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Skin Debris on the Hairs of Holy Maria-Magdalena: A SEM-EDX Analysis

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Abstract: We have found, by SEM observations and EDX-analyses, numerous skin debris kept on the surfaces of the hairs of Maria-Magdalena. Some of them are of very recent origin, but most are more ancient. A few of them, located near cut extremities of hairs, are those of the fingers that cut these hairs (that were initially longer). Some of these skin debris are dirty or/and salted. We observed also on some hairs quasi-intact dandruff piles. We have determined the soap (a "black soap", potassium-rich) that washed the hairs. Finally we have found among hairs and studied in details two samples of epidermal micro-plaques, two pieces of skin shreds (one of them being conserved by salt), and one sample of scalp shred containing osseous material.

Holy Maria-Magdalena (3?-63?) is the most abundantly cited woman in the Four Gospels. According to the French "tradition des Saints de Provence" [**1**], she landed on (in 43?) the French (The Gaule at this era) Mediterranean shores, in a region corresponding to the current part of Les-Saintes-Maries-de-la-mer. Some relics (bones, flesh and hairs) of Maria-Magdalena were kept in the Saint-Maximin basilica, where a large lock of the presumed Maria-Magdalena 's hairs is arranged in a dedicated reliquary.

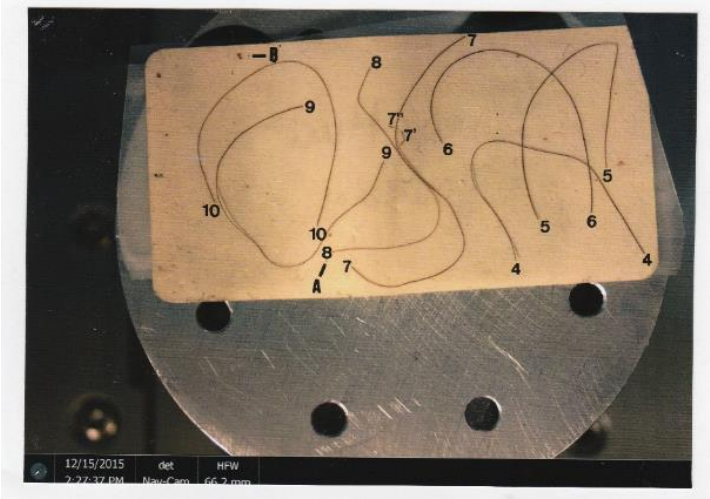
We have obtained from the parish priest of the Saint-Maximin basilica some hairs (they are cut hairs) of this lock, for scientific purposes (microscopic examination and chemical analyses). Our first published study of these hairs is a genetic study [**2**]: by DNA extraction from the hair number 10, that had a capillary bulb, we established that it corresponds to the chromosomal XX formula of a Jewish woman.

Desquamated epithelial cells-named as "skin-debris" (SD) were initially studied by SEM-EDX [**3, 4**] in a forensic science perspective. In the present study we describe in details, in a similar way to that of the work we have realized for the Turin Shroud [**5**], the SDs deposited on the hairs of Maria-Magdalena.

MATERIAL AND METHODS

The ten hairs (numbers 1-10) – of red colour [**6**] – of Maria-Magdalena studied were loaded on sterile dedicated scotch-tapes (Figure 1). They were examined further by Scanning Electron Microscopy (SEM), for the SDs deposited on their hair surfaces.

Figure 1 : Optical view (3x) of hairs numbers 4 to 10 (plus 7' and 7'') located on a sterile scotch-tape, itself loaded on the platine of the electron microscope. A : location of skin shreds (below hair number 8) ; B : location of the skin shred covered by salt (above hair number 10).



Some of the hairs were examined in confocal stereoscopic micrography. All the ten hairs were examined by the SEM apparatus FEI model Quanta FEG (an environmental electron microscope apparatus). Elemental analyses were achieved by using Energy Dispersive X-ray spectroscopy (EDX), the SEM microscope used being equipped with the probe model X-flash 6/30. Both LFD (Large Field Detector) and CBS (Circular Back Scattering) procedures were used, the last one to better detecting heavy elements.

Each elemental analysis is given in the form of a spectrum, with kiloelectrons / Volts (ke/V) on the

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abscissa and elemental peak heights (cps/eV) in ordinates. High resolution spectra are obtained by enhancing the cps/eV values along to the ordinates axis.

EDX-mapping were obtained (power : 20 kV ; distance : 9.9 mm ; acquisition time : 15 min.) for the main elements of the SDs : carbon, oxygen, sulphur, calcium and chlorine.

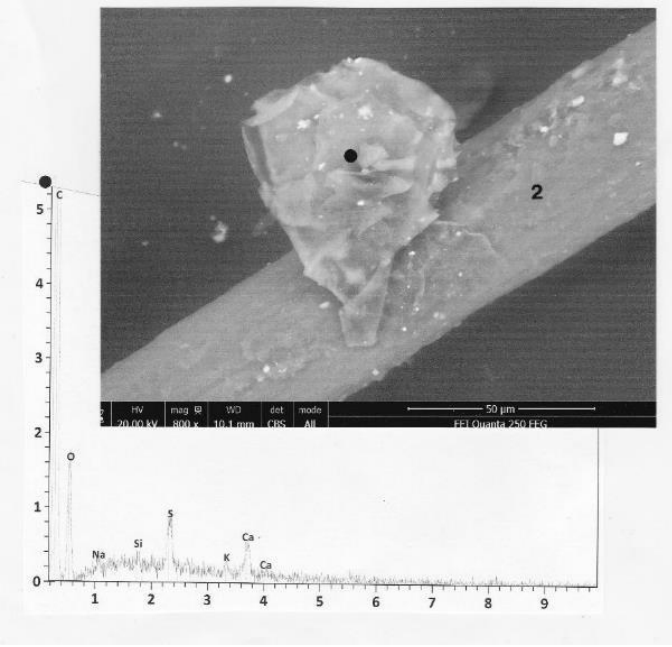
Results And Discussion

All the SDs observed on the hair surfaces, but also dandruffs and epidermal micro-plaques, are illustrated on the following figures.

Recent SDs

Figure 2 concerns a first SD, located on hair number 2. The SEM photograph of this figure shows that it is a relatively thin SD, with well delimited outlines ; it is constituted of a coat of angular epithelial cells, with very few deposits of mineral particles on the surface.

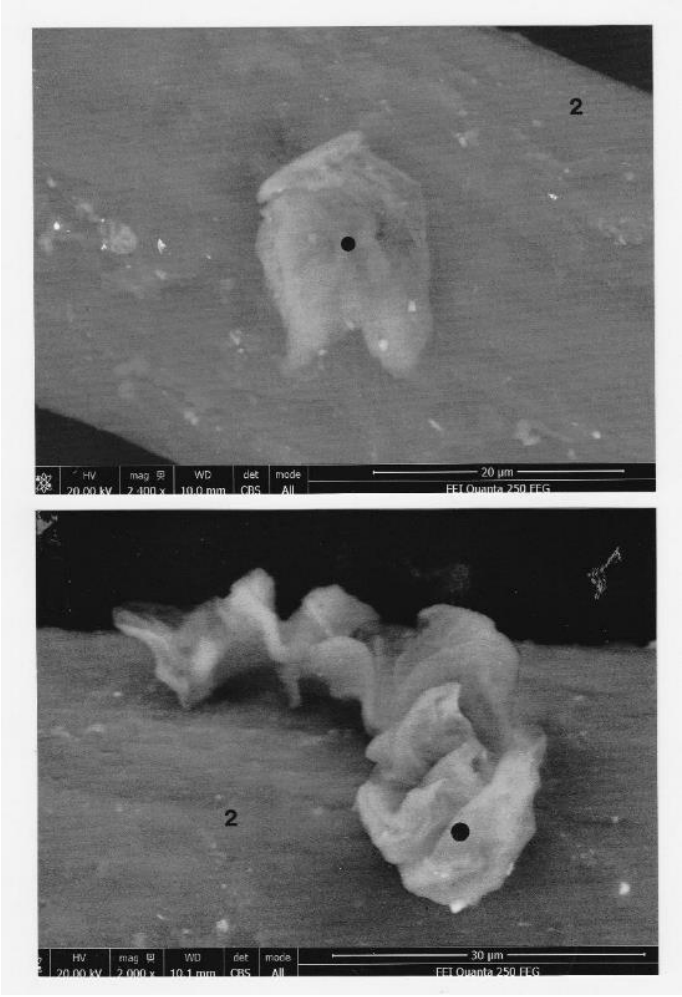
Figure 2 : A first SD located on some part of hair number 2. *Above* : SEM photograph (in CBS, 800x) of the SD. The black point, located on the SD (outside of the hair surface), indicates the area where EDX analysis is realized. *Below* : spectrum at the black point. C : carbon ; O : oxygen ; Na : sodium ; Si : silicium ; S : sulphur ; K : potassium ; Ca (two peaks) : calcium.



Elemental analysis establishes that it is mainly compounded of organic material (carbon and oxygen), with a little peak of sulphur ; there are calcium, potassium and sodium more little peaks. Traces of silicium and of (some part) of calcium are indicative of mineral deposition on the SD surface.

By its aspect and composition, this SD was loaded recently on the hair surface. Because the experimentors worked with masks and gloves, we deduce that this SD originates from the fingers of the Saint-Maximin basilica priest (F. Racine), who came out the hairs of the reliquary. Figure 3 shows two other recent SDs (the first being of little size and the second, very more voluminous, overflowing the hair surface) located on other parts of the hair number 2 surface.

Figure 3 : A second and a third SDs, located in other parts of hair number 2. *Above* : SEM photograph (in CBS, 2 400x) of the second SD. *Below* : SEM photograph (in CBS, 2000x) of the third SD.



Ancient SDs

Figure 4 shows a SD located transversally on some part of the hair number 9 surface. Though its spectrum is similar to that of the SD illustrated on figure 2, its morphological aspect is very different : it is very narrow, with relatively thick outlines, and we do not observe individual cells on the SD surface. We deduce that this SD is an ancient SD.

Figure 5 shows two other ancient SDs, located near or at the border of two different parts of hair number 7.

Figure 6 shows an ancient SD, located near one cut extremity of hair number 6. Because of its unusual location, we infer that it belongs to the fingers of the individual who cut this hair. It is also the case (Figure 7) for the four ancient SDs located near the cut extremity of hair number 8.

Because of its preliminary abundance in ancient SDs at one of its extremity, the hair number 8 surface was systematically explored for further SDs (from one extremity to the other) ; six other ancient SDs were found : the first (Figure 8) is a little ancient SD, with thick outlines. The second (Figure 9) is another little ancient SD, located near the hair 8 border. The third and the fourth (Figure 10) are two little ancient SDs located on each side of the hair 8 borders. The fifth (Figure 11) is a relatively voluminous (of more than 25µm of maximal length) ancient SD, located on the hair 8 border. The sixth (Figure 12) is a more voluminous (of more than 39µm of maximal length) ancient SD, of very fine thickness and with folded layers.

Figure 4 : A first ancient SD, located on hair number 9 . *Above* : SEM photograph (in CBS, 2 000x) of the SD. *Below* : spectrum at the black point . C : carbon ; O : oxygen ; Na : sodium ; S : sulphur ; Cl : chlorine ; K : potassium ; Ca : calcium.

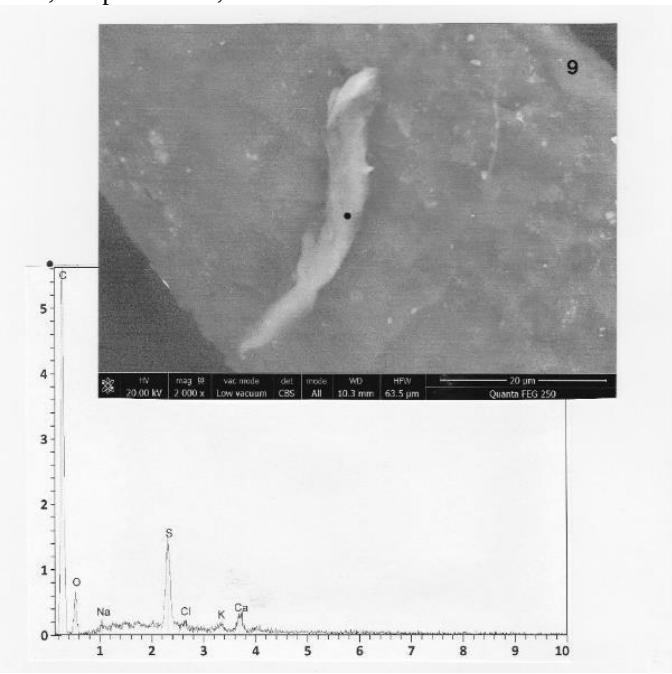


Figure 5 : A second and a third ancient SDs, located on two parts of hair number 7. *Above* : SEM photograph (in CBS, 2000x) of the second SD. *Below*: SEM photograph (in CBS, 3000x) of the third SD.

