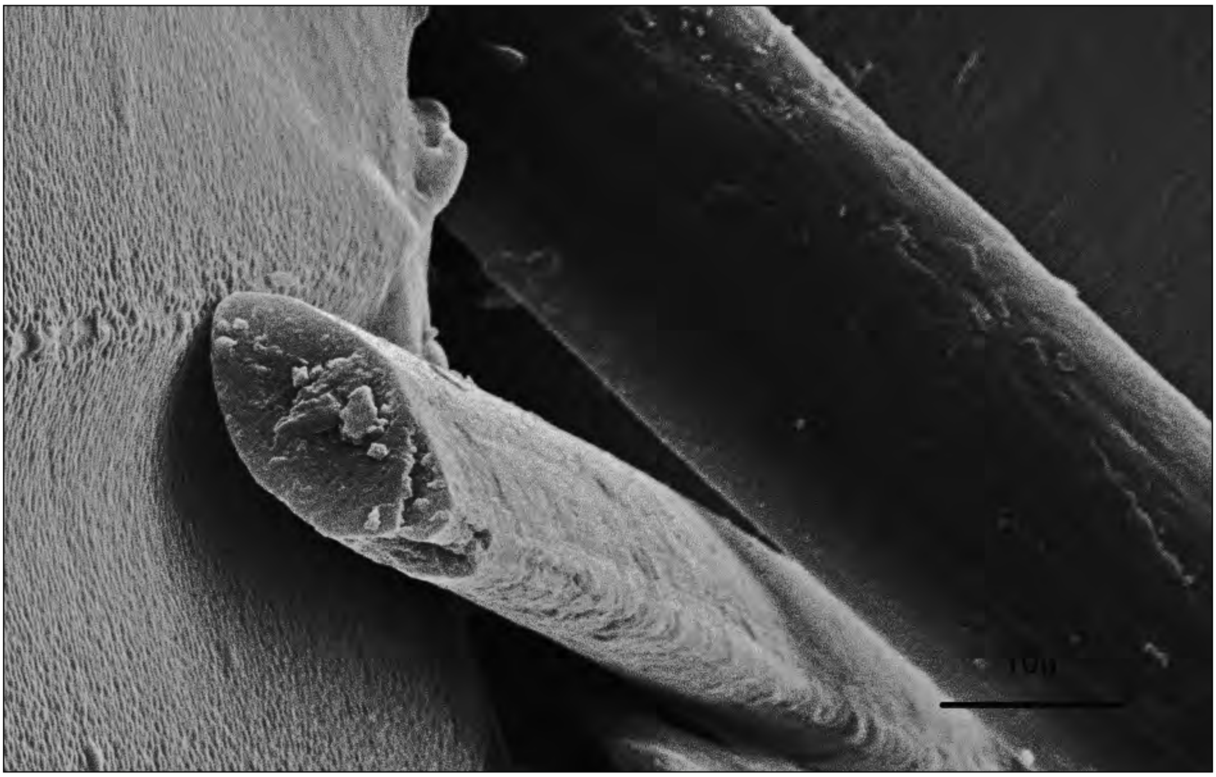

Fig. 304. Pinna silk, modern

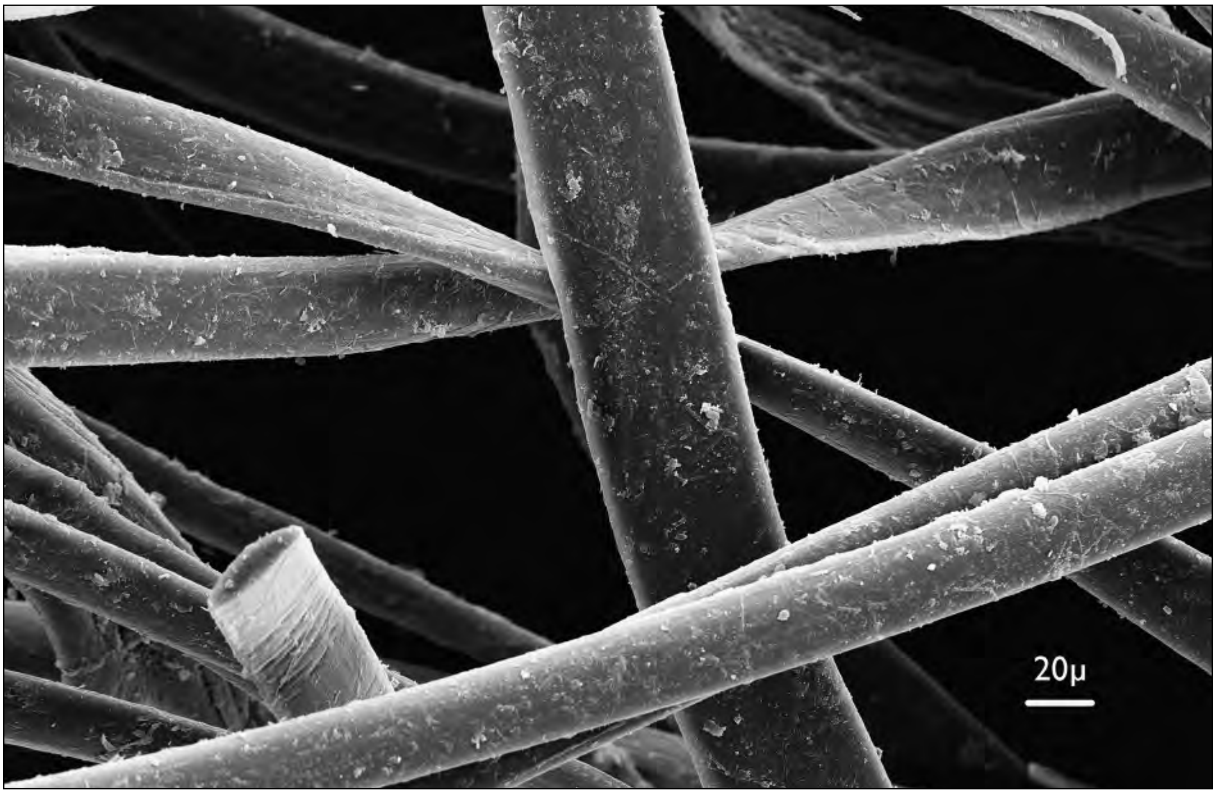

Fig. 305. Pinna silk, with flat longitudinal view, modern

5. Others

5.1 Mineral fibres: Asbestos

Asbestos is the only mineral fibre used in textile production (*Fig. 306*). Asbestos is a Greek word meaning "inextinguishable". It is a silicate mineral which is then separated into fibres that appear white. The fibres can be up to 5.6 cm long and are spun with a hand spindle (Cameron 2000). Asbestos was employed widely in Ancient Greece and Rome but also in Asia and China. Writers from these times report the use of asbestos for lamp wicks in the Athenian temple (Paus. 1,26,7). Pliny the Elder and Strabo state their knowledge of the fibres coming from India (Plin. nat. 37,54). The Romans made clothing for the deceased to be cremated, with a resultant white coloration of the asbestos cloth after burning (Plin. nat. 19,4). In Thailand, asbestos was already in use during the Neolithic and Bronze Ages; used in textiles by the elite classes, it was known for its lustre and incumbustibility. In East Asia such cloths were traded (Cameron 2000).

In Europe, there is not much archaeological evidence of asbestos, although there is a single report from Early Modern times about finds in an Ancient Roman inhumation (Gilroy 1853, 395). H.J. Hundt published work on a candle wick from Enns (A), but the object being in a private collection cannot, unfortunately, be verified (Hundt 1976, 128, Anm. 7).

In China, asbestos has been used since the first centuries BC for cloth but also for roof and wall insulation. It has been described as cloth for the Buddha by the King of Kashgar (Cameron 2000).

Gilroy quotes a source from 1707 describing that socks, stockings and undergarments were made in Arabia to be worn as protection against the heat when travelling though Asia. For the cloth to be soft, the fibres had first to be beaten, then steeped in oil followed by combining them with flax fibres before being spun. This woven cloth was then put into a fire for the purpose of burning off the oil and flax (Gilroy 1853, 396f.). Today, asbestos has become famous for the severe health problems it causes . It's presence as insulation material, for use within roof and wall panels for instance, has been known to cause terminal respiratory problems, cancer or abestosis in workers exposed to the substance. Asbestos has subsequently been forbidden as a material for such things (*Fig. 306*).

5.2 Metal threads

