

OLD KINGDOM COPPER TOOLS AND MODEL TOOLS

Martin Odler

with contributions by

Jiří Kmošek, Ján Dupej, Katarína Arias Kytnarová, Lucie Jirásková, Veronika Dulíková,
Tereza Jamborová, Šárka Msallamová, Kateřina Šálková and Martina Kmoníčková



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To my parents
and grandparents

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is 91 HV0.1. Microhardness of the intensively worked razor ÄMUL 5513 with the average content of 3.6% As has a surprisingly high value of 157 HV0.1. The standard deviation of the measured microhardness values is caused by the inhomogeneous structures of the artefacts, from the point of view of inclusion distribution and non-uniform thermo-mechanical processing. The results clearly indicate that microhardness depends more on the thermomechanical processing of the artefacts than on the content of arsenic, in accordance with the results of other studies.⁸²⁶ The production technology of the selected artefacts was probably divided into several individual steps consisting of alloy preparation, casting, forging and recrystallization annealing operations. Various combinations of these operations could have resulted in very different mechanical properties of the final products, depending on the different functions of the artefacts. We have not enough data to compare the thermomechanical processing technologies of working tools and their models, because all microstructural analyses involved working tools.

Conclusion

The results of the analysed collection of artefacts from ÄMUL provided insight into the fields of corrosion deterioration, material composition, microstructure features and mechanical properties of Egyptian working tools and their models dated to Dynasty 5 and 6. Out of the set of more than thirty artefacts from the Giza necropolis, only eight artefacts could be sampled for the purposes of the analysis, due to the considerable degree of corrosion deterioration. The metallic cores of the other artefacts were completely transformed into corrosion products. The corrosion products of the analysed artefacts consist on the one hand of a mixture of copper oxide minerals (cuprite and tenorite) with higher amount of arsenic, and on the other hand of a mixture of copper chloride minerals (atacamite, clinoatacamite and paratacamite). The corrosion products contain a certain portion of sand particles, represented by quartz, gypsum and rutile. The chemical composition of the alloys in the analysed set indicates a fairly consistent composition, corresponding to arsenic copper alloys containing arsenic up to 3.6%, iron up to 0.5% and admixtures of tin, silver, nickel and lead. There is only one exception – the razor ÄMUL 2131, which contains higher portion of arsenic, tin and silver and surprisingly does not contain lead. The chemical composition of the working tools and their models seems to be unstable in the proportion of arsenic and there is no visible correlation between the chemical composition and the function of the artefacts. Two out of the three examined microstructures were annealed and contain slip lines on the surface. The third microstructure was fully worked and contains a large amount of slip lines. An As-rich γ phase in the intergranular regions

was documented in one case, related to the presence of inverse segregation during solidification after casting. Two types of inclusions were identified in the structure of metallic cross sections. The first type is represented by mixed oxides of copper and iron, and the second type by copper-iron sulphide inclusions with a portion of selenium, tellurium and lead in some cases. The results of Vickers microhardness tests of three artefacts are comparable with the results obtained earlier by other authors and confirm that the hardness of the artefacts was intentionally achieved by mechanical hardening rather than by the alloying effect of alloys with a higher portion of arsenic. The techniques of casting, alloying, hot or cold working, annealing, final cold working and surface finishing were used in the production of the artefacts. From the obtained results it is not possible to distinguish which technology was used for the production of the arsenic copper alloys, but at least the artefacts ÄMUL 2129, 2131 and 5513 were made from rich sulphide ores, which is indicated by the presence of selenium and tellurium.

11.2. Morphometrical and statistical case study of Old Kingdom adze blades

Martin Odler⁸²⁷ and Ján Dupej⁸²⁸

Introduction

The tools of geometric morphometry have been used in anthropology and biology for decades now. On the other hand, their application in other fields, such as archaeology, has been somewhat slower. Geometric morphometry is the quantitative study of shape with the application of multivariate statistical and geometric approaches in the evaluation of the data. The historically earlier traditional morphometry used distances, lengths and angles to describe a particular specimen in the set. In contrast, geometric morphometry (GM) describes shapes using landmarks. The term originates in geography and refers to a well recognizable feature used for navigation. In GM, this term is used for an anatomically significant locus, present and repeatable in all the studied specimens.⁸²⁹ Each specimen in the set must be described by an equal number of landmarks, placed in these anatomically equivalent loci. This property, referred to as homology, is crucial for a successful application of statistics on the data.

The configurations of landmarks describing a specimen are generally in random locations and orientations

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⁸²⁹ Bookstein (1997b).

⁸²⁶ Pereira *et al.* (2013); Lechtman (1996); Junk (2003).

Context	Site	Part of site	Structure	Owner	Social status
AR6	Abu Rawash	Cemetery F, Old Kingdom necropolis	Mastaba F 19	unknown	unknown
AR7	Abu Rawash	Cemetery H	Rock tomb H1	unknown	unknown
AR9	Abu Rawash	Cemetery F, Old Kingdom necropolis	Mastaba F 21	<i>H-k3=f</i>	legal department
AR10	Abu Rawash	Cemetery F, Old Kingdom necropolis	Mastaba F 21	<i>H-k3=f</i>	unknown
A2	Abusir	AC 22: Pyramid complex Lepsius 24	Burial chamber of pyramid Lepsius 24	most probably queen	royal family – queen ?
A15	Abusir	Cemetery of pyramid of Nyuserra	AC 10: Princesses Khaemmerernebty and Meretites, and Kahotep	<i>K3(-j)-htp</i>	high-ranking dignitary
A17	Abusir	Royal cemetery	AC 25: Tomb Q	<i>Nh.t-s3-Rc.w</i>	royal family – king's son
A21	Abusir	Royal cemetery	AC 24: Lepsius no. 25/2	unknown	royal family – king's daughter or sister of Hanub
A28	Abusir	Djedkara's family cemetery	Tomb AC 15	<i>Hkr.t-Nb.ty</i>	woman from the royal court
A31	Abusir	Abusir South	AS 68d, Tomb of Nefer	<i>Nfr-Hwt-Hr.w</i>	priestess, wife of a high-ranking dignitary
A32	Abusir	Abusir South	Tomb AS 67	<i>Nfr-šps</i>	high ranking dignitary, department of organization of labour
A37	Abusir	Abusir South	AS 27: Tomb Lake of Abusir 5, Shaft 2	unknown	unknown
A40	Abusir	Abusir South	AS 17: Tomb of Qar Jr.	<i>K3r</i>	legal department
A41	Abusir	Abusir South	AS 17: Tomb of Qar Jr.	<i>K3r</i>	legal department
A45	Abusir	Abusir South	AS 22: Tomb of Inti	<i>Jn.tj</i>	legal department
A46	Abusir	Abusir South	AS 22: Tomb of Inti	<i>Jn.tj</i>	legal department
A48	Abusir	Abusir South	AS 22: Tomb of Inti	<i>Jn.tj nh-Pp.y</i>	department of royal documents
A49	Abusir	Abusir South	AS 22: Tomb of Inti	<i>Jn.tj nh-Pp.y</i>	department of royal documents
Ay1	Abydos	Middle cemetery	Tomb 918	unknown	unknown
Ay11	Abydos	unknown	unknown	unknown	unknown
Ay14	Abydos	Middle cemetery, Garstang tombs	Tomb 747, A.09	unknown	unknown
Ay18	Abydos	Temple of Osiris	Building west of structure H	settlement	–
An1	Aniba	Cemetery N	Grave N 958 b	unknown	unknown
B15	Balat	Cemetery of the governors in Dynasty 6	Mastaba III	<i>Dšr.w II</i>	governor of the oasis
B25	Balat	Cemetery of the governors in Dynasty 6	Mastaba II	<i>Jm3-Pp.y</i>	governor of the oasis
B28	Balat	Palace of governors in Dynasty 6, ka sanctuaries	Ka sanctuaries, first alignment of service structures, zone west, Room 11	settlement	–
Ba4	Bubastis	Tombs of season 1970, west of the El-Mu'ahada road and to the east of the Cat Cemetery	Tomb 161	<i>Mr(y)-Mr-n-Rc.w</i>	rank title, no further data
Dd5	Dendera	Old Kingdom necropolis	Tomb 304	<i>Mrw (?)</i>	unknown
Ed2	Edfu	Old Kingdom necropolis	Mastaba IX	unknown	nomarch ?