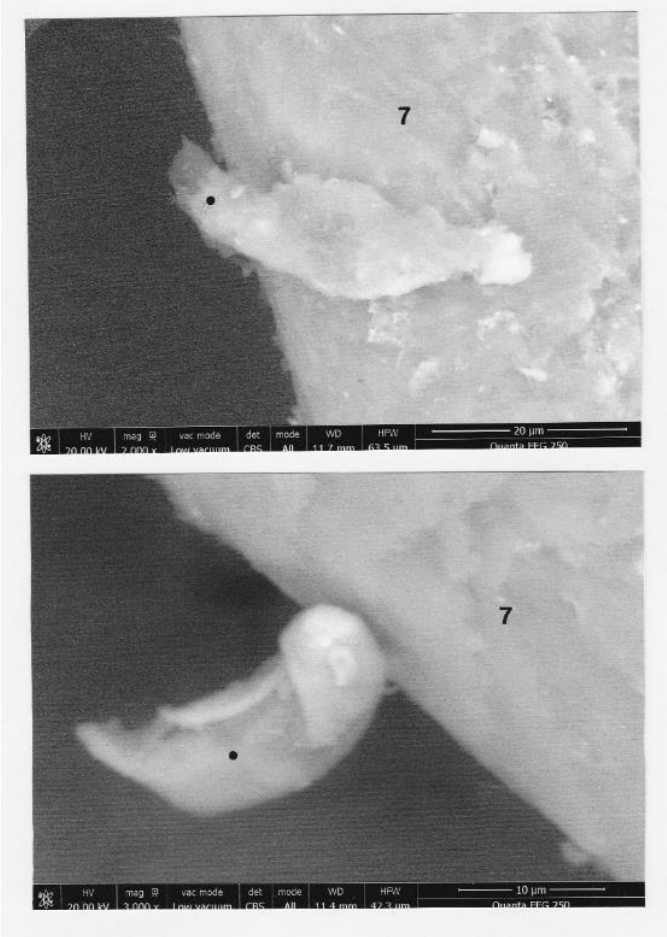


Figure 6 : An ancient SD located at the extremity of hair number 6. *Above* : SEM photograph (in CBS, 1000x) of the hair extremity. *Below* : spectrum at the black point. C : carbon ; O : oxygen ; Na : sodium ; S (two peaks) : sulphur ; Cl (traces) : chlorine ; K : potassium ; Ca (two peaks) : calcium.

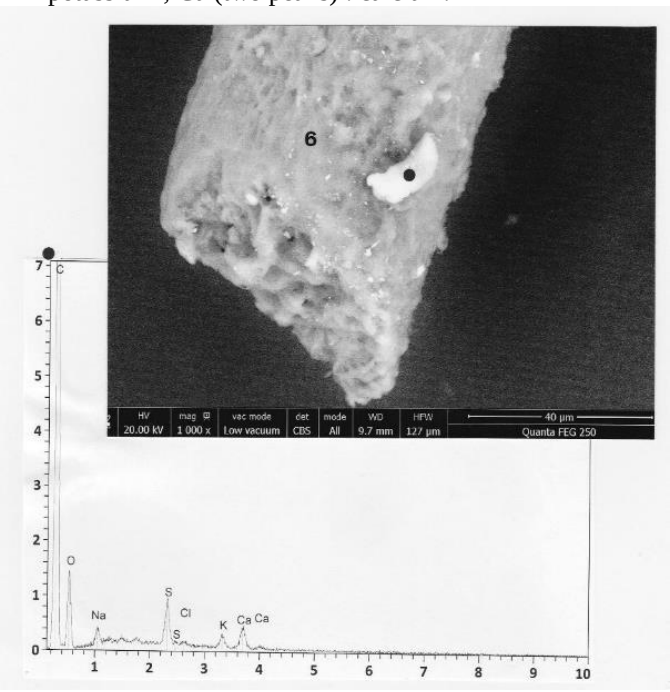


Figure 7 : Four (**1-4**) ancient SDs located near one extremity of hair number 8. *Above* : SEM photograph (in LFD, 600x) of the hair extremity. *Below* : common spectrum of the **1-4** SDs. *Below* : C : carbon ; O : oxygen ; S : sulphur ; Cl : chlorine ; K : potassium ; Ca (two peaks) : calcium.

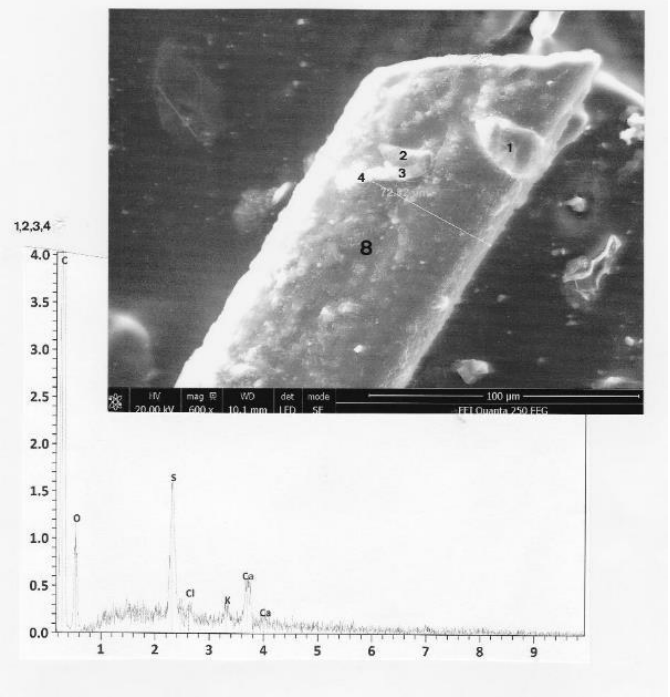


Figure 8 : The first ancient SD found along the hair number 8. *Above* : SEM photograph (in CBS, 1200x) of the SD. *Below* : resolutive spectrum at the black point. C : carbon ; O : oxygen ; S : sulphur ; Cl : chlorine ; K : potassium; Ca : calcium.

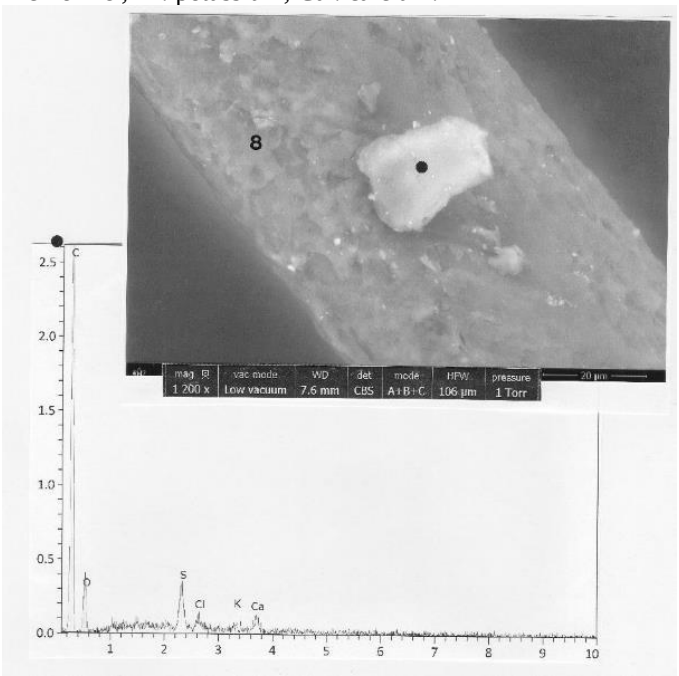


Figure 9 : The second ancient SD found along the hair number 8. *Above* : SEM photograph (in CBS, 1200x) of the SD. *Below* : spectrum at the black point. C : carbon ; O : oxygen ; Si : silicium ; S : sulphur ; K : potassium ; Ca : calcium.

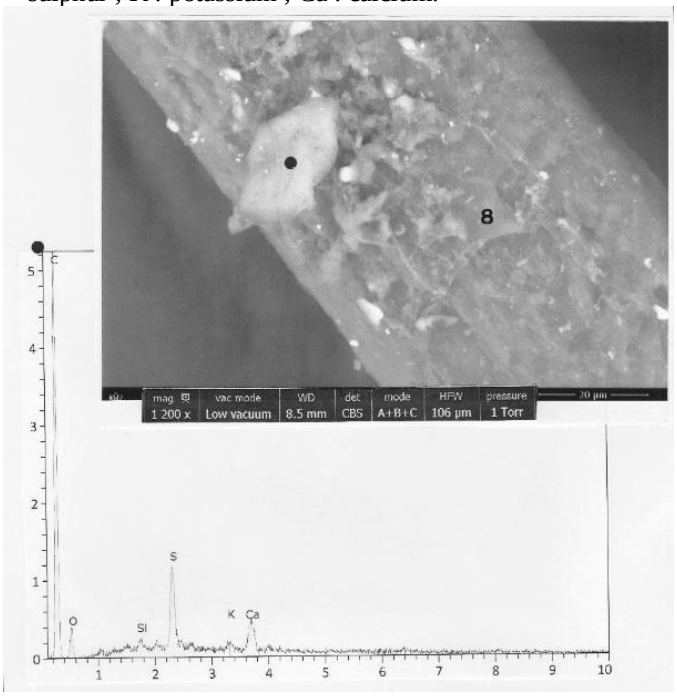


Figure 10 : The third and the fourth ancient SDs found along the hair number 8. *Above* : SEM photograph (in CBS, 1000x) of the SDs (**1** : the third SD ; **2** : the fourth SD). *Below* : resolution spectra of **1** and **2** at the black points. C : carbon ; O : oxygen ; S : sulphur ; K : potassium ; Ca (two peaks) : calcium.

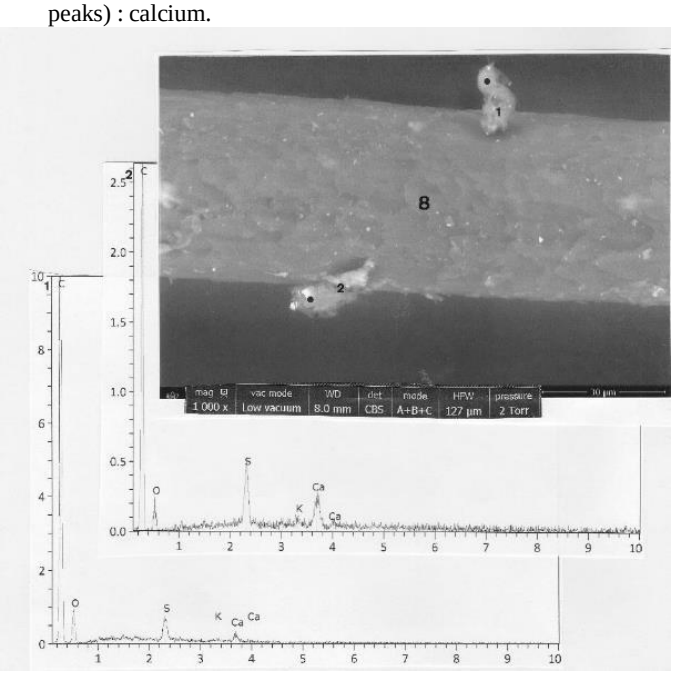


Figure 11 : The fifth ancient SD found along the hair number 8. *Above* : SEM photograph (in CBS, 2400x) of the SD (numbered **1**). Distance is in µm ; **2** : a mineral particle. *Below* : resolution spectra of **1** and **2** at the black points. C : carbon ; O : oxygen ; S : sulphur ; Cl : chlorine ; K : potassium ; Ca (two peaks) : calcium. Spectrum of **2** is that of a calcium carbonate particle.

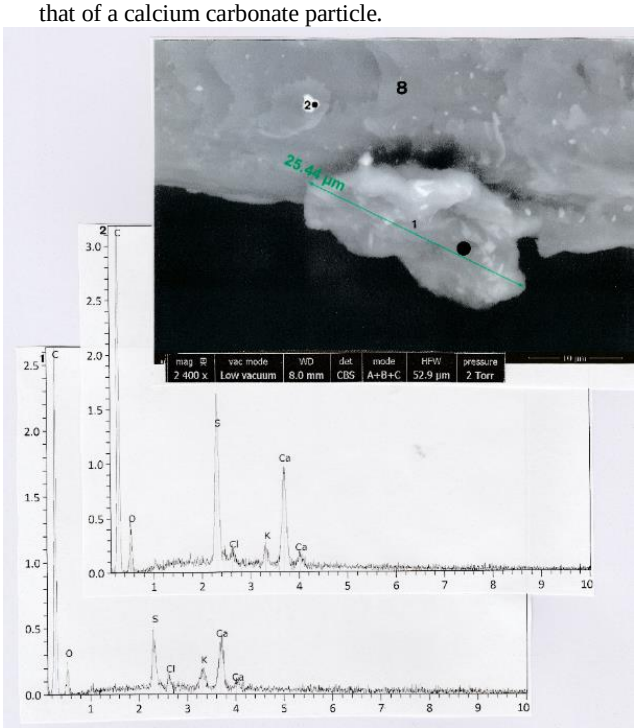
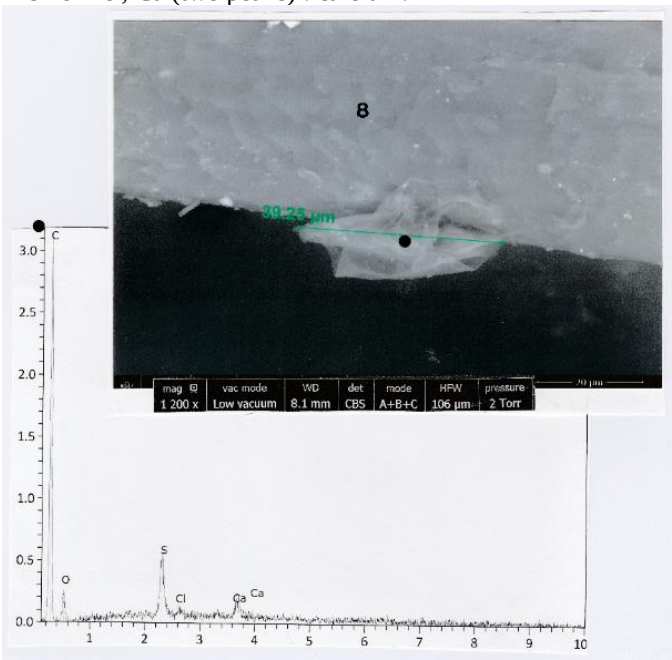


Figure 12 : The sixth ancient SD found along the hair number 8. *Above* : SEM photograph (in CBS, 1200x) of the SD. *Below* : resolutive spectrum at the black point. C : carbon ; O : oxygen ; S : sulphur ; Cl : chlorine ; Ca (two peaks) : calcium.



Dirty and salted SDs

Figure 13 shows one of the recent SD located on hair number 2 ; but its surface is covered by numerous and relatively great mineral particles. Elemental analysis of a set of these particles establishes that they are of two sorts : particles of calcium carbonate, and particles of an aluminosilicate that contains iron (a typical mineral of clays). So this recent SD is "dirty", because somehow contaminated with the earth ground.

