Greek Minuscule

Script Mensuration

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Graphoanalysis, chirographical analyses and or graphometrics are all terms which imply some sort of handwriting analysis, [though graphometrics can refer to the analyzing of mechanical and computer output as well]. Graphology typically refers to the psychological aspects related to handwriting, which is not relevant to this present paper. Graphometrics refers to the measuring of various styles of handwriting, or other forms of mechanical expression. In this paper, I prefer the phrase "script mensuration".

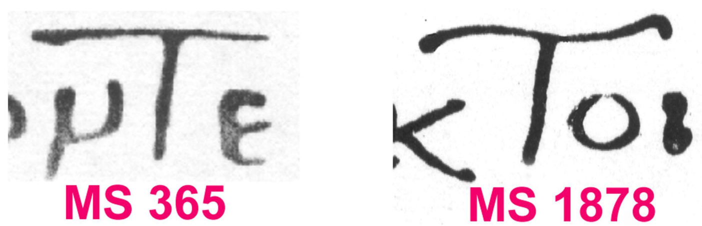
In the paleographical study of Greek (in particular, of theological manuscripts) minuscule manuscripts, none of the above mentioned sciences are well developed. In this paper we shall discuss some of the methods being developed by the author (Mr. Dykes) for the systematic measuring of Greek minuscule scripts. We shall examine some proposals for certain standards, and we shall hopefully learn of the benefits of such measurements—script mensuration. The techniques described herein are also applicable for the evaluation of Chinese and Bengali, besides most Indo-European scripts.

The primary goal of script mensuration is to identify and validate a script; and secondly, to organize a database of numerous scribal scripts/hands, as concerns the various measurements. Once a database is organized, the examiner can better access the relationships of the scripts involved and determine these important criteria:

- if the scripts (in the single manuscript) are by the same scribe
- if the scripts in several manuscripts are by the same scribe
- if a forgery or some sort of alteration exists
- compare measurements to known exemplars, styles and locales
- determine and validate the total number of various hands present in a manuscript

Certainly, it is understood that other features are involved in the overall examination of any one manuscript. Besides measurements (mensuration), all sorts of paleographical features should be considered, such as letter forms, punctuation, page formatting, tachygraphical types, frequency counts of various forms and abbreviations *et cetera*. However, we shall occupy ourselves with the mensuration processes.

To repeat myself, script mensuration is most useful for validating a particular script, and then recognizing departures from that measured script. Many minuscule manuscripts are obviously by different hands; no measuring is required when comparing two visually distinct scripts. Script mensuration's strength is most appreciated when we are examining very similar scripts and wish to prove that they are or are not by the same scribe. For example note these two uncial tau's:



When an examiner views the entire manuscripts of 365 and 1878, it is clear that they are by different hands. Consequently measuring **and comparing** these two glyphs (the uncial tau) is like comparing apples to kiwi, it is a waste of time. But, as independent entities, each should be measured and recorded, not for comparison purposes between these two hands, but for future purposes, as perhaps in the future a manuscript may be examined which is very close to MS 1878, or is of the same style or atelier. In which case a prior mensuration can become useful.

Numerous papers on the subject of graphometrics, though quite informative and useful, rely upon excessively complicated algorithms or various complex mathematical and Euclidean formulae.* In many methods, the script samples are placed upon a grid, or the script image is converted to binary data, or outline contours are generated for analysis. Stroke density and stroke widths are measured and compared. Slope plots as well as connection distances (that is, the spaces between various elements within a word) are minutely examined and plotted. Some of these methods are not fully necessary for the purposes of the Biblical textual critic who wishes to analyze and compare minuscule scripts. The processes outlined and demonstrated in this paper are very basic. Their utter simplicity also allows most investigators to perform the mensuration of various minuscule scripts.

The tools needed are fairly common: a computer, a flat bed scanner (or, a medium resolution, five megapixel-plus digital camera), or images on a disk, or printed copies from a 35mm film, a good image editing program, several tools for on-screen measurements (see image on next page), and a good sized sample of script. Ease of use, ease of implementation and easy to understand graphical results are the benefits of the system I propose.

The use of computers has made my research in this area feasible. Many of the measurements would be difficult without the advantage of enlarging, on-screen, the assorted glyphs and words, and then using on-screen rulers (and other implements) to actually measure the distances or degrees. After which, the data can easily be entered in a searchable computer database. Extensive script mensuration of a complete (for example a manuscript with 250 folios) minuscule manuscript would produce a very large database, composed of—potentially thousands of glyph samples! However, for most purposes, a script mensuration process need not be so extensive: especially when a researcher only wishes to examine or confirm a single manuscript's contents, or to simply compare two scripts.

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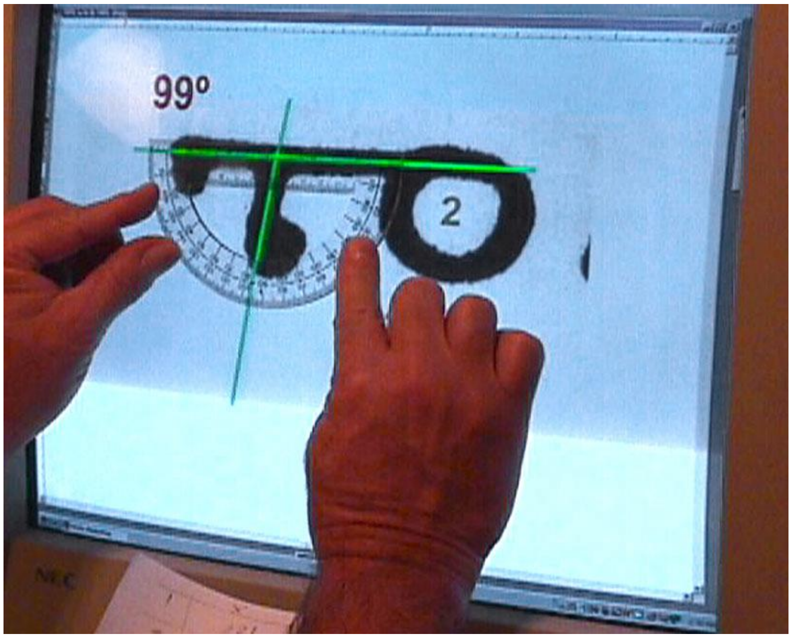
* refer to references concluding this paper



In the above image, a clear protractor is placed on the actual screen to measure the angles formed by the correctly placed green lines.