FIGURE 235: OLD KINGDOM CONTEXTS WITH COMPLETE ADZE BLADES. THE CATEGORY OF SOCIAL STATUS WAS DETERMINED BY VERONIKA DULÍKOVÁ (1).

OLD KINGDOM COPPER TOOLS AND MODEL TOOLS

EK1	el-Kab	Silo concentration at the north-west corner of Nekhbet temple enclosure	silo L	settlement	—
EK2	el-Kab	Old Kingdom necropolis	Tomb of Kaimen	<i>Kȝ(-j)-mn.j</i>	<i>hem-netjer</i> priest; only partly survived titulary
G5	Giza	West field, Cemetery G 1200	G 1201	<i>Wp(j)-m-nfr.t</i>	royal family – king's son
G10	Giza	West field, Cemetery G 4000	G 4610 A	unknown	unknown
G20	Giza	Eastern cemetery of Khufu	G 7530-7540	<i>Mr(y)-sj-ȝnh</i>	royal family – queen
G25	Giza	Pyramid complex of Menkaura	Valley temple of Menkaura, Magazine III-6	<i>Mn-kȝ.w-Rȝ.w</i>	king
G33	Giza	Central field	G 8260	<i>Bȝ-bȝ=f-Hnmw-bȝ=f</i>	royal family – king's son
G34	Giza	East field	G 7560	unknown	unknown
G35	Giza	West field, Cemetery G 4000	G 4140	<i>Mr(y).t-jt(j)=s</i>	royal family – king's daughter
G37	Giza	South field	Mastaba V (Junker) / G IV S (Reisner) / Lepsius 52	<i>N(y)-ȝnh-Rȝ.w</i>	unknown
G39	Giza	Central field	G 8250	unknown	royal family – king's daughter ?
G41	Giza	Central field	G 8980	<i>Htp-Wtȝ</i>	rank title, no further data
G44	Giza	West field	G 5232, Shaft A	unknown	unknown
G46	Giza	West field, Cemetery G 4000	G 4631	<i>Nn-sdr-kȝ(-j)</i>	priestess, wife of high-ranking dignitary
G50	Giza	West field	G 4920	<i>Tn.tj</i>	high-ranking dignitary
G53	Giza	Central field	Mastaba of Shaft 559	unknown	unknown
G55	Giza	West field, Cemetery G 6000	G 6051	unknown	unknown
G57	Giza	East field	G 7112, Shaft A	unknown	unknown
G59	Giza	West field, Cemetery G 6000	G 6010	<i>Nfr-bȝ.w-Pth</i>	priest, steward of the great estate
G61	Giza	West field	D 20, Shaft 1	<i>Tp-m-ȝnh</i>	titles connected to <i>pr-ȝȝ</i> , <i>jry ht nswt pr-ȝȝ</i>
G63	Giza	Central field	G 8656, Shaft 585	<i>S:ȝm</i>	privacy of King
G66	Giza	West field	D 37, Shaft 1	<i>Rȝ.w-hr-kȝ(-j)</i>	legal department
G68	Giza	West field, Cemetery G 4000	G 4520	<i>Hw(j)=f-wȝ-ȝnh</i>	sphere of entertainment
G69	Giza	Central field	G 8402, Mastaba of Shaft 648	unknown	unknown
G71	Giza	Central field	G 8853	<i>Kȝ(-j)-ȝpr</i>	legal department, chief of one of six administrative pillars
G86	Giza	West field	G 4733, Shaft E	unknown	unknown
G92	Giza	Central field	G 8640	<i>ȝnh-hȝ=f - Kȝr</i>	department of treasury
G97	Giza	West field, Cemetery 2300	G 2381, Shaft A	<i>Mr(j)-Pth-ȝnh Mr(j)-Rȝ.w Špss-Pth Jmp.y</i>	vizier
G98	Giza	West field, Cemetery 2300	G 2381, Shaft Z	unknown	unknown
G107	Giza	West field	Shaft 316 at G 5070	unknown	unknown
G109	Giza	West field	Mastaba of Setka and Ptahhetep, Shaft 890A	<i>ȝt-j-kȝ=j, Htp-Pth</i>	legal department

FIGURE 235: OLD KINGDOM CONTEXTS WITH COMPLETE ADZE BLADES. THE CATEGORY OF SOCIAL STATUS WAS DETERMINED BY VERONIKA DULÍKOVÁ (2).

G112	Giza	West field	Shaft 315 at G 5070	unknown	unknown
G119	Giza	Central field	G 8172	<i>'nh-m-R'.w</i>	royal family – king's son, vizier
G123	Giza	unknown	Context III	unknown	unknown
G124	Giza	unknown	Context IV	unknown	unknown
M2	Meidum	Old Kingdom necropolis, north part	Mastaba 6	<i>Htp-R'.w</i>	royal family – king's son
Mr1	Meir	Southern Cemetery D	Tomb of Pepyankh, the Middle	<i>Hw.t-j-h</i>	priestess, wife of the vizier
QH4	Qubbet el-Hawa	Rock tomb necropolis	Tomb QH 35e, Burial chamber β SK II	<i>Szb-n=j</i>	high-ranking provincial dignitary
S2	Saqqara	Pyramid complex of Wenis	Tomb of Ptahshepses	<i>Šps-Pth</i>	royal family – king's son
S4	Saqqara	Teti cemetery	Grave 240 in Mastaba of Kaemsenu	unknown	unknown
S7	Saqqara	Teti cemetery	Tomb of Ankhmahor	<i>'nh(=j) (?)-m-(.w)-Hr.w</i>	vizier
S8	Saqqara	Teti cemetery	Tomb of Mereruka	<i>Mrr.w-k3</i>	unknown
S10	Saqqara	Teti cemetery	Pyramid of Iput	<i>Jp.wt</i>	royal family – queen
S14	Saqqara	Teti cemetery	Tomb of Khentika	<i>Hnt.j-k3</i>	vizier
S20	Saqqara	West of Netjerykhet pyramid complex, Polish concession	Tomb of Nypepy (Tomb XV), chamber of Shaft 32	<i>N(.y)-Pp.y</i>	privacy of King
S22	Saqqara	West of Netjerykhet pyramid complex, Polish concession	Tomb XLI	unknown	unknown
S23	Saqqara	Teti cemetery	Tomb of Semdenti	<i>Smdn.tj</i>	department of provisioning, storage and redistribution
S24	Saqqara	Pepy II cemetery	Mastaba near pyramid of Pepy II	<i>Wzš-Pth</i>	privacy of King
S27	Saqqara	Pyramid complex of Netjerykhet	Complex of Netjerykhet	<i>Ntr.y-ht</i>	king
S28	Saqqara	Pyramid complex of Netjerykhet	Complex of Netjerykhet	<i>Ntr.y-ht</i>	king
X1	unknown	unknown	unknown	<i>Snfr.w</i>	king
X5	unknown	unknown	unknown	<i>Wsr-k3=f</i>	king
X6	unknown	unknown	unknown	<i>Wsr-k3=f</i>	king

