Comments on the “Report Museum of the Bible Dead Sea Scroll Collection Scientific Research and Analysis”, C. Loll, Art Fraud Insights, November 2019.

In the absence of reliable reference materials, scientific analysis may identify forgery only if anachronistic features are securely identified as being an original part of the object. To exploit the advantages offered by destructive analysis (sample extraction), each representative sample must be carefully assigned to undergo testing by different techniques. The Bundesanstalt für Materialforschung un -prüfung (BAM) and Staatliche Kunstsammlungen Dresden (Dresden Gallery of Art) established a protocol for representative sampling, setting out the visual, multi-spectral, radiographic and µ-XRF imaging examinations that assist in targeting sampling locations, the number of samples and the sampling methods. It is important to be clear about the degree of homogeneity of the sample when using methods with an extremely small interaction volume as required for techniques such as electron microscopy (e.g. SEM), µ-Raman, and µ-FTIR.

In this review, we are commenting on the following features of the report presented by the Art Fraud Insights (AFI):

1. Structure of the report, documentation of the sampling and analysis and the presentation of the results.
2. Comparison of the results and their relevance to the question of identification of forgery concerning a single fragment SCR000121 most extensively studied for this report.
3. The historic part, information on the makeup of the DSS and cited literature.
4. Conclusions

1. Structure of the report, documentation of the sampling and analysis and the presentation of the results.

The first striking feature of this 212-page report is that it contains several autonomous reports composed by three members of the team, Abigail Quandt, Jennifer Mass and Aaron Shugar (AQ, JM and AS, respectively).

The report as a whole is incoherent as pages and the figure numbers have not been merged into a unified presentation. This makes for exceptionally difficult reading. We encounter double pagination 108-167 / 1-60 (Jennifer Mass) and 168 – 187 / 1-20 (Aaron Sugar1) as well as repeated numbering of the figures and tables. For example: on the page 17 of the Summary of Elemental and Molecular Analysis, the reader is referred to Figure 1 for the summary of the minerals on the fragments. There are 6 different images named Figure 1 to choose from, namely those on the pages 8, 18, 114 / 7, 171 / 4, 191 and 208. Table 1 appears on page 16, 111/4 and 196. In contrast, AQ (pp 29- 106) subjects the reader to long computer files names, which indicates a level of accuracy inconsistent with the lack of inclusion of a simple scale in many of the images.

The “rigorous scientific protocol”, purported to have been designed and conducted by the AFI eludes us (see p.1).

On page 3 it is stated that “the extensive research carried out at the MOTB has resulted **in the creation** of a rigorous and reproducible protocol”. On page 4 this is rescinded, it is noted that the team conducted its research “**according to standard and internationally accepted** protocols recognized by museums and scholars in a manner consistent with respect to …**texts of similar age**…” While there are no universal protocols of analysis, it is universally understood that protocols of working methods are required to be outlined in full as a means of assessing degree of accuracy and repeatability of the results. Finally, texts of similar age onto the DSS writing supports have not been investigated by the international community of material scientists.

Instead of the protocol, the techniques are listed. On pages 2, 5 and 6, the MSI / RTI appears on the list for no apparent reason as results are not included in this report. Is it because the imaging was conducted by a different team many years earlier? If so, why it is it not acknowledged? Micro Raman analysis is mentioned on page 2, however, again no results or references are provided making it redundant. Curiously, the team seems unaware that micro-Raman was found to be the technique of choice for identification of the presence of tannins (published by Bicchieri et all 2018).

All the MOTB fragments underwent visual analysis however, only 6 (JM) and 4 (AS1, XRF) were picked for in depth analysis. The strategy for sampling is not explained in the general summaries section (pp.2-29), which impacts negatively on the overall relevance of the sample analysis. To illustrate this point, let us compare sampling of the fragment SCR000121 (pages 33 and 114 /7).

With reference to page 33 in the AQ section, five regions on the hair side of the fragment are pointed out as being of interest (in contrast to basic conservation protocol, the flesh side was not documented or marked for closer investigation).

On page 114 /7 in the JM section, two sampling areas are marked for high-resolution FTIR analysis on the hair side and a further two on the flesh side. The areas of interest in the AQ and JM sections do not coincide, with the exception of perhaps JM Region 2, which is in rough proximity to AQ region 3. With reference to p. 35 of the AQ-Report, the bottom micrograph of region 3 corresponding to an approximate area of. 4mm x 4 mm (unreadable scale) illustrates the extent of heterogeneity of the fragment. How many micron sized samples (studied by JM) would be needed to characterize this area? Interestingly, the FTIR results corresponding to the area 2 are not presented. i.e**. there is no correspondence between the studies conducted by AQ and those conducted by JS.**

Alleged ink sample that was studied by JM was extracted from the flesh side of the fragment, on which no text appears. This fact invalidates all the attributions concerning the ink in this fragment.