Figure 14 shows an ancient SD, also located in another part of hair number 2. Its surface is covered by little mineral particles ; some of them, which are dull-to-electrons, are cubic crystals of salt (ClNa). So, this ancient SD is said as "salted".

Figure 15 shows two adjacent ancient SDs, that are located on some part of hair number 3. One of them is salted, and with calcite deposits on its surface.

The SEM photograph of Figure 16 shows one part of hair number 1, where numerous deposits (Table 1) are loaded.

Table 1 : The six sorts of deposits on this era of hair number 1.

Formation numbers	Deposits
1	a steatite stick
2	a salted SD
3	a micro-plaque of copper sulphate
4	a micro-sphere of iron oxide
5	two particles of gypsum
6	a mineral particle of an aluminosilicate with iron

Figure 13 : A recent, but dirty, SD on hair number 2. *Above* : SEM photograph (in CBS, 1500x) of the SD. The rectangle delimitates the area where EDX analysis is realized. *Below* : resolutive global spectrum in the rectangle. C : carbon ; Fe (three little peaks) : iron ; Na : sodium ; Mg : magnesium ; Al : aluminium ; Si : silicium ; S : sulphur ; Cl : chlorine ; K : potassium ; Ca (two peaks) : calcium.

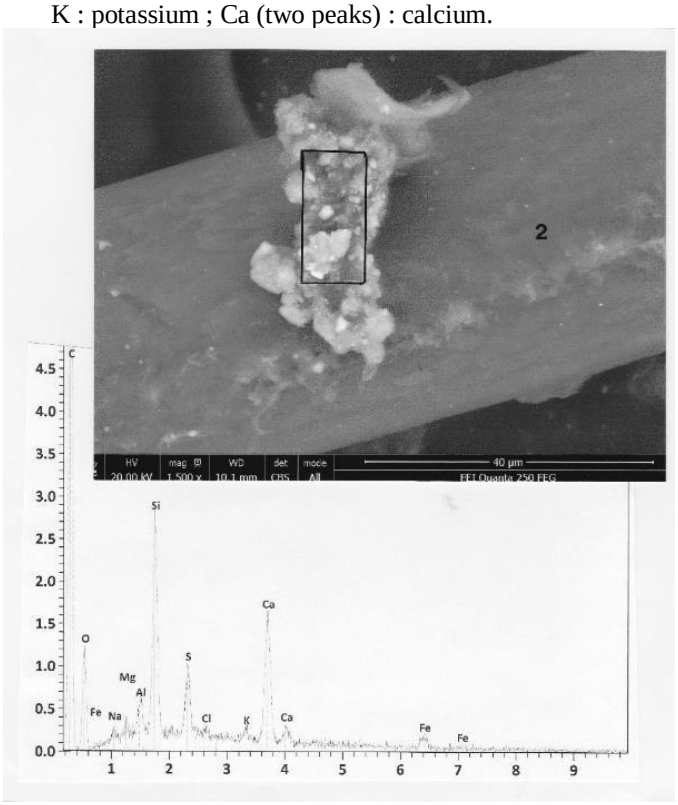


Figure 14 : An ancient, but salted, SD on hair number 2. *Above* : SEM photograph (in CBS, 2000x) of the SD. *Below* : resolutive spectrum at the black point. C : carbon ; O : oxygen ; Na : sodium ; Mg : magnesium ; Al : aluminium ; Si : silicium ; S : sulphur ; Cl : chlorine ; K : potassium ; Ca (two peaks) : calcium.

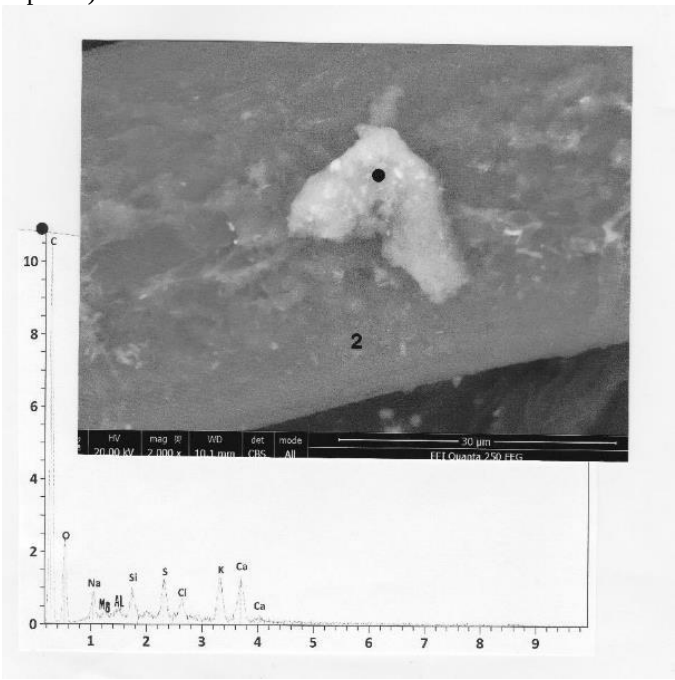


Figure 15 : Two ancient (one salted) SDs on the same part of hair number 3. *Above* : SEM photograph (in CBS, 2200x) of the two (1 and 2) SDs. *Below* : highly resolutive spectrum of **1**. C : carbon ; O : oxygen ; Na : sodium ; Si : silicium ; S (two peaks) : sulphur ; Cl : chlorine ; K : potassium ; Ca (two peaks) : calcium.

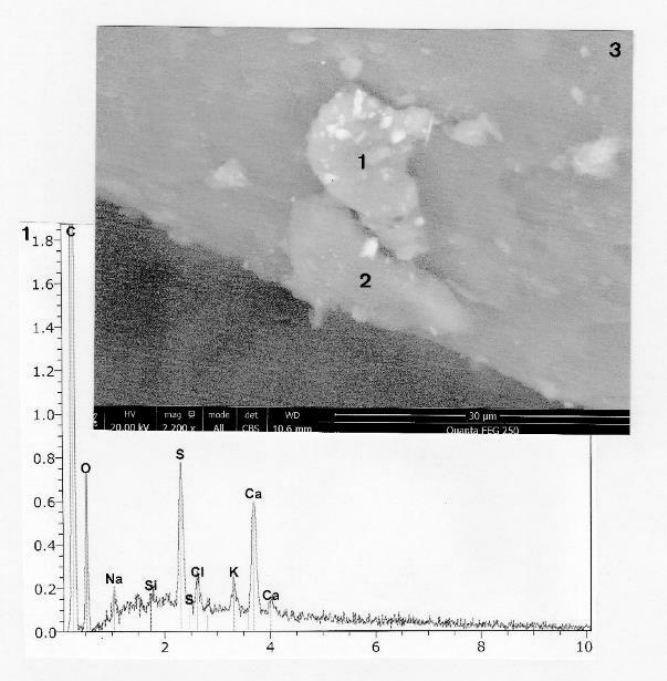
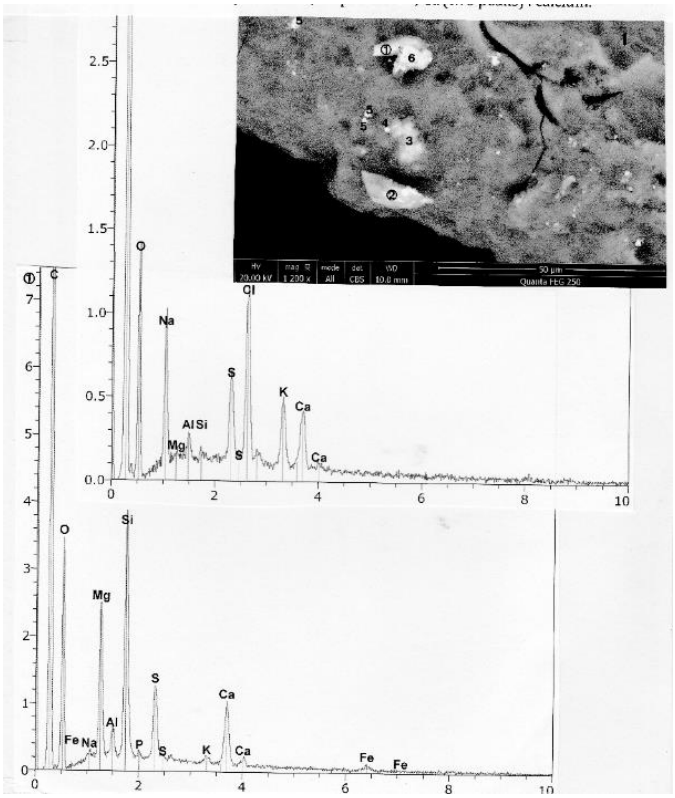


Figure 16 : An ancient salted SD, located on hair number 1. *Above* : SEM photograph (in CBS, 1200x) showing the SD (number **2**) location on this part of the hair. ①, **3**, **4**, **5** and **6** are other formations at this location. *Upper spectrum* : that of ②, in a high resolution form. *Lower spectrum* : that of ①. C : carbon ; O : oxygen ; Fe (three peaks) : iron ; Na : sodium ; Mg : magnesium ; Al : aluminium ; Si : silicium ; P : phosphorous ; S (two peaks) : sulphur ; Cl (two peaks) : chlorine ; K : potassium ; Ca (two peaks) : calcium.



. Formation ② is an ancient salted SD.

Formation ① corresponds to a little rod of steatite. Steatite is a soft rock , with a similar composition to that of the talc [**7**]. Its nickname is "soap 'rock'", because it is obvious that it was used as soap in ancient times. Figure 17 shows the colour, the aspect and the composition of a steatite fragment of reference (Minéraux du Brésil, Paris) ; by its aspect in SEM and by its elemental composition in EDX, it is identical to formation ①.

Formation **3** is a micro-plaque compounded of copper sulphate.

Formation **4** is a micro-ball of iron oxide. We have already observed some examples of such formations on the hair surface (Figure 18) ; they are relatively usual metallic deposits on some hairs [**8**].

Formations **5** are three micro-plaques of gypsum ($CaSO_4$. $2H_2O$). We have already some examples of such formations on the hair surface (Figure 19) ; they indicate that the hairs were in a maritime environment [**9**].
Formation **6** is a particle of an aluminosilicate with iron.

Figure 17 : Study of a steatite sample of reference. *Upper photograph* : optical : optical view (5x) of the steatite powder. The black point region, chosen because it is located outside of the red colored zone, is the location where observations and EDX analyses are realized. *Lower photograph* : SEM photograph (in CBS, 100x) of the powder. *Below* : resolutive spectrum at the black point . C : carbon ; O : oxygen ; Fe (three peaks) : iron ; Mg : magnesium ; Al : aluminium ; Si : silicium ; K : potassium ; Ca (two peaks) : calcium.

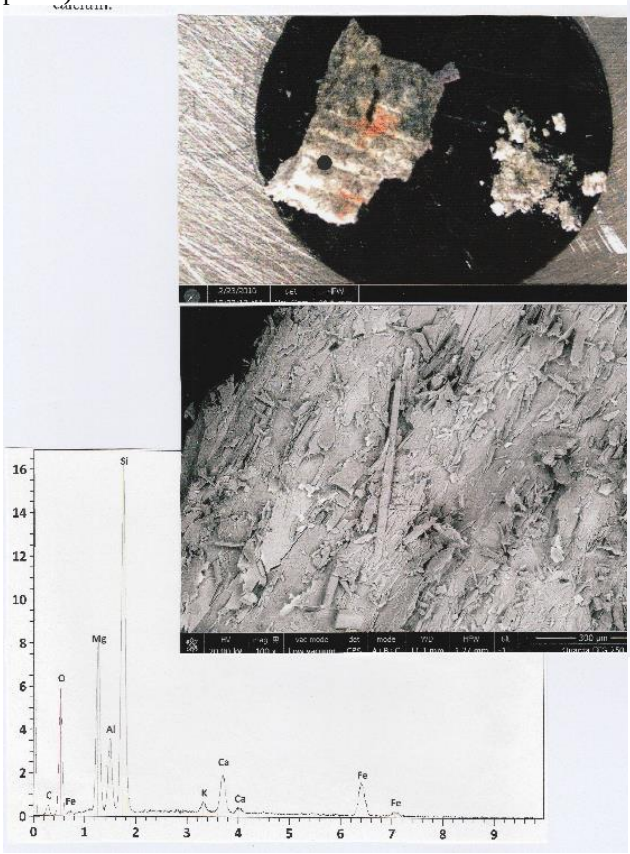


Figure 18 : Example of a micro-plaque of copper sulphate ③ and of a micro-ball of iron oxide ④ loaded on some part of hair number 1. *Above* : SEM photograph (in CBS, 5000x) of this part of the hair. The two mineral particles numbered as **5** are of calcite. *Upper spectrum* : highly resolutive spectrum of ④. Lower spectrum : resolutive spectrum of ③. C : carbon ; O : oxygen ; Fe (three peaks) : iron ; Cu (three peaks) : copper ; Na : sodium ; Mg : magnesium ; Al : aluminium ; Si : silicium ; S (two peaks) : sulphur ; K : potassium ; Ca (two peaks) : calcium.

