12 How Much Text do the Closed Rolls Contain? A Quantification Attempt

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Pythagoras (according to Aristotle)

How much text still hides inside the unopened rolls of the *Officina dei papiri* in Naples? In view of the "foreseeable" virtual of these rolls, the actual obvious question hasn't yet been asked, i.e. yet no nontrivial qualification attempt has been attempted. However, a quantitative orientation with the newly developed mathematical-bibliometric methods (see 13.1.4) can be obtained without too much effort and with a certain significance. (How many columns? How many words? How many reference pages?)

For this purpose, we should keep in mind, that the various windings of a papyrus roll (more precisely: the cross-section of a papyrus roll), which strictly speaking resembles an Archimedean spiral (see 13.1.4), can be approximated as concentric circles around the center of the roll. They are spaced between 0.1 and 0.25 mm apart from one another, depending on the "firmness" of the winding and the thickness of the papyrus, respectively. [148] As a result, the width of the windings in the wounded state of the papyri usually decreases by about 1-2 mm per winding (from left to right).

148 On this Holger Essler, "Reconstruction of Papyrus Rolls on a mathematical Basis," *CErc* 38 (2008): (273–307), 286.

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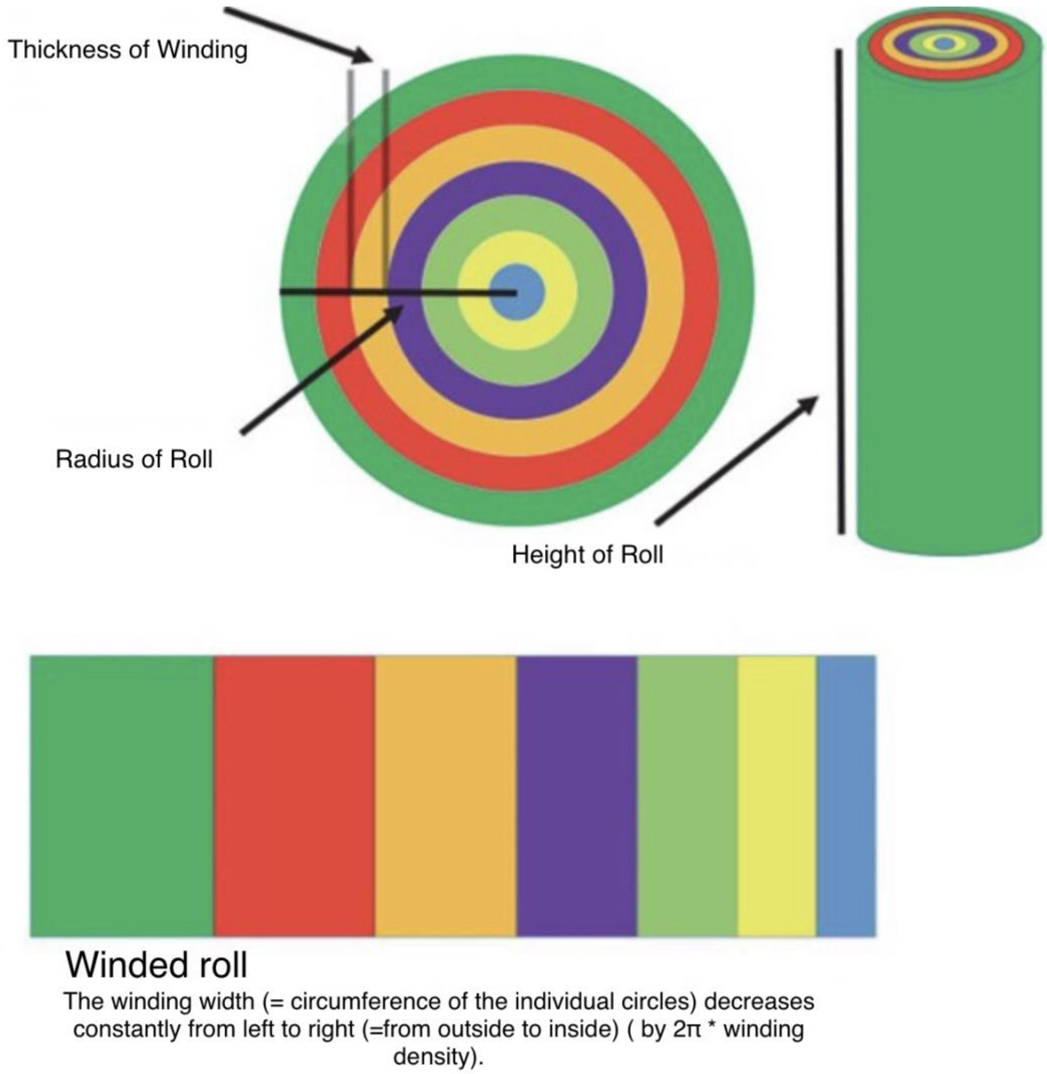