FIGURE 235: OLD KINGDOM CONTEXTS WITH COMPLETE ADZE BLADES. THE CATEGORY OF SOCIAL STATUS WAS DETERMINED BY VERONIKA DULÍKOVÁ (3).

with respect to one another. Therefore, the information contained in these landmark coordinates includes not only the shape and size of a particular object but also the location and orientation of the object at the time it was digitized (with respect to a coordinate system). This introduces considerable unwanted variability into the data and, therefore, individual translation and rotation, which must be in some cases removed by performing a rigid alignment. Generalized Procrustes analysis (GPA)⁸³⁰ is ideal for this task, as it calculates rigid transformations (rotation, translation and scaling) for each specimen that would ideally align the landmark configurations (in least-squares sense). The landmark configurations transformed with these fitted rigid transformations are ideally aligned and suitable for further processing.

⁸³⁰ Gower (1975).

Unfortunately, many biological objects offer very few landmarks, which makes them difficult to analyse with landmark-based methods. This is both due to uneven coverage of the particular specimen and placement error of landmarks on non-salient features. We face a similar problem with archaeological material, such as the outlines of ancient Egyptian adzes. The shape consists of a smooth butt and a blade, usually with blunt edges. There are no obvious landmarks. These situations are usually addressed using algorithms that place landmarks automatically, according to specific rules, which are then considered homologous and used as if they were identified manually. Such landmarks are dubbed semilandmarks.

We have applied GM to represent the shape of 199 complete Old Kingdom adze blade outlines (Figure 235).

Furthermore, we have used multivariate statistics to compare the form⁸³¹ and shape⁸³² of the adzes within these representations across the periods and sites. Before we approach the description and interpretation of the results, it needs to be noted that a thorough reassessment of the category of models and full-size tools will be possible only if more analyses of the chemical composition of the material itself are published. From typology alone, we cannot infer sufficient information about the division between models and full-size tools. It can be inferred that very small objects are models and rather big artefacts are full-size tools or their models (different possibly only in alloy). But artefacts of a middle-size between these outliers can have traits of both models and full-size tools.

Related work

The adze outlines were digitized as closed curves. Several approaches handling automatic landmark placement on such curves have been proposed. A simpler class of algorithms places semilandmarks according to a common rule. Several of these rules have been tested and the resulting representations analysed in terms of their discriminative power for sex estimation.⁸³³ Two automatic semilandmark placement rules and four other methods of deriving shape variables have been tested.

If the curves are more irregular, more sophisticated methods such as sliding semilandmarks need to be used.⁸³⁴ The curves are represented as semilandmarks that are initially automatically placed on the curves, for instance using equal curvilinear increments. This procedure is iterative, repeating two stages until a satisfactory alignment has been achieved.⁸³⁵ The first stage aligns the curve representations using GPA and calculates the mean curve by averaging the corresponding semilandmarks. The second stage refines the representation of each curve by sliding the semilandmarks along the curve in such a way that would minimize the alignment error. The implementations of the sliding semilandmark method vary in this aspect. Some use the Procrustes distance as the error metric,⁸³⁶ while others used TPS bending energy.⁸³⁷ A lengthy discussion of these approaches is beyond the scope of this paper; a good comparison has been presented by Perez, Bernal and Gonzalez.⁸³⁸

Material and methods

We have used 199 outlines of ancient Egyptian adzes. These outlines were digitized in Morphome3cs (www.morphome3cs.com

⁸³¹ Form is defined as a shape assessed together with size.

⁸³² Shape is defined as a shape assessed with the mean size of the specimens.

⁸³³ Velemínská, Krajíček, Dupej *et al.* (2013).

⁸³⁴ Bookstein (1997b).

⁸³⁵ Perez, Bernal and Gonzalez (2006).

⁸³⁶ Andersen, Bookstein, Conradsen *et al.* (2000).

⁸³⁷ E.g. Bookstein (1997a).

⁸³⁸ Perez, Bernal and Gonzalez (2006).

morphome3cs.com) using closed cubic Hermitian splines.⁸³⁹ Furthermore, two landmarks were placed on each outline, one on the butt and one on the blade midpoint. The landmarks served only to pre-align the shapes and accelerate the convergence of sliding semilandmarks. No shape information was inferred from these landmarks. Sliding semilandmarks represented each curve with 30 landmarks homologous across the sample, which we will refer to as the *form*. We have also created a representation called the *shape*, which is the form rescaled to a unified size. To calculate the size of an object, we used the widely accepted metric, centroid size (CS), where p_i is the landmark coordinate of a specimen and t is the centroid of these landmarks (Figure 236).⁸⁴⁰ The following analyses were performed twice, once for the shape and once for the form.

The dimension of each specimen is still high. Some statistical methods, such as the Hotelling's T^2 test, require that the dimension of the data not exceed the specimen count of the smaller group. A dimension reduction is therefore usually performed after GPA or sliding semilandmarks. The most commonly applied method is the principal component analysis (PCA),⁸⁴¹ which finds mutually independent directions in the dataset with the greatest variability. Using those directions, the data set can be transformed into scores. Depending on how structured the data are, they can be represented with a handful of principal component scores while maintaining most of the variability. We visualized the PC scores in the first two principal components in scatter plots.

The question of how many principal components should be kept is a nontrivial one, and many rules have been proposed that address it. A good review is presented by Peres-Neto, Jackson and Somers.⁸⁴² We have used the broken-stick rule to ascertain the amount. According to that rule, both form and shape are sufficiently represented with four principal components.

We have used MANOVA to assess the dependence of the shape and form on the period and site where the adze was found. MANOVA, however, does not specify which groups are responsible for the differences. Therefore, we use nonparametric two-sample Hotelling's T^2 test to check whether specific two group means differ. The statistical significance at the level $\alpha = 0.05$. The statistical

$$CS = \sqrt{\sum_{i=1}^m \|p_i - t\|^2}$$

FIGURE 236: FORMULA OF CENTROID SIZE.