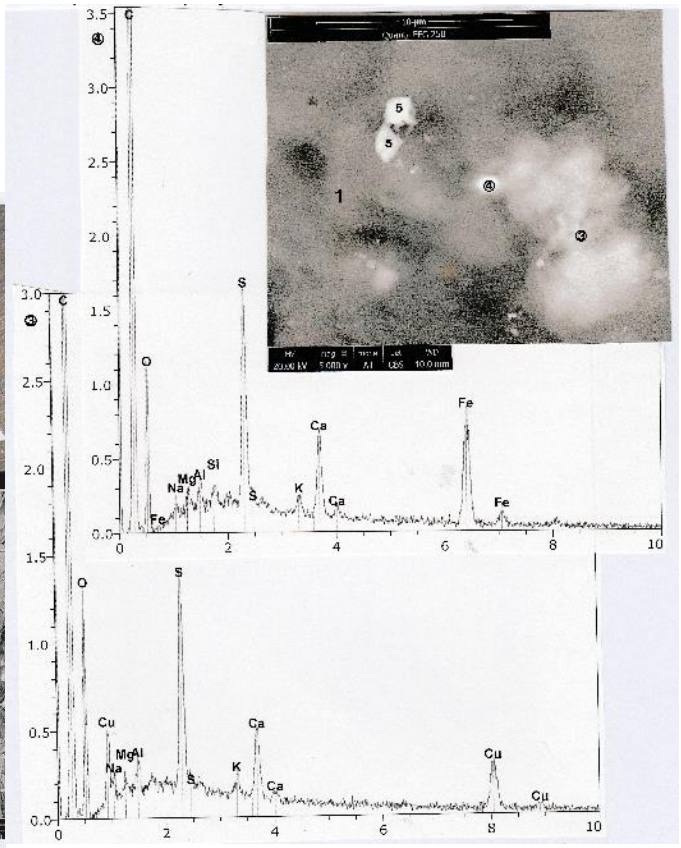


Figure 19 : Example of two micro-plaques of gypsum, loaded on some part of hair number 2. *Above* : SEM photograph (in CBS, 5000x) of this part of the hair. **1** and **2** are the two micro-plaques analysed. *Below* : spectrum of **1** and **2**. C : carbon ; O : oxygen ; S (two peaks) : sulphur ; K : potassium ; Ca (two peaks) : calcium.

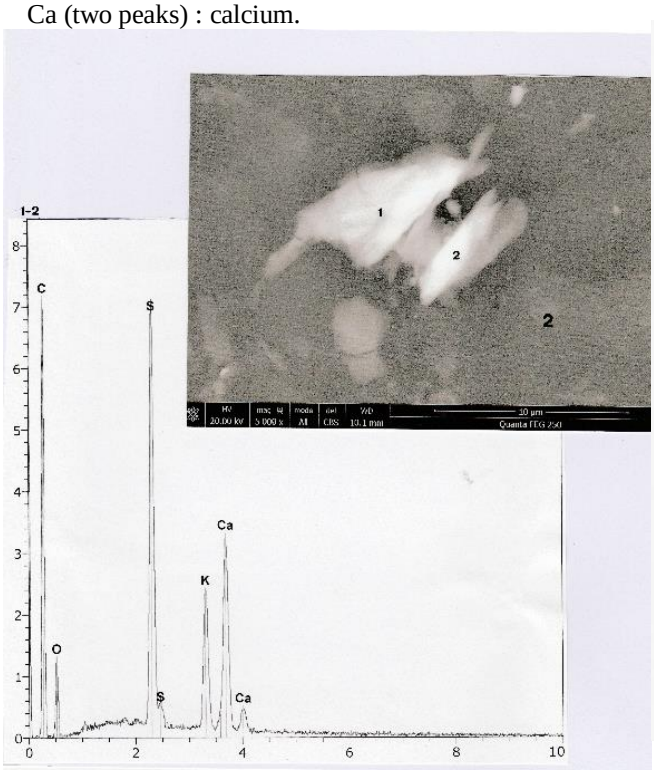
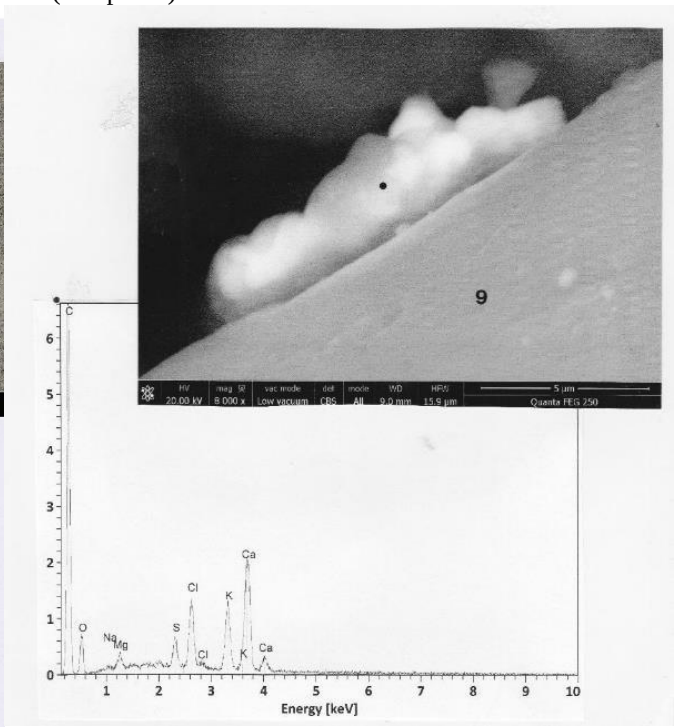


Figure 20 : A first example of a dandruff on the surface of hair number 9. *Above* : SEM photograph (in CBS, 8000x) of the dandruff. *Below* : spectrum at the black point. C : carbon ; O : oxygen ; Na (traces) : sodium ; Mg : magnesium ; S : sulphur ; Cl (two peaks) : chlorine ; K (two peaks) : potassium ; Ca (two peaks) : calcium.



Dandruffs.

Contrary to S, which are layers of corneous dead cells, dandruffs are voluminous piles of nucleated cells that are arranged together to confer some thickness to the structure [**10**].

Figure 20 shows a first dandruff, located at the border of some part of hair number 9. It is a thick (about 4 µm of maximal height) structure, where bumps of cellular piles are well visible, of a maximal length of more that 12 µm ; the dandruff outline is clearly delimitated from the hair surface.

Its spectrum is similar to that of an SD, but chlorine and potassium peaks are relatively more elevated.

Figure 21 shows a second example of a dandruff, also located on hair number 9, and a third located on hair number 10. In both cases, the dandruff outlines are definitely demarcated from the surface borders of the hairs. This second dandruff, of a maximal size of about 20 µm in length, is smooth , whereas the surface of the second (of a maximal size of about 30 µm in length) is swollen ; adjacent to this last dandruff are three hematies, recognizable by their characteristic features.

Figure 22 shows a fourth example of a dandruff (of length of about 20 µm), located on the left border of another part of the hair number 10. On that location, but on the hair surface, is a more voluminous (about 30 µm of maximal length) but fine SD that is of the folded type (like that shown on the photography of figure 12).

Above this SD on the hair surface is a group of hematies. For at least three of them, the biconcave disk characteristic aspect is clearly distinguishable.

Spectras of figure 22, which are obtained in similar conditions, permit useful comparisons between elemental compositions of the hair, of the dandruff and of the SD. Constitutive elements (carbon and

oxygen) of the organic matter and sulphur (of cysteine and cystine disulfur bridges of the keratin), calcium, potassium, chlorine and sodium, are the same in the three cases, but their proportions differ between the three :

The proportions of carbon and sulphur are more elevated in the hair, compared to those of the dandruff and the SD.

Figure 21 : A second and a third examples of dandruffs, located on hair numbers 9 and 10. *Above* : SEM photograph (in CBS, 4000x) of the second dandruff. *Below* : SEM photograph (in CBS, 2400x) of the third dandruff. P : three different parts of the dandruff ; the contour limits of the three membranes of hematies (h1, h2 and h3), adjacent to the dandruff, are underlined in red.

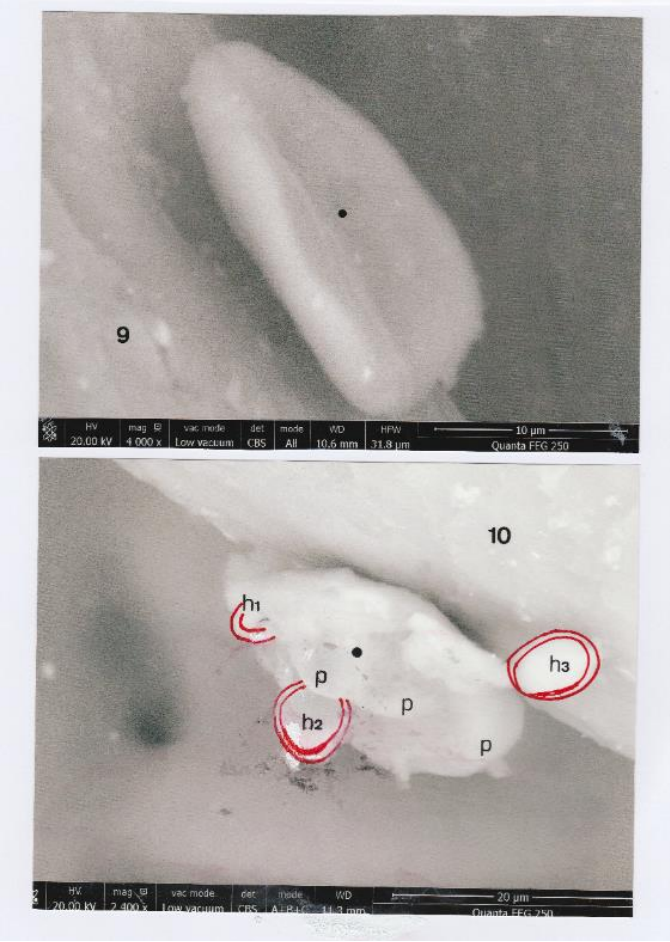
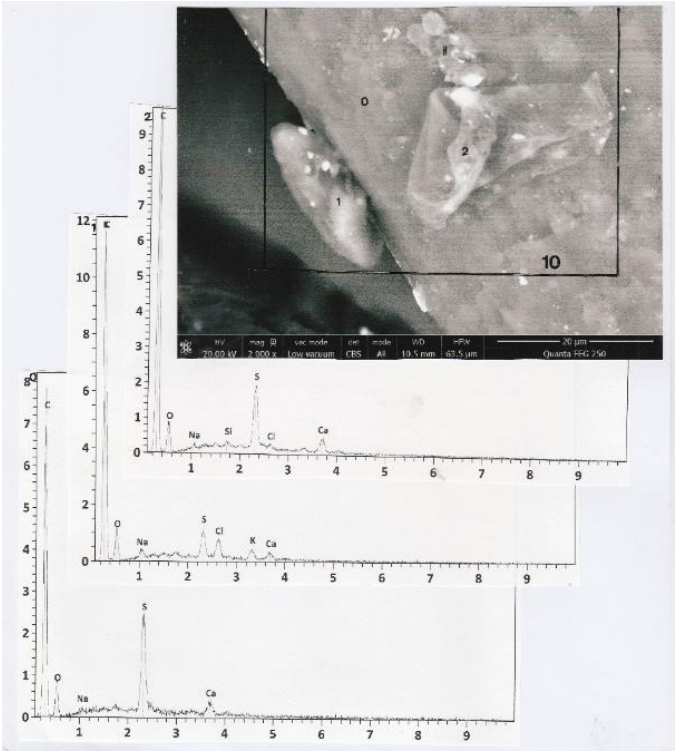


Figure 22 : A fourth example of a dandruff (**1**), located at the border of hair number 10. *Above* : SEM photograph (in CBS, 2000x) of this region of the hair. **0**, **1** and **2** are locations where elemental analyses are realized ; H : the group of hematies. The area delimitated by the rectangle is increased in the following photograph. *Lower spectrum* : that of **O** (the hair). *Medium spectrum* : that of **1** (the dandruff). *Upper spectrum* : that of **2** (the SD). C : carbon ; O : oxygen ; Na : sodium ; Si : silicium ; S : sulphur ; Cl : chlorine ; K : potassium ; Ca : calcium.

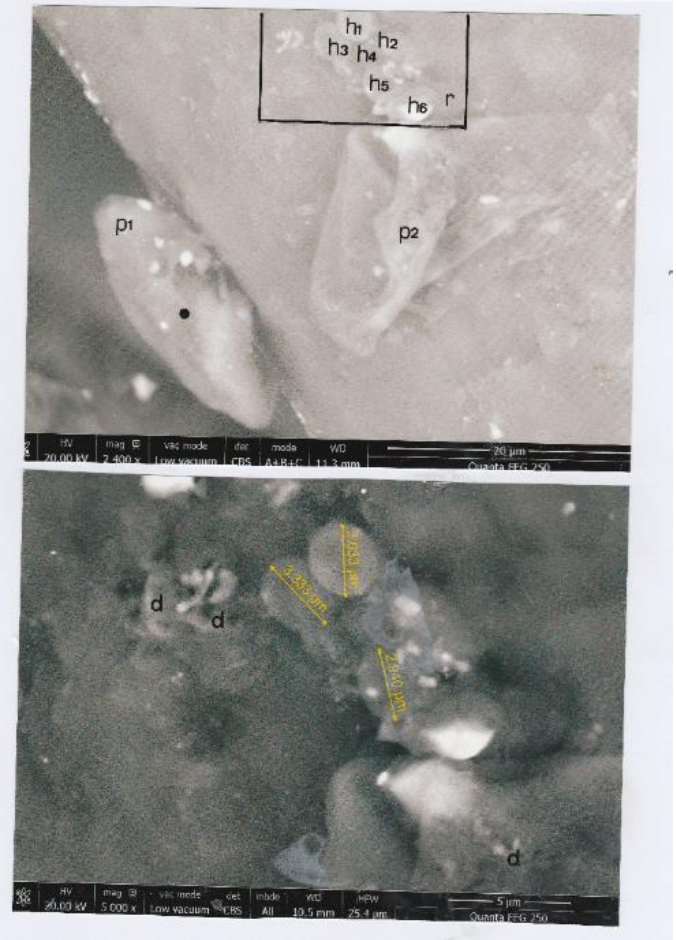


As already signalled, the proportions of chlorine and potassium are more elevated in the dandruff than those of the SD.
In the dandruff and the SD, the simultaneous presence of chlorine and sodium is indicative of the salt (sodium chloride) of the sweat.

On the upper photograph of Figure 23, we can distinguish in the group at least six (h1 to h6) hematies. On the lower photograph of this figure are indicated the precise measurement of the diameters (of about 3 µm) of three of them.

