A Methodology for the Digital Reconstruction of Dead Sea Scroll Fragmentary Remains

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Introduction

As part of this publication of the MOTB Dead Sea Scrolls (DSS) fragments, the West Semitic Research Project of the University of Southern California (WSRP; see http://www.usc.edu/dept/LAS/wsrp/) was engaged in the task of imaging these fragments, digitally readjusting their physical layout and alignment and finally reconstructing and restoring them digitally to the extent possible, in line with the proposals made by the various editors of the fragments. The intent of the following discussion is to explain the underlying methodology that guides these reconstructions. The advantage of this reconstructive process is that it offers an unparalleled means for testing various proposals, regarding how a given text was originally laid out (especially for clarifying unclear readings, testing proposals for filling out *lacunae* in the lines of a text, establishing column widths and the number of lines within a column, along with other important considerations), with a degree of precision that was not previously possible. While it must be granted that a given reconstruction—even when it seems to fit the physical space and conforms to grammatical, syntactical, stylistic and other expected norms—can never serve as a letter-by-letter confirmation that a given proposal is valid, it is an effective means through which to subject such a proposal (or competing proposals) to a rigorous standard of analysis in order to measure its (or their) degree of credibility. Moreover, even if a particular reconstruction can never be affirmed to be absolutely correct, in a number of instances a proposed reconstruction can be decisively *excluded* for a simple but persuasive reason: that the proposed reconstruction is incompatible with the available space.

Imaging Technology Employed for Documentation of the Fragments in This Edition

The actual documentation of the fragments was done by WSRP, taking advantage of recent advancements in digital photography, especially in terms of advances in hardware and software applications. The advancement of technology in the fields of digital imaging and image manipulation in recent years has led to a paradigm shift in the study and decipherment of ancient texts, in particular, the DSS. Although the DSS and similar manuscripts written on soft media (parchment or papyrus) ostensibly appear to be two-dimensional, new technologies, coupled with powerful imaging tools and programs, have allowed scholars to see, reclaim and reconstruct DSS in a dynamically heuristic fashion that adds, both literally and figuratively, a whole new dimension to the process. These new technologies are constantly evolving, allowing for an increasingly better understanding of these texts, based on far superior imagery than was ever available previously. Indeed, what is becoming progressively clear is that a single, conventional static (usually infrared [=IR]) image, which has been routinely relied upon as the primary evidence in past DSS studies, should no longer be seen as entirely adequate for capturing and analyzing the full range of image data that can be recorded for the scrolls and other ancient manuscripts. Likewise, such an image is also seriously inadequate for documentation of the DSS for purposes of conservation evaluation.

It has long been recognized that a host of details that are inaccessible to the unaided eye become visible when imaged in discrete, narrow bandwidths of the near-IR spectrum. Such IR images are therefore crucial for understanding and reconstructing these texts, particularly given their highly fragmentary state. Yet on the other hand, visible light color (= VLC) images—especially in the high-resolution versions available today—

reveal crucial, but subtle information that is often masked in even the highest resolution IR image. While side-by-side comparisons of IR and VLC images offer some significant insight, the images are better compared and with far greater precision when matched and superimposed as discrete matched and stacked layers that can be added or subtracted with a mouse-click in an image-processing program such as Photoshop.

The West Semitic Research Project (WSRP) has developed most of the reconstructive tools and techniques presented below. WSRP's primary goal has always been to couple scholarly knowledge of epigraphy (the study of the material evidence, through which a given text's information is conveyed) with sophisticated photographic and computer imaging techniques to advance the study, reclamation and analysis of a wide range of ancient texts and other artifacts.

In order to capture a more comprehensive range of data from the DSS, the WSRP currently primarily relies upon three photographic techniques for the initial capture of primary image-data which, in aggregate, constitute a major advance over what was previously available: conventional, high-resolution VLC digital photographs, high-resolution digital photographs in the near-IR bandwidths, and detailed images created through a process known as Reflectance Transformation Imaging (RTI)—both in VLC and IR. This primary image data is captured with newly developed cameras that have significant, innovative capabilities. For example, as noted above, near-IR photographs are particularly critical for DSS analysis, since many scrolls are illegible to the unaided eye or in VLC images, primarily due to the lack of contrast between the carbon black ink of the script and the often-blackened or darkened parchment or papyrus surfaces, upon which the scrolls were written. Due to the changing characteristics of reflectivity for DSS soft-media, as one moves through the spectrum, the near-IR photographs, with wavelengths measuring between 850 and 900 nanometers, usually provide maximum differentiation between the often blackened/darkened writing surfaces and the dark text (the former becoming more highly reflective and thus registering in a gray-scale image as light gray or white, while the latter continues to absorb light and thus to remain black), allowing for the decipherment and study of scrolls that would be otherwise unreadable (see fig. 1).

Figure 1: GC-SCR-Micah Obverse, Visible Light Color (left) and Infrared (right) (*Images by Bruce and Kenneth Zuckerman and Marilyn Lundberg, West Semitic Research*).

The ability of IR to bring out details of DSS was quickly recognized not long after the scrolls were discovered. As a result, the vast majority of DSS images made in the twentieth century were done with IR-sensitive, chemical emulsions on plastic or glass based negatives. However, these films and plates were notoriously poor in resolution due to the coarse grain of the emulsions and often not in precise focus due to the difficulties inherent in focusing images illuminated in IR-bandwidths. This, in turn, seriously restricted researchers' abilities to use these images effectively. However, once high-resolution digital cameras became available, beginning around the turn of the twenty-first century, the IR images that could be digitally produced registered a vast improvement in resolution. Because the sharpest focal point in the IR is slightly different from that which can be seen in visible light by the unaided human eye, these advanced digital cameras preview the IR image using a "live view" feature, employing an embedded video sensor in the camera. This sensor captures a test video display that automatically converts IR into a visible image that can be seen on a computer screen and focused accordingly in real time with far greater precision than would otherwise be the case.

