Is Plump Later ?
The Possibilities of Dating Sarcophagi by means of their Proportions Checked by PCA-analysis on the North-Western Necropolis Sarcophagi of Hierapolis (Phrygia, Turkey).

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The inductive inference

Until now, undecorated sarcophagi have generally been neglected in archaeological research, because of their minimal art-historical value. Moreover, sarcophagi, without any decoration or inscription, cannot be dated using the traditional stylistic and epigraphical methods (Koch 1993:55).

However, on the basis of a number of observations in the field, some authors have stated that, in general, sarcophagi get plumper, the later their date (Machatschek 1967: 47-48; Asgari and Firatli 1978: 47 & 49; Koch and Sichtermann 1982:486 Fig.10; Asgari 1990: 111; Money 1990: 41-42), thus, making an inductive inference. The qualitative-subjective term, 'plump', used in this induction, has been quantified by these authors, by way of five proportions, which are considered to be indicative.

1. The proportion between the height and the width of the coffin: if the coffin is higher than it is wide, then the coffin is plump; if it is wider than it is high, the coffin is slender (Asgari and Firatli 1978: 47 & 49). The definition of slender and plump, as given by these authors, does seem quite unusual. One is more inclined to formulate the definition in the opposite way; it seems that when the coffin is more wide than high, it should then be considered plump. This, as a matter of fact, makes the subjective character of qualitative statements very apparent, at once.

2. The proportion between the width and half the length of the coffin: if the width of the coffin is smaller than half its length, the coffin is slender; if the width is greater than half the length, then the coffin is plump (Asgari and Firatli 1978: 47 & 49).

3. The size of the corner acroteria on the lids: the bigger the acroteria are, the more plump the lid appears to be (Asgari and Firatli 1978: 47 & 49; Asgari 1990: 111).

4. The steepness of the lid: the later the dating of the lid, the steeper it will be (Machatschek 1967: 47; Money 1990: 41-42; Asgari and Firatli 1978: 47 & 49); the steepness is expressed as the proportion, between the height of the lid and half of its length (Money 1990: 41-42).

5. The socles of the coffins and the mouldings of the lids: these become more flat, i.e. their projection/recession decreases, as the sarcophagi are dated later in time (Machatschek 1967: 48).

All criteria apply to marble, as well as sarcophagi, made out of other materials.

The test

The inductive statements, on the chronological significance of sarcophagus proportions, were tested on the travertine sarcophagi, from the north-western necropolis of Hierapolis (Phrygia, Turkey) (Figure 1).

Three necropoles surround the city, the most extensive of which, is the north-western, consisting of tumuli, dated from the second century BC, to the first century AD, sepulchral buildings, and marble and travertine sarcophagi, dated from the first to the fourth century AD (Schneider Equini 1972: 128; Ronchetta 1987).

In order to deal with the large number of sarcophagi in a fast and accurate way, an appeal was made to principal component analysis (using the SAS-program).
The aim of PCA-analysis is to summarize the information, of a given set of variables, into a new, smaller set of variables, containing the same information. These new sets (components) replace the original set of variables, which may be internally correlated, by less and uncorrelated variables (Doran and Hodson 1975: 191). The variables, in our case, are the lengths, heights and widths of sarcophagi.

If proportions, *i.e.*, relationships between certain variables, are, indeed, diagnostic for a certain period of time, and thus, applicable as dating criteria, we would expect clear-cut clusters, of more or less contemporaneous sarcophagi, with similar proportions to appear on the PCA-graphs.

Several selections were carried out, in order to have a homogeneous and representative data set.

First, only travertine sarcophagi were included in the study, since these form the majority (1,474 or 89.9%) of the sarcophagi at Hierapolis. Second, only the completely preserved lids (390) and coffins (407) were included in the database, for the PCA-analysis. And third, in order to avoid illegibility on the resulting graphs, because of the large number of points to be represented (390 + 407), and to be able to determine whether the occurring variation was indeed, chronologically induced, only dated sarcophagi were selected for representation on the graphs.