⁸³⁹ The data were entered by Bc. Markéta Kobierská, and we would like to thank for her invaluable help in the project.

⁸⁴⁰ Bookstein (1997b).

⁸⁴¹ Bishop (2006).

⁸⁴² Peres-Neto, Jackson and Somers (2005).

processing has been performed in the open-source statistical software R.⁸⁴³

Finally, we plotted the mean shapes and forms with groups by averaging the corresponding semilandmarks within groups.

Results and discussion

Form

The PC analysis of the form of adze blades (Figure 237) has shown that the size of the adze blades, which is mostly expressed in PC 1, is the decisive component in the corpus covering 97.51% of its variability. The cluster of most adze blades is probably reflecting the existence of a category of model blades with minor differences in size. The cluster of adze blades under the factor loading 100 can be explained by the existence of a category of model blades of a regularized size. Outliers occurred throughout the Old Kingdom, representing full-size blades and their models in Dynasty 6. The PC analysis of adzes according to the sites shows that the largest adzes have been found at Giza, Saqqara and Balat (Figure 238). The range of adze blades from Giza covers everything from the smallest to the largest adze blades.

Figure 239 displays the effects of the first principal component, which is the size of the adze blades in this case. The second most important principal component was the width of the blade with 1.77% of the variability in the corpus, which was confirmed also by the archaeological evidence (Figure 240).

The enlargement of adze blades can be observed on the mean shapes of the periods. The adze blades were getting progressively larger through Dynasties 4–6; the butts were larger and the blades wider in Dynasty 6 (Figure 241). The variant means reflect the difference in size among the variants; Variant D4 is significantly larger and with wider blade than other variants. The mean shapes of Variants D1 and D3 are smaller than the mean shape of the adze blades (Figure 242).

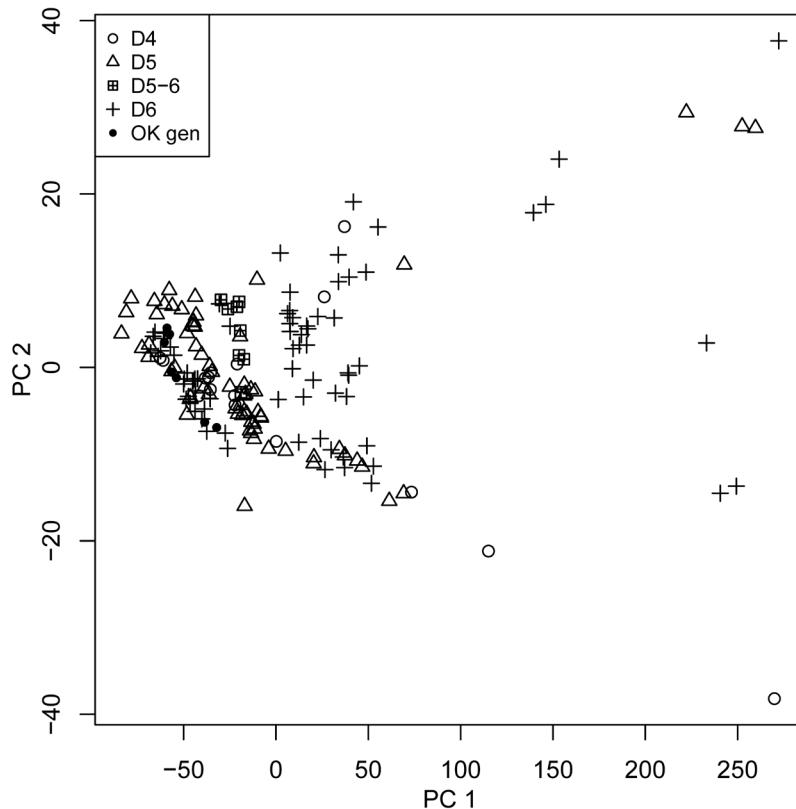


FIGURE 237: FORM OF OLD KINGDOM ADZE BLADES, RESULTS OF THE PCA ANALYSIS FOR PERIODS (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

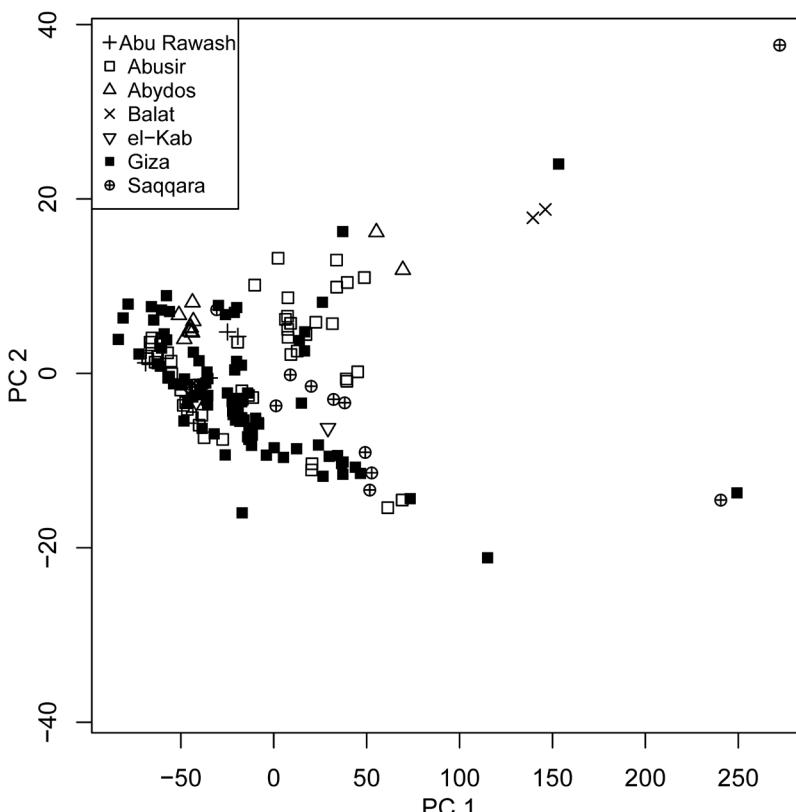


FIGURE 238: FORM OF OLD KINGDOM ADZE BLADES, RESULTS OF THE PCA ANALYSIS FOR SITES (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

⁸⁴³ Team RC (2015).