While nearly all commercially available digital cameras contain an internal IR-blocking filter, the cameras employed by WSRP have been custom-altered so that this filter has been removed. Filtration is then done using removable IR filters within the camera or in front of the lens (and/or, alternatively, appropriate illumination employing newly available LED lights at the appropriate bandwidths). In this way one can create very closely matching images in both VLC and IR using the same camera and set-up for each. This is crucial to facilitating optimal matching of IR and VLC as stacked layers in a Photoshop image.[1] Although the two images will never precisely match pixel-for-pixel due to the fact, previously noted, that the IR focal point is slightly different from that of VLC images, the match is closer and the images more easily and precisely compared than was previously possible. To the eye, the minute difference between matching, stacked VLC and IR layers in a Photoshop image viewed on a computer screen is negligible.

One of the most valuable technologies employed by the WSRP is RTI. Indeed, WSRP pioneered its use in combination with both VLC and IR for the imaging of DSS and other cultural heritage artifacts. This technology involves taking a series of pictures (typically, 32 to 45 successive images) with a camera mounted in a fixed position, while a light source is moved more-or-less evenly around a target, either manually, making a virtual dome of lights, or with an actual dome with an array of lights affixed into it. This allows for the creation of an image known as a texture map, created either with an algorithm called Polynomial Texture Mapping (PTM) or Hemispherical Harmonics (HSH). This texture map, or RTI, is not actually a composite of the original images but is better described as having been mapped, as it were, drawing upon the aggregate data from the series of images. Once it has been processed, such an RTI allows the viewer to control a virtual light source (or a combination of two virtual light sources) that may be moved around the image using a computer mouse or similar tracking device in real time. As the mouse moves, so moves the light, thus revealing surface texture from any lighting perspective desired. Other transformations of RTI images are also available that can, for example, dramatically boost the reflectivity of a surface (specular enhancement) or significantly sharpen and give more contrast to the image (diffuse gain) (fig. 2). This allows scholars to select interactively and dynamically a wide variety of information from an artifact or text in a manner that transcends the inherent limitations of static VLC or IR images.

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[1] For an earlier discussion, see B. Zuckerman, "The Dynamics of Change in the Computer Imaging of the Dead Sea Scrolls and other Ancient Inscriptions," in *Rediscovering the Dead Sea Scrolls; An Assessment of Old and New Approaches and Methods*, ed. M. Grossman (Grand Rapids: Eerdmans, 2010), 69-88. A substantially revised and expanded electronic version of this article is available at www.usc.edu/dept/LAS/wsrp/information/DynamicsDSS, containing many inter-active illustrations. All further page references to this article are in accordance with this latter, expanded electronic edition. In this case, see pp. 4 ff.

Figure 2: RTI Derivatives—Visible Light and Specular Enhancement (*Images by Bruce and Kenneth Zuckerman and Marilyn Lundberg, West Semitic Research*).

While this remarkable technology is more obviously useful for illustrating objects with prominent, textured third-dimensions, such as bas-reliefs, incised inscriptions and cuneiform tablets, it has also proven to be highly useful when dealing with the DSS—as the WSRP was the first to show, convincingly. For one thing, since RTI allows viewers to distinguish and delineate the slightest variations in a targeted surface, this technology has proven to be invaluable for assessing the condition and deterioration of scroll pieces for purposes of conservation monitoring. Reviewing and closely comparing older images and RTI dynamic images allows for a more complete understanding of the nature and the process of damage incurred within a given scroll or fragment over time.

RTI can also serve a valuable function in scroll reconstruction. Patterns in surface damage, which can be visually enhanced, when viewed dynamically as an RTI image, provide a potential means of linking related DSS fragments. Additionally, scribal guidelines (ruling) incised in the parchment or papyrus, which are often invisible to the unaided eye or in static images illuminated with diffuse light, can often be reclaimed and well delineated, especially with the aid of specular enhancement and/or diffuse gain, thus providing invaluable clues regarding the more precise placement of related fragments that share such guidelines.

One can also pay close attention to the hair-follicle patterns on the skins used for DSS parchments—which an RTI image is particularly adept at illustrating. Not only does the demarcation of the follicle-textures aid in identifying the type of animal skins employed, but the patterns are also as unique as fingerprints and thus can help one recognize what fragmentary pieces come from the same scroll—sometimes even when they are not contiguous.[2] Finally, an RTI image can on occasion be so sensitive that it can delineate the thicknesses of ink-strokes on a DSS surface and where and how given strokes overlap.. Such information is invaluable for tracking the *ductus* (the order and direction of strokes forming each of the letters) of a given scribal hand and/or style (fig. 3).

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[2] For further discussion see Zuckerman "Dynamics", 27-29