The image is typically greatly enlarged as above, which makes for easy and extremely accurate measurements! The monitor, in the above, is a 21 inch monitor, which is nice, but even a 15 inch monitor can produce accurate images for measuring purposes. For your information, the original size of the green lines, when first applied to the glyph, is eight pixels wide, which works fine for my work environment.

When a collection of styles and glyphs from a **group** of scribes, in a number of various manuscripts—representing a scriptorium, or a monastery, or a certain chronological period (for example)—is produced the result would be a rather large database. I anticipate such a database developing, one which will and should include script mensurations! Such a database can also assist with broad text-type associations and evaluations. In this paper I will present my nine features or glyphs I recommend for mensuration.

CONTROLLING PARAMETERS

The object of my investigations, Greek minuscule manuscripts, presents several features which assist with limiting the various types of probes and measurements. For one, minuscule scripts can be written on an inscribed line, below a line or bilinear (between lines). Some scribes use no lines, other scribes will present scripts which will wander over, below or even on the line. Consequently I do not rely upon the relationship of the words/glyphs with any associated lines. My measurements remove the factor of line/glyph relationship.

Another factor which I remove is the width of the pen stroke. As is well known, the scribe's stroke width varies as per the preference of the scribe, or via the combination of the ink, pen construction and the material written upon. Even within the same manuscript the broadness of the strokes varies as on the flesh side of parchment manuscripts the strokes are finer, on the hair side the ink tends to spread out more (form a wider impression). Factoring out these elements makes our job of mensuration easier and also by necessity, presents us with better control, in that the results are more uniform not having to consider these extraneous variables.

Density of the inks is another factor not examined. Due to use, age, and type of inks involved this measurement is not a reliable measurement within our discipline. Thus density is not a factor in my research. Slope considerations are in relationship to the adjoining glyphs, **not** to the line or to the page formatting. Thus, the slope is related to the word itself, severing it from a connection to anything else external (other than the viewing monitor). Herein we obtain a good reliable constant, which is measurable for every scribe in every manuscript, regardless of ruling types!

TYPES OF FEATURES FOR EXTRACTION

One could imagine all sorts of elements to measure. I imagine that hundreds of features could be examined. But herein lies the problem. In order for the scripts to be evaluated some precise controls must be in effect. The examined features must, I repeat **must** be applicable to the vast majority of minuscule manuscripts. Measuring elements within a rare ligature may be fine for those few manuscripts which incorporate that particular ligature, but totally useless for those manuscripts which do not contain the feature. As a result, the selection of features for extraction (via an image editing program, on-screen, *et cetera*) should be a carefully thought-out process. Since most measurements concern the comparison between two very similar hands, we can alter some of the measuring techniques to adjust to the distinctive features of the manuscripts being investigated, as long as each manuscript shares both types of glyphs or features!

Not all features are common to all minuscule scripts. Nevertheless I have attempted to create and utilize many that are common to most minuscules. For example, let us assume that we are using my "M_1 metrics" which works with about nine types of glyphs. It is probable that most of the nine features (certainly 7 out of 9) are present in the manuscripts being evaluated. If only seven features are present, data can still be generated. This is certainly better than trying to work with four hundred and eleven features, many of which are not seen in numerous manuscripts; and or, many of which may not be good constants.

When a possible glyph or feature is being considered, it should meet the following criteria:

- should be a normal glyph, not elaborated
- should not be a first letter of the line, nor any of the letters in the top or bottom lines of the page
- should be extracted from within the body of the typical, normal text
- not part of any correction or alteration, or incipit or gloss
- if a single letter, then—not part of any unusual or flourished word forms, nor extracted from cramped or expanded lines.

The above stipulations will hopefully ensure that the measurements are from the typical glyph or word form, thus maintaining a standard regularity. This data (from the simple set of "M_1 metrics" for example) can be used with other types of investigations. But the point is—to critically and scientifically examine two (or more) sets of scripts and to accurately measure them. When this is done, the examiner can with assurance declare that the scripts are by the same scribe, or not. Obviously, script mensuration is most useful when the differences between the scripts are not clearly, visually apparent.

A STANDARD set of features will enable Mr. XXXX in Turkey to examine his manuscript(s) and compare his results with those of Dr. XXXXXX in New Zealand. There needs to be a standard, known and accepted by the profession. Perhaps this paper will contribute to such a goal, and perhaps the features herein demonstrated can be seen as features which make good sense, which are visible and measurable in most Greek minuscule manuscripts.

MEASURING THE SCRIBE

Anatomically, each human (as in scribe) varies. No two hands are created alike. No two writing styles are fully identical. It is true that in many scriptoriums a particular style is/was propagated. Student scribes emulated the hands of their masters or of their exemplars. (We do possess, however, many manuscripts of a very independent nature—such as manuscript 1424, or 910 [all manuscript numbers are per Nestle/Aland's nomenclature]). Some scribes imitated their teachers' hand very well. Some writing styles have many common features, which to the untrained eye, would seem as if the various manuscripts containing this single style were all by the same scribe. Thus the need for good and standardized measurements.