Unfortunately, no images of the samples that were extracted for high-resolution FTIR are presented in this report. In contrast, the two samples that were extracted for the study by AS are depicted in fig. 11 (p26) and fig.1 (p. 191) but the orientation is unclear as is the place from which they were taken.

2. Comparison of the results and their relevance to the question of identification of forgery concerning a single fragment SCR000121 most extensively studied for this report.

Let us now compare the results from the study conducted by AQ (pp. 33-37), JM (pp. 114-115 / 7-8), AS (p.173 / 6, XRF) and (p. 206, 2 samples studied in depth) offered by AS.

Team Member	Method	Resolution	Result
AQ, pp. 33-37	Microscopy	Different magnifications	Animal glue[2] (sic!), sediment on ink.
JM, pp. 114-115 /7-8	FTIR (trans)	µg	Animal glue[2], usual sediments[1], cellulose, alkyd polymer
AS, pp.172-3 /5-6	XRF	0,5 mm	Usual sediments[1]
AS, p. 206	FTIR (ref)	50 x 100µ	Oil[3]
	Microscopy		Oil[3]
	SEM/EDX		Sediments, no oil(?)

[1] Sediment on top of the ink layer seems more in line with what we would expect, than sediment found UNDER the ink which would indicate an overwritten defect.

[1]All the sediments identified (JM) or suggested (XRF, AS1) do not have enough specificity to indicate provenance or dispute the possibility of authenticity. Therefore, the data bears little relevance to the question of the forgery. Curiously, none of the team members realized that absence of aragonite would at least indicate a location different from Qumran.

[2]Animal glue seems to have been identified visually by AQ and JM (though in a slightly different context). Gelatinized leather and gelatinized tanned parchment take on the appearance of an “amber-coloured” coating. Moreover, they display FTIR spectra of prepared animal skin glue simply because in the gelatinized state they are transformed into animal skin glue, it is tautological. Fig.1 (of this review) compares the top figure from the AQ report on page 37 and a detail of a fragment of the Thanksgiving Scroll 1QH^a. Its dark surface superficially resembles leather due to the effects of tanning, it has shiny regions of gelatin films (see white arrow).

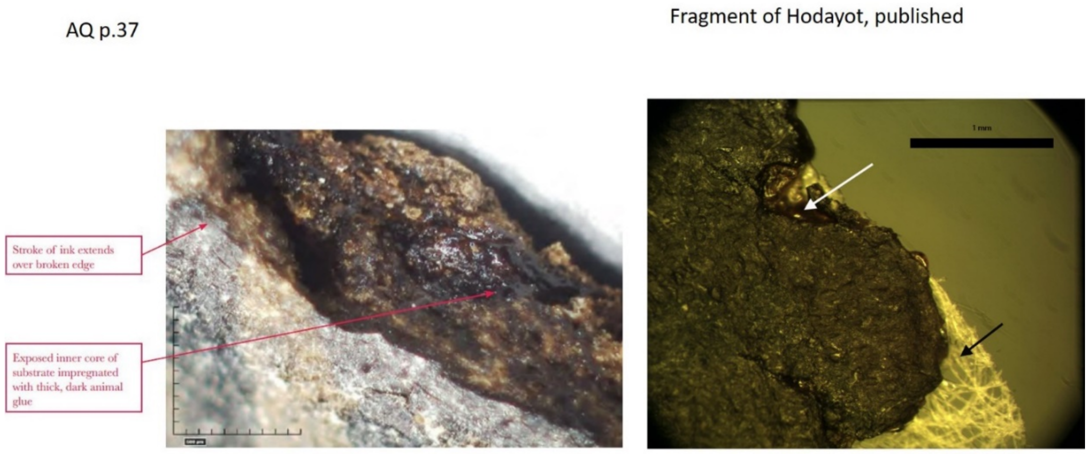

Fig. 1 Micrographs of fragment SCR000121 (left) and a fragment from the scroll 1QH^a (reprinted from Rabin & Hahn (2012) Restaurator 33, p. 106).