OLD KINGDOM COPPER TOOLS AND MODEL TOOLS

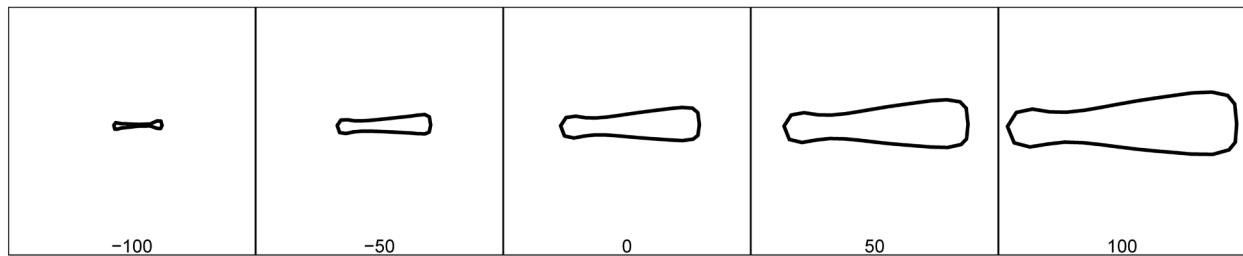


FIGURE 239: FORM OF OLD KINGDOM ADZE BLADES, EFFECT OF THE PRINCIPAL COMPONENT 1 (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

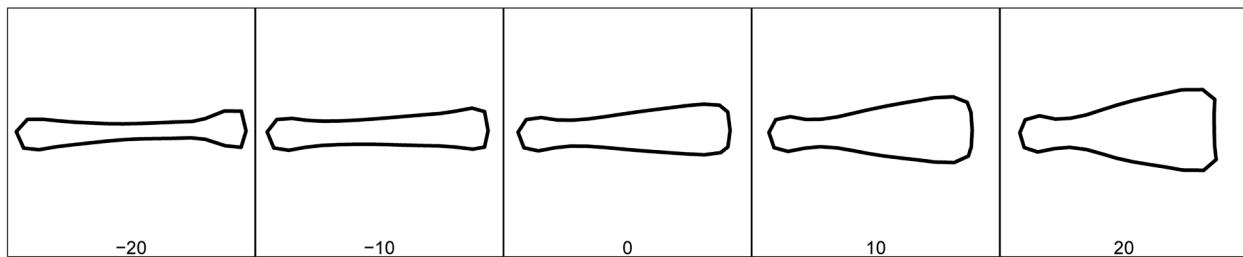


FIGURE 240: FORM OF OLD KINGDOM ADZE BLADES, EFFECT OF THE PRINCIPAL COMPONENT 2 (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

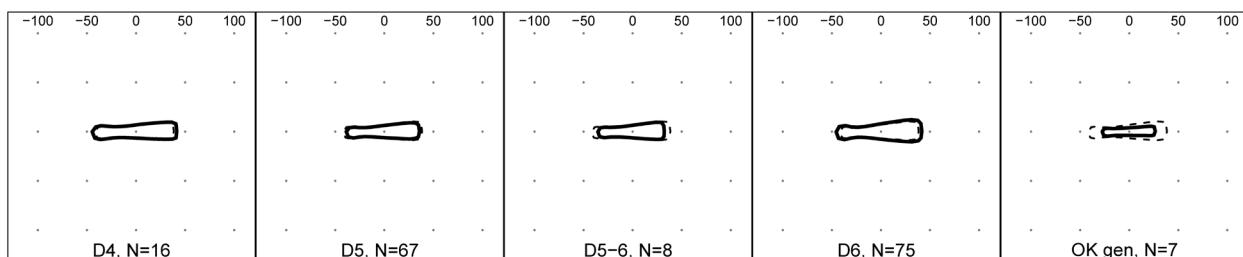


FIGURE 241: FORM OF OLD KINGDOM ADZE BLADES, MEAN FORMS OF THE PERIODS (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

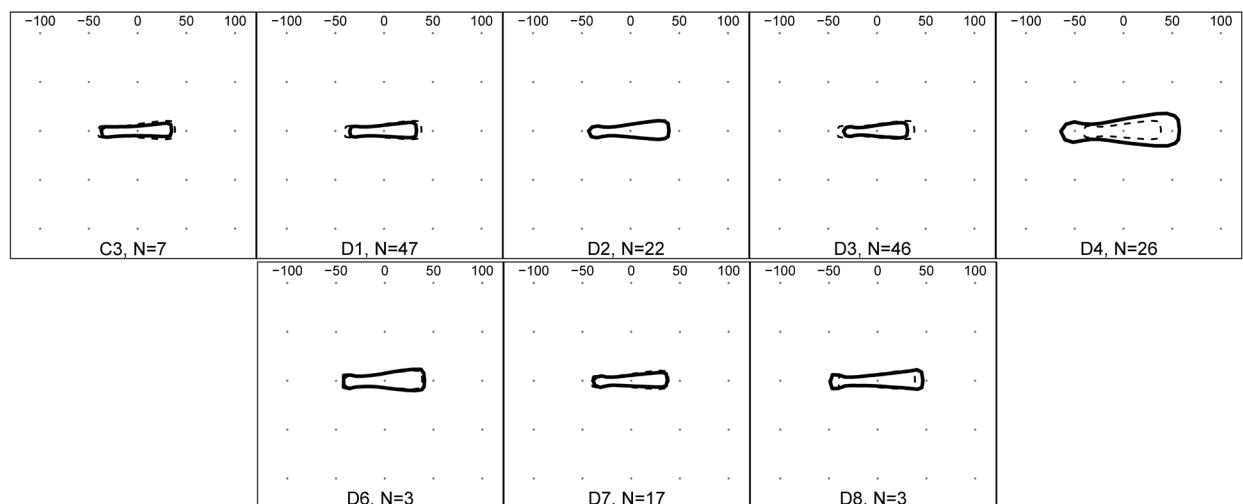


FIGURE 242: FORM OF OLD KINGDOM ADZE BLADES, MEAN FORMS OF VARIANTS (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

The differences among the sites are displayed using the site means (Figures 243). The mean shape of the Old Kingdom adze blades is closest to the sites Giza and Abusir, which comprise the largest corpora of the material. Yet nonparametric two-sample Hotelling's T^2 test has shown that there are significant differences even between Giza and Abusir. The mean shape of Saqqara

adze blades is larger than the general mean shape, which can be explained by high social status of the persons buried at Saqqara and possibly better access to the copper sources. The adzes from Abu Rawash, Abydos and el-Kab were smaller than the mean shape, whereas the adzes from Balat were larger, which once again shows differences in the production of Old Kingdom adze blades.