Three dating methods were used: the stylistic, the epigraphical and the relative methods.

Through comparison of occurring decoration, with dated parallels, 35 lids and coffins could be dated, generally, within a range of 50 years. In order to reduce the risk of circular reasoning, involved, since the parallels, which are used, are often dated on the basis of the decorations themselves, as many parallels, as possible, were sought after, for the decorated sarcophagi at Hierapolis, all located within the same geographical unit (Phrygia).

All inscriptions, at Hierapolis, are in Greek. We did not use their morphological aspect for dating, but the presence, in some, of these inscriptions of Latin *gentilicia*-names, are derived from the imperial *gentilicium*-name. People who were granted Roman civil rights, generally adopted the *gentilicium* of the emperor, under whose rule they obtained Roman citizenship. Subsequently, this name was used by all their offspring. Whenever one of these *gentilicia*-names occurs, a terminus post quem is provided for the inscription. For example, the Aurelius *gentilicium* refers to emperor Caracalla, and must be later than 212 AD, when he granted Roman citizenship to all free inhabitants of the Roman Empire. However, a *gentilicium*-name dates the inscription, and not necessarily the sarcophagus, on which is inscribed. The relationship between the inscription and its bearer, the sarcophagus, must be considered. For this study, we assumed that if only one inscription occurs, it was applied, when the sarcophagus was cut, thus, dating the sarcophagus. When two inscriptions occur, and it is possible to determine which one was cut first (for instance, because the shapes of the letters indicate two different periods in time), the earliest inscription is considered to be the original, and, thus, dates the sarcophagus. For 228 lids and coffins, a *terminus post quem*, on the basis of a *gentilicium*, could be proposed. Ten of these were previously stylistically dated, and, except in one case, both dates matched.

The relative dating method is based on the position of undated sarcophagi, versus dated sepulchral buildings, or sarcophagi. For instance, when a sarcophagus is placed on top, or inside, a sepulchral monument, then it must be contemporary to, or later than, this monument. When a sarcophagus, whose decorated or inscribed side is hidden by a monument or another sarcophagus placed against or close to it, it is, most likely, older than that monument, or sarcophagus. The application of this dating method yielded a terminus post quem for 23 lids and coffins. Three of these had been dated, on the basis of their decoration, and all dates were consistent with each other.

In total, 273 lids and coffins were dated, of which, 219 were preserved completely enough, to be used for the PCA-analysis, and be presented on the graphs.

Two principal component analyses were carried out, one using 'rough' measurements, and one using measurements, normalized towards the length, meaning that all absolute heights and widths were divided, by their corresponding length. For instance, the total width of the lid was divided by its total length; the width taken at the recessed moulding was divided by the length, taken at the moulding. We decided to do this because, first of all, the correlation analysis clearly indicated that length, width and height are highly, positively correlated for lids and coffins (with $r > +0.6$ or < -0.6), meaning that, when one of the three variables mentioned, increases or decreases, the other two increase or decrease, as well. Second, the correlation of height with length, and of width with length appeared to be stronger, than the correlation of height with width. Apparently, the correlation between height and width is to be explained, mainly, by the fact that both correlate highly with a third factor, the length, thus, hiding the actual relationship, between height and width.

On the graphs, a drawing is added, in order to visualize how lids and coffins look at the four meaningful corners.

When plotting the dated coffins on orthogonal graphs (Figure 2 and 3), representing their position, according to the components PRIN 1 and PRIN 2, no chronologically determined groups appear, using rough, as well as normalized, measurements (the figures presented here only show the normalized measurements). The group of coffins, dated from 125-175 AD, on the basis of their decoration, is spread throughout the graph, as well as the group, dated later than 212 AD, which is a *terminus post quem*, furnished by the *gentilicium* Aurelius.

It looks as though, when the number of coffins dated from the same period increases, the internal variation of the proportions increases, as well. When plotting PRIN 2 versus PRIN 3, for both data sets, all coffins are situated close to one another on the graph, indicating a small global variation.