Figs. 46–47: Closed roll in longitudinal and cross-sections, and wound roll.

The circumference of each of these circles (windings) can be easily calculated by the formula 2*π*r (equivalent to d*π) known from school, where r is the radius and d is the diameter. To determine the circumferential area of the roll over each circle, one now simply multiplies by the height, since the rolls can (approx.) be regarded as cylinders. If you now add together the circumferences of all circles (windings), you get the length of the roll; If you add together the surface areas of all cylinders, you get the surface area of the roll. [149] For our purposes it is important to note that for the length of the roll, one can also multiply the average radius (= r* π) or the average shell area (= r* π*h) by the number of windings (of the circles).

Now for about 600 rolls or parts of roll under the indication “non svolti” (not wound up), both the height dimensions and the diameters can be found in the *chartes* database (see 13.2.2) [150] which is sufficient to determine the (hypothetical) length of the roll in the wound up state, respectively its surface area, given the decrease of the widths of the windings in the wound up state (thus implicit the thickness of a winding). The thickness of a winding or the distance between windings is similar for all (closed) rolls of the collection.

PHerc.-Number (unopened rolls)	**Height h (cm)**	**Dia-meter d (cm)**	**Radius r (cm)**	**Number (Z) of windings When changing the winding width by**		
				0.10 cm	**0.15 cm**	**0.20 cm**
7	9.5	5.7	2.85	179	119	89
8	9.3	4.5	2.25	141	94	71
12	8.2	4.8	2.40	151	100	75
20	10.2	5.2	2.60	163	109	82
22	15.5	4.9	2.45	154	103	77
23	10.4	6.8	3.40	214	142	107
…						
1810	11.0	2.8	1.40	88	59	44

The number of windings was rounded to whole numbers. It is obtained by dividing the radius by the (constant) thickness of a winding in the unrolled state (three different values in the table).[151]

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149 Alternatively, one can multiplicate the height of the roll with the added circumferences of the circles.

150 For help in creating the raw Excel table as part of the course “Buried by Vesuvius – The Papyri of Herculaneum in the Digital Age (An Introduction)” that I held in WS 2018/2019 at the University of Würzburg, I thank Linnea Behncke and Sebastian Schmidt. Rolls for which no or no complete data were available were not considered.

151 The thickness is obtained through division of the change in winding width in the rolled-up state by 2 u, ergo equates to a 0.10 cm (0.15cm/0.20 cm) change in winding width about a thickness of 0.16mm (0.24 mm/ 0.32 mm).

PHerc.-Number (unopened rolls)	Area (F) of the roll when changing the wing width by		
	0.10 cm	**0.15 cm**	**0.20 cm**
7	15218 cm²	10117 cm²	7566 cm²
8	9264 cm²	6176 cm²	4665 cm²
12	9331 cm²	6180 cm²	4635 cm²
20	13573 cm²	9077 cm²	6828 cm²
22	18363 cm²	12282 cm²	9182 cm²
23	23761 cm²	15766 cm²	11880 cm²
…			
1810	4255 cm²	2853 cm²	2128 cm²
Sum of all rolls	8.356.499 cm²	5.573.886 cm²	4.179.041 cm²

To calculate the area of the rolls, multiply the surface area of the average cylinder (2*π*(r/2)*Z*h) by the number of windings. Thus, for PHerc. 7, assuming a change in winding width of 1 mm per winding (= 0.16 mm thickness of winding), one would calculate as follows: 2*π*(2.85/2)*179*9.5 = 15218cm².[152]