Historically, metal threads were predominantly of gold, this being employed because of its high efficiency in being worked into fine foils without breaking. It was made into such things as:

- gold foil strips wound around a core (silk or linen); beaten and cut gold foils
- wire (torn wire)
- guilt membrane threads (membrane made from gut, leather or paper)

Threads of gold have been dated to the Bronze Age where they were used as wire for rings or decorative pieces. The Late Bronze Age inhumation of Vösendorf holds examples of this kind of work (A) (Reinecke Ha A) (Grömer 2012, Fig. 1.3). Then there are the richly decorated textiles from the tomb of Philippe II in Vergina (GR) which are dated to the Hellenistic Period in which gold has been woven in tapestry technique with a purple ground weave (Spantidaki – Moulhérat 2012, 196). Scythian costumes from Eastern Europe are famous for their decorative small gold foils or embroidery. The gold threads in these cases are two-ply with an animal gut core (Gleba – Krupa 2012). Ancient writers describe the garments of the Lydians and the Persians as having an integration of gold. Penelope wove a beautiful upper garment with threads of gold for Ulysses with the depiction of a dog holding a fawn (Hom. Od. 225–235).

During the Roman Period, threads of gold (spun around a core) are quite frequently found. According to Strabo, Gauls of the elite class also wore clothing incorporating gold (Strab. Geogr. IV, 4.5; χρυσοπάστος = embroidered with gold). Early Roman gold threads found in Spain are dated to the Augustan Age and are made from nearly pure gold, although the core has not been found (Alfaro Giner 2012, 343). Similarly, threads from a hair net found in Croatia are of the same quality, spun around a silk core with edges that are irregular and seemingly uncut (Rast-Eicher, unpublished) (*Fig. 307*). In a 3rd century AD sarcophagus found near Cologne (D), the deceased had been covered with a textile woven in tapestry technique made of cashmere and wild silk with gold threads (Stauffer 2007). Eastern Roman gold threads from Palmyra (Syria) have clearly cut edges (Schmidt-Colinet *et al.* 2000, Taf. 104), the latest dating from the end of third century AD. Very fine gold threads have been discovered in a Roman grave from Naintré (F). Although not able to be fully analyzed, radiography has nevertheless made the design elements visible, revealing Palmyraen motifs and showing that it is very probably an Eastern Roman production (Desrosiers 2000).