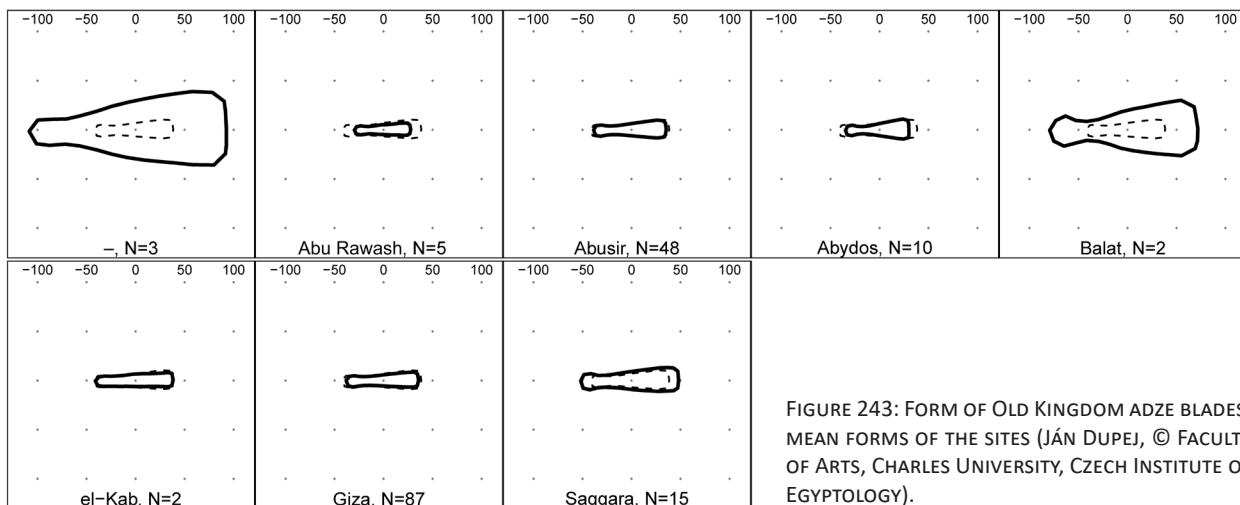


FIGURE 243: FORM OF OLD KINGDOM ADZE BLADES, MEAN FORMS OF THE SITES (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

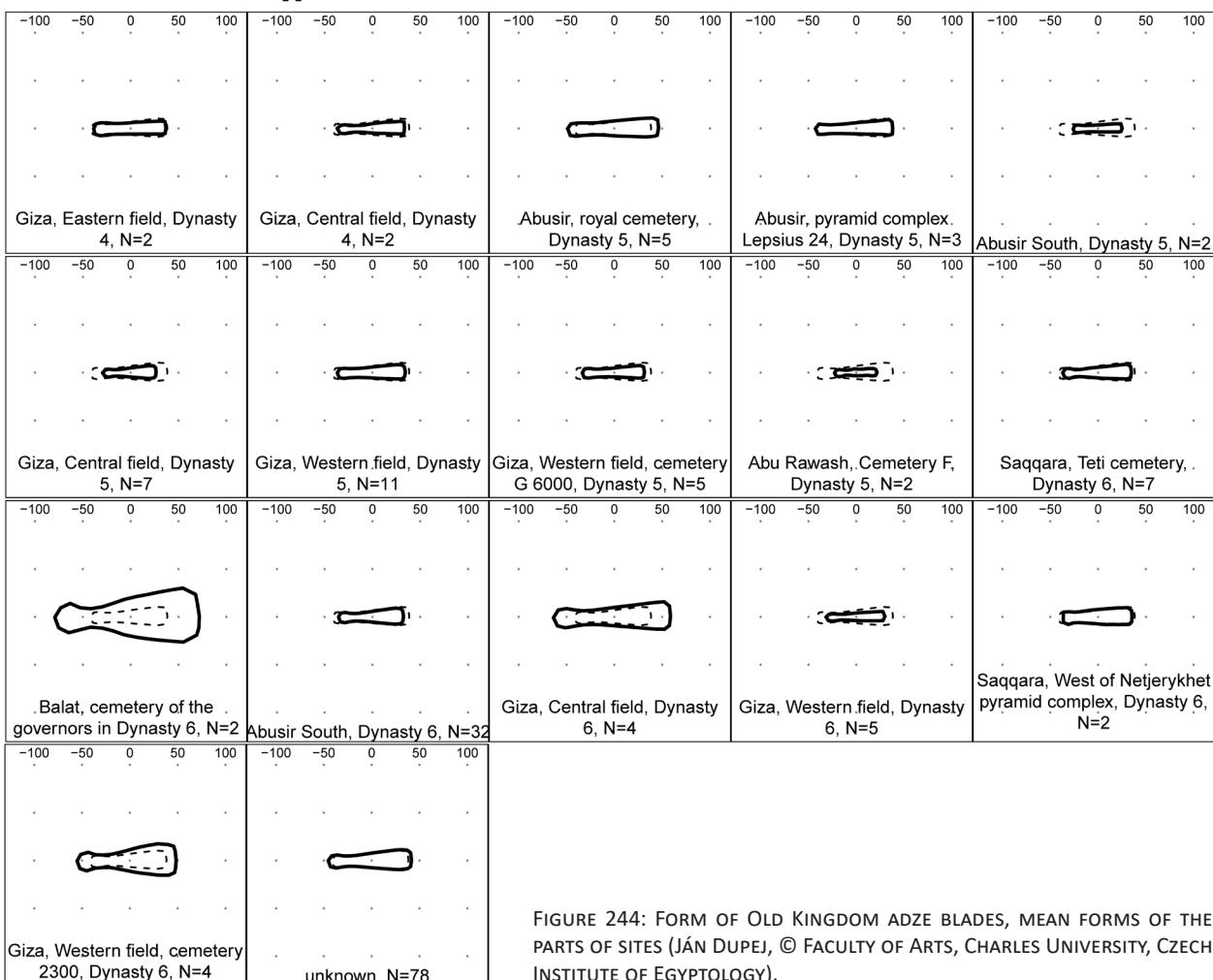


FIGURE 244: FORM OF OLD KINGDOM ADZE BLADES, MEAN FORMS OF THE PARTS OF SITES (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

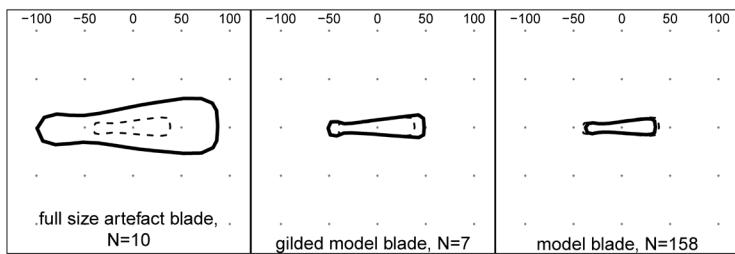


FIGURE 245: FORM OF OLD KINGDOM ADZE BLADES, MEAN FORMS OF FULL-SIZE BLADES AND MODEL BLADES (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

Differences are apparent also if we compare tools according to the parts of sites (Figure 244). Forms significantly larger than the mean form come from unprovenanced contexts; in these cases, we suppose a presence of full-size blades. The mean is exceeded also by adze blades from Balat and from the West Field at Giza, Cemetery 2300; both site parts are from the reign of Pepy II of late Dynasty 6. The adze blades from the royal cemetery at Abusir and Teti pyramid cemetery are slightly larger than the mean form. The forms from the Central Field at Giza are roughly comparable to the mean, while the adzes from other West Field parts than Cemetery 2300 are below the mean. The adze blades from Abu Rawash and the Middle Cemetery at Abydos are also significantly smaller than the mean form of the adze blades. Morphometry has confirmed differences in the size of adze blades. Morphometrical analysis shows significant dissimilarities in the shapes

of the Old Kingdom adze blades from the individual sites and parts of sites. These typological differences need to be confirmed by the analyses of the chemical composition and supposedly different craft traditions at the Old Kingdom sites.

The categorization of full-size adze blades, gilded model blades and model blades was included in the descriptive fields of the database on the basis of the artefact size. Full-size artefact blades were significantly larger than so-called model blades (Figure 245). Gilded model blades were longer than the mean shape. They have occurred in the burials of high officials from the Teti pyramid cemetery.