However, the hundreds of bent rolls (parts) often don't have a true cylindrical shape, a circumstance which must be taken into account by a correction factor. The "diameter" given in the database usually means the widest extension of the base area of the roll. However, the base area of many rolls is elliptical: others resemble a polygonal stump. The area of the base surface is therefore usually smaller than that of a circle with the corresponding diameter. Much more important is the fact that the rolls often resemble cones in height and not perfect cylinders. Furthermore, they are sometimes formed into contourless and complex shapes that have a smaller area than a cylinder.[153]

A cone would have the surface area $\pi * r * \sqrt{h^2 + r^2}$, which is always (considerably) Smaller for our rolls than the surface area of a cylinder (2*π*r*h), with limit property to the effect that the surface area of the cylinder of

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152 For π was calculated with 3.14. The number "two" shortens out pleasantly.

153 Concerning the rolls, comparatively few cases are excluded here, in which due to the curvature of the roll the height measured in the vertical direction underestimates the volume and the surface area of the roll.

the same diameter is almost twice as large as that of the cone. One could now fictitiously consider all the rolls obtained as cones, which would mean that the values in the table would have to be approximately halved (multiplication by 0.5) to determine the true area of the roll. One could object that such a cone consideration is somewhat exaggerated for the roll parts obtained, against which one could again object that the base area of many rolls is rather elliptical, which would "compensate" for the exaggerated cone consideration. The many different roll or truncated shapes, which are hidden among the approximately 600 numbers considered, are difficult to bring to a common denominator. Therefore, three correction factors are used as examples in the following table, whereby the factor 0.5 – which goes in the direction of the cone or in the direction of its lateral surface – corrects most strongly.

PHerc.-Number (unopened rolls)	**Area (F) of the roll with change of winding width By 0.10 cm Correction factor**			**Area (F) of the roll with change of winding width by 0.15 cm Correction factor**			**Area(F) of the roll with change of winding width by 0.20 cm Correction factor**		
	0.75	**0.6**	**0.5**	**0.75**	**0.6**	**0.5**	**0.75**	**0.6**	**0.5**
7	11413	9131	7609	7588	6070	5058	5675	4540	3783
8	6948	5559	4632	4632	3706	3088	3499	2799	2333
12	6998	5599	4666	4635	3708	3090	3476	2781	2317
20	10180	8144	6787	6808	5446	4538	5121	4097	3414
22	13772	11018	9182	9211	7369	6141	6886	5509	4591
23	17820	14256	11880	11825	9460	7883	8910	7128	5940
…									
1810	3191	2553	2128	2140	1712	1427	1596	1277	1064
All rolls (in Mill. cm^2)	6.3	5.0	4.2	4.2	3.3	2.8	3.1	2.5	2.1

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154 The expression $\pi * r * \sqrt{h^2 + r^2}$ for the inner concentric circles tends more and more towards $\pi * r * h$ Even for the largest outer circle, the expression is quite close to $\pi * r * h$ for the vast majority of the tabular values.

155 Certainly, there are also isolated rolls that protrude upwards only at one end, for example, and whose surface area would thus still be overestimated even by the surface area of a cone.

Now, the average Herculean papyrus roll has about a height of 22 cm.[156] Thus, the fictitious length of the still-to-be-unrolled (fictitious full) rolls of the collection would be between 950 and 2850 meters, depending on the winding width and correction factor. Assuming a distance of 6.5 cm between the beginning of the columns (intercolumnar space), one arrives at between 15,000 and 43,000 (complete!) columns.

	Text in all still unrolled rolls When changing the winding width by								
	0.10 cm Correction factor			0.15 cm Correction factor			0.20 cm Correction factor		
	0.75	0.6	0.5	0.75	0.6	0.5	0.75	0.6	0.5
Length (m)	2849	2279	1892	1900	1520	1267	1425	1140	950
Columns (Thous.)	43	35	29	29	23	19	22	18	15
Words(Mill.)	4.9	3.9	3.3	3.3	2.6	2.2	2.5	2.0	1.6
OCT Pages (Thous.)	25	20	16	16	12	11	12	10	8
OCT Volumes	98	79	65	65	52	44	49	39	33