We seek to examine the unconscious movements, to examine those letters and words which a scribe makes without much thought. Common features which he/she executes over and over. These will add to our concept of regularity, and are an important part of the process in selecting which features to extract for measurement. We wish to avoid the extravagant, the abnormal or unusual. We seek those innate unchanging traits common to a particular scribe! Biometric traits seen in his/her script.

A scribe can alter his/her script. However, when enough of the text is available for examination, the examiner will usually find those traits which are distinctive to that scribe. The motion of the wrist, the movement of the finger joints, and even the position of the arm and shoulder determine and help to provide observable and consistent results. Each scribe is anatomically different, and time can alter this physical being—the scribe.

As a scribe ages his/her script may enlarge (due to eyesight/vision changes). In certain situations, a manuscript may have to meet specifications which forces the scribe to make adjustments, such as: tighter spacing, use of special inks (gold and or silver), changing his or her's usual preference for a single or double column format, adding inserted matter (quotes) in a different script and thus changing "fonts" as it were. Other variables can also have an impact: the material written upon, the amount of ink the quill or pen holds and the number of times the scribe must move to refill the pen, changing pens or using a new pen or quill. If the manuscript is being made as a product to sell, or if it is being requested by important dignitaries, this too can affect the scribe's output.

A manuscript copied by a person who is not a professional scribe will display a very different script—it usually lacks staid regularity, and displays numerous inconsistencies (manuscript 910 may be such an example). Some Biblical minuscule manuscripts have been copied by plain ordinary folks who did not do very much writing, however most surviving manuscripts reflect the work of a mature writer/scribe—to varying degrees.

Nevertheless, certain features should still remain distinctive, and that is what drives my selection concerning the demonstrated features in this paper. Proportion and angles are usually not impacted by the size of the script; however, an altered slope or crowding together of the letters, can alter some measurements. When possible, measurements should not be extracted from such sections (crowding together the words so as to save space, or expanding the spacing to fill space). Even when space saving measures are utilized certain distinctive traits remain! Consequently, should a scribe's script evolve over time, certain proportions and angles should remain the same (though not all). And as stated above, we should make every attempt to extract features from that script which is considered typical or normal, not crowded/expanded or flourished words or sections.

As scribes mature, their handwriting should improve! The handwriting should be easier to read, it should display more regularity. In many cases, professional scribes, over time, ADD to their repertoire of forms and glyphs they use. Note the following epsilons:


Both epsilons are from MS 1878, and both occur frequently in various positions within the main text. Here we have an example of a mature/accomplished scribe utilizing his/her skill in calligraphy. This variety was often esteemed, and added character to the manuscript. The work of one scribe, but one who can display varieties of the same letter and word forms. But maturity can also bring out other manifestations. With great age, we may discern a lack of fluidity, as perhaps the nerves are showing their age, or an injury has occurred. Again, despite these potential changes, certain traits should remain. It is these traits we hope to exploit and capitalize upon!

INTRODUCING THE "M_1 metrics" SYSTEM

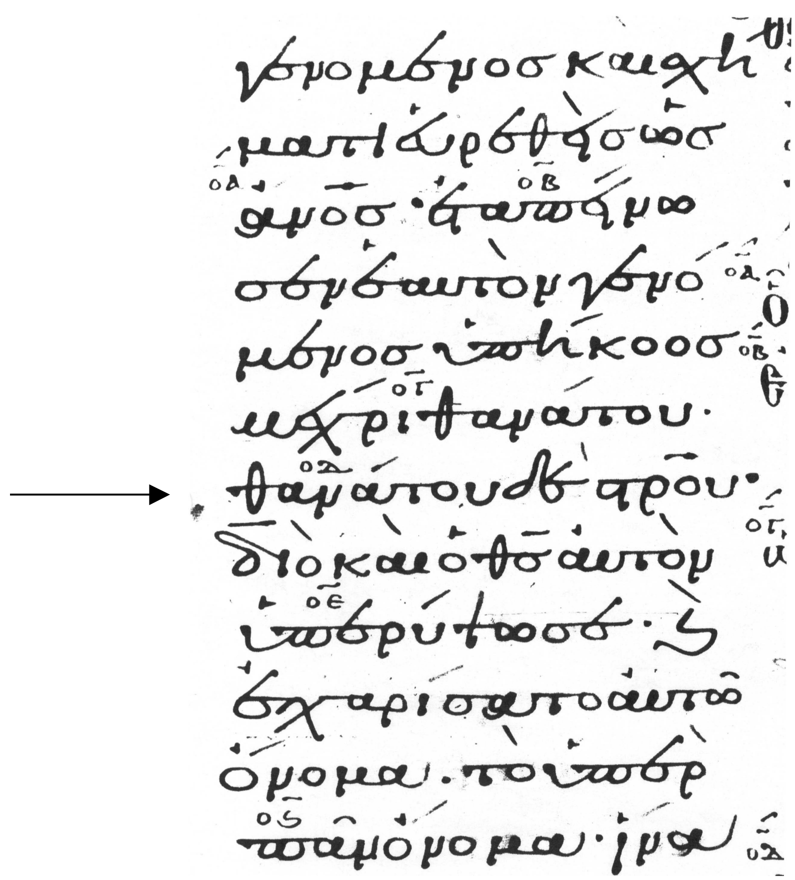
The M_1 metrics system is a collection of nine glyphs or features which are used as measurement models and guidelines. They are designed exclusively for Greek minuscule manuscripts (circa A.D. 750 - 1300). These features present measurement guidelines I use for evaluating and comparing the scripts of any number of manuscripts. Detailed measurements can assist with identifying a particular scribe, or a particular style. The M_1 metrics system is a PART, nay a component, of a comprehensive system via which minuscule manuscripts can be evaluated. Other components, in my methodology, besides script mensuration, are:

- examination of ligatures and abbreviations
- examination of all diacritical marks, accents and punctuation
- graphic comparison of numerous word forms and styles
- iconographic and ornamentation analyses