Although too little to correspond to the standard measurement of human hematies, their reduced diameters is indicative of their oldness (because of the well-known relationship between decrease of hematy diameter and time).

Figure 23 : The above SEM photograph (in CBS) is a 2400x view of the area contained in the rectangle of the previous SEM photograph (p1 : the dandruff ; p2 : the SD ; r : superior fold of the SD) ; h1 to h6 are the six observed hematies of the group. The area delimitated by the rectangle is increased in the below photograph. The below SEM photograph (in CBS) is a 5000x view of the area contained in the rectangle of the above SEM photograph (dimensions are in µm) ; D : diatoms.



Potassic soap

Figure 24 shows a little (of 10 µm) particle of squared form, fitted near the border of some part of hair number 2. Its spectrum is similar to those of dandruffs and SDs, but with a relatively higher content of potassium (and of calcium).

This is a residual fragment of black soap [**11**]. The black soap, that is a potassium-rich product, is a corporal soap that is used since many times in Turkish baths as a traditional soap (in North-Africa and in Maghreb countries) ; because of its wealth in potassium salts, it is applied under the form of a dough on the skin after a warm bath and permits the elimination of the dead skin debris.

Figure 25 shows the colour, the aspect and the composition of a black soap wealth of reference (sold as "Beldi soap", a traditional product in Morocco). Its elementary composition, which corresponds mainly to organic matter, is very rich in potassium.

Figure 26 shows a micelle [**12**] of black soap, located on the border of hair number 1. It is a little sphere (of about 30µm of diameter), for which elemental composition establishes that is a highly structured mixture of black soap material and organic matter (mainly that of the sebum).

Figure 27 shows an example of a little dandruff (of about 15 µm of length), that is loaded on the border of some part of hair number 3. Its elemental composition establishes that it is soaked with black soap (and it contains numerous particles of calcium carbonate).

Figure 24 : A black soap fragment on hair number 2. *Above* : SEM photograph (in CBS, 2000x) of the fragment. *Below* : resolutive spectrum at the black point . C : carbon ; O : oxygen Mg : magnesium ; Al : aluminium ; Si : silicium ; P : phosphorous ; S : sulphur ; Cl : chlorine ; K : potassium ; Ca (two peaks) : calcium.

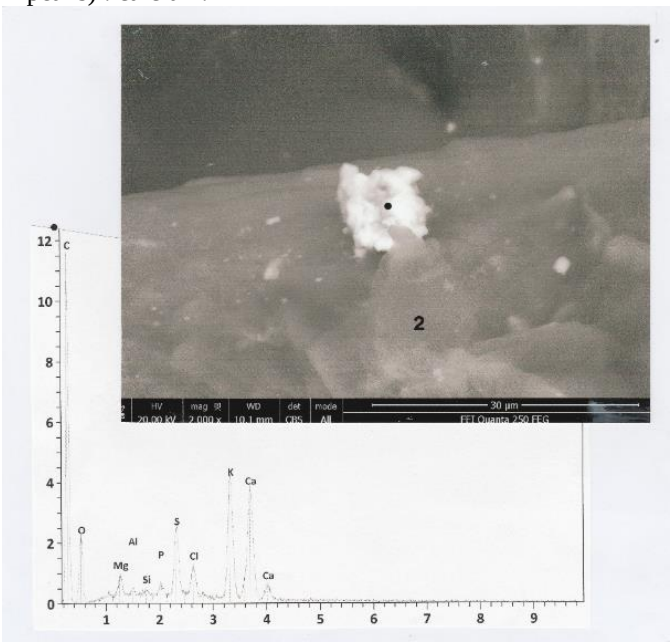


Figure 25 : Study of a black soap of reference. *Insert* : optical view (3x) of the sample. *Above* : SEM photograph (in LFD, 150x) of some part of the dough. *Below* : global resolutive spectrum of the dough. C : carbon ; O : oxygen ; Na (traces) : sodium ; Al (traces) : aluminium. K (two peaks) : potassium.

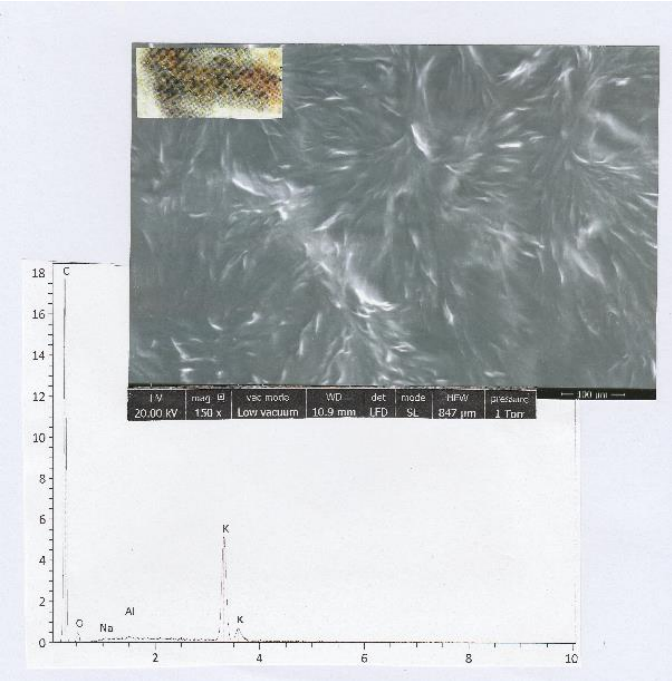


Figure 26 : A micelle of black soap, loaded on hair number 1. *Above* : SEM photograph (in CBS, 1000x) of the micelle. *Below* : highly resolutive spectrum at the black point. C : carbon ; O : oxygen ; Na : sodium ; Mg : magnesium ; Al : aluminium ; Si (traces) : silicium ;P : phosphorous ; S (two peaks) : sulphur ; Cl (two peaks) : chlorine ; K : potassium ; Ca (two peaks) : calcium.

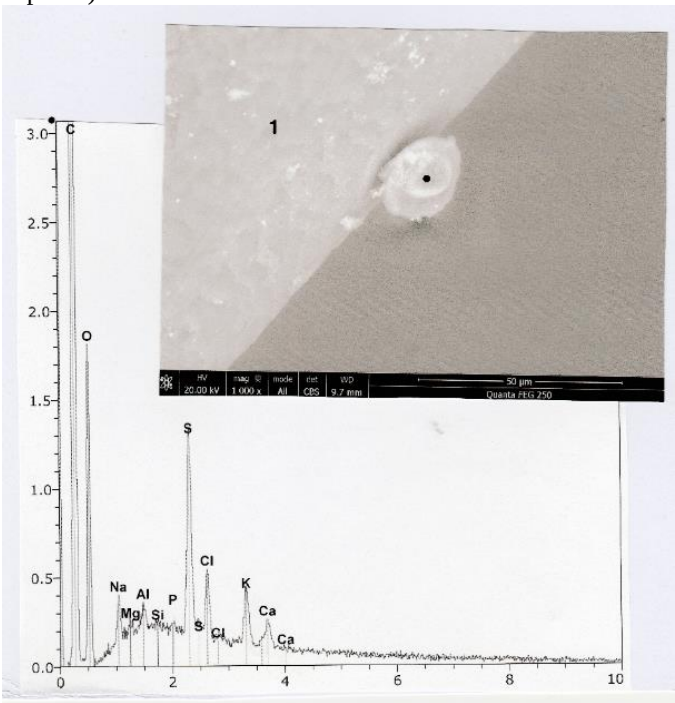
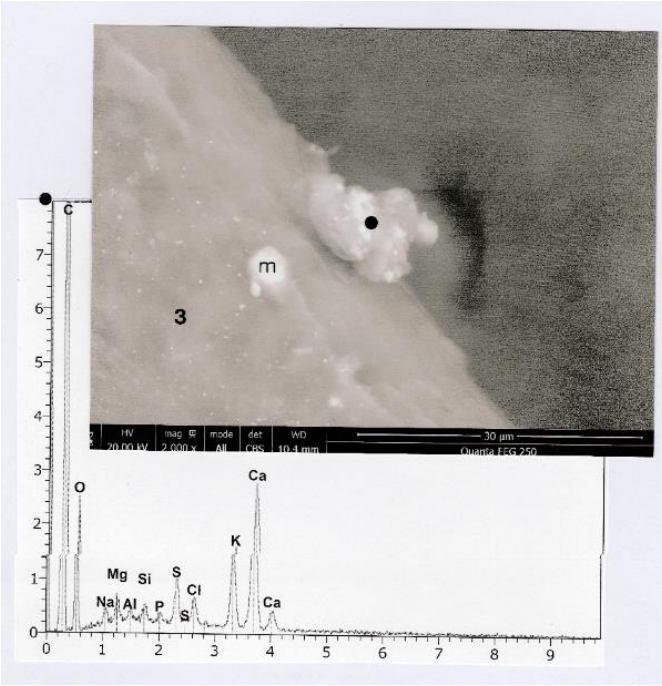


Figure 27 : A little dandruff with black soap, located on the hair number 3. *Above* : SEM photograph (in CBS, 2000x) of the dandruff ; m : micelle. *Below* : spectrum at the black point. C : carbon ; O : oxygen ; Na : sodium ; Mg : magnesium ; Al : aluminium ; Si : silicium ; P : phosphorous ; S (two peaks) : sulphur ; Cl : chlorine ; K : potassium ; Ca (two peaks) : calcium.



The photograph of Figure 28 represents the special observation of a scale fragment, on some part of hair number 6, that is partially pulled up to the hair and maintained on its surface by a fiber portion. Intact black soap fragments (at least six) and also calcium carbonate mineral particles are located at the periphery of the scale.

Figure 29 shows, at the border of some part of hair number 4, a special concentration mass of ancient black soap (this product is on a bed of an iron-rich aluminosilicate and a calcium phosphate).

Some part of hair number 10 is covered by numerous and similar particles (with the appearance of a manufactured product) that are artefacts. One of them is shown on Figure 30 ; it is a little (of about 50µm of maximal dimension) particle, white-to-electrons and with angular outlines (there is evidence of partial destruction of the hair cortex at its level).

Elemental analysis of this particle establishes that it is a grain of a powder of a modern detergent, rich in potassium sulphate and in soda (NaOH). This powder was likely used recently, to clean the interior of the reliquary glass.

Figure 28 : A detached scale of hair number 6, with black soap fragments at its periphery. *Above* : SEM photograph (in CBS, 2000x) of the detached scale (**0**). **1** are bright-to-electrons mineral particles ; **2** are black soap fragments ; F : a fiber. *Upper spectrum* : that of **1** (at the black point). *Lower spectrum* : resolutive spectrum of **2** (at the black point). C : carbon ; O : oxygen ; Na : sodium ; Mg : magnesium ; Al : aluminium ; Si : silicium ; P : phosphorous ; S : sulphur ; Cl : chlorine ; K : potassium ; Ca (two peaks) : calcium.

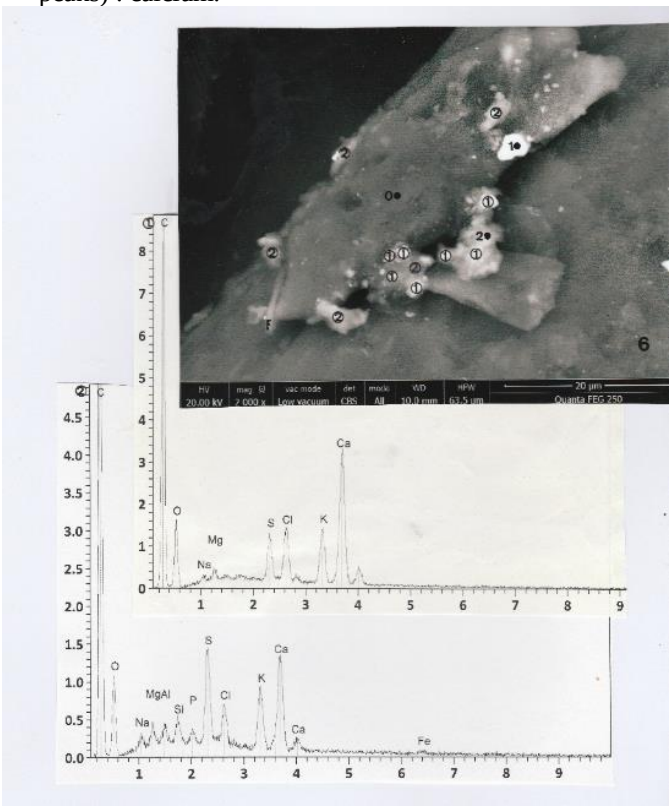


Figure 29 : A special concentration in ancient black soap on hair number 4. *Above* : SEM photograph (in LFD, 1200x) of the concentrate. *Below* : resolutive spectrum at the black point. C : carbon ; O : oxygen ; Fe (two peaks) : iron ; Na (traces) : sodium ; Mg : magnesium ; Al : aluminium ; Si : silicium ; P (traces) : phosphorous ; S : sulphur ; Cl : chlorine ; K (two peaks) : potassium ; Ca : calcium.