On average, about 17 cm of this height are written on (a little more than 2 cm upper and lower margin), i.e., the height of a column corresponds to about 17 cm, in which on average about 32 lines find place.[158] Assuming about 3.5 words per line, it can be concluded[159] that in any case more than 1.5 million words would be read in today's still unrolled rolls of the Herculean collection. Now, I have assumed about 200 words for a typical page of prose text in the Oxford Classical Texts (OCT) series, and about 250 pages for a typical OCT prose volume.[160] Depending on the assumption of the two vari

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156 156 Cf. Cavallo, *Libri scritture scribe* (as note 65), 16. For the following calculations, the plausible assumption was made that the parts of the rolls ultimately complement each other in terms of margins or no margins, which is also justified by the fact that many of the parts of the rolls are quite obviously from identical rolls that are broken into pieces.

157 For the width, see Cavallo, *Libri scritture scribe* (as note 65), 18–19 (the number is conservatively chosen in view of the number of columns). For comparison: Philodems *De morte IV*, of which only the last 40 or so columns have survived incomplete, had 118 columns.

158 Cavallo, *Libri scritture scribe* (as note 65),18.

159 Estimate based on the average line length of about 18 letters per line, cf. Cavallo, *Libri scritture scribe* (as note 65), 18.

160 Own count or own estimate. Values are set rather conservatively, i.e., tended to estimate more words per page and more pages per volume. One ables change in winding width (or thickness of winding) and correction factor, there would thus still be text in the range of about 8000 to 25,000 OCT pages (equivalent to about 30-100 volumes) hidden in the rolls. These would probably originate from about 300 different (fictitiously complete) rolls (works) (300 with considerable variance), to which the 600 roll parts recorded for the table calculations (and additionally dozens of unrecorded roll parts) are to be added. In a "control calculation" about 3-10 fictitiously complete rolls would result in an OCT volume, which is plausible (depending on the average roll length).

Now, certainly, the ἄγραφα and the υρντόυολλα, i.e. the blank sheets at the beginning and end of rolls, as well as partly *umbillici*[161] would have to be deducted (which would perhaps be compensated by several rolls not taken into account because of missing data in my calculation), and some would perhaps with even greater (exaggerated) caution apply the above variables differently (even more conservatively), so that for reasons of precaution I will limit my evaluation only to the lowest values in the table (far right - correction factor 0.5 and winding width change 0.2 cm). Even in this "worst" case according to my calculations, there would still be about 8000 "reference pages" of ancient text to be gained by *virtual unrolling*. Since so far rather the better-preserved rolls were opened and the Latin rolls belonged quite obviously rather to the more badly to be opened rolls, the past predominance of Greek to Latin Papyri of approximately 10:1 might be less pronounced with the unopened rolls. Among 8000 new pages there would certainly be several hundred pages of Latin literature.[162] In the case of the roughly estimated 300-400 works in the still unopened rolls, in those cases where almost complete rolls are preserved today, probably 70-100% of the text would be recoverable or combinable, in the case of the smaller "stump remains" partly less than 10%.

These figures show what a large amount of text can still be *theoretically* recovered from the rolls. However, the considerations and calculations are based on the assumption that *virtual unrolling* works relatively problem-free by machine and, in particular, that no mergers (fusions) of windings have taken place inside the rolls, which could have

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also recognize that the values for 0.10cm/0.5 correction and 0.15cm/0.75 correction are identical except for rounding errors.

161 Some rolls were wound around thin rods (*umbillici*) attached to the end of the rolls.

162 However, for these considerations, differences in form must be taken into account.

damaged the text inside the rolls. Fortunately, the identification of windings over almost the entire height of closed rolls (see 11.2) and the previous *virtual unrolling* attempts (11.3) tends to speak against such internal, destructive mergers on a larger scale (for multiple rolls). In any case, this first quantification of the textual *potential* of still closed scrolls (parts of scrolls), supported by mathematical bibliometrics, should have made clear what amount of new text is available in case of a successful *virtual unrolling* and what is meant by

"There is still a lot of text in the unopened scrolls!" Even with the (realistically chosen) most conservative variables, one gets to over 8000 OCT pages, i.e. over 30 volumes of new text. Even if we again subtract possible problems, at least a dozen modern norm volumes of antique literature could be won. The new texts would cover a broad spectrum of authors and genres, certainly with a dominance of Greek Epicurean texts.