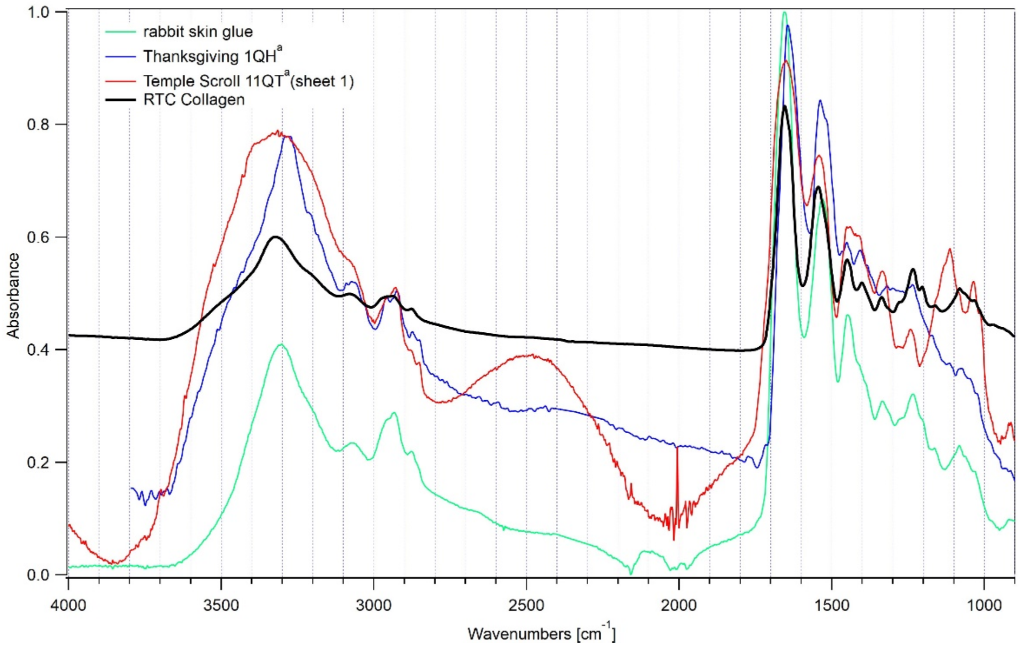

Fig.2 FTIR spectra collected in transmission mode from rabbit skin glue (green), 1QH^a (blue), 11QT^a (red), RTC (black).

Fig. 2 compares the FTIR spectra from two gelatinized DSS parchments with gelatin, represented by rabbit skin glue and pure collagen extracted from rat tails (RTC), a common reference in medicine. As one can see, the range, 1800 – 1000 cm^{-1} looks quite similar in all four spectra. Note that the amide peaks that serve to identify collagen / gelatin vary slightly between 1650 and 1540 cm^{-1}. This makes a differentiation between gelatin and collagen hardly possible with this method.

Figures 1 & 2 prove that there is no reason to believe that a gelatin coating was applied to this or other fragments. The mistake is inexplicable: the very first paper describing the appearance of the gelatinized DSS fragments by Plenderleith appears in the list of references in the JM report.

A notable inconsistency was not addressed in this report, namely that linseed oil was found by AS in two samples using FTIR spectroscopy whereas JM using the same FTIR spectroscopy, did not find it in any of her samples. The reader is left in suspense: was oil found or not? Was it a minute contamination just in the two samples extracted by AS? If so, they cannot be representative of the fragment. Similarly, alkyd polymer was found only by JM on one of the samples. How relevant are these findings to the question of forgery?

All in all, there are only two statements relevant to the question of forgery:

1. **(p.7 AQ, p. 15 JM) All the texts but one, are written on leather which is determined by the visual analysis only.** There are several ways to distinguish between leather and parchment. The team adopted the least reliable of all (spot tests) and failed, which is probably why the results were not included in the main summary pp. 15-28, nor did they raise doubts in the identification of the material. But even if we accept this identification, would it unequivocally prove that the fragments are forgeries? The answer is no, because we do not know how many authentic scrolls were written on leather.
2. **(p. 15 JM) The leather fragments were produced by lime-depilation process.** If this is the case, this would be unequivocal proof of forgery since lime-treatment is anachronistic to the DSS. Unfortunately, this assertion is not substantiated by analysis offered in the report. Moreover, on page 111 / 4 of the report this statement is explicitly negated: “Aside from unambiguous conservation materials, **no anachronistic or anomalous** materials were identified in the studied fragments.” The literature offers at least, two different ways to identify the depilation method, one by FT-Raman, another by sectioning of a fragment and comparing the FTIR spectra of the surface layer to those of the core layer.

3. Historic Section; material information and cited literature

Explanatory text shedding light on skin-based materials is interspersed throughout the report along with a great deal of speculation and conjecture. The numerous inaccuracies and irrelevancies render the report hard to follow or digest. On page 15, JM presents her introduction to the DSS and we learn that they were predominantly written on parchment – no reference supports this critical generalization, which forms the team’s main indicator of authenticity. We also learn that “**A preliminary study of the mineral deposits on the MOTB fragments, published in 2018, led to the suggestion that these deposits were inconsistent with the fragments being authentic Dead Sea Scrolls.**” This fact is thrown in with no references enabling the reader to access the research for consultation. Similarly, on page 6, AQ presents the main differences between leather and parchment in relation to the tanning of the DSS, again, the relevance of this information is critical to the arguments that follow yet the source of the information is blithely omitted. The aim of the study is clearly stated “**… clarify the manufacturing process of the fragments (if it can elucidate whether it is leather or parchment)”**, however, for example, fragment SCR000121, is called both parchment and leather (parchment: pages 189, 196 and 203 and leather: pages 192,194,200 and 205).