Metal threads are quite frequently found from the Early Medieval Period in rich graves throughout Europe (Crowfoot – Chadwick Hawkes 1967; Stiefel-Ludwig 2012; Rast-Eicher – Périn 2011). Most of those from the graves of Saint Denis/Paris (F) were incredibly fine (dm. 0.2 mm) and regular, with others being a bit larger (up to 0.4mm). The strips completely enclose the thread giving it the appearance of a wire. The core has been found to be consistently of silk (see *Fig. 13*; *Fig. 308*). SEM analyses of areas around the edge, in addition to crystallization of the gold, have shown that these Early Medieval gold threads have been cut from a foil. Recent analyses documented the traces of different cutting instruments (Schneebauer-Meissner 2012, 291ff.). Schneebauer-Meissner able to identify different cutting traces (from knives or scissors) in Early Medieval finds by comparing them to modern reproductions (*Fig. 309*). Short foil strips have been added, one after the other, to create a long wire with these connection points being visible at certain intervals.

Spun threads are most often used as brocading threads or, less seldom, as surface embroidery. Cases of the latter have been found in Saint Denis with the embroidered sleeves of a garment from Queen Arnegundis (Fleury – France-Lanord 1998, II-159; Rast-Eicher in press Saint Denis). The woven gold threads (strips or spun threads) usually decorated tablet woven borders (brocading or surface brocading).

Iron plates with holes of different sizes, including very fine diameters, have been found in the Mediterranean although not north of the Alps until the Medieval Period. In Europe they appear by the 10th c., such as in Haithabu or Sweden (Tylcote 1987, Fig. 7.22; Oddy 1977, Fig. 4). The technique to produce wire was developed in the 14th and 15th centuries using first and foremost water powered devices (Garside 2014).

When gold is referred to as a pure metal, it must also be understood that in its natural state it always contains small amounts of silver or other elements. Analyses can be made under SEM and/or by the PIXE method. SEM-EDS will help to determine surface composition, but the PIXE method will aid in a much deeper examination with a more detailed list of elements present (Enguita *et al.* 2002; Rezić *et al.* 2010).

With Merovingian threads, for example, metal analyses have shown a considerable mix of elements with a large amount of silver in addition to copper and other elements. This composition comes close to that of the coinage of the time and may show that objects were remelted for different uses (Calligaro *et al.* in prep.).

From the Medieval Period, descriptions of metal thread production have been given in texts, such as with the writings of Theophilus Presbyter (beginning 12th c.; Theophilus presbyter I, 24). Gold is described as being beaten between leather into foils, then cut into fine strips. Torn threads (round profile) have certainly been made since the Roman Period.

Metal threads constructed of pure gold strips have been discovered from 12th century sites; gilt silver threads seem to have first been constructed in the 11th c. but are more often seen in the Late Medieval and Renaissance (Jarò 1990; Hacke *et al.* 2004; King 1963; Orfinskaya – Engavatova 2009). Gold threads found in a medieval grave from the monastery of St John in Müstair (CH), illustrate the type of high quality thread that can be found from this era. The grave, which is situated well below a well-dated layer from 1499, contained a chasuble that incorporated gold threads as part of a tablet-woven band on the front and back (Rast-Eicher 2005c) (*Fig. 310*).

So-called "Cyprus-gold" – using a gilt membrane of gut or leather strips – began to be used by the 11th/12th c. However, this type is probably of Chinese or Japanese origin and incorporates a paper membrane (Jarò 1990, 50).

Gilt leather strips were more flexible and less heavy which made it possible to weave complicated patterns such as lampas weaves (Jarò 1990, 50). The Hungarian coronation cloak, made in AD 1031 of dark purple silk embroidered with gold threads, has 50 kilometers of gold thread (Jarò 1990, 46)! The core, silk or flax used inside the spun thread – at least in the Medieval Period – seems to be linked to S- or Z-spun gold strip (Jarò 1990, Tab. 3).

5.3 Feathers

Feathers have often been found in inhumation contexts, especially in Early Medieval tombs. Some researchers interpreted them as additions to funerary rituals (Hundt 1972; Siegmüller 2011) but there is also the possibility that they were simply used as filling material, as it has been the case in many Scandinavian graves of the Iron Age and the Viking Period (e.g. Geijer 1938; Mannering 1997). Thanks to the particular structural characteristics of feathers – with the presence of such identifying features as the calamus, vanes and barbs among other things – they are easily identifiable even in a mineralized context. A simple view under the stereo-microscope will do. With minute remains, of course, it is more difficult to make a determination. Down remains can be identified as belonging to a certain bird family owing to the particular form of the barbs (Day 1966) (*Fig. 311*).

Written sources show the prices of different feather and down fillings (Price edict of Diocletian: Lauffer 1971). Pliny the Elder reports that geese can of course be eaten but that their feathers can be considered an additional source of income (Plin. nat. 10,27). The German goose was especially esteemed. Even the Roman auxiliary soldiers desired pillows filled with goose feathers, something commonplace during Pliny the Elder's time.

There are other reports from this time that consider as well swan or even partridge down (Mart. 14,46; Mommsen – Blümner 1893, 146). Martial reports a peacock's feather fly flap (Mart. 14,67).

A 16th c. list from Venice (I) shows how feathers were used for trimming: on it, for example, is a yellow silk train lined with white feathers as well as a pink one brocade edged with peacock feathers (Davey 1895, 26).