When plotting the lids on PRIN 1 versus PRIN 2, and PRIN 2 versus PRIN 3 (Figure 4 and 5), using rough and normalized measurements, the same trend, as seen for the coffins, appears: the more sarcophagi dated to the same period, the larger the internal variation becomes.

Discussion

The results of these PCA-analyses point out, that coffin and lid proportions are of no chronological significance.

However, this does not mean that, *a priori*, proportions do not change consistently through time. Only a small number of sarcophagi was used. Moreover, the fact that the analyses did not give positive results, may be due to the fact that the dates of the lids and coffins used, were not correct. This could be true for the sarcophagi dated by the stylistic method, where, as mentioned before, the risks of reasoning, in a vicious circle, are a reality. However, two factors allow us to say, with some certainty, that incorrect dates were not involved. First, only parallels, from within the same geographical frame, were used. Second, the dates provided, by the stylistic dating method, were successfully matched with the dates, provided by the epigraphical and relative methods. Even if some of the sarcophagi were incorrectly dated, the results of the PCA-analyses would remain unchanged, since the sarcophagi, reliably dated on the basis of an inscription, mentioning the Aurelius *gentilicium*, to later than 212 AD, are spread throughout the PCA-graphs, meaning that, within the same chronological group (later than 212 AD), all kinds of proportions occur. One has the impression that when the number of sarcophagi involved increases, the internal variation does, also.

Both facts, the probably correct dates and the occurrence of an increasing variation, within an increasing number of sarcophagi, point out that the negative result, of the PCA-analyses, is reliable.

Conclusion

We conclude that, on the basis of the specific data used in this analysis, one cannot justify that chronologically significant proportions occur, and, especially not, that sarcophagi become 'plumper' through time. It, rather, appears that proportions were determined by the dimensions of the blocks, that could be obtained in the local quarries.

Other (statistical) methods, applied to sarcophagi found elsewhere, may, however, lead to positive results, of a more local applicability. Proved through this case-study, we state that the inductive hypothesis of universally significant, chronological sarcophagi proportions, is false. Moreover, this study has shown the weakness of inductive inferences: inferring general statements, from singular ones, may always turn out to be false. As Popper (1977: 27) stated:

> *"No matter how many instances of white swans we may have observed, this does not justify the conclusion, that all swans are white."*

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Table 1. Principal Component Analysis for Coffins (absolute parameters)

Table 1a. Correlation matrix

	1	2	3	4	5	6
1	1.000	0.9488	0.6966	0.7374	0.5917	0.5707
2	0.9488	1.000	0.6804	0.7552	0.5810	0.5662
3	0.6966	0.6804	1.000	0.9067	0.6224	0.5918
4	0.7274	0.7552	0.9067	1.000	0.6703	0.6399
5	0.5917	0.5810	0.6224	0.6703	1.000	0.8002
6	0.5707	0.5562	0.5918	0.6399	0.8002	1.000

with 1 = length above socle; 2 = total length (at socle); 3 = width above socle; 4 = total width (at socle); 5 = height above socle and 6 = total height

	Eigenvalue	Proportion	Cumulative Value
PRIN 1	4.4617	0.7436	0.7436
PRIN 2	0.7270	0.1211	0.8648
PRIN 3	0.4745	0.0790	0.9439

Table 1c. Eigenvectors for the parameters

	PRIN 1	PRIN 2	PRIN 3
1	0.4182	- 0.4037	0.3945
2	0.4172	- 0.4162	0.3930
3	0.4137	- 0.1115	- 0.6343
4	0.4332	- 0.1010	- 0.4697
5	0.3870	0.5458	0.1439
6	0.3774	0.5859	0.2152

Table 2 . Principal Component Analysis for Lids (absolute parameters)