AQ states that the majority of the authentic DSS are of “lightly tanned or untanned parchment” with a certainty that could only be derived from knowledge of a complete survey of the DSS collections, however such a comprehensive study has yet to be conducted. We know very little about the common traits of all the scrolls or how they may be grouped. It is apparent that the team misses out on the key points of DSS research that has already been carried out leading to misconstrued observations. This section of the report is not without a bibliography, 14 references are listed on page 28. Of these, the two which relate to the makeup of the DSS (ref.5 Poole and Reed from 1962 and ref.11 Rabin & Hahn from 2013) are not cited for this information, but rather in relation to the identified sediments, and the reference to alum is cited from Rabin/Hahn hidden under “Rabin et al.” rather than M. Derrick (ref 3) who was the first one to identify alum on the DSS.

The Summary of the elemental and molecular analysis on pages 15-28, contain impressive tables and lists, but their relevance to forgery identification is not explained. On page 16, “Mineral deposits”, chalk is classed as a mineral but is in fact a sedimentary rock; aragonite classed as a ”**rare mineral**” is found in abundance in the natural and artificial caves of Qumran (A. Katz and A. Starinsky, “Geochemical History of the Dead Sea,” Aquat Geochem 15 (2009): 159–94. Aragonite was not identified in this study despite the claim in Table 1 page 16.

The report comprises a visual examination (AQ) and three scientific reports (JM, AS1 and AS2) – it is possible that an effort was made to give everyone a free hand to carry out his study independently in the name of independence of thought, however the result was four autonomous reports which do not relate to each other or support one another. The review of each report is attached as an appendix to this overview.

4. Conclusions

The report that was submitted by Art Fraud Insights, LLC is a compilation of individual reports of two scientists and a conservator recruited to confirm or refute the authenticity of each fragment. Each of the fragments were not subjected to the same barrage of tests but rather the group of twelve fragments was seen as a set of deliberate forgeries. This is why only 6 (FTIR) / 4 (XRF) fragments were set aside for sediment and ink analysis and only a single fragment for further SEM / EDS analysis. The conclusion that all are forgeries was in effect based on a visual assessment only – none of the individual scientific reports (JM, AS1, AS2) arrive at this conclusion. Despite the luxury of destructive sampling, scientific expertise and state-of-the-art facilities we conclude that the team failed to

a) prove that any of the MOTB fragments was forged;
b) determine the type of the material (leather or parchment);
c) determine the production method, in particular the dehairing method (using lime or enzymes).

The reason for the missed opportunity lies not in the scientific expertise but in the coordination and synchronizing of the team in terms of testing the same areas of interest and fastidiously focusing the analysis on the characteristics that are pertinent specifically to authentic DSS material. The path to determination of a forgery should have been made clear to the team, that is, inspection to prove unequivocally that each fragment is not DSS through chemical and physical analysis. Instead the team sought to associate the fragment skins with other archaeological finds through visual comparison and get bogged down with unnecessary analysis of conservation materials and non-specific minerals.

Appendix

A. Quandt Section pp. 6-14, 33

The strategy of this examination is based on the preconceived notion that all the MOTB are forgeries. The AQ report does not commence with a full description of each of the fragments setting out their possible commonality with authentic DSS. A formal check list of examinations shedding light on evidence of skin type, scribal practice, texture and degradation was not carried out. This would have permitted deviations from the expected characteristics to be described and prioritized for analysis by the team scientists. This was not done. Instead attention is drawn to Roman leather and the work of the alleged forger.

The quest for the answer to the riddle (how were these fragments forged?) takes priority over the question (how are these the same as DSS?) for the very fragment (SCR.004742), which at first glance held the most promise for being authentic, was not signaled for complete profiling; instead a "fake" fragment (SCR.000121) was chosen, supposedly for being representational of all the MOTB fragments.

The report begins with a summary in the form of a list of imaging setups, most of which were not used by AQ or discussed in the report. The list is followed by a general discussion on leather and parchment without supporting footnotes or bibliography. This is followed by a section dedicated to Roman shoe leather and several Schøyen fragments neither of which were examined by the team. The MOTB fragments are finally compared to themselves, Roman leather and poor photographs of two fragments in the Schøyen collection, concluding that none are authentic DSS.