The above are the primary elements of my personal system of minuscule manuscript evaluation, thus a total of five broad elements (counting the present demonstration of script mensuration). No one element gives a complete or full result. Typically, to satisfy my cravings, a full analysis incorporates at least four of the five elements (iconographic and ornamentation features do not occur in all minuscule manuscripts, as a result it is not a necessary ingredient in the essential processes). **Other manuscript features such as rulings, ink colors, foliation, canon order, quotations,** *et al*, **are not examined as part of this system, however, they too should be fully examined when possible.**

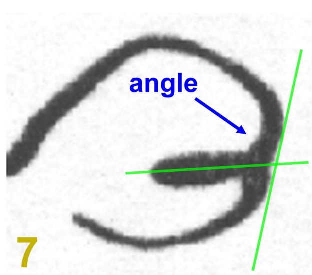
The M_1 metrics system presents nine glyphs which should appear in many minuscule manuscripts. It soon becomes apparent to the busy investigator that some of the features do not occur in certain manuscripts. Yet a sufficient number should be observable, and use of the glyphs which do appear can provide pertinent results. It is assumed that at least seven of the features will be present in nearly all minuscule manuscripts. Working with the full nine features provides more validation, but the system works well with as few as seven feature measurements.

As mentioned above, some forms of the M_1 metrics system do not appear in certain minuscule manuscripts. For example in MS 1878 [circa A.D. 1050-1150] we find no forms matching our M_1 metrics number eight, a delta + epsilon combination, note the sample below of MS 1878:



In the line indicated, we see the form for 1878s δε which is a very different form from the style depicted in test number eight (see M_1 metrics test eight, below). Thus, were we to compare manuscripts 1319 and 1878, we could not use this particular test. However, if both manuscripts under investigation used a similar form for this conjunction (δε), or even a similar free-standing epsilon, we could then compare. Despite this difference, MS 1878 does present us with eight other COMMON measurable features. Such is to be expected; having all nine features present is best, but definitely not mandatory. When the researcher simply visually scans MSS 1319 and 1878, it is immediately apparent that mensuration is not needed for comparison purposes betwixt these two manuscripts, they obviously differ.

The first of the nine feature-glyphs in the M_1 metrics system is measurement of the letter "ʒeta" (ζ). Zeta has several forms in minuscule manuscripts, and many scribes will use several forms for this Greek letter. Here is the form of ʒeta I use for mensuration purposes in the first of the M_1 metrics:



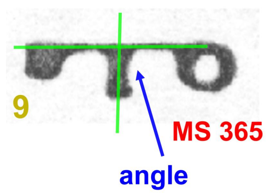
MS 365

The letter was taken from a black and white 35mm film (via a microfilm printer), then scanned and measured in an image editing program (as are many of the M_1 metrics glyphs). The green lines are added to show what is being measured. The green "vertical" line, on the right, touches both extrema points of the "bows", that is the line is tangent to two points of the bows. Once it is drawn, another line is drawn to intersect it, which passes through the center curl of the letter. This "center" line is placed on the center of the MASS of the (often closed) central curl, it passes through the intersection point of the two bow halves, on the right side of the inner curl. Where this line intersects with the first line, we measure the resulting angle, indicated above. This angle measurement gives us the data for this particular letter/glyph - ȥeta. Note that the width of the strokes of the letter are not a factor, nor is the relationship of the letter to any inscribed ruling lines. Nor is the slope an important factor. We have eliminated these as influences, and are left with a rather pure and simple piece of data. A difference of more than five degrees is significant! When multiple samples are tested and measured, an average is then to be recorded.

As with each of the nine features extracted in M_1 metrics, the researcher should exhibit at least three of the letters for measurement. When two very similar scripts are being compared, as many as 10 or 20 individual glyphs may be needed. [Note the sister paper to this document, titled: "Manuscripts 365 and 1319 Mensurated", for a clear example of the complete M_1 metrics system displayed].

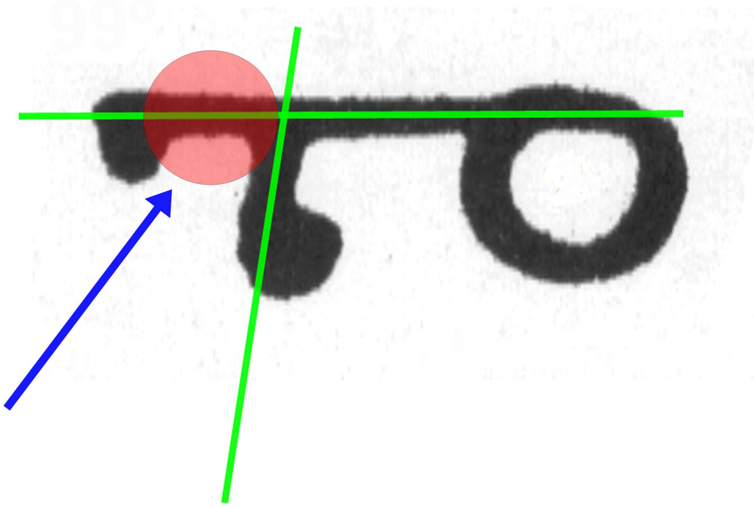
Scribes who imitate the same teacher, exemplar or style, may at times appear to be one and the same person, when indeed we are dealing with several scribes and several hands. Thus precise measurements can detect the minor differences apparent within the same style or school of calligraphy.

The second M_1 metrics test glyph is a tau-omicron connection (often the Greek article (το)).