Archaeological finds from grave sites reveal feathers from the Iron Age and Early Medieval times, as well as from 18th century inhumations. A large Roman textile found in Egypt is full if feathers, but this is probably the remnants of a filling material (Schrenk 2004, 140). Cushion fillings of feathers were found in the Sutton Hoo ship burial, described as a "white flock-like material" (Bruce-Mitford 1983, 888). In a 10th c. grave from Starigard/Oldenburg, a filling with feathers has been documented on a knife (Gabriel – Farke 2003). Feathers have also been documented in threads that have been spun with wool. In an Iron Age tunic found in the bog of Bernuthsfeld (D), feathers were clearly spun in wool weft threads (Farke 1998, 103).

Large feathers have also been known for their decorative value throughout history, from before the ancient Romans to modern man. Archaeological finds may well be mineralized (*Fig. 312*) and have, for example, been found fixed by buttons, e.g. for a hat decoration (both civilian and military), from all ages (*Fig. 313*; Rast-Eicher, unpublished/Welschenrohr).

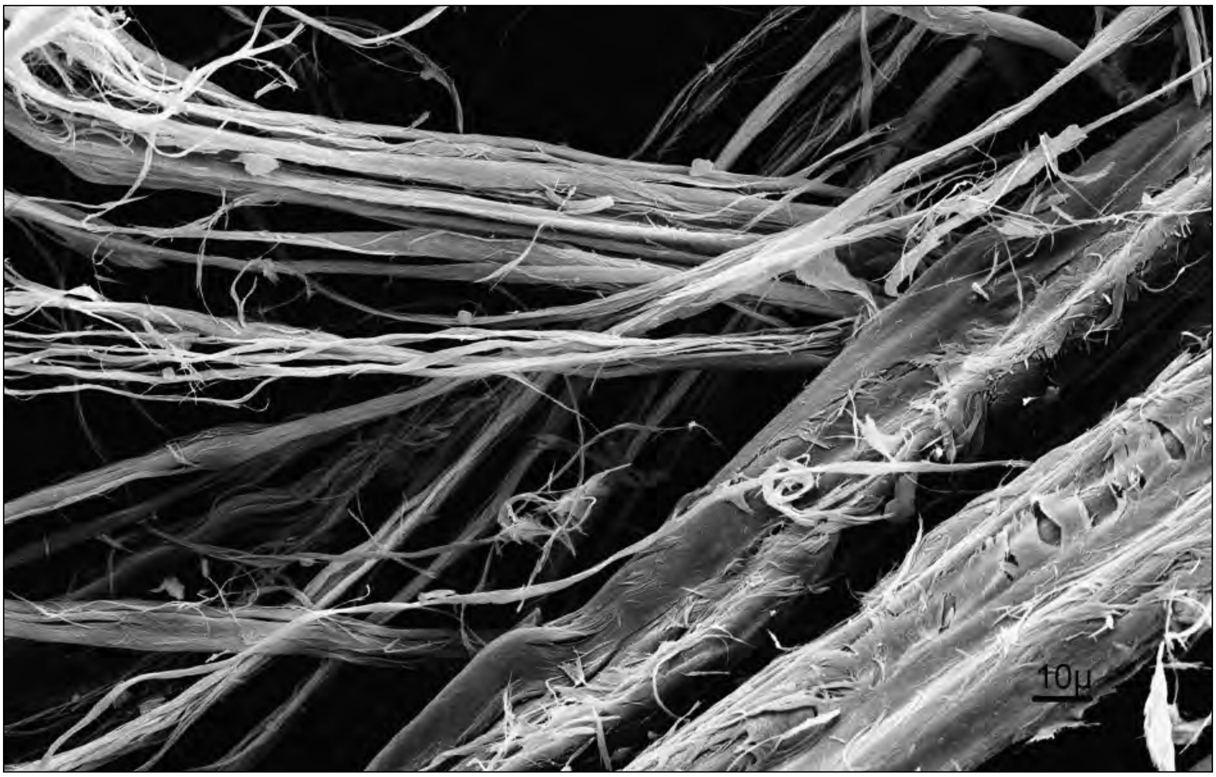

Fig. 306. Modern asbestos fibres

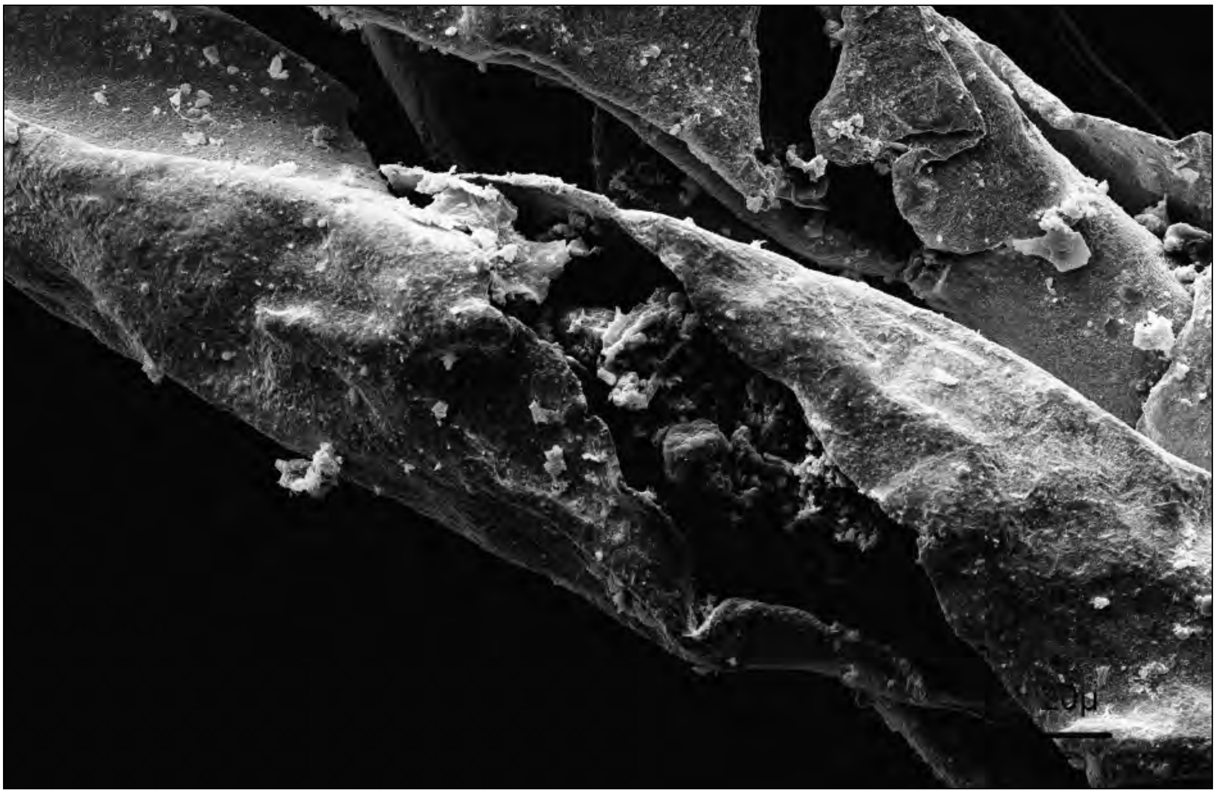

Fig. 307: Roman gold thread, Roman, Zadar (HRV)

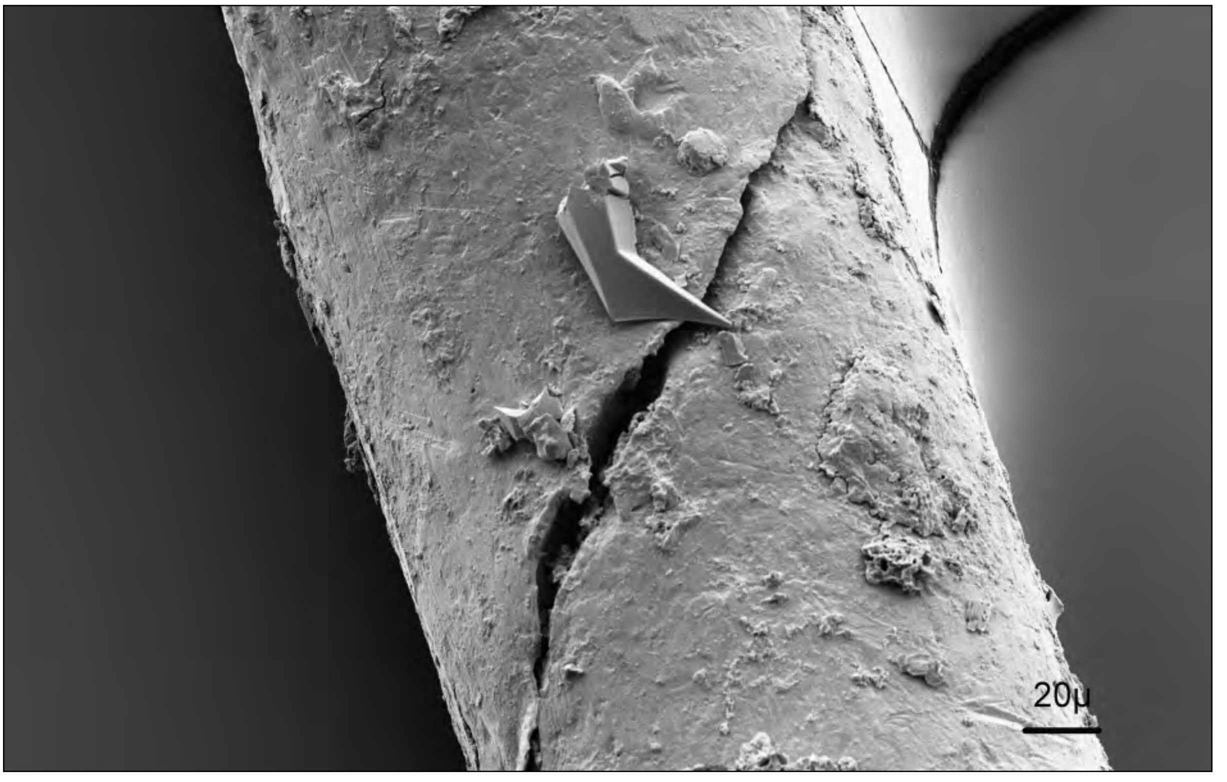

Fig. 308. Gold thread with silk core, Early Medieval, Saint Denis/Paris (F)