The evaluations that the fragments are of leather is based in part upon skin thickness as the surface textures are noted as being obscured by an amber coating. The study does not proceed to compare measured thicknesses with expected thicknesses of DSS so "thick and thin" is rendered a somewhat subjective determination.

It is possible that because the fragments are looked upon as forgeries the amber coating is automatically considered to be an applied proteinaceous material rather than gelatinized skin. On page 12 there is a telling comment:

"The possibility that the black layer below the writing is a coating was considered, yet no pigmented materials were identified during analysis with FTIR." Why was black pigmentation considered? Gelatinization of DSS skins can certainly be black. Infrared images would immediately distinguish between gelatin and carbon-based pigment. This leads to the question why the ink flow study was not carried out using infrared illumination rather than visible light. This would certainly have prevented confusion between blackened gelatin and carbon ink.

Taking fragment SCR. 000121 p. 33, as an example of the descriptive section, a description is missing of the top B/W image of the fragment shot under 450 nm
(cf. Fig. 1 p.171). Missing is a description of the appearance of the fragment as a whole, front, back, the fact that is broken into two, cracks and associated broken flake. The imaging technique of the coloured image is not specified nor has it a scale. The fragment as a complete object is not assessed.

J. Mass section pp. 108-167 / 1-60

Note: These comments do not aspire to provide every omission found in the report but rather to highlight the most striking ones.

I. Sampling, technique, and instruments (p. 167 / 60)

The following information is missing: sample images before and after flattening, which spectra were taken at the MOTB museum, aim of the follow up analysis; which spectra belong to the follow-up analysis; which spectra were taken with which instrument.

If multicomponent search was performed, why isn't there a comparison with resulting multicomponent spectrum or an indication of the meaning of the "best match" in percentage?

II. Fragment SCR000121: FTIR study

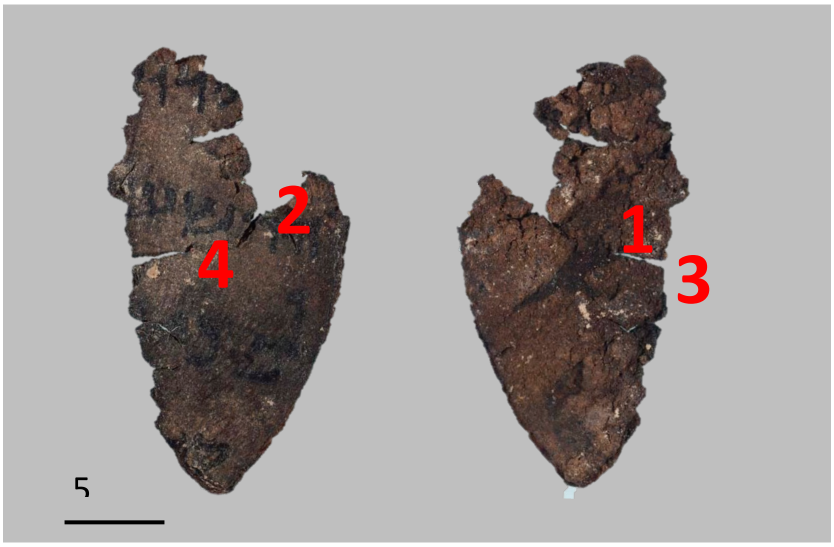

Figure 1. SCR 000121, text: Psalms, inventory group no. 1, figure of fragment recto (*left*) and verso (*right*) with sampling locations marked on it. (this figure with the caption is copied from the p. 114 / 7)

Table 1. SCR 000121 summary of Fourier Transform Infrared Spectroscopy (FT-IR) results (the caption and the columns "Sample, Material, Phases Identified" is copied from p. 114-115 / 7-8)

Sample	Material	Phases identified	Comments Hahn-Rabin-Rimon
3	ink	animal skin glue, cellulosic material [best match hemicellulose]	JM independent investigation of the flesh side. Analysis not supported by the necessary preparatory investigations using microscope or IR photography confirming presence of carbon ink. In addition, Brill publication makes no mention of text in any type of ink on the flesh side. (Dead Sea Scrolls Fragments in the Museum Collection (Leiden:Brill, 2016) pp. 190-199.) **The attribution of the spectra to the ink binder is, therefore, wrong and should be attributed to the gelatinized portion of leather that has brown-to black colour when degraded.** Here, FTIR would help identify the presence of tannins (Cf. Bicchieri). On the mixing or organic and inorganic phases see Rabin & Hahn 2013, DSS by advanced techniques). Spectra: Fig.11-14, pp. 131 / 24 – 133 /26 . Red curves: It is a pity that the peak positions were not given or compiled in table format facilitating interpretation of the results. Moreover, overlying all spectra from the skin area would have proven to be helpful.