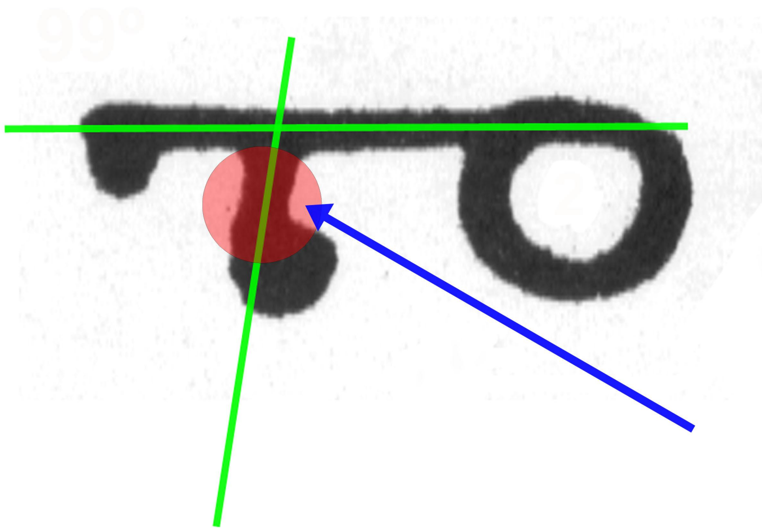


Again an angular measurement is the result. Again the measurement is independent of any linear rulings, and as the lines pass through the centers of the letter strokes, we remove the factor of line width. An illustration of where the center of the strokes is, follows on the next page. This sample uses a το COMBINATION to achieve greater regularity and precision. Note that the tau which is being measured is always connected to its right with an omicron. Also note that there is no connection to the tau's left. This ensures that the movement of the scribe's hand is fairly consistent, he/she anticipates the omicron following, and thus executes a tau which should be consistent and uniform in each sample. All of which helps provide accurate data for this feature.

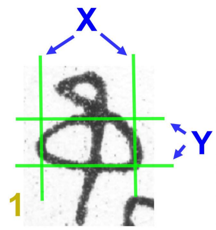
Again after numerous samples are averaged, a difference of five degrees or more is significant, in the associated tests of minuscules 365 and 1319, we saw an average difference of nine degrees.



The "center" is the center within the shaded areas, this would be the very center of the width of the stroke(s). We do not create or use any type of a center in the serif or added "blobs". We use the main body stroke(s).

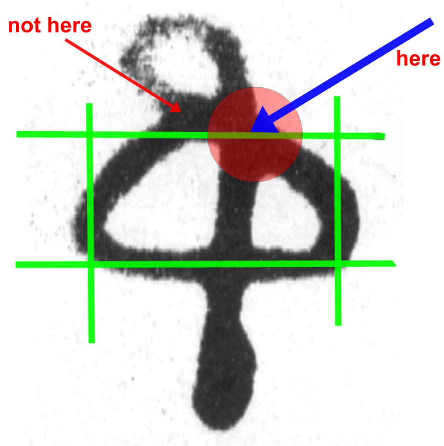


M_1 metrics glyph number three is the Greek letter phi (ϕ):



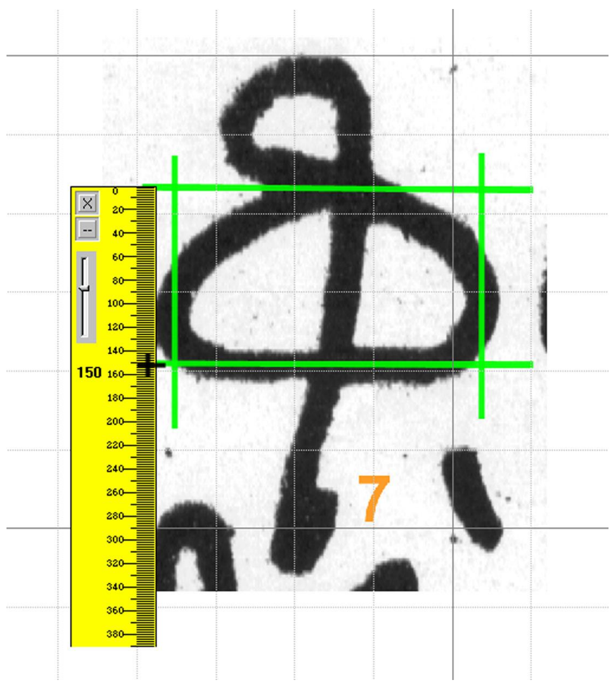
Here we are creating a ratio, not an angle. The two side-bearing lines are placed at the widest points of the central bowl, passing through the centers of the strokes (see the images on the following page), tangent at 90° (hopefully); the two horizontal lines are placed such that the lower one is tangent to the center of the stroke at lowest point of the bowl, and the upper line passes through the center of the union of the right-side bowl curve and the central stem stroke. The measurement is the distance between the two X lines, divided by the distance between the two Y lines. (*i.e.* X ÷ Y). The ratio is the key, not the units (which can be in pixels, inches or whatever). A difference of 3/10s is significant. In the 365 and 1319 samples, we note a difference of the ratios as merely 0.22, which shows much similarity in some aspects, but not exact duplication!

In this particular glyph, one should rotate (if needed) the sample phi so that the widest points can be relatively vertical to the plane of the horizontal lines, as this ensures that the widest points are appreciated and utilized. In the above example, the letter could have been rotated counter clockwise about four degrees for absolute accuracy. The following images clarify the procedure.

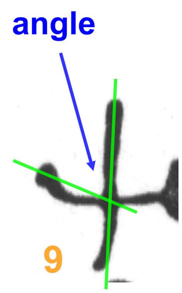


Note that all lines are drawn within the centers of the strokes. The upper line passes through the union of the RIGHT up curving stroke and the central stem, even when the "left side curve" does not perfectly fit at the joint. Use the center as indicated in the shaded area above.