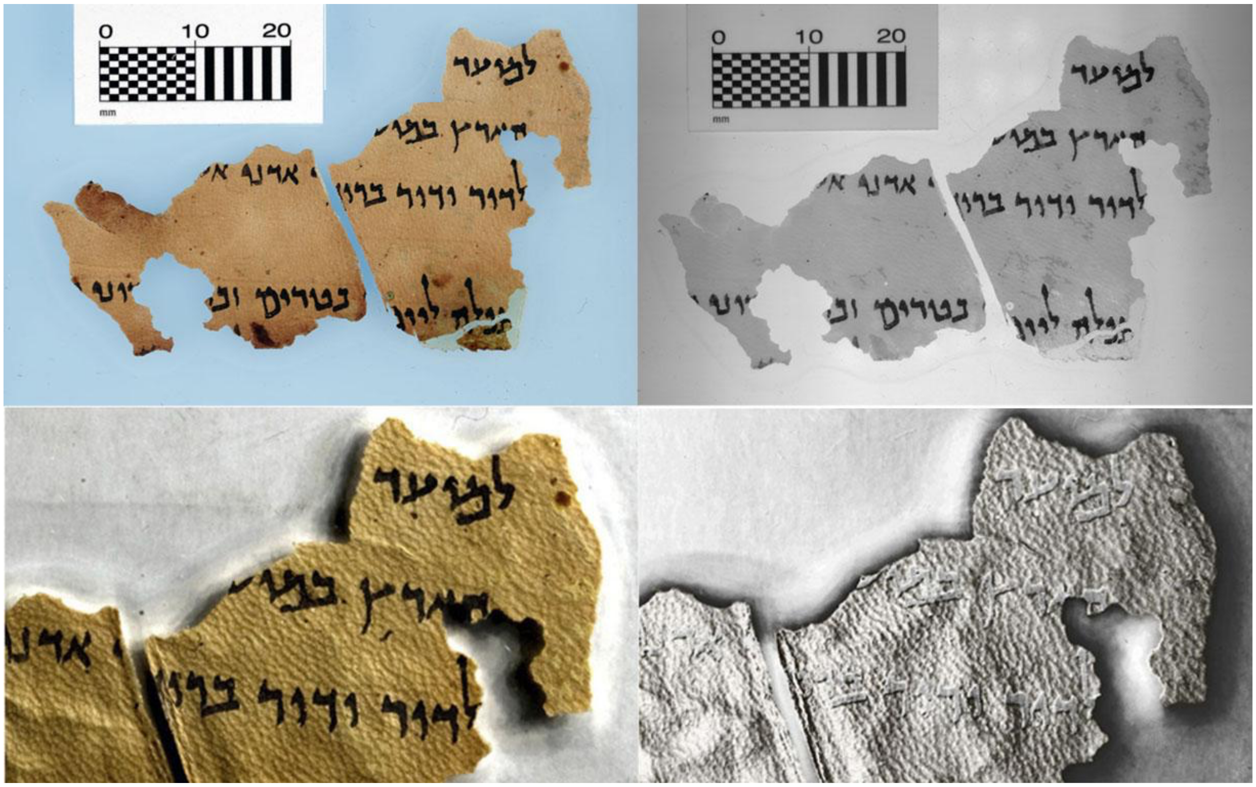

Figure 3: Top left: high resolution static VLC image of a DSS fragment; top right: high resolution IR image; bottom left: RTI derived VLC image, showing hair follicle patterns and traces of horizontal rule lines (above the written lines); bottom right: RTI derived image, detail with specular enhancement, showing ink thicknesses (*Images by Bruce and Kenneth Zuckerman and Marilyn Lundberg, West Semitic Research*).

Unfortunately, when working on reconstructions in a Photoshop environment, a scholar does not have the facility to access dynamic RTIs directly in their original form, since Photoshop and similar image-processing programs do not yet accommodate RTI. This limitation can be overcome to a great extent, however, by employing various statically captured images taken from an RTI, scaled and matched to other images, and imported into Photoshop as part of the layered stack of images, along with conventional, static high resolution IR and VLC versions. While not directly relevant to the images and reconstructions found in this volume, it is worth noting that almost all the previous, chemically-based photographic images of the DSS, going back to the very first photographs taken in the 1940s, are generally available in digital form in one venue or another, and these images can also be employed as part of the available data for purposes of comparison. While granted, all these older images are of significantly poorer quality than the high-resolution digital images that can be captured today; nonetheless, they frequently preserve invaluable data that is no longer available due to the ongoing deterioration of the scrolls.

In summation, due to the significant increase in both the quality, quantity and accessibility of the image data for DSS, the ability to reconstruct fragmentary texts has become far more feasible for a specialist in the study of DSS on his or her own without sophisticated knowledge of image processing and manipulation procedures. Most importantly, scholarly proposals as to how a text should be restored can—and, arguably, *must*—be tested with a precision never previously possible. Indeed, in case-after-case it has been demonstrated that, without subjecting such proposals to the kind of rigorous testing that reconstructions demand, even the most experienced scholars can be misled into proposing restorations that can be completely disqualified through the reconstructive procedures presented below.

Basic Principles and Procedures Underlying Dead Sea Scroll Reconstructions

In the discussion of methodology, the focus is on the means for establishing a given DSS text-depiction as a fully documented, complex, multi-layered assemblage of images that present the aggregate opinion of the editors of this volume as to how the various texts should best be physically reconstructed. It should be noted that such a complex image cannot be printed and published conventionally as a static illustration on paper, and that even multiple static-images, displaying comparative layers (as was done in fig. 3, for example) are far from adequate for giving an independent observer sufficient image data to judge the validity of the various decisions that have led to a given set of reconstructions. Only when the images are viewed dynamically as a complex image file in a Photoshop or similar software environment can the data be best understood. To be sure, the illustrations in this printed chapter and the overall illustrations in this printed volume endeavor to give the reader/viewer a visual summation of the reconstructive process, but in order to access optimally the reconstructions of the DSS in this volume, a scholar will need the following: access to the full Photoshop files; the necessary hardware and software adequate to employ and manage these files; and finally the basic knowledge of the tool-box employed in Photoshop or similar imaging program. In order to gain access to these files, appropriate permissions will need to be granted by the editors of this volume and the Museum of the Bible Collection. Methodological discussions below refer to how these files are built and the rationales for doing so.

Documentation and Transcription Protocols

Any digital reconstruction of DSS will inevitably involve building a complex, composite Photoshop (or similarly processed) image comprised of numerous layers embedded in collapsible groups and sub-groups. Indeed, the key element in this reconstructive procedure is the ability to toggle on-and-off various stacked groups and layers for purposes of close, precise yet easy-to-accomplish comparisons. Because of the complications that necessarily follow from the complexities of stacking layers and groups of layers, careful labeling and documentation of each layer is essential. Without keeping track of these parameters, one can easily lose the ability to recall the source of each element of a reconstruction. In order to accommodate most easily the transcriptions of Semitic (Hebrew and Aramaic) letters needed for referencing layers in a Photoshop environment, we developed the transcription system recorded in fig. 4.

Alep א	*Bet* ב	*Gimel* ג	*Dalet* ד	*He* ה	*Waw* ו	*Zayin* ז	*Ḥet* ח	*Ṭet* ט	*Yod* י
’	b	g	d	h	w	z	#	+	y

Kap כ	*Lamed* ל	*Mem* מ	*Nun* נ	*Samek* ס	*'Ayin* ע	*Pe* פ	*Ṣade* צ	*Qop* ק	*Reš* ר
k	l	m	n	s	(	p	&	q	r

Šin ש	*Tav* ת
$	t

Figure 4: "Photoshop" transcription system employed by WSRP.