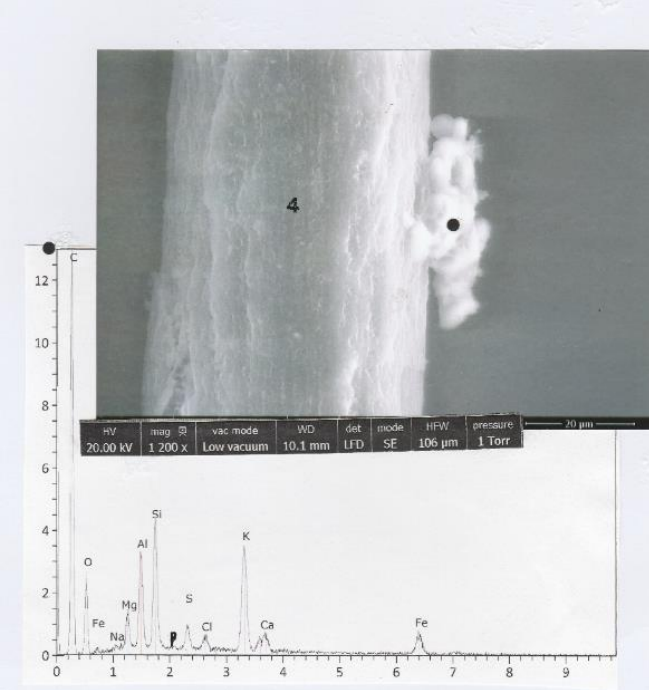
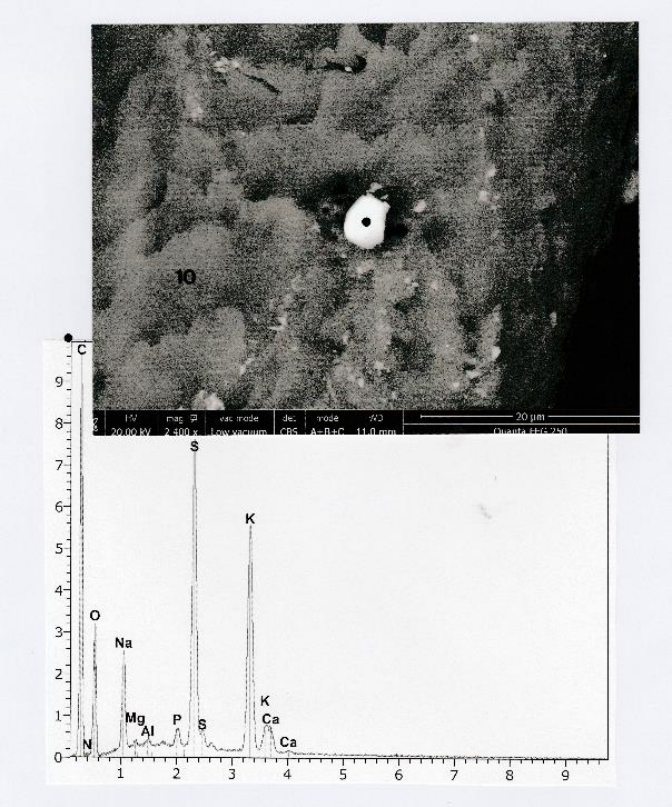


Figure 30 : A particle of a modern detergent, located on the hair number 10 surface. *Above* : SEM photograph (in CBS, 2400x) of the particle. *Below* : spectrum at the black point. C : carbon ; N (traces) : nitrogen ; O : oxygen ; Na : sodium ; Mg : magnesium ; Al : aluminium ; P : phosphorous ; S (two peaks) : sulphur ; K (two peaks) : potassium ; Ca (two peaks) : calcium.



Epiderm micro-plaques

The SEM photograph of Figure 31 shows an epidermal micro-plaque (of maximal diameter of about 150µm), located on the border of some part of the hair number 9. This micro-plaque is maintained here by some fibers of cotton (flat fibers of diameters of about 15-20 µm, with characteristic regular twists along the length of the fibers).

The polygonal outlines of epithelial cells that compound this epidermal micro-plaque are well seen by comparison of the two SEM photographs of Figure 32, which are taken in accordance with LFD and CBS procedures.

Elemental analysis of the micro-plaque establishes that it is constituted of carbon and oxygen (corresponding to organic material), of sulphur (that of keratine), of chlorine and sodium (those of the salt of the sweat) and of calcium.

Figure 31 : The epidermal micro-plaque on the hair number 9. SEM photograph (in CBS, 500x) of the micro-plaque. P : the micro-plaque ; CO : cotton fibers 1 and 2 ; L : a louse nit.

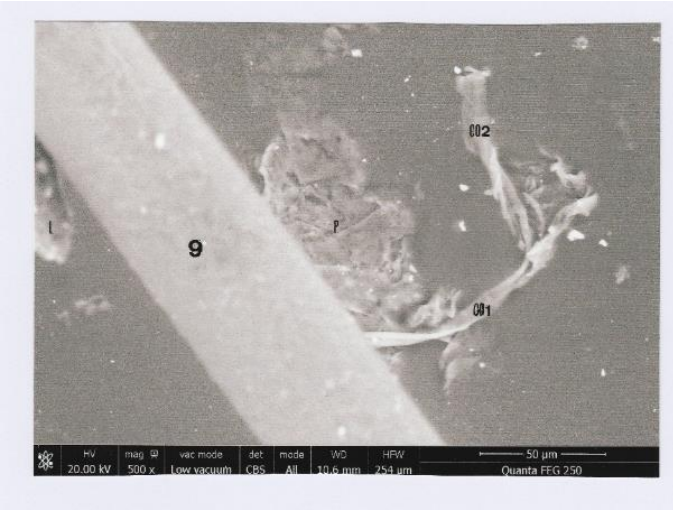


Figure 32 : LFD and CBS comparison of the micro-plaque. *Upper photograph* : SEM photograph (in LFD, 600x) of the micro-plaque. *Lower photograph* : SEM photograph (in CBS, 600x) of the micro-plaque. P : the micro-plaque ; F : fibers 1 and 3 ; arrow point indicates a third (3) coton fiber (the micro-plaque lightly shifted during time to the right, between this photograph and that of the previous figure). *Below* : resolutive spectrum at the black point. C : carbon ; O : oxygen ; Na : sodium ; S : sulphur ; Cl : chlorine ; Ca : calcium.

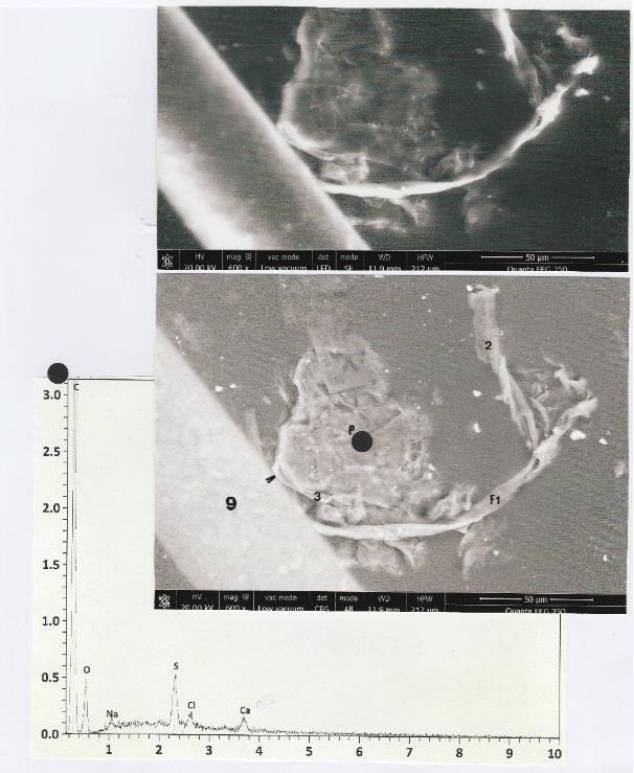


Figure 33 shows the EDX-mapping of elements that constitute the micro-plaque, the hair and the fibers :
. Carbon and oxygen maps establish that these two elements are more abundant in the hair and in the fibers than in the micro-plaque.
. Sulphur soap establishes that this element is more abundant in the hair, compared to the micro-plaque.
. Chlorine is mainly concentrated in the micro-plaque.

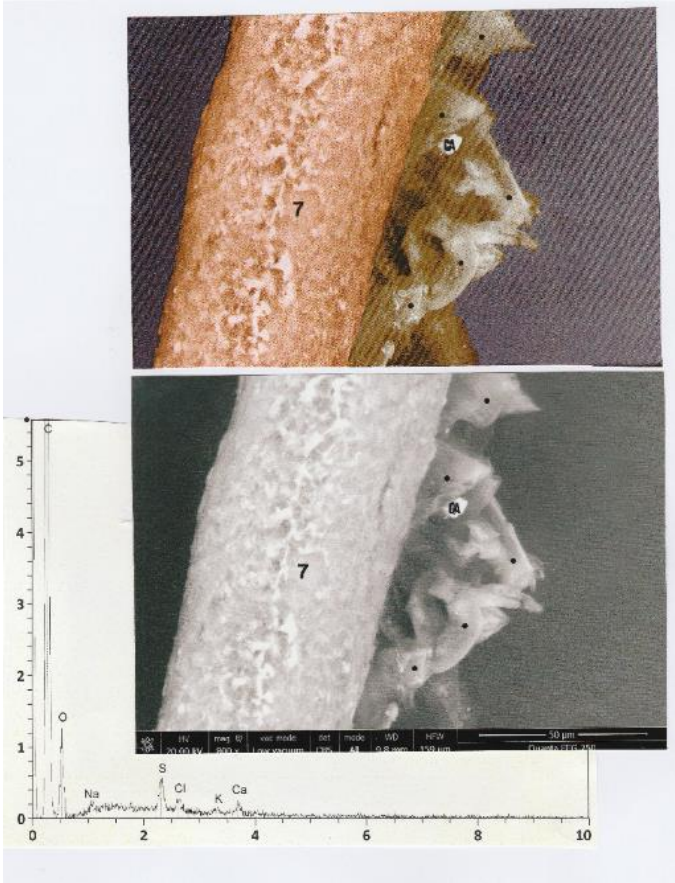
The calcium map reveals only mineral particles of calcium carbonate that surround fibers 1 and 2 at their junction.

The SEM photograph of Figure 34 shows another epidermal micro-plaque (of more than 100 µm of length), located on the border of hair number 7. In this microplaque, individual cells are rarely with angular outlines : most of them are rolled up, as dessicated corneous cells. Their spectrum is that of typical epithelial cells.

In the false coloring representation proposed for this micro-plaque, hair is in red [**6**] and cells of the micro-plaque are in yellow-clear brown.

Figure 33 : EDX-mapping of the hair, the fibers and the micro-plaque. *First row* : the SEM photograph of the region of reference. *Second row* : C map ; O map. *Third row* : S map ; Ca map. *Fourth row* : Cl map.

Figure 34 : The micro-plaque of corneous cells located on the hair number 7. *Lower photograph* : SEM photograph (in CBS, 800x) of the micro-plaque. Ca : a calcite particle. *Below* : spectrum at the black point. C : carbon ; O : oxygen ; Na : sodium ; S : sulphur ; Cl : chlorine ; K : potassium ; Ca : calcium. The upper image is a representation in false-colours of the below SEM photograph.



Some pieces of skin shreds

Figure 35 shows some skin shreds, located on the scotch-tape at the proximity of one extremity of the hair number 8. A special characteristic of the hairs studied is their extreme dryness [**13**] ; so, when the hairs were loaded (in folding back them) on the scotch-tape, some of the relatively dense rests-like the pieces of skin shreds adhering to hairs were dropped on the scotch-tape at the proximity of the hairs where they were initially loaded (see figure 1 for the location of the skin shreds on the scotch-tape).

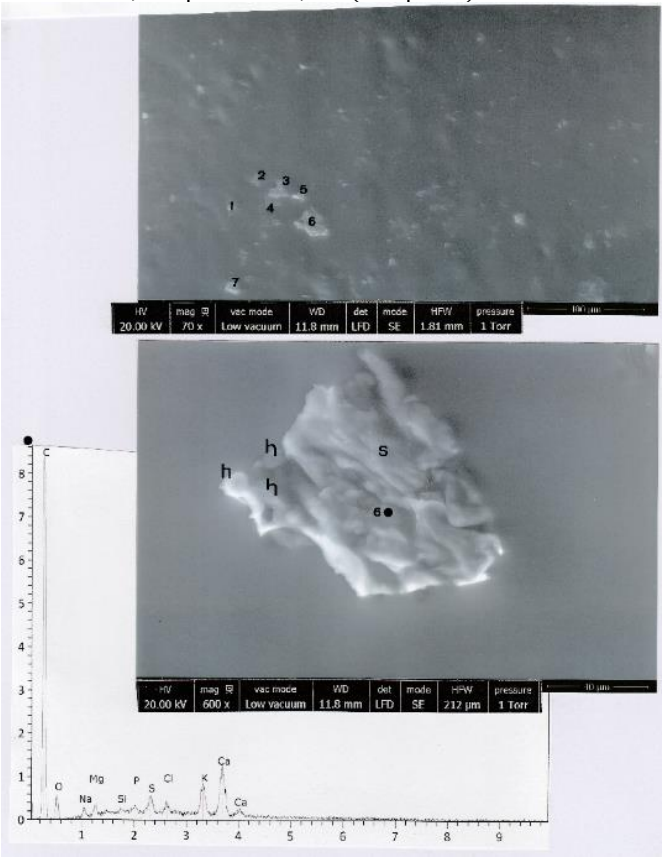
There are at least seven pieces of skin shreds at this location. The biggest one (of about 30 µm of greater dimension), numbered **6** , is of approximate triangular outlines ; it has a wrinkled surface. At least three hematies are visible at its left corner.

Near the superior edge of the triangle, we recognize a little fragment of a silk thread : at least five silk fiber

portions, smooth and of cylindrical forms, are visible as longitudinally oriented along this silk thread.

Spectrum of **6** corresponds to that of a salted and potassic soap cleaned piece of a skin shred.

Figure 35 : Skin shreds, in the proximity of hair number 8. *Upper photograph* : a SEM photograph (in LFD, 70x) of the shreds (numbers **1**-**7**) ; 8 : one extremity of hair number 8. *Lower photograph* : a SEM photograph (in LFD, 600x) of the skin shred number **6**. S : a silk thread fragment ; h : three hematies. *Below* : spectrum at the black point. C : carbon ; O : oxygen ; Na : sodium ; Mg : magnesium ; Si : silicium ; P : phosphorous ; S : sulphur ; Cl : chlorine ; K : potassium ; Ca (two peaks) : calcium.



One piece of a skin shred, enclosing a silk fiber, is conserved by salt crystals. This piece is located on the scotch-tape, above hair number 10 (see figure 1 for the localisation of this piece). The piece (Figure 36) is a relatively great (of about 150 µm of width on 200 µm of length) elongated skin shred. Its surface is pleated. It surrounds a silk fiber, that is divided in silk fibrils in the middle part of the piece. At last four diatoms are visible on its surface. The middle, lower and left parts of the surface of the piece are covered by white-to-electrons mineral particles. The spectrum of its middle part (Figure 37) is that of a salted and potassic soap cleaned piece of skin shred.