				Why is the detection range expanded here to 500 cm^{-1} in comparison to the one indicated in the experimental section (650 cm^{-1}) p.60? All spectra from the sample (red curves) show peaks due to amide I & II at ca. 1650 & 1540 cm^{-1}, resp.; the peaks most probably corresponding to CH$_2$ wagging vibrations at 1448 and a carbonate ca. 1420 cm^{-1}. The key to determining the presence of tannins is the reversal of the intensities at 1081 and1032 cm^{-1}. In the FTIR spectrum of collagen, either fully gelatinized or not, *I*(1083) > *I*(1032) as can be seen in the spectrum of rabbit skin glue. If tannin is present, the intensity is reversed (see Fig. 20 top red curve). Finding cellulosic material would be consistent with the conservation history described on page 14, but the spectra does not actually show that it is present.
1	sediment	cream particle	calcium carbonate, phyllosilicate clay [best match illite], quartz	Fig.7-10, pp. 129 / 22 – 131 / 24. Why are the intensities due to quartz and carbonate reversed in the longer scans (Figs.9-10) as compared to the shorter scans (Figs.7-8)? Was the first scan conducted prior to flattening the sample with a roller? Isn't such a remarkable difference between two spectra of the same region worth a comment? Why are the scans of this sample / region cropped at just below 800 cm^{-1}? No comments are made on the different number of scans in the experimental section (p. 60).
5		tan particle	calcium carbonate, phyllosilicate clay [best match kaolinite]	Sampling regions 5 & 6 do not appear on Fig.1, p. 114, these sampling areas are, therefore, disregarded. It would have been appropriate to include detailed images of the samples here – easily achieved (every microscope probably has a camera).
6		black particle	calcium carbonate, phyllosilicate clay [best match montmorillonite], quartz	See above
5	coating	saturated fibrils	animal skin glue, cellulosic material [best match hemicellulose], poss. bromine compound [best match 2,5-dibromonitrobenzene]	See above
4		pink accretion	alkyd polymer (a synthetic drying oil)	Fig. 15-16, pp. 133 / 26 – 134 / 27. Sample red curve perfectly matches the blue calcite (chalk) curve. In contrast, the red sample curve does not exhibit any of the strong absorption peaks in the ca. 1350 -1000 cm^{-1} region, as seen in the Arolon 970 (green curve) Thus, the attribution is not supported by the spectral evidence.

One of the questions that arose while reviewing the attributions of the phases concerns the unconventional use of reference spectra, which is not explained.

For example, for identification of calcite (or chalk?) JM uses **calcite** (IMP00241) as a reference spectrum for region 1 (Fig. 10, p. 131 / 24) but "**calcite chalk**" of unknown origin as a reference spectrum for region 4 (Fig. 16, p. 134 / 27).

Similarly, “rabbit skin glue” serves as a reference for the spectrum 3 region 3 shown in Fig. 14 (p.133 / 26) but NIKAWA (Japanese hide glue) reference is preferred for the spectrum 1 of the same region 3 shown in Fig.12 p. 132 / 25.

III. Use of the bibliographic references, Section: Context, pp. 119 / 12 - 124 / 17

This autonomous report contains an overview of the DSS makeup in section “Context” that doesn’t seem to bare any relation to the information presented in the summaries section (pp. 1-28). The following table sets out several examples illustrating typical poor citing choices. On the right are excerpts from the text that as it appears in the “Context” section, on the left, texts from different articles dedicated to the DSS. Similar passages without attribution are highlighted in yellow; lifted verbatim passages - highlighted in turquoise.