A Basic Operating Principle: *Never* Replace, *Always* Supplement

A major operating principle for this work involves the need to place stress on the reconstructive process' inherently theoretical nature. A reconstructed text—no matter how "realistic" it may subliminally appear to the viewer—should *never* be taken as an authoritative point-of-reference. Much like a scholar's drawing or other graphic representation, a digital reconstruction only presents one hypothetical reconstruction of a text. Although a digitally reconstructed text may look visually more convincing than a hand-drawing, substantively the two share the same purpose—to represent a given, informed scholarly *opinion* as to how a text originally appeared. Although it is possible with basic Photoshop skills to manipulate DSS fragments digitally in so convincing a fashion as to leave the impression that the resulting reconstructions are "correct" and thus authoritative, it is of great importance that scholars (including the ones who are reconstructing a text) view such reconstructions as nothing more than hypothetical models. Granted, the goal of a given reconstruction is to present to the observer a detailed picture of what the text might have originally looked like and, to the extent possible, all the textual information that it originally might have possessed when it was in more pristine condition. Still, to reiterate: no matter how seemingly realistic they appear to be, digitally rendered reconstructions only reflect a given scholarly *viewpoint* based on informed scholarship—no more, no less.

As already preliminarily indicated in the discussion above on comparing matching IR and VLC images (that is, equivalent images with as close a pixel-for-pixel match as is possible), one of the most powerful functions of Photoshop is its ability to facilitate close comparisons through the "stacking" of discrete layers and groups of layers, all of which are as closely matched, in terms of content and scale and which, for purposes of easy comparison, can be added or subtracted singly or in combination with the click of a control device (e.g., a computer-mouse or track-pad). One of the most important underlying principles that guides the use of such stacked layers and/or groups of layers is that one *never replaces* a given layered image/group with another.

Rather, one maintains a chain-of-evidence by *superimposing* layers/groups so that the starting point(s) can always be reexamined by deactivating the layers stacked above. .[3]

Establishing a "Primary Layers" Group

Before initiating any subsequent reconstructions, one begins by establishing a group entitled "Primary Layers," which constitutes a collection of the most useful original images of the targeted text fragment(s) with minimal manipulations, matched as closely as possible in terms of scale and resolution. The picture-of-reference for this group is usually a static, high resolution, digital near IR image (visually represented in grayscale), since it normally displays the maximum contrast between the writing surface (parchment or papyrus) and the written text (usually composed with a nibbed pen, using carbon-based inks). If the data is available, this near IR master-image is superimposed over a high-resolution, static VLC layer, which has been as closely matched as is possible. In order to facilitate these closely matched IR superimposed over VLC layers, ideally one begins with sets of IR/VLC images that were made at the same time, with as identical image-documentation setups as is possible. This was done for all the DSS fragments in this volume.

Occasionally, if the skin of a given DSS fragment has darkened to such an extent that the ink is impossible or very difficult to distinguish from the background in VLC, a third composite "VLC/IR" layer can be added to the "Primary Layers" group. This is a composite layer, in which a semi transparent infra-red layer is bonded ("flattened," to use the appropriate Photoshop terminology) onto a VLC layer so that the text is legible but the color of the original surface is visible at the same time. Such a layer, which is then stacked between the VLC and the IR primary layers, often proves to be highly useful for allowing a researcher to keep track of where the inked text is located, when the primary concern is to see it in context with the VLC data (fig. 5).

When possible, it is often useful to add other layers to the stack in the Primary Layers group,or example, static images derived from PTM images. Also, although not applicable to the fragments in this volume, older images, even if they lack the kind of resolution that can be achieved today, can often be useful—especially if they contain information, which has been lost due to the deterioration of a fragment in the intervening time. Beyond this, if available, it is sometimes useful to add images of the verso side of a scroll fragment (using a flipped mirror image so it will match the other layers). IR verso images can prove particularly valuable when there is some sort of interference on the recto's surface. For example, a piece of skin (typically from a previous layer of the original scroll but now bonded to the surface and not easily removable) may block or obscure textual data on the writing surface in an image of the recto. Each of these various layers in the Primary Layers group is available for viewing separately or in combination. This not only facilitates comparisons (done by adding or subtracting given layers) but also allows the user to keep track of the data and know from which source the image data of each is derived.

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[3] See Zuckerman "Dynamics", 4