Below is a sample of the on-screen ruler (J Ruler) in use. It is set to indicate pixels, and the reading is 150. A very handy tool, available for download from: www.BIBLICAL-DATA.org [navigate to the "software's" page]



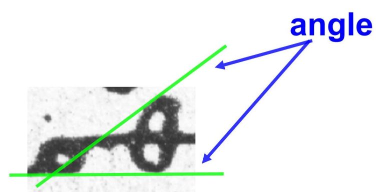
M_1 metrics test glyph number four is the Greek letter psi (Ψ):



An angular measurement in degrees would be the result of this test. The green vertical line passes through the center of the vertical stem of the letter (not being swayed by any curvations of the lower extremity). The green line on the left, passes through the center of the outer tip of the left arm of the bowl, and from thence it intersects with the center of the lower bowl and vertical stem. The angle for measurement is always on the left side. In most cases the letter is not connected on the left, it may be connected on the right. A variation of more than seven degrees is significant.

One should view the samples in the sister document "Manuscripts 365 and 1319 Mensurated", so as to observe how the differing curves in the bowls of numerous scripts are negotiated (also described in the M_1 metrics tests number eight and nine, below). In some scripts, the arms lie flat with no curve, in which case we still get good measurements, often close to 90°. Recall, that typical forms are used herein for test purposes, avoid excessively enlarged forms of this and other glyphs, unless such elaborated forms are indicated in the test glyph.

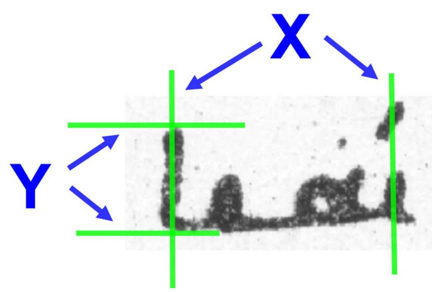
M_1 metrics test glyph number five is the combination of a non-ligatured sigma-theta (σ and θ):



An angular measurement is generated via this featured glyph. This letter combination is typical in most cursive scripts, it is not a ligature. Usually the combination is seen within a word form, often in a penultimate position within the word. Since the sigma is normally connected also to its left side, the left side of the sigma may display various alterations (sometimes squarish, sometimes more elliptic) due to the type of connections stroke(s); to remove this potential alteration factor, we should lay the bottom green line tangent to the point below the CENTER of the sigma's interior, and extending it to the lowest point of the connected theta. From the point below the center of the sigma we add an intersecting line which extends to the upper point of the theta. We then measure the resulting angle. A variation of three or four degrees is noteworthy.

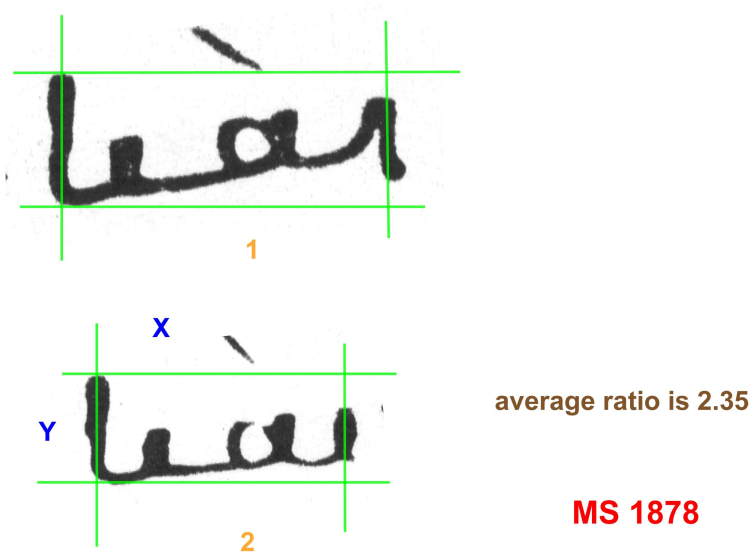
As with most angular measurements, the opening of the angle is determined by at least two factors: the length of the sides of the angle, and the length of the side opposite the vertex angle. Typically a scalene type triangle results when a third line is suspended from the upper extremity of the theta to its point of contact with the lower green line. At times a right angle may result, and this should be noted. Angular measurements thus measure two aspects of the scribes motion, a movement to the right as well as a movement upwards or downwards. In the case of most of the angle measurements in the M_1 system, we are measuring an unconscious motion of the scribe. This forms one of the reasons why certain glyph features are examined. We seek to observe the usual, "innate" movement, and thus generate measurements which measure this repetitive-movement—biometrically gauged motion, unique to the hand performing the action.

M_1 metrics test glyph number six, is a whole word. The conjunction και, or "and", composed of three letters: kappa, alpha and iota.



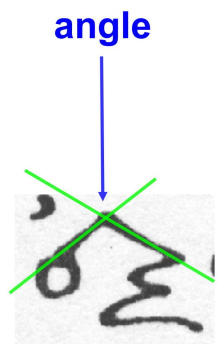
This mensuration technique here generates a ratio, X ÷ Y. This measurement requires care in setting up. The goal is to form a rectangle around the word, such that it maintains four interior angles of 90°. Rotation of the extractions may be required, so as to position the kappa's back straight up-and-down relative to the viewer (or the monitor screen, see example on next page). Then from the top and bottom extrema points of the kappa's back, parallel lines extend to the right. (In the above illustration, I did not bother to fully extend the upper and lower lines). The final line, is placed through the center of the mass of the stroke of the iota such that it is parallel to the line passing through the back of the kappa. We now have our sides to measure.

This is one of the most common words a scribe will write. It is assumed that when it is written in standard unadorned fashion, that we have instances of the natural regular movement of the scribe. Consequently this common form serves as a fine feature to exploit. As formed above, it is quite common (with a cursive kappa), so common that only careful measurements can often detect differences. Notice in the method of measurement that the size factor, linear rulings, and width of pen strokes are all factored out. In the above sample, a variation in the resulting ratio of only 0.20 is notable when two scripts (or averages) are being compared.