Rabin, Material Analysis of the fragments, Gleanings from the Caves Dead Sea Scrolls and Artefacts from the Schøyen Collection Editor(s): Editor(s): Torleif Elgvin, Michael Langlois, Kipp Davis, p. 62	*JM, p. 119 / 12 (not cited)*
In antiquity, this was customarily carried out by application of dung, flour, or vegetable baths. The production involved drying under tension, a stage that provided this material with properties similar to those of parchment. Unlike the medieval process, vegetable tannins were sometimes applied to the surface in the last stage of the treatment, which produced an interesting hybrid between leather and parchment (Poole and Reed 1962). This general description of the manufacture of the parchment of the Dead Sea Scrolls lacks detail with regard to skin treatment after flaying, the use of materials to assist drying, and finishing steps. From the detailed descriptions of parchment making in the Middle Ages we know that chalk and powdered pumice were applied on the flesh side to assist cleaning and drying of the de-haired skin.(ref to a parchment – making site) Certainly, similar steps must also have existed in antiquity.	After being flayed, the skin was soaked in water to prepare it for a prolonged bath of dung, flour or fermented vegetable matter. Other materials described in the dehairing process include goat’s milk, vegetable oils and animal fat. Details regarding ancient methods and materials used to finish the skins are not well documented, but it is presumed that they are not dissimilar to methods recorded in the middle ages in which chalk and powdered pumice were applied to the flesh side to assist with degreasing and smoothing the surface. Vegetable tannins (plant polyphenols) were sometimes applied to the surface in the last stage after cleaning and drying, or were applied as a treatment before the writing surface would be inscribed with ink.
Nir-El Broshi (1996), DSD3, p. 165	*JM p. 121 / 14 cited, not in quotes*
However, ancient carbon-based inks contained, in addition to the pigment, various binding materials, e.g., vegetable gum, animal size, oil or honey. These materials can affect the chemical and physical properties of parchment and cause its deterioration in the regions of ink application.	Other additives contained in ancient carbon based inks include animal glue, oil, or honey. These materials can affect the chemical and physical properties of parchment and cause its deterioration in the regions of ink application.
Caldararo, N, (1995) Radiocarbon 37, p.26	*JM p. 124 / 17 cited, not in quotes*
Alum was often applied by restorers to increase the adhesion of ink and to prevent mold.	Alum was often applied by restorers to increase the adhesion of ink and to prevent mold
Caldararo, N, (1995) Radiocarbon 37, p.26	*JM p 124 / 17 cited out of context, not in quotes*

Wilson (1969) reported extensive treatment with **moisture and oils, including castor oil**, to remove clay from the surface or to relax the skin. Some of these uses **may be derived** from Wachter (1962b) who listed spermaceti, sperm oil, neatsfoot oil, lanolin, milk, unbleached beeswax, Japan wax (from sumac plants) and Zapon (nitrocellulose applied in acetone).	**Other reported materials used for this purpose include** spermaceti wax, neatsfoot oil, lanolin, milk, unbleached beeswax, Japan wax, nitrocellulose (in acetone), and glycerin.

A. Shugar section 1:

MA-X-Ray Fluorescence Scanning of Four Dead Sea Scroll Fragments, pp. 168-187 / 1-20

Here, we will continue to concentrate on fragment SCR000121.

This report raises a number of questions and invites several comments:

1. (p. 170 / 3) “The fragments were placed on a suspended inert paper”. What is inert paper? How were the fragments suspended? No schematic representation or photograph illustrates this unusual set up.
2. A resolution of 0.5 mm is blind to the heterogeneity of the sediment distribution on the sample, evident from the blurry images in Fig 2, p. 171 / 4. Scale bars are not included as is standard procedure not that it would particularly improve interpretation of results in this case. It is not clear from the description whether helium flush was employed and if used how it affected the detection of the elements.
3. Why were the fragments scanned only from the hair side?
   Light elements have a low information depth and, if the sediment distribution on the hair side is different from that on the flesh side it would be indicative of the forgery. It is particularly important because the flesh side absorbs sediments more readily than the hair side.
4. On page 184 / 17, we see a plot of the ratio Cl/Br. No explanation on quantification method is offered, i.e. on how the measured intensities were translated into the quantities. Since Cl and Br have markedly different information depths, a direct comparison of the intensities always delivers the wrong results.
5. The cited publication Rabin 2013 does not suggest that ratio of the amounts of Cl and Br might be indicative of degradation.
6. Fig.1, p. 171 / 4 shows 4 images. Multi-modality imaging is not defined or explained, it is also not understood how is it related to MA-XRF? The origin of this set of images, technique of production and interpretation is not clarified. The image taken at 365 UVP is not discussed at all.
7. Results on p. 173 / 6 demonstrate that the elements aluminum and silicon have a positive correlation. How is this correlation pertinent to the detection of a forgery taking into account the ubiquitous presence of these elements?
8. Pages 185-187 / 18-20 list 31 entries, unfortunately, two thirds, (20) of them are not referred to in the body of the text; what is the purpose of the bibliography? Reference “Rabin, Ira. 2016. "Material analysis of the fragments." can’t be accessed as cited and the “Hahn, Oliver, and Ira Rabin. 2018. Material Analysis if Five DSS Fragments. BAM.” doesn’t exist.

A. Shugar section 2:
Optical Microscopy, SEM, and Reflectance FTIR analysis of two DSS Fragments of Sample SCR000121, pp. 188-206

This study does not work on the assumption that the fragments are forged. It sets the aims to elucidate the manufacture process and determine the material type (leather or parchment), however, *the criteria for the differentiation* between leather and parchment and for sampling locations are not defined or indicated. However, the terms leather and parchment are used with free regard throughout this report, which indicates that the aim was possibly not internalized.

Without information on the place the samples were taken from or their orientation, their context is lost in relation to the fragment, which must have had an impact on the interpretation of the results.

The Executive summary on p. 189 says that oil was found in both samples, with a larger amount in *Sample 121a*.