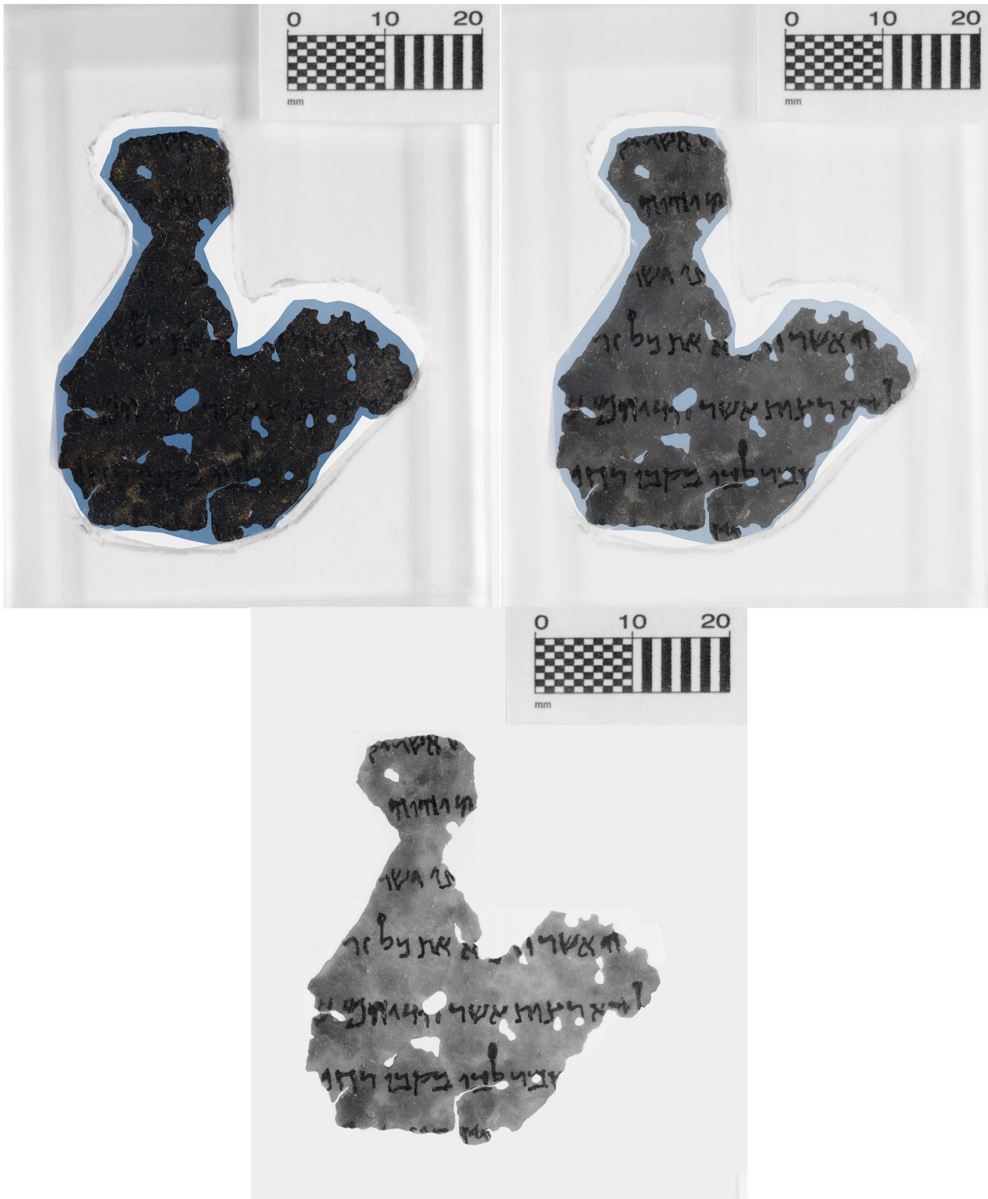

Figure 5: VLC (left); semi-transparent IR over VLC (center); and IR images (right) can be matched and superimposed as discrete layers in an Adobe Photoshop environment (*Images by Bruce and Kenneth Zuckerman and Marilyn Lundberg, West Semitic Research*).

"Primary Layers Aligned" Group

Once the Primary Layers group has been established, as described above, the next concern is to bring a DSS fragment (or a set of related fragments) into approximate, overall horizontal alignment. This is done through superimposing a group labeled, "Primary Layers Aligned" over the "Primary Layers" group. The intent here is to bring the orientation of the stack of images for a given fragment or group of closely related fragments into proper alignment with one, another and, beyond this to orient this group, in reference to the written lines of the text, roughly to a common, horizontal axis.

Because DSS are usually written on animal skins or papyri, these materials—especially if they are fragmentary—are highly susceptible to shifting in their mounts, wrinkling, warping, cracking, splitting, curling, shrinking and/or expanding over time, especially along their edges. This makes precise horizontal orientation of *all* the text-lines of a given fragment (or assemblage of fragments) frequently difficult to achieve. The aim of the "Primary Layers Aligned" group is simply to make a rough adjustment so that the reference line(s) are brought as close to horizontal alignment as possible.

Patches

One of the most useful means of reconstructing a fragment, is a technique, which we have elsewhere[4] labeled as "patching." Such patches, once created, are stacked in a "Patches" group directly above the "Primary Layers Aligned" group. As noted above, the physical remains of a fragment are highly prone to various types of movement—all of which can distort the relative placement of letters and lines of letters, thereby inhibiting optimal reconstruction. This is a problem that cannot usually be solved "globally" by applying correctives (e.g., rotation) that are done to the entire assemblage undergoing reconstruction. Rather, one can better fine-tune the needed corrections in each instance of distortion by individually "patching" the area under consideration (fig. 6). Since patching is a more invasive repair, it is particularly crucial for the sake of transparency that the "seams" in the repair remain visible, especially when the image is magnified. That is, no effort should be made to use the cloning or other smoothing functions in Photoshop to "clean up" a given patch. It should be emphasized that patches should be done as part of a *supplementary* group. That is, the observer should be able to toggle them (individually and by group) in order to be able to judge the extent to which the patch is appropriate.

4 Cf. Zuckerman, "Every Dot," 189.

Figure 6: Detail of GC-SCR-00124 before (left) and after (right) "patching," as shown by the reconstructed ruling of the scribe indicating the improved alignment of the text.

Line Reconstructions and the Criteria for Letter Cloning

Once what appears to be the optimal alignment and patching of a given DSS fragment or assemblage of fragments has been established, one can proceed to letter, word and line reconstructions. The primary means for doing such reconstructions is a technique, which we have elsewhere characterized as "letter-cloning."[5] That is, when a text is fragmentary or partially missing and therefore the readings are uncertain and/or in need of complete restoration, one may "clone" letters or letter-combinations, using clear (or clearer) letter-examples from elsewhere in the text, copy them onto new layers and then superimpose them over ink traces of partial letters or areas where letters/words are completely missing (fig. 7). This serves the primary function of a reconstruction of the type described here, which is to test the validity of proposed reconstructions.