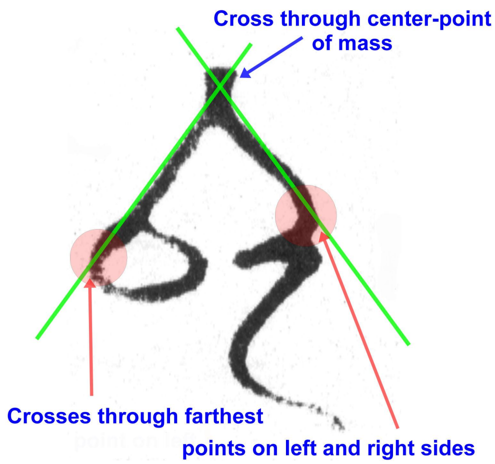
Note that both glyphs have been rotated so that the backs of the kappa are relatively vertical. In the upper glyph, we can see how a "split" iota is measured—the line passes through its downward side.

M_1 metrics glyph number seven, is a ligature "ex", epsilon + xi:



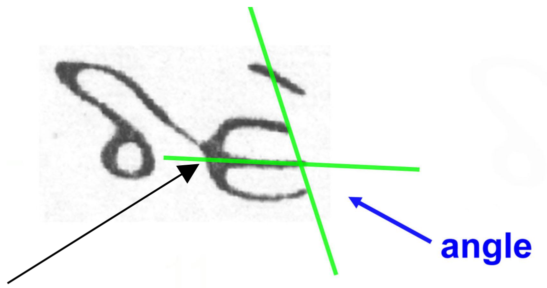
The feature will give us an angular measurement. The union of the two letters (epsilon and xi) forms a pointed "top". The goal is to place the measuring lines so as to intersect through the central "point" within the pointed peak. If the sides are curved, or heavily bowed downward (and this is seen in some forms of this ligature) draw the two lines such that they connect with the outermost points of the two letters, then intersecting through the middle of the mass of the peak union. (Refer to the example on the next page). Draw the lines through the middle of the stroke widths—if the strokes of the sides rising up to the "peak" are relatively straight.

A difference in the averages of two or three degrees is significant; as this common ligature is often closely imitated (but as **we are able to discern**, not perfectly imitated!).



Note the differing shape of the Xi, this sample is from MS 1878. On the page preceding, the sample is from MS 365. Though a different form of the Xi is utilized, I see no reason why it cannot be compared with those of the MSS 365 and 1319 types.

M_1 metrics glyph number eight is the letter epsilon ϵ:

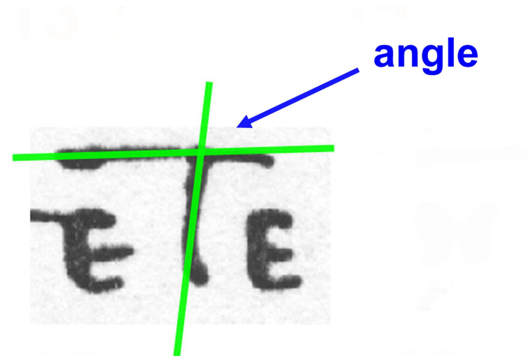


In manuscripts 365 and 1319, the scribes present us with very similar forms as per the above illustration [do note the associated file, "Manuscripts 365 and 1319 Mensurated"]. In these manuscripts this epsilon is often enlarged, being an uncial-style epsilon. In other examples from these same manuscripts, we observe the form with a much smaller epsilon. Though possible to measure, the form with the smaller epsilon is **not** recommended in the mensuration of this feature.

The green measurement lines are placed so that one line connects the very outer ends of the upper and lower arms of the epsilon. The central green line passes through the union of the epsilons arms (the point where all three intersect [note black arrow in the above illustration]); it then extends out along the central arm of the epsilon to pass through the tip. The requirement to "pass through the tip" ensures a regularity even if the arm is highly curved. A variation of five or more degrees of the average is significant. It is suggested that at least eight or more samples are measured.

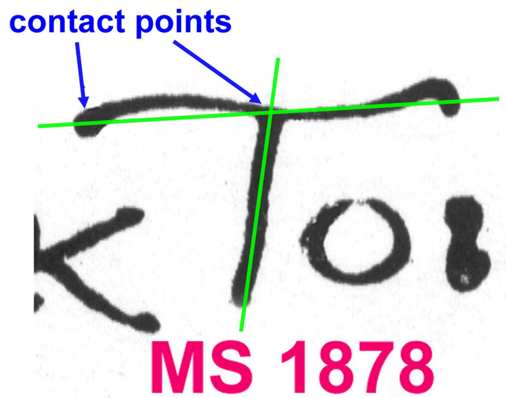
The larger epsilon, as above, is a common and stunning visual feature in many minuscule hands. Often the same letter is enlarged and stands, in other usages, unconnected—it stands out. It is assumed that scribes therefore, practice the precise execution of this particular epsilon. By requiring that our measurements stem from a delta-epsilon WORD we are assured that the resulting epsilon is began with the same motion of the hand as it leaves the preceding delta. Hence ensuring a uniform measuring environment.

M_1 metrics glyph number nine is an uncial Tau (T):



Recall that in M_1 metrics #2, [a tau-omicron connection] we measured the supplementary angle of the above. In this feature we measure the angle as indicated above. The top line passes through the middle of the upper stroke, it does not vary or curve to follow the terminal curve at the right tip. The primary direction is indicated by the LEFT side of the upper stroke, the straight line is controlled/directed by this side! The second line intersects the upper line at the center of the two strokes of the Tau. It passes downward through the middle of the downward stroke, again not curving to meet the tip (as per the above illustration).

Should the upper stroke of the Tau be curved, then the green line should pass through the **center** of the left end, and then through the center of the tau's two strokes, as below:



Accuracy is important, and with finely penned strokes, it may be difficult to place the lines in the very centers of the strokes, so some minor variation can occur. Hence, at least eight or more samples should be evaluated, so as to form a stable average. Variation of four or more degrees is significant.