I. Optical microscopy

Identification of the oil is inconclusive for Sample 121a because Figs. 2 & 3, pp. 192-3 were not properly described. In the absence of a reference image, it is not clear how the *"The lower region fluorescence is indicative of an oil impregnation"(Fig.2).* The presence of oil is not mentioned in the analysis of *Sample 121 b*.

The optical microscopy study did not identify oil.

II. FTIR

FTIR in reflection mode cannot be compared directly with FTIR spectra collected in transmission or ATR (Attenuated Total Reflectance) modes. The reason for this is that the calculation of the absorption spectrum from the reflectance spectrum is not trivial. In the spectra shown in Figs. 18, 19 pp. 205- 6, it is not always understood how a peak is defined, i.e. whether the absorption maximum corresponds to the peak or the valley in the sample spectra. The required detailed description, including processing of the raw spectra is not given. Unfortunately, no x-axis grid facilitates comparison of the spectra. In our opinion, only the reference spectrum for calcium carbonate shows a persuasive coincidence with the FTIR spectrum of *Sample121b*: cf. Fig.19. p. 206, where the *maxima* at ca. 1450 and 870 cm^{-1} in the calcium carbonate absorption spectrum coincide with the respective *minima* of the sample spectrum. Evident from the reference spectra provided, the FTIR spectrum of the sample does not exhibit the characteristic bands of gypsum, calcium oxalate or oil. Further to the optical microscopy studies, there is insufficient similarity between the oil reference spectrum and the sample spectrum Fig.18, p. 205 to unequivocally prove presence of oil.

III. Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray spectroscopy (EDS)

SEM /EDS are powerful methods for studying surfaces. Since XRF and EDS deliver complimentary information, the results are usually presented and discussed in combination. This is not the case here, moreover, the results were not checked for consistency using the two methods.

The analysis and the results are not presented well or discussed plainly. It is not clear from the description whether the samples were analyzed under high or low vacuum. Since the color coding of the elemental maps was not kept the same throughout the report, comparison of these charts is difficult; in addition, the annotations pinpointing the areas for the individual spectra are difficult to discern.

Sample 121a, pp. 194-196, *Sample 121b*, pp. 200-204

1. Caption of Fig. 4, p. 194 is difficult to understand because of the missing colour key. The set of elemental maps (Fig. 6) and BSI image (Fig. 5) are not combined to facilitate a correlation between the element maps and the micrograph of the surface. The same applies to the sets Figs. 12 / 13, p. 201 and Figs. 14/15 p. 202. The maps corresponding to the purple area Fig. 11 p. 200 are missing.
2. It is clear from the elemental distribution maps that the bright mineral inclusion (Fig. 5-7, pp.195-6) contains the following elements O, Na, S, K, Ca. The element Cl shows a negative image (black) because it is covered by sulphates. AS must have missed this correlation as he does not mention sodium and potassium sulphates, a significant omission, as these are indicative of DSS sediment types. The additional spectra of small regions Fig 7 p. 196, do not contribute new information because this information is easily obtained from the elemental maps. There is a distinct disadvantage in analysing small spots as they may not display the characteristics of a heterogeneous material. Moreover, they can distract attention from correlations that may be derived from the mappings (Fig.7 and Table 1, p. 196). Note that in the last column of Table 1, AS presents his interpretation of what was most likely found. For example, AS determines calcite in region 6 overlooking that calcium carbonate ($CaCO_3$) has a number of polymorphs (calcite, aragonite, and vaterite) which can't be differentiated by EDS.
3. The question of oil remains unanswered. Could this not be identified by SEM/EDS? What does the smooth surface Fig. 5 & 7, pp. 195-6 correspond to?
4. Similarly, the question of sodium and potassium salts in the samples is not clarified. A correlation between K and Cl was found using MA-XRF. If no correlation was found by EDS between Cl and Na or K, what class of compound could this belong to?
5. For analysis of *Sample 121a*, Table 1, p. 196 says "Region 2 shows the parchment has a high Ca concentration and has **some** salts present (K, Na, or Mg salts)". In the caption of Table 2, p. 203 belonging to *Sample 121b* it states that "Region 18 shows the parchment has a high Ca concentration and has salts present (K, Na, or Mg salts)." The composition of both regions is basically identical, so why is there a difference in the interpretation?

Comparison of the elemental composition of the Regions 2 and 18 resp.

Region	O	Na	Mg	Cl	K	Ca
Region 2 (121a)	61.53	4.87	3.19	11.4	3.74	13.65
Region 18 (121b)	60.02	4.88	3.98	11	3.62	14.96

The mineral omphacite was detected in this report however not confirmed by a different technique; omphacite was not discussed or related to in the rest of the report.

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