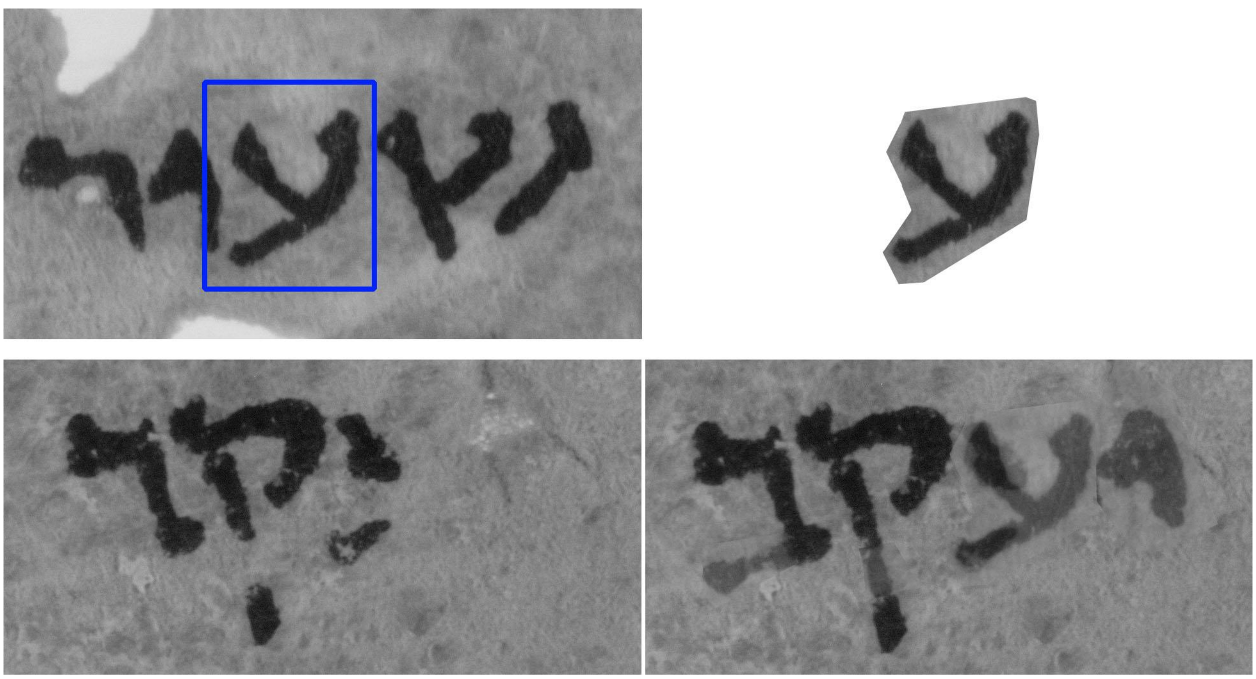

Figure 7: Steps in letter "cloning": the letter *'ayin* in its original environment (top left); a "clone" of the letter (top right); a different word with traces of an *'ayin* (bottom left); and the cloned *'ayin* superimposed over the traces of an *'ayin* (bottom right).

There are several issues that can be tested through this letter-cloning process. For instance, if a given letter reconstruction has been proposed and a clone of that letter is spatially incongruent with the deteriorated but still visible ink traces over which it has been superimposed, it can be seriously questioned whether this is the correct reading. Conversely, if the cloned letter, when superimposed, well matches the existing letter traces, then it may be deemed a good match. Further, if from a contextual standpoint, several possible readings might

[5] See Zuckerman, "Every Dot," 193 and further, Zuckerman, "Dynamics," 13 ff.

be proposed where the text itself is visually unclear, one may test each potential reading to determine which best conforms to the existing space and traces by superimposing letter-clones in order to determine which of them can make a compatible, physical match. Also, if there is a lacuna in a given line for which a restoration (or restorations) may be proposed, one can then move letter-clones into the gap in order to determine whether they make a reasonable fit. If the letters overly crowd the lacuna (or simply cannot be "squeezed in" at all) or, conversely, if there is too much space in the restoration to fill the lacuna adequately, such a restoration becomes obviously open to challenge and adjustment. Most importantly, if the text breaks off across a number of lines so that either the right or left vertical column margin (or both) cannot be determined based on the physical evidence, one may use letter-clones to fill out potential words and lines in order to test whether a given reconstruction of the column width is supportable. Note that in such cases, not only must gaps be appropriately filled in, but the overall vertical orientation must be reasonably compatible as well. That is, when the right margins of all the restored lines are flush, then the left margin must reflect a relative evenness as well. If this does not prove to be the case, or, alternatively, if given letters are too crowded and/or the spaces between the letters too extensive when a given column width is assumed, then the reconstruction needs to be reexamined and probably readjusted,

There are several underlying methodological principles that should be followed in choosing the most appropriate examples for letter-cloning. First, when choosing which letter(s) to clone, three primary criteria need to be considered: letter-position, letter-environment and letter-proximity.[6] These criteria all speak to the underlying assumption that letters are never written in isolation and preferably should therefore not be restored individually. In regard to letter-position, when choosing letters to clone, one should consider the letter's position in a word, phrase, or line—especially, whether it is in initial, medial or final position—since this will have an impact on the way letters are written. This is obviously so in the case of the so-called "final" Hebrew and Aramaic letter-forms, namely, *kap*, *mem*, *nun*, *pe* and *ṣade*; but close examination of other letters reveals that they too will display differing tendencies in a given scribe's hand, depending on their respective position in a word. For instance, often times, an initial letter in a given scribe's hand will be larger than a medial letter, and the same can sometimes prove to be the case for a letter in final position. In consideration of this, when a clone is needed to reconstruct a letter in word-initial position, one should clone an initial letter, if possible, in order to produce a more accurate reconstruction. This pertains to letters in medial and final position as well.

In regard to letter-environment, it should be noted that letters also change shape, stance or relative size, depending on the immediate environment of the letters that precede and follow. For example, certain letters in a given scribe's practice will tend to be ligated (e.g., *nun* followed by *waw* or *yod*) and thus will tend to use less space. Due to considerations of letter-environment, it is optimal, whenever possible, to clone letter-combinations, in order to reflect more accurately and authentically the stylistic characteristics of a given scribe's hand.

The third criterion, that of letter proximity, is based on the assumption that the closer the letter chosen for cloning is to the area of text that is being reconstructed, the more accurate it is likely to be. This takes into account a tendency which we have elsewhere described as "scribal drift."[7] This assumes that various factors, such as fatigue or even the progressive dulling or resharpening of the tip of a scribe's writing implement, can contribute to an increasing lack of consistency as a scribe moves from column-to-column. Therefore, as a general rule-of-thumb, the closer a letter is to the area of text being reconstructed the more accurately the reconstruction will likely reflect the scribal tendencies in the area of text in question. In general, letter-clones should be chosen according to these criteria in priority: letter position, first; letter environment, second and letter proximity, third. However, one should show a degree of flexibility in regard to establishing

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[6] For earlier discussions, see B. Zuckerman, L. Dodd,"Pots and Alphabets: Refractions of Reflections on Typological Method," *Maarav* 10 (2003) :. 89-113; esp. 111-113 and Zuckerman, "Dynamics," 13-14 .

[7] Zuckerman, "Dynamics," p. 14.

these priorities. Moreover, since one can work with multiple layers, one can try out letter-clones that reflect some or all these alternative criteria.