SOME FINAL CONSIDERATIONS

We can expect some slight unwanted variations to occur in our measurements. However, undesirable variations can be reduced. Some of these variations are dependent upon several factors inherent in the manuscripts and in the equipment and materials used:

- quality of original image (sharp resolution reduces variation)
- enlargement or working size generated by the graphics environment
- number of glyphs collected for evaluation (more glyphs will clarify and sharpen the core average)
- accidental mixing of scribal hands
- improper feature selection
- maintaining consistent scanning and sizing techniques

"Accidental mixing of scribal hands" can occur when we move through the folios of a manuscript to find good candidates, and unknowingly select from portions written by another scribe. This can occur if the two hands are very similar. For obvious reasons, this corrupts the data.

Consistent sizing means; not comparing a six inch scanned output sample with a one inch output sample, try to keep them near a one-to-one proportion.

Over time, and as many hands and manuscripts are evaluated, a very useful table of recorded averages can be generated. If all nine features (for example) are seen in 20 different manuscripts, and laid out in a table—I could quickly observe and form some general opinions as to which may reflect the same styles, or which may be from the same locale. Such data can save time, enhance my ability, and **scientifically validate my findings**. Recall that M_1 metrics, is most powerful as a tool via which similar scripts can be compared and distinguished, with a high degree of accuracy.

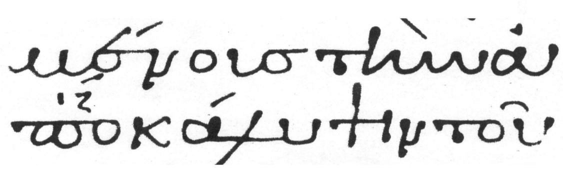
By joining the information garnered from M_1 metrics, with other criteria (other paleographical features), I can continue to enhance my knowledge and use of the mass of Greek New Testament minuscule manuscripts. Perhaps others may find the methods demonstated herein valuable and useful as well.

Below are the sample test results from three manuscripts. As can be seen MSS 365 and 1319 are much closer in agreement than 1878. In fact via numerous other tests, it is known that MSS 365 and 1319 are in the same style, probably written in the same scriptorium within 20 years of each other. Or written by scribes who were trained by the same master. When one actually views the scripts the similarities are apparent. But they are not written by the same scribe.

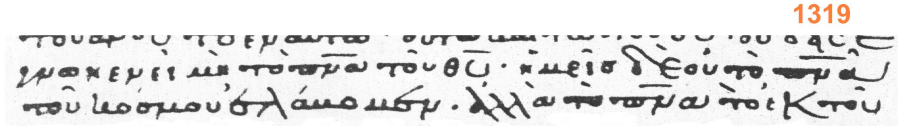
The chart reveals that MS 1878 is another animal, and is not related to 365 nor 1319 as far as writing styles are concerned.

TEST #	1	2	3	4	5	6	7	8	9
MSS									
365	101	92	1.86	75.4	43.2	2.36	112.2	81.38	84.3
1319	94	83	1.64	71.6	40.5	2.29	113.5	73.25	81.3
1878	94	99.4	1.77	104	58.4	2.35	82.2	—	76.3

1878

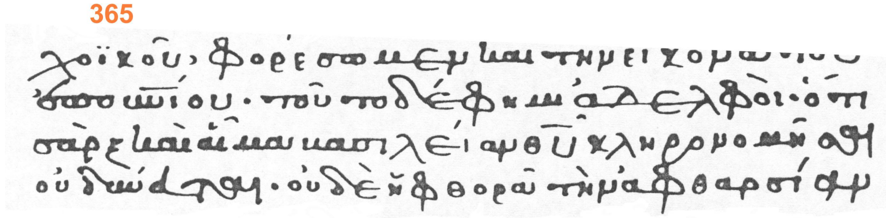


1319



NOTE: shown to approximate, but not exact scale.

365



References

Morris, N.. *Forensic Handwriting Identification: Fundamental Concepts and Principles*, Academic Press. 2000.

Q. Yingyong, B. R. Hunt. "Signature Verification Using Global and Grid Features", Pattern Recognition - vol. 22, no. 12, Great Britain, 1621-1629. 1994.

A. J. Elms. "The Representation and Recognition of Text Using Hidden Markov Models", Doctoral Thesis, University of Surrey, U.K. 1996.

Audet, Samuel, Peyush Bansal, and Shirish Baskaran. "Offline Signature Verification Using Virtual Support Vector Machines". ECSE 526 - ARTIFICIAL INTELLIGENCE, FINAL PROJECT, April 7, 2006 (revised May 7, 2006).

M. A. Ferrer, J. B. Alonso, and C. M. Travieso. "Offline Geometric Parameters for Automatic Signature Verification Using Fixed-Point Arithmetic", IEEE Trans. Pattern Anal. Mach. Intell., vol. 27, no. 6, pp. 993-997, 2005.

Bulacu, M., Shomaker, L.. "Writer Identification Using Edge-Based Directional Features", Proceedings of 7th International Conference on Document Analysis and Recognition (ICDAR 2003), IEEE Computer Society, pp. 937-941, vol. II, 3-6 August, Edinburgh, Scotland. 2003

Cha, S. H.. "Use of the Distance Measures in Handwriting Analysis". Doctoral Thesis. State University of New York at Buffalo, EUA. 2001.

Gonzalez, R. C., Woods, R. E.. *Digital Image Processing*, Addison-Wesley Publishing Company.1992.

W. Guerfali and R. Plamondon. "The Delta LogNormal Theory for the Generation and Modeling of Cursive Characters", Proceedings of the ICDAR, Vol. 2, pp. 495-498. 1995.

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