Shape

The digitized adze blades were ‘normalized’ in the following phase of the analyses, disregarding their size. The results of this morphological analysis *sensu stricto* are somewhat surprising, because they did not provide clear groupings or clusters of the adze blades throughout the Old Kingdom, except for the slightly clearer case of wide adze blade edges in late Dynasty 6. The morphology of adze blades in itself does not seem to be a sufficient basis for the dating of these artefacts.

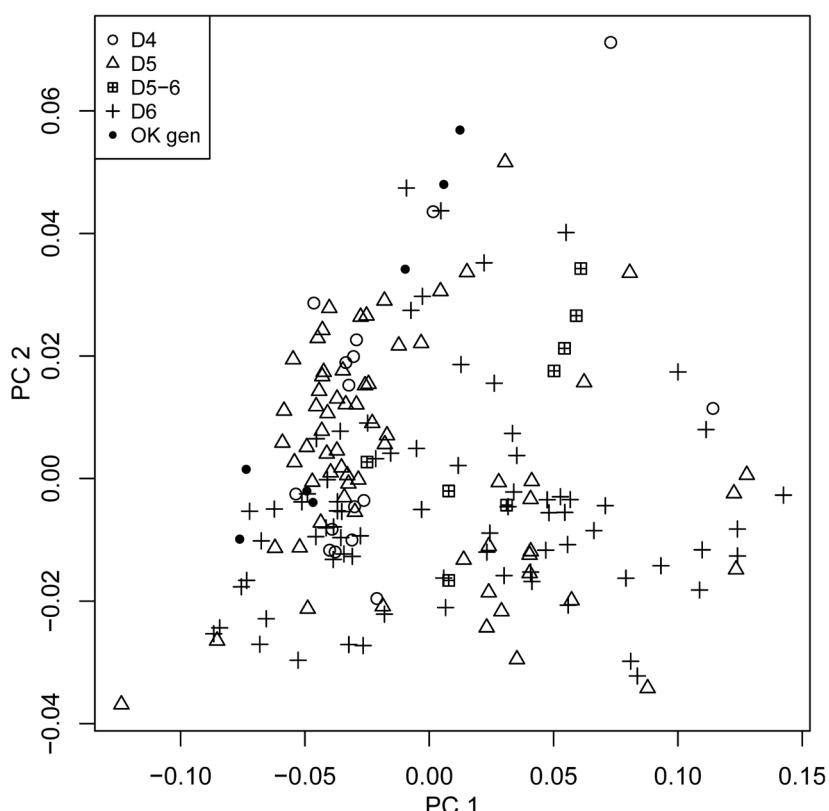


FIGURE 246: SHAPE OF OLD KINGDOM ADZE BLADES, RESULTS OF THE PCA ANALYSIS FOR PERIODS (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

A rerun of the principal component analysis provided another set of principal components. No apparent clusters occurred for the periods; the better represented adzes of Dynasties 5 and 6 appear along the loadings of the first component on the x axis (Figure 246). No apparent grouping is visible on the PCA diagram for the Old Kingdom sites, either (Figure 247). The most important component, with 68.45% of the variability of the corpus, was the width of the blade (this component was second in the first run of the PCA, after the size of the adze blades) (Figure 248). The second component with 9.30% of the variability covers the size and width of the adze butt and neck (Figure 249). The period mean of the adze blades is closest to the shapes of the adzes from Dynasties 5 and 6, which comprise the bulk of the specimens (Figure 250). The variant means are mostly influenced by Variants D1 and D3 (Figures 251). The

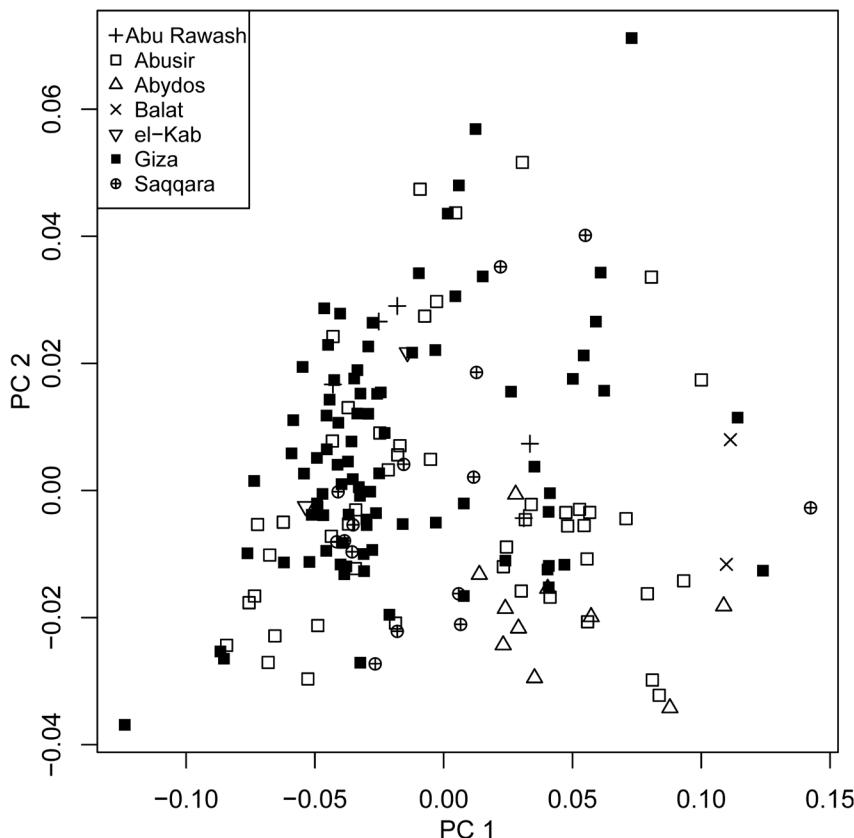


FIGURE 247: SHAPE OF OLD KINGDOM ADZE BLADES, RESULTS OF THE PCA ANALYSIS FOR SITES (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

site means are closest to Abusir and Giza; the adzes from Balat and Abydos were wider, the adzes from Abu Rawash and el-Kab narrower (Figures 252). The shapes of the adze blades from parts of sites clearly differentiate Dynasty 6 adze blades (Giza, Cemetery 2300; Saqqara, pyramid complexes of Netjerykhet; Abydos, Middle Cemetery; Balat). The most numerous adze blades from the Central Field at Giza and Abusir South had the greatest influence on the mean shape and are closest to the mean (Figure 253). Older blades, even from early Dynasty 6 (Teti pyramid cemetery) or earlier (the West Field at Giza, except Cemetery 2300; the East Field at Giza) tend to be narrower

than the mean. The form and shape of the Old Kingdom adze blades show that full-size blades were generally wider than plain and gilded model blades (Figure 254). Altogether, the PCA of the shape of adze blades points to the importance of the size of adze blades in the interpretation of their morphology and, most of all, chronology in the Old Kingdom. Interplay of different variables will require further statistical research in the future.