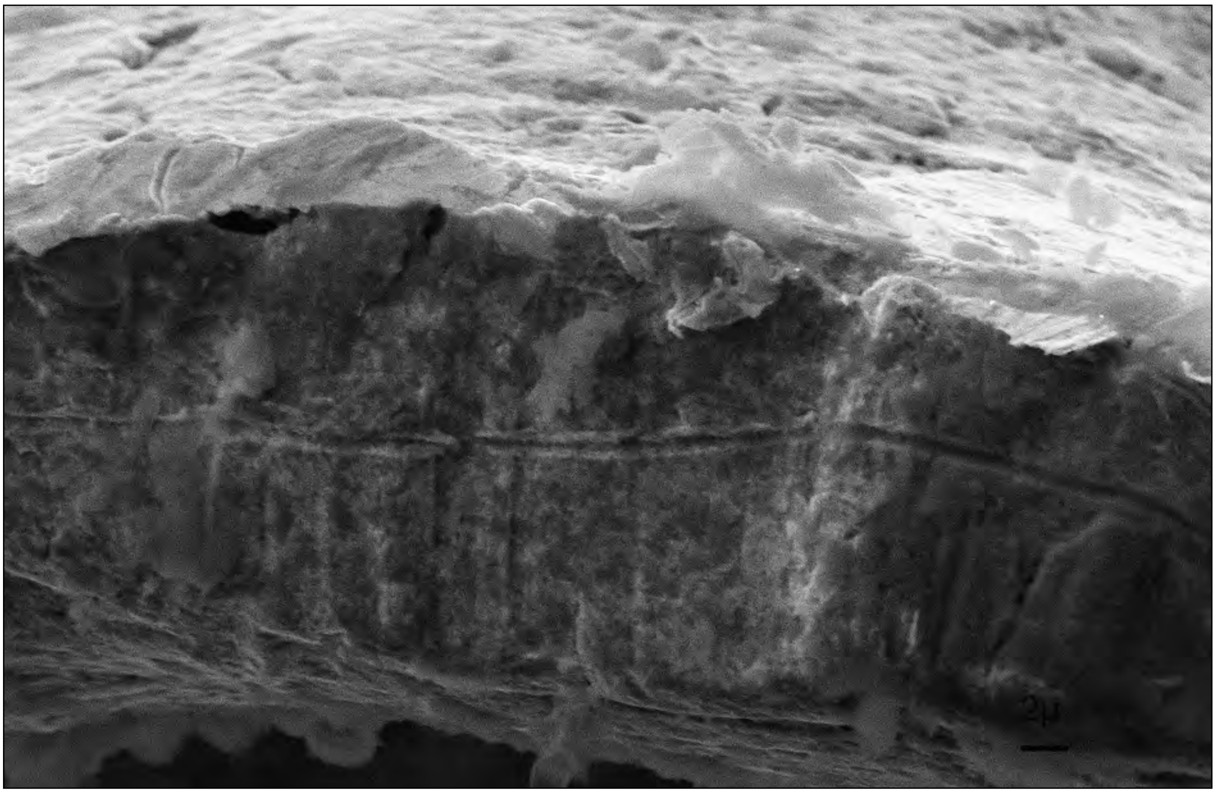

Fig. 309. Cutting marks, gold thread, Early Medieval, Saint Denis/Paris (F)

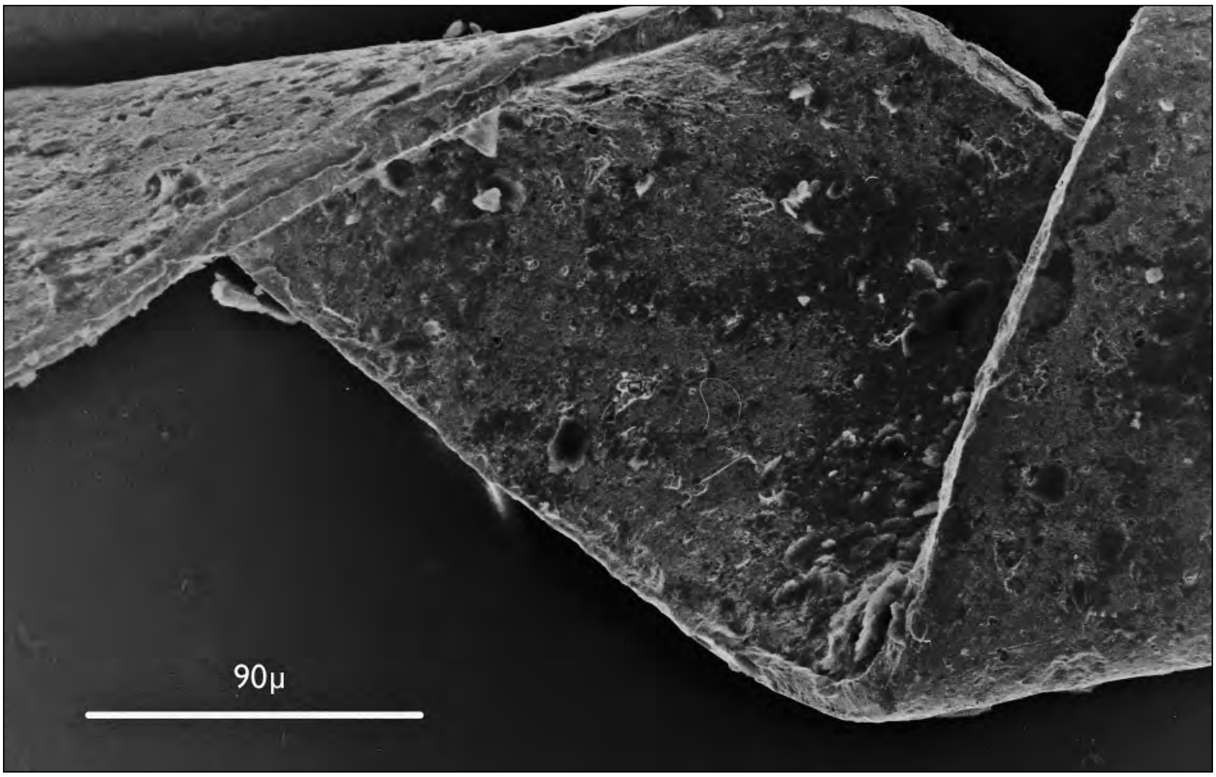

Fig. 310. Medieval gold thread from Müstair (CH)