Figure 36 : SEM photograph of the piece with LFD and CBS procedures. *Above* : SEM photograph (in LFD, 300x) of the piece. S1 : the silk fiber ; S2 and S3 : silk fibrils ; D : four diatoms (in the orientation of their great axis) ; C : cells with angular outlines. Below : SEM photograph (in CBS, 300x) of the piece.

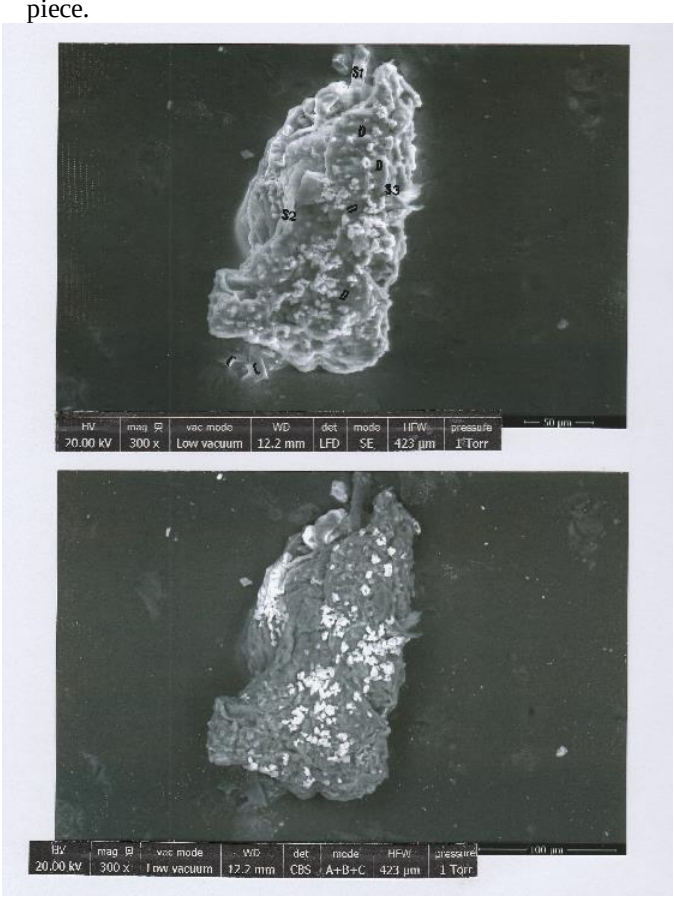
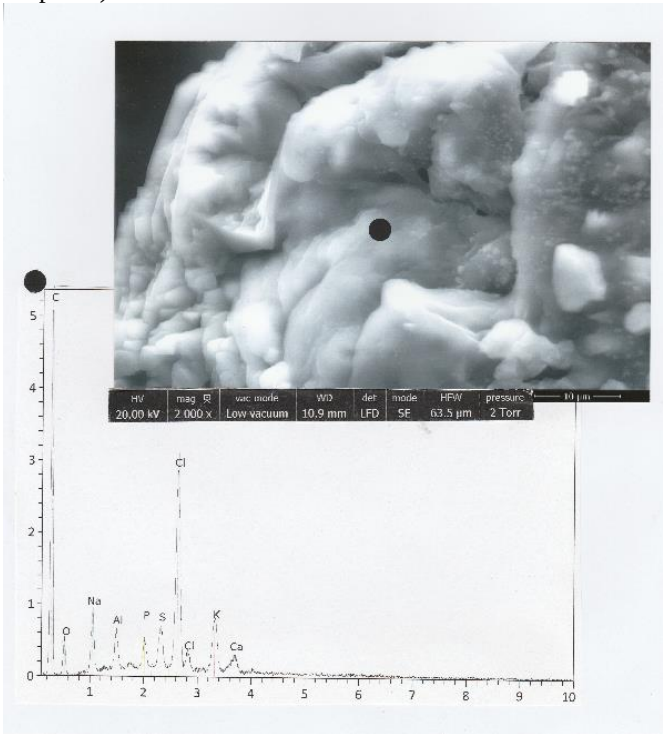


Figure 37 : Elemental analysis of the middle part of the piece. *Above* : SEM photograph (in LFD, 2000x) of the central part of the piece. *Below* : spectrum at the black point. C : carbon ; O : oxygen ; Na : sodium ; Al : aluminium ; P : phosphorous ; S : sulphur ; Cl (two peaks) : chlorine ; K : potassium ; Ca (two peaks) : calcium.



The part of the fiber located on the top of the piece is a silk fiber (Figure 38), because it is a smooth fiber of cylindric form and of a diameter of about 10µm ; its composition (mainly of carbon and oxygen, with some traces of nitrogen) is characteristic of the silk. Silk fibrils (Figure 39), of a mean diameter of about 4.5 µm, are of the same composition ; they are covered (as the matter of the piece surrounding) by little particles of magnesium phosphate.

Silicium is characteristic of the diatom frustule (Figure 40). Their presence indicates that the piece was in close contact to a contaminated water containing these sorts of micro-organisms.

The numerous white-to-electrons mineral particles that cover the most part of the piece (Figures 40 and 41) are crystals (of the cubic form) of salt (NaCl) ; they correspond to a fine powder of a manufactured product. As salt is one of the most ancient chemical product used to preserve meat [**14**].

We infer that their presence – in number – on the surface of the piece signifies that the experimentor will is to preserve in a long term this sort of skin shred.

Figure 42 shows three epidermal cells (with angular outlines), cleared from the lower part of the piece.

Figure 38 : Study of the S1 fiber. *Above* : SEM photograph (in LFD, 2000x) of the fiber. *Below* : spectrum at the black point. C : carbon ; N (traces) : nitrogen ; O : oxygen ; Na (traces) : sodium ; Al (traces) : aluminium ; Si (traces) : silicium (this spectrum, as the three followings, was obtained on a special SEM : Auriga FEG-FIB, from Zeiss).

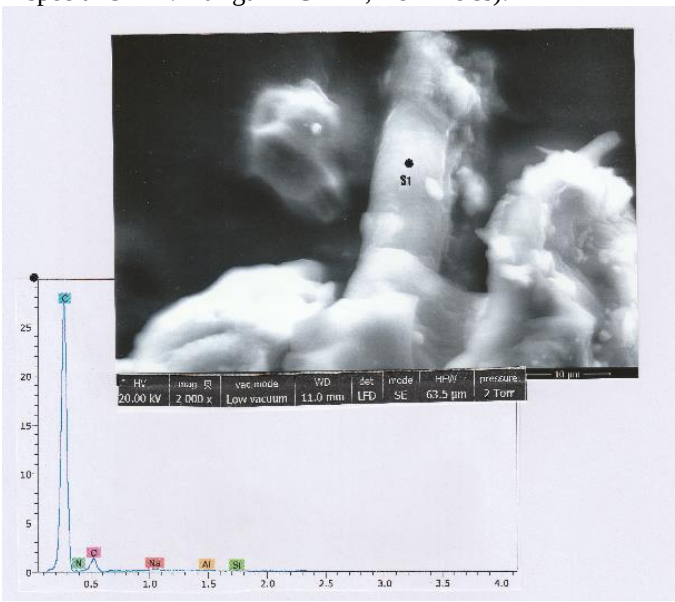


Figure 39 : Study of the F2 fibrils. *Above* : SEM photograph (in LFD, 2000x) of the fibrils (dimensions are in µm) ; the little circle encloses a very little of the particles that cover the fibrils. *Upper spectrum* : that of the particle. *Lower spectrum* : that of the fibrils. C : carbon ; N : nitrogen ; O : oxygen ; Na : sodium ; Mg : magnesium ; P : phosphorous.

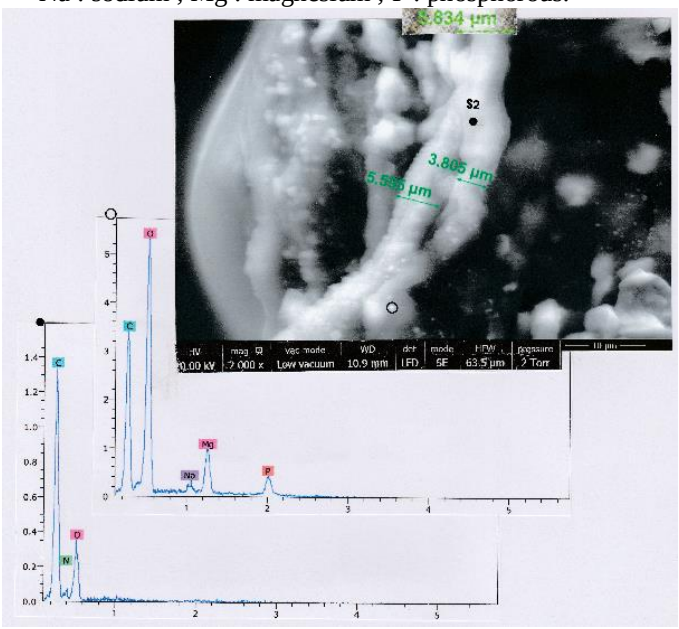


Figure 40 : Study of the white mineral particles. *Above* : SEM photograph (in CBS, 1200x) of the main area where white particles occur. **1** : the central part of the piece ; **2** : one of the white particles ; D : diatom. *Upper spectrum* : that of the diatom. *Lower spectrum* : that of **2** (in black), staked on that of **1** (in red). C : carbon ; O : oxygen ; Fe : iron ; Na : sodium ; Mg (traces) : magnesium ; Al : aluminium ; Si : silicium ; P : phosphorous ; S : sulphur ; Cl (two peaks) : chlorine ; K : potassium ; Ca : calcium.

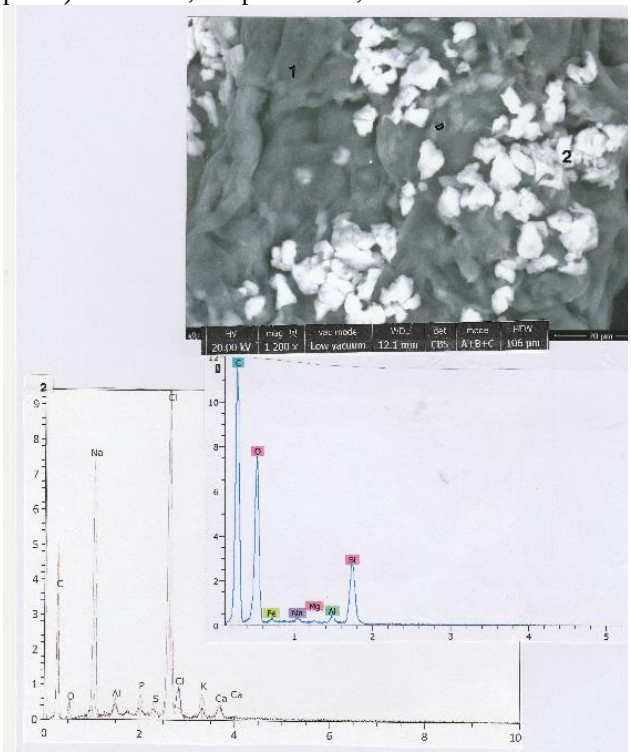


Figure 41 : Study of crystals of salt. *Upper photograph* : SEM photograph (in LFD, 2000x) of some salt crystals ; dimensions are in µm. *Lower photograph* : SEM photograph (in CBS, 2000x) of salt crystals located on the left part of the piece. *Below* : spectrum at the black point. C : carbon ; O : oxygen ; Na : sodium ; Al : aluminium ; P : phosphorous ; S : sulphur ; Cl (two peaks) : chlorine ; K : potassium ; Ca : calcium.

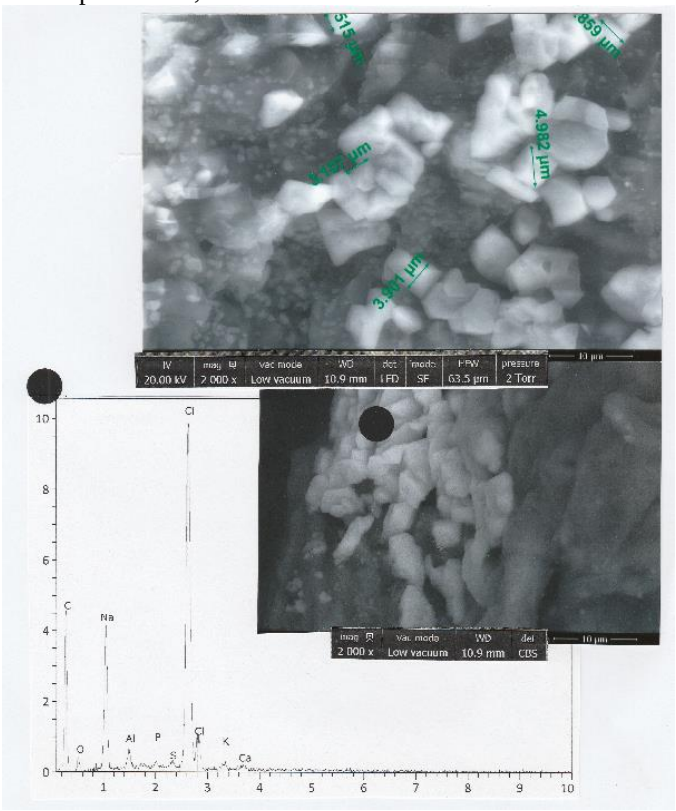
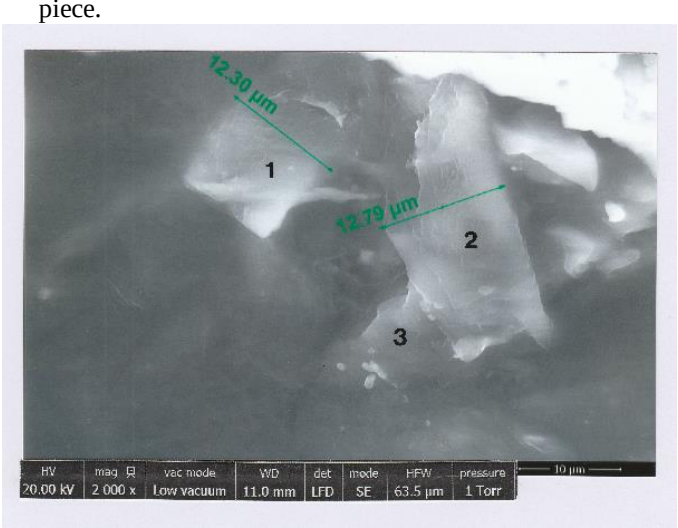


Figure 42 : SEM photograph (in LFD, 2000x) of three (1-3) cells, located on the lower part of the piece.