Social status

If we compare the form of the adze blades by the social status of the buried persons (Figure 255), a pattern of increasing size emerges with a higher social status, with most of the high ranking officials⁸⁴⁴ having adze blades bigger than the mean form. The sharpest divide is between high and low rank officials. It is also interesting to note that adze blades of royal daughters are smaller than the mean form of the adze blades. When reduced to

shape (Figure 256), differences of adze blades are less visible, with exception of two late Dynasty 6 adzes of governors of oasis Balat.

Conclusion

The case study of Old Kingdom complete adze blades has shown that morphometry can provide significant results. The differences in the size and morphology of the tools can be evaluated on the basis of statistics, using controlled and repeatable analyses. Morphometrical analysis confirms differences in the synchronic and diachronic phenomena in the Old

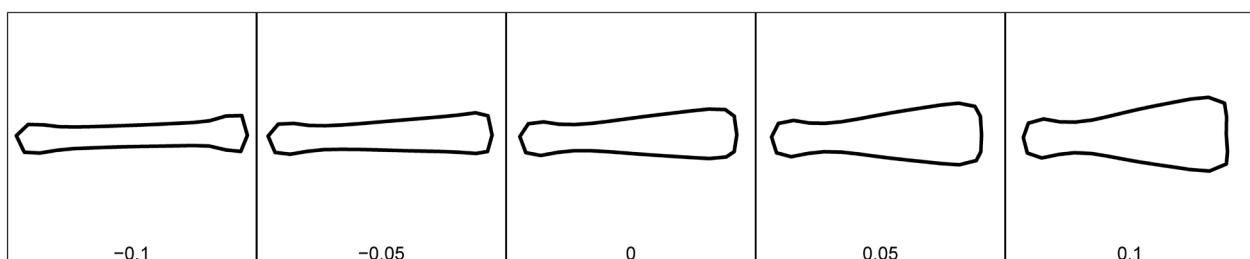


FIGURE 248: SHAPE OF OLD KINGDOM ADZE BLADES, EFFECT OF THE PRINCIPAL COMPONENT 1 (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

⁸⁴⁴ Viziers and holders of the six highest titles in the Old Kingdom administration – Strudwick (1985).

OLD KINGDOM COPPER TOOLS AND MODEL TOOLS

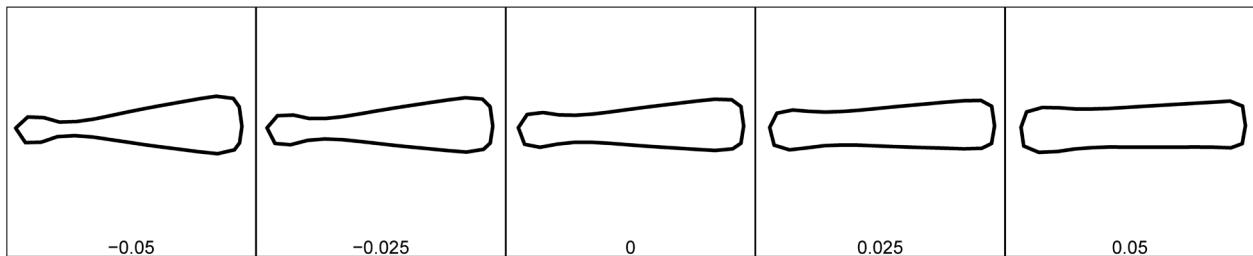


FIGURE 249: SHAPE OF OLD KINGDOM ADZE BLADES, EFFECT OF THE PRINCIPAL COMPONENT 2 (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

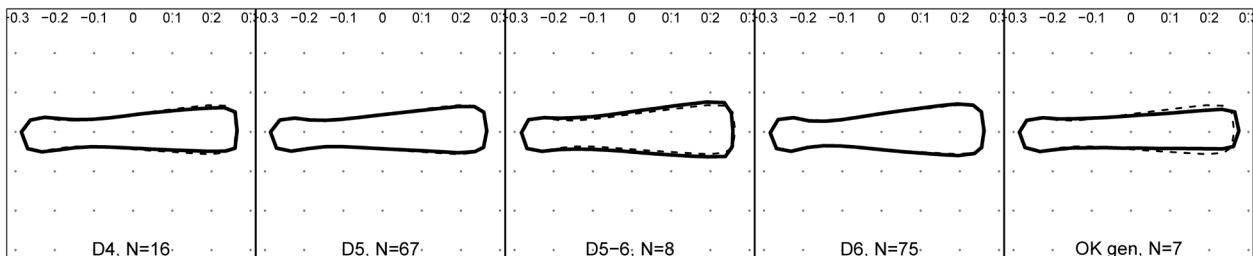


FIGURE 250: SHAPE OF OLD KINGDOM ADZE BLADES, MEAN SHAPES OF THE PERIODS (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

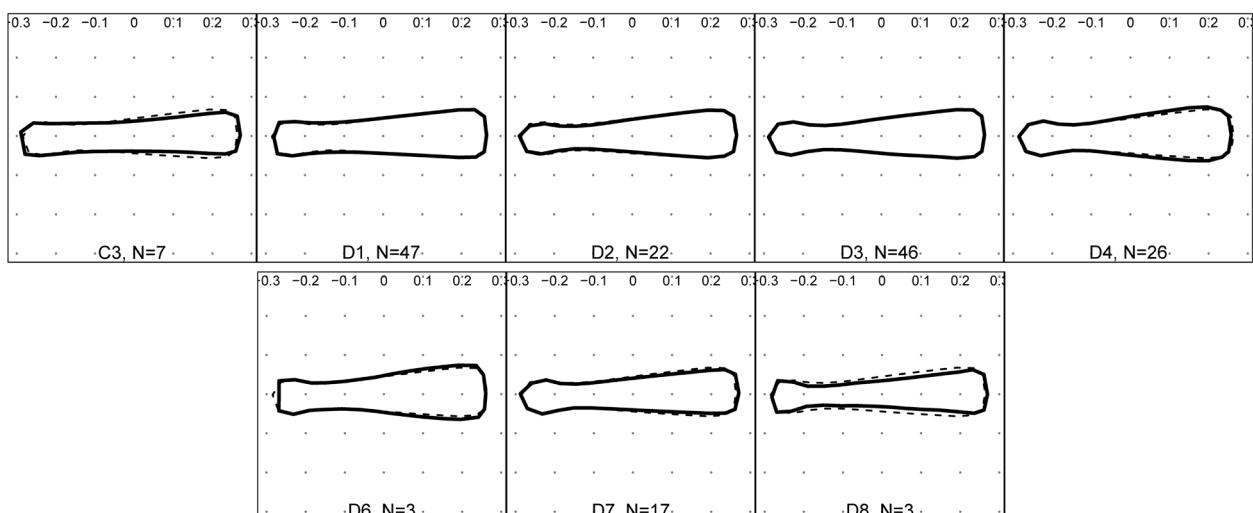


FIGURE 251: SHAPE OF OLD KINGDOM ADZE BLADES, MEAN SHAPES OF VARIANTS (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