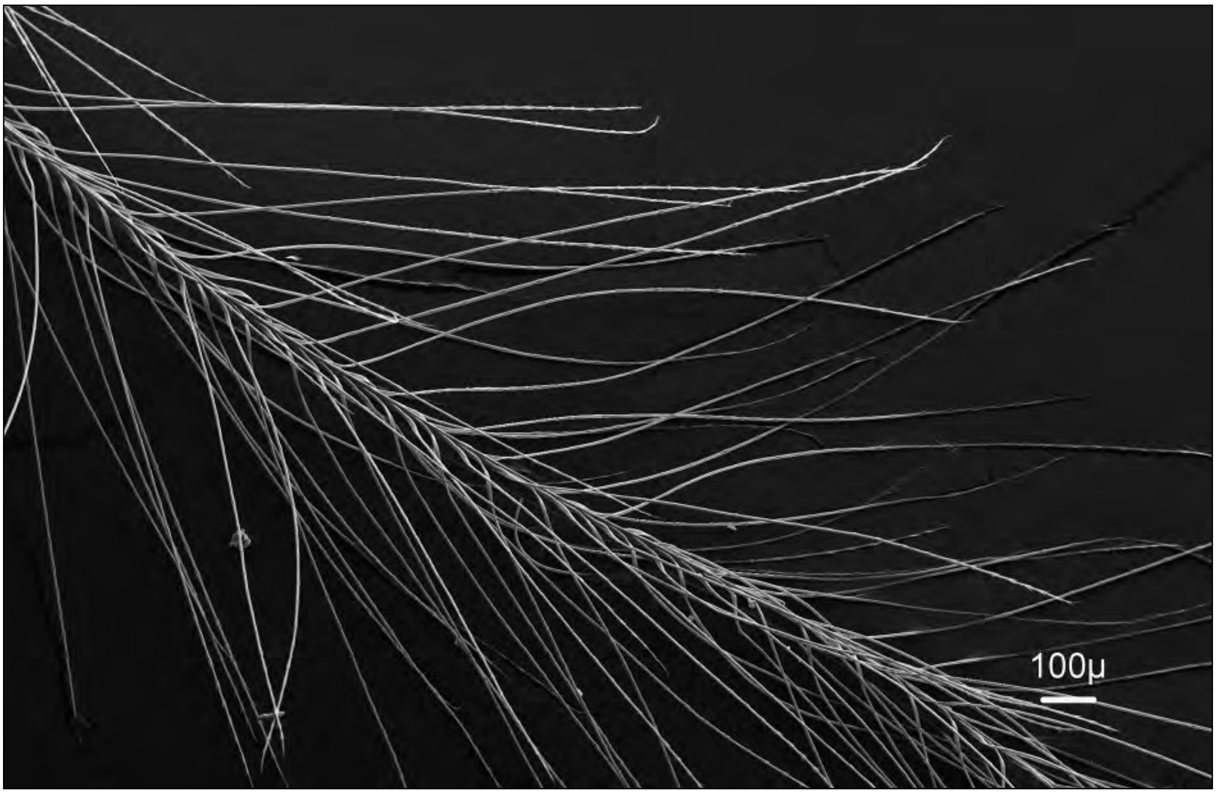

Fig. 311. Duck down feathers, modern

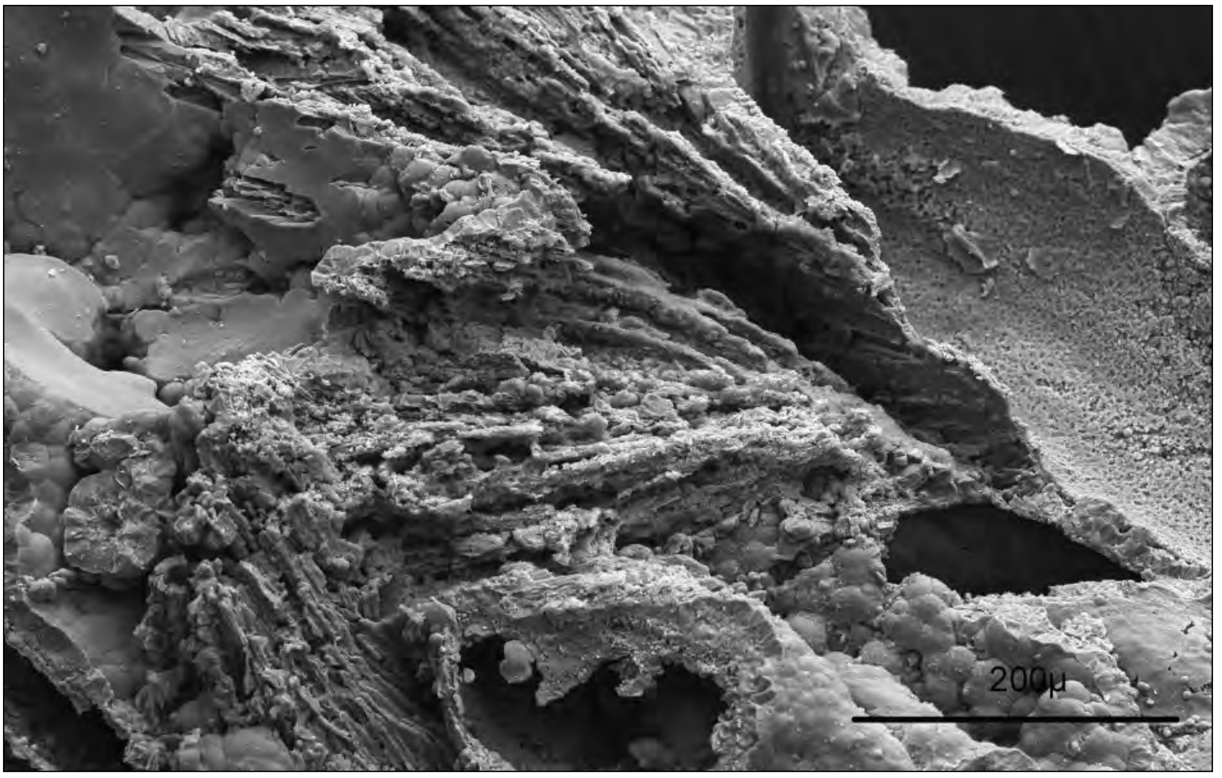

Fig. 312. Mineralized feathers found in a grave, Early Medieval, Baar (CH)

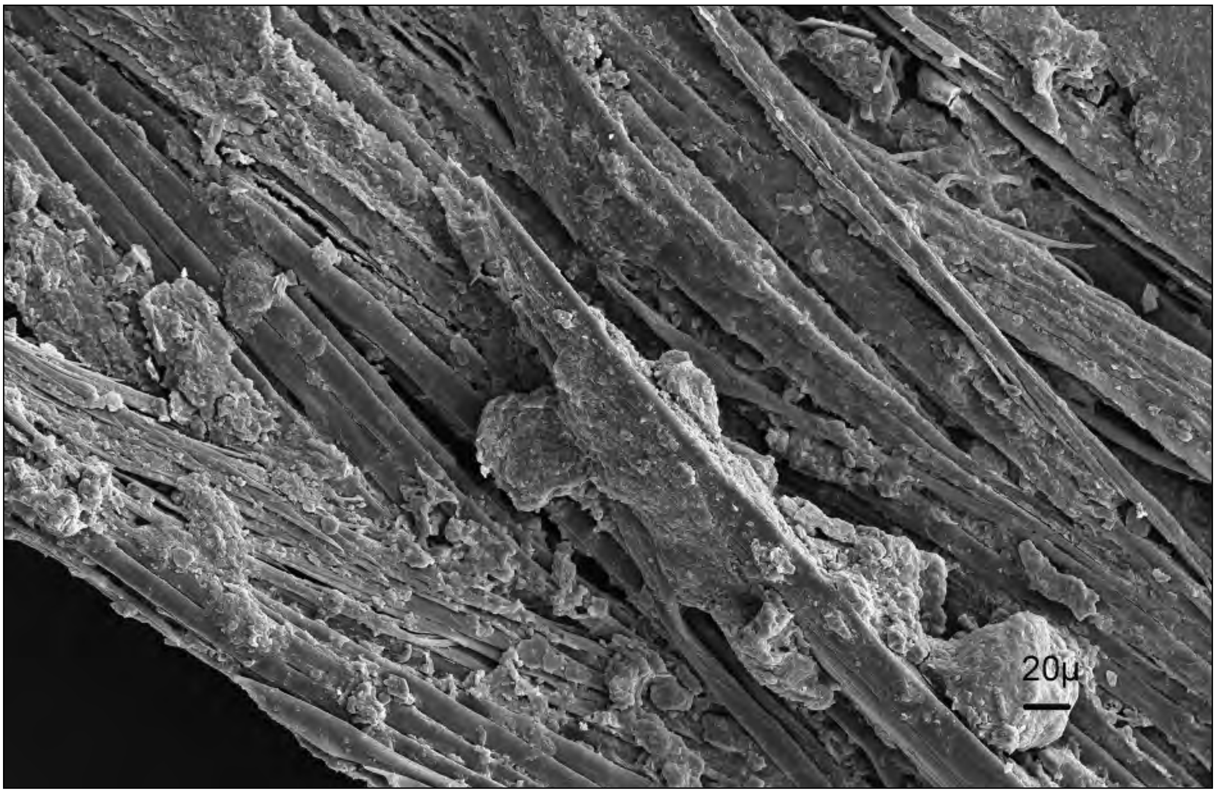

Fig. 313. Feathers of Early Modern context, Welschenrohr (CH)

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Fibres used in the manufacture of archaeological textiles are full of information. Unfolded microscopically, analysis of such textiles and furs has become an important field of archaeological study. Fibre type and even fibre processing may become visible. Scanning electron microscopy has made analysis of metal-replaced and charred finds possible, something that was not determinable by light microscopy. Examination under the SEM has enabled a new world to become visible and is so presented in this book. A variety of archaeological examples and their modern day counterparts are assembled as well as a chapter devoted to the historical background of each fibre and its use in Europe

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