A small piece of scalp

The SEM photograph of Figure 43 shows a large plaque (of about 50 µm of length) that is stuck up the border of some part of hair number 9.

This plaque (of about 15 µm of thickness) is constituted of at least three (C2, **P** and C1) stratified layers of cells. The C1 layer is an epidermal shred, that is detached from the below (dermic) **P** layer. It constitutes a more convincing evidence of a piece of scalp than that shown in [**6**].

Elemental composition of the P layer is that of a cellular layer of the previous forms ; but cellular outlines are not distinguishable both in CBS or in LFD, inside of the dermic layer.

In the false-colouring representation proposed for this piece of scalp, which is compounded of a basal thick dermic layer surmounted by a more thin exfoliated epidermal shred, hair is in red and the piece of scalp is in dark-brown.

The mineral particle number **2**, located inside of the dermic layer, is of calcium phosphate (Figure 44). The study of its elemental composition shows that it is constituted of hydroxyapatite, the mineral component of the osseous material. It is not surprising that a plaque of scalp contains some residual particles of hydroxyapatite, originating from the osseous material of the cranium.

Figure 43 : The piece of scalp, on hair number 9. *Lower photograph* : SEM photograph (in CBS, 500x) of the piece (**P**). C1 and C2 are other parts of the piece. **1** : a silica particle ; **2** : a calcium phosphate particle ; **3** : a calcite particle. *Below* : spectrum at the black point of **P**. C : carbon ; O : oxygen ; Na : sodium ; Si : silicium ; S : sulphur ; Cl : chlorine ; Ca (two peaks) : calcium. The upper image is a representation in false-colours of the below SEM photograph.

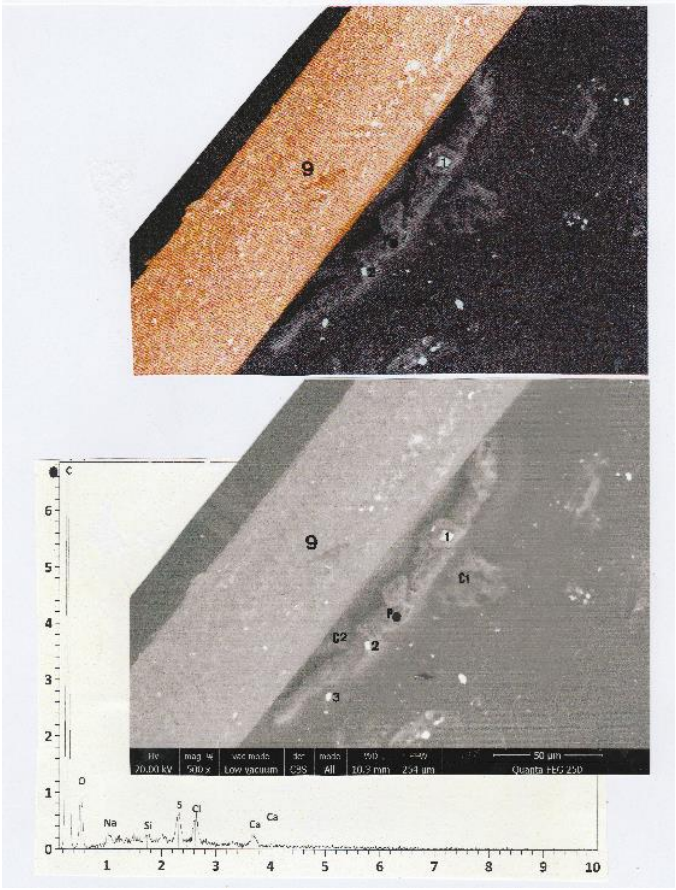
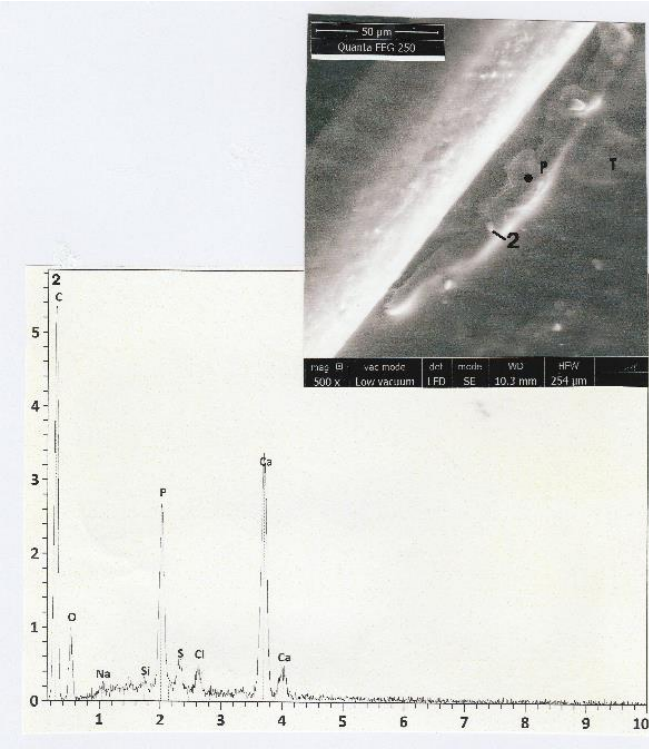


Figure 44 :Study of the mineral particle number 2. *Above* : SEM photograph (in LFD, 500x) of the particle (**2**). P : the piece ; T = C1 : another part of the piece. *Below* : spectrum of **2**. C : carbon ; O : oxygen ; Na : sodium ; Si : silicium ; P : phosphorous ; S : sulphur ; Cl : chlorine ; Ca (two peaks) : calcium.



This particle is one of the numerous examples of calcium phosphate particles we found on the hair surfaces [**8**]. As another example, Figure 45 shows a group of calcium phosphate particles loaded on hair number 7.

The SEM photograph of Figure 46 shows an enhanced view of piece C1. It is a typical epidermal shred, with pores and pleats on its surface. For comparison Figure 47 shows an epidermal shred of reference (that originates from the face of a living 30 – years old man [**5**], with characteristic pores and pleats.

Figure 45 : Example of calcium phosphate located on hair number 7. *Above* : SEM photograph (in CBS, 1200x) of the particles. *Below* : spectrum at the black points. C : carbon ; O : oxygen ; Na : sodium ; Al : aluminium ; P : phosphorous ; S : sulphur ; Cl (traces) : chlorine ; K : potassium ; Ca (two peaks) : calcium.

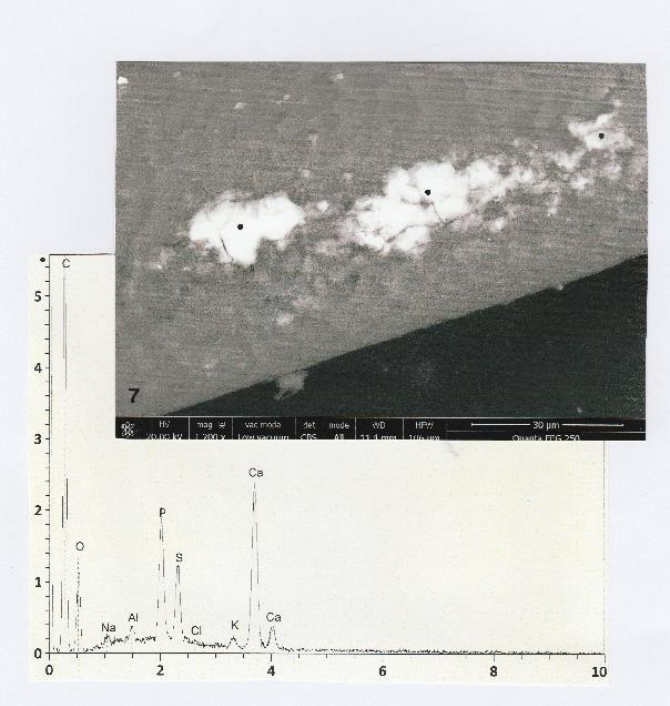


Figure 46 : A detailed study of piece C1. *Above* : SEM photograph (in LFD, 2500x) of the piece. PO : pores ; PL : pleats. *Below* : spectrum at the black point. C : carbon ; O : oxygen ; Na : sodium ; Si : silicium ; S : sulphur ; Cl : chlorine ; Ca : calcium.

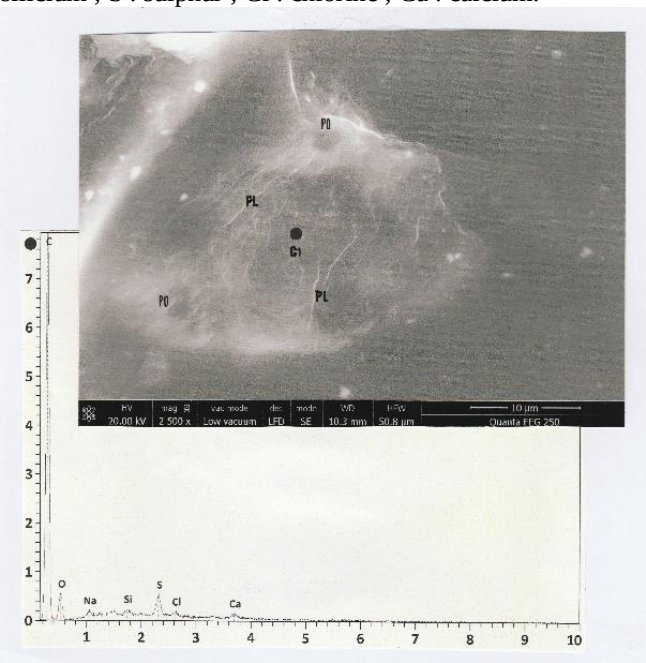
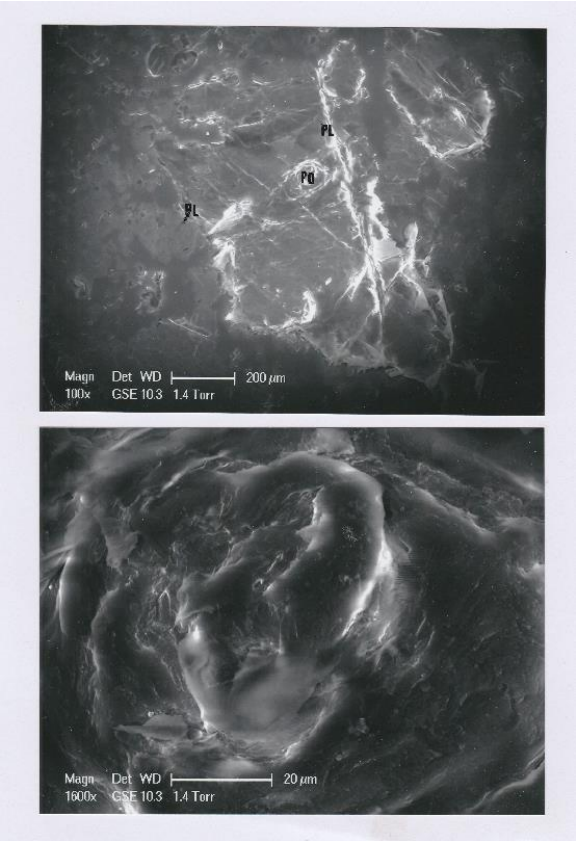


Figure 47 : Study of an epidermal shred of reference. *Above* : SEM photograph (in BSE, 100x) of the shred. PO : pore ; PL : pleats. *Below* : SEM photograph (in BSE, 1600x) of the pore.



Conclusion

We have observed numerous skin debris on the surface of Maria-Magdalena's hairs. Some of them, located near cut extremities, are those of the fingers of the people who cut these hairs (that were initially longer) ; consequently, these skin debris dated from that of cutting.

Some of the skin debris are dirty, because we observed mineral ground particles on their surfaces. Some other hairs are salted, or/and coated with calcium carbonate and calcite particles.

We observed also, kept on some hairs, some quasi-intact dandruff piles.

We have determined the soap that washed the hairs. Three different sorts of soap residual rests were identified (Table 2):

Table 2 : The three different sorts of soap identified.

Soap sorts	Soap compositions	Corresponding figures
1	steatite	figure 16
2	black soap	figure 24
3	modern detergent	figure 30

We identified only one steatite road, and the modern detergent particles are artefacts. The soap that was used to clean the hairs is an ancient black soap, potassium-rich.

Incidentally, we discovered on some part of hair number 10 (figures 22 and 23) one little group of hematies. Its dimensions are reduced compared to those of standard human hematies ; but they can be red blood cells of Maria-Magdalena, their dimension reductions being a consequence of their age.

We observed two samples of epidermal micro-plaques, stuck on the surfaces of hair numbers 9 and 7 respectively. While the morphology of epithelial is intact in the first micro-plaque, that of those of the second one is somehow that of corneous shrivelled cells.

Among the pieces of skin shreds studied, two of them are coated with silk thread or fibers. The surface of the largest of them is covered with a fine powder of salt (figures 40 and 41). That is an intentional conservative procedure, that was probably used for the preservation of the precious tissues of the "*Noli me tangere*" [**15**].

Finally we observed a true specimen of a scalp shred, with epidermal and dermic components, adhering to some part of hair number 9.

Aknowledgments

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