Table 2a. Correlation matrix

	1	2	3	4	5	6	7	8	9
1	1.000	0.9555	0.6423	0.6009	0.2445	0.4144	0.1805	0.1439	0.1815
2	0.9555	1.000	0.5777	0.5655	0.2225	0.3624	0.1889	0.1584	0.1825
3	0.6423	0.5777	1.000	0.9700	0.3656	0.4910	0.3034	0.2246	0.2320
4	0.6009	0.5655	0.9700	1.000	0.3626	0.4662	0.3114	0.2230	0.2262
5	0.2445	0.2225	0.3656	0.3626	1.000	0.8341	0.3938	0.5778	0.2905
6	0.4144	0.3624	0.4910	0.4662	0.8341	1.000	0.3174	0.4680	0.2686
7	0.1805	0.1889	0.3034	0.3114	0.3938	0.3174	1.000	0.7421	0.5864
8	0.1439	0.1584	0.2246	0.2330	0.5778	0.4680	0.7421	1.000	0.7265
9	0.1815	0.1825	0.2320	0.2262	0.2905	0.2686	0.5864	0.7265	1.000

with 1 = total length; 2 = length at recessed edge; 3 = total width;
4 = width at recessed edge; 5 = height of pediment; 6 = total height;
7 = width acroteria; 8 = total height acroteria; 9 = actual height acroteria

Table 2b. Eigenvalue, proportion, cumulative value

	Eigenvalue	Proportion	Cumulative Value
PRIN 1	4.3728	0.4859	0.4859
PRIN 2	2.0270	0.2252	0.7111
PRIN 3	1.0743	0.1194	0.8305

Table 2c. Eigenvectors for the parameters

	PRIN 1	PRIN 2	PRIN 3
1	0.3444	- 0.3825	0.1824
2	0.3313	- 0.3681	0.2257
3	0.3830	- 0.2752	0.0117
4	0.3773	- 0.2640	0.0175
5	0.3266	0.2242	- 0.5732
6	0.3575	0.0803	- 0.5510
7	0.2913	0.3774	0.3001
8	0.3078	0.4671	0.1224
9	0.2616	0.3834	0.4221

Table 3. Principal Component Analysis for Coffins (relative parameters)

Table 3a. Correlation matrix

	1	2	3
1	1.000	0.3974	0.3583
2	0.3974	1.000	0.7116
3	0.3583	0.7116	1.000

with 1 = width above socle; 2 = height above socle and 3 = total height

Table 3b. Eigenvalue, proportion and cumulative value

	Eigenvalue	Proportion	Cumulative Value
PRIN 1	1.9979	0.6660	0.6660
PRIN 2	0.7152	0.2384	0.9044
PRIN 3	0.2869	0.0956	1.000

Table 3c. Eigenvectors for the parameters

	PRIN 1	PRIN 2	PRIN 3
1	0.4722	0.8798	0.0534
2	0.6287	- 0.2933	- 0.7202
3	0.6179	- 0.3739	0.6917

Table 4. Principal Component Analysis for Lids (relative parameters)

Table 4a. Correlation matrix

	1	2	3	4	5	6
1	1.000	0.3694	0.4307	0.3614	0.2856	0.2795
2	0.3694	1.000	0.8531	0.4546	0.6255	0.3399
3	0.4307	0.8531	1.000	0.3820	0.5349	0.3173
4	0.3614	0.4546	0.3820	1.000	0.7711	0.6123
5	0.2856	0.62554	0.5349	0.7711	1.000	0.7433
6	0.2795	0.3399	0.3173	0.6123	0.7433	1.000

with 1 = total width; 2 = height pediment; 3 = total height; 4 = width acroteria; 5 = total height acroteria; 6 = actual height acroteria

Table 4b. Eigenvalue, proportion and cumulative value

	PRIN 1	PRIN 2	PRIN 3
1	0.2933	0.3035	0.8884
2	0.4320	0.4251	- 0.3315
3	0.4128	0.5128	- 0.2273
4	0.4247	- 0.3601	0.1005
5	0.4752	- 0.2872	- 0.1884
6	0.3883	- 0.5021	0.0600

Table 4c. Eigenvectors for the parameters

	Eigenvalue	Proportion	Cumulative Value
PRIN 1	3.5061	0.5844	0.5844
PRIN 2	1.0836	0.1806	0.7649
PRIN 3	0.7512	0.1252	0.8901

All Figures in CD-ROM.