Beyond these aforementioned methodological criteria, there are two other factors that should be considered in constructing and employing letter-clones. First, one should resist the tendency to closely "cut out" cloned letters, making them essentially no wider than the widths of the ink strokes of the scribal hand. Not only is it difficult and time consuming to make such cut-outs, but this also introduces a degree of subjectivity, since the outside observer cannot as easily tell if the trimming has been done accurately. It is far better and, for that matter, far easier, to leave a significant margin around the clone of a letter or letter-combination.[8] By using block-framed clones, it is far easier for the viewer to see where the cloned letters begin and the actual evidentiary remains end.

The second factor involves cases in which letter clones are superimposed over areas where some ink traces of a letter still remain. In such cases the letter-clone should be made semi-transparent so the viewer can look *through* the clone to see the underlying traces that the clone endeavors to match. Thus the viewer can easily grasp the extent to which the reconstruction appears valid. In cases where letters are being restored in *lacunae* where no surface remains, clones can be kept at 100% opacity.

Reconstructed Letters

In some cases, especially when the text being reconstructed is highly fragmentary, one may not have clear and complete letters to serve as clones, since such complete versions of the letters do not occur in the extant text. In cases where some evidence, nonetheless, remains of a letter needed for cloning, one can develop and employ what may be labeled as "reconstructed" letters. For example, if the top of a *taw* remains in one line while the bottom of this same letter is preserved in another one can combine these remains to reconstruct a complete *taw* . In such cases, the reconstructed additions are, once again, made semi-transparent so that the viewer can see more clearly how the reconstruction has been put together. In all instances, care should be taken *not* to use various available Photoshop tools to smooth things out so that the joins appear seamless.

Hypothetical Clones ("Frankenletters")

When a letter needed for restoration on a given fragment or assemblage of fragments is missing or unclear and there are no other examples or even partial examples of that given letter available elsewhere, one can still create and restore hypothetical clones or what may be characterized as "Frankenletters," that is, letters that are *completely* "stitched together" out of portions of other letters. The rationale and justification for creating these "letter-monsters" are based on the principles of calligraphy and further assume that the trained scribes, who wrote most of the DSS, self-consciously followed calligraphic practices. Indeed, the general, implicit assumption, long followed by those who study and analyze DSS palaeography and the development of scribal styles (usually broadly characterized as Hasmonean and Herodian scripts and variations thereof), only makes sense if one assumes that the scribes knowingly followed these fundamentals of calligraphy (fig. 8).

[8] For further discussion of "pixel editing", see Zuckerman, "Dynamics," 19-20.

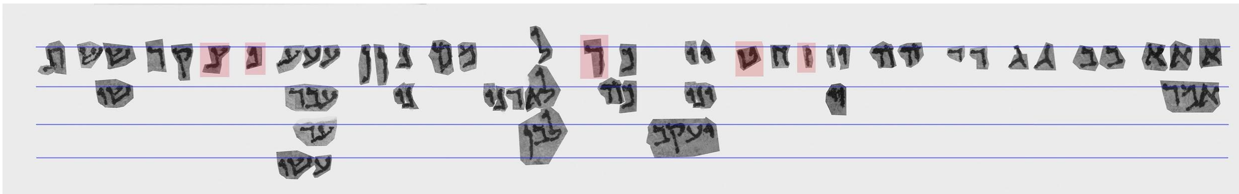

Figure 8: Alphabet group, with cloned letters, reconstructed letters, and "Frankenletters." "Frankenletters are marked with a reddish "flag" to indicate that they are completely reconstructed and should be viewed as inherently more speculative. Note that groups of letters or words that occur more than once in a text are also cloned for use in reconstruction.

An ancient scribe trained in calligraphic practices does not think in terms of inscribing complete letters. Rather, he or she is trained to employ a specific repertoire of a given number of similarly styled, discrete strokes—school-figures, as it were—which are put together in various, precisely ordered combinations in order to form letters and letter-combinations. Indeed, it is the shared characteristics of these strokes that give a script its specific "look" in stylistic terms.[9] Hence, the underlying rationale for constructing Frankenletters is that one may *reverse* this process by breaking letters down into the repertoire of calligraphic strokes, out of which they were built and then combine them to form other letters. This is obviously the most speculative and hypothetical procedure employed in letter-cloning, in particular, and DSS reconstruction, in general—a point that should be made prominently *clear* to the viewer. Thus, one should take particular care to make the "scars"—that is, the demarcated areas between the strokes —prominently visible without any attempt to smooth the joins.

It need hardly be said that such a "monstrous" letter form should *never* be used as the basis for any serious paleographic analysis. On the other hand, a particular Frankenletter is likely to be fairly accurate in terms of filling the space in a given word, phrase or line in order to approximate the physical layout of a reconstructed text better than might otherwise be the case (see fig. 9 for line reconstructions that use the principles of letter cloning).

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[9] Cf., e.g., A. Yardeni, *The Book of the Hebrew Script; History, Paleography, Script Styles, Calligraphy & Design* (Jerusalem: Carta, 1997), 294 ff. and esp. fig. 245 on p. 295; also C. Marks, *The Handbook of Hebrew Calligraphy* (Northvale, NJ: Aronson, 1990) esp. 38 ff.

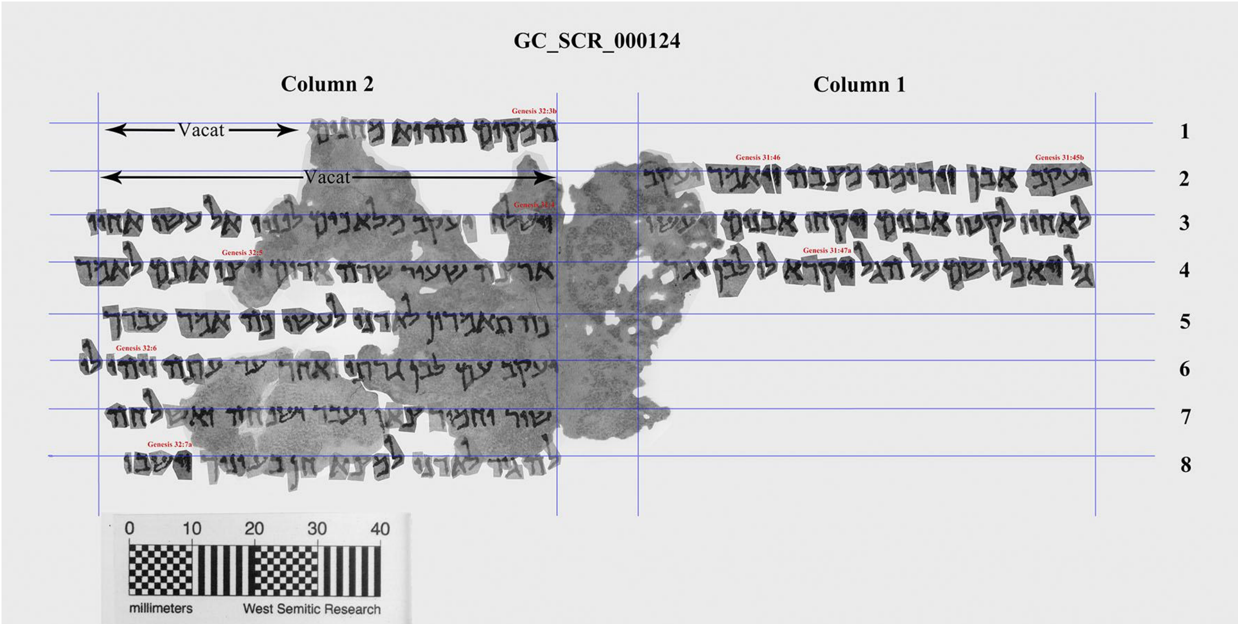

Figure 9: Reconstruction of GC-SCR-00124 Genesis using the principles of letter cloning and reconstruction outlined above (*Image by Bruce and Kenneth Zuckerman and Marilyn Lundberg, West Semitic Research*).

Establishing Alphabet and Strokes Groups

As one collects and deploys various letter-clones, including reconstructed forms and hypothetical or Frankenletters, it is advantageous to collect, organize, and document these clones for ease of further reference and additional use as the reconstruction of a given fragment continues to be developed. For this reason, an “Alphabet Group” should be established where all letters used for reconstruction can be visually indexed in an intuitive manner and thus made available for further reference and use by both the constructor and ultimately by the user/observer (fig. 10). Letters that have been reconstructed at least in part should be labeled as “reconst.” in the Alphabet Group with a superimposed detailed note (see next paragraph) that documents and explains the basis for the reconstruction. In the case of Frankenletters an even more detailed note should be superimposed over the letter, explaining precisely how individual strokes were stitched together to compose this hypothetical letter-form. It is useful to “flag” Frankenletters by superimposing over each of them in the Alphabet Group a semi-transparent rectangular patch colored red, as a means of making them more easily identifiable to the viewer as being hypothetical.

As one isolates individual strokes derived from certain letters, it is also useful to establish a “Strokes” Group where they can be easily accessed for use in the building of other partially reconstructed letters as Frankenletters.

Figure 10: Alphabet Group in the Layers palette of Photoshop. Each letter of the alphabet has its own Group with separate Layers for each example.

Establishing a "Detailed Notes" Group

The use of detailed notes is essential in the reconstruction process. This procedure gives the constructor the necessary means through which to keep track of and document every decision that led to a given reconstruction; further such notes allow the reader/observer to have the means by which to judge the rationales that guide each and every significant issue that is relevant to the reconstructive process. Fortunately, image-processing and management programs such as Photoshop have highly flexible means through which to write detailed textual notes of this nature on separate text-layers that can be grouped under the heading "Detailed Notes." These notes can be physically located and superimposed *directly* over the part of a reconstructed image to which they are relevant and toggled on, when one needs to consult them and toggled off, when one wants to get them out of the way.

It often proves to be useful to write a general introductory note on the reconstruction entitled "Read me first."

Other Groups

Besides the basic working groups described above, other groups may be added to a reconstruction, usually toward the end of the process, whose aim is to supply visual cues for the reader/observer to facilitate her/his navigation around the reconstructed text (fig. 10).

The most prominent of these is the "Titles" Group. In this group can be listed those elements that identify and classify a fragment undergoing reconstruction, e.g., its official designation in accordance with the established protocols for DSS *sigla* or other conventional designations (e.g., catalogue designations for fragments in privately held collections) as well as a more common title, e.g., "11Q10=11tgJob: Targum of Job from Qumran Cave 11." Column designations can also be added as appropriate and physically centered above each column as reconstructed. Likewise, a "Line Numbers" group can be established: thus "1" designating the first line, "2" designating the second line, and so on. Closely related to this "Line Numbers" group is the "Rule Lines" group. Such a group may be divided into two sub-groups: a "Ceiling Lines" subgroup that highlights and demarcates the horizontal ceiling rulings associated with each of the numbered lines and upon which all (or nearly all) letters for that line are "hung." The second sub-group designates "Column Lines"; that is, the vertical rulings that a scribe employed to order a given scroll into columns of text. In both cases, the lines can be based on physical evidence visible on the surface of the scroll fragment itself, e.g., incised lines scored into an animal skin by the scribe. However, in many cases the surfaces are too deteriorated to show where these scored lines were likely to have been, in which case these ceiling and column lines are reconstructed in order to demonstrate where one thinks they ought to have been.

Finally a "References" Group may be added where appropriate. This allows the constructor to indicate text references that connect the text under reconstruction to other texts with which it shares a common set of references (e.g., biblical chapters and verses). The most obvious such usage is to note the relative position of chapter and verse references for biblical texts. Again, noting these references in an easy-to-see color serves to aid the reader in keeping track of where one is when the reconstructed text is compared to other texts with which it apparently shares a common tradition.

Conclusion

The aim of this discussion has been to offer an overview of the way in which West Semitic Research has approached the reconstruction of DSS texts, as illustrated by the text reconstructions in this volume, using approaches that can be transformative to the study of DSS and other ancient texts. We believe that newly available imaging technologies coupled with these methodologies, offer the ability for a scholar to test proposed reconstructions of ancient texts with unparalleled precision and accuracy, thereby allowing them to test various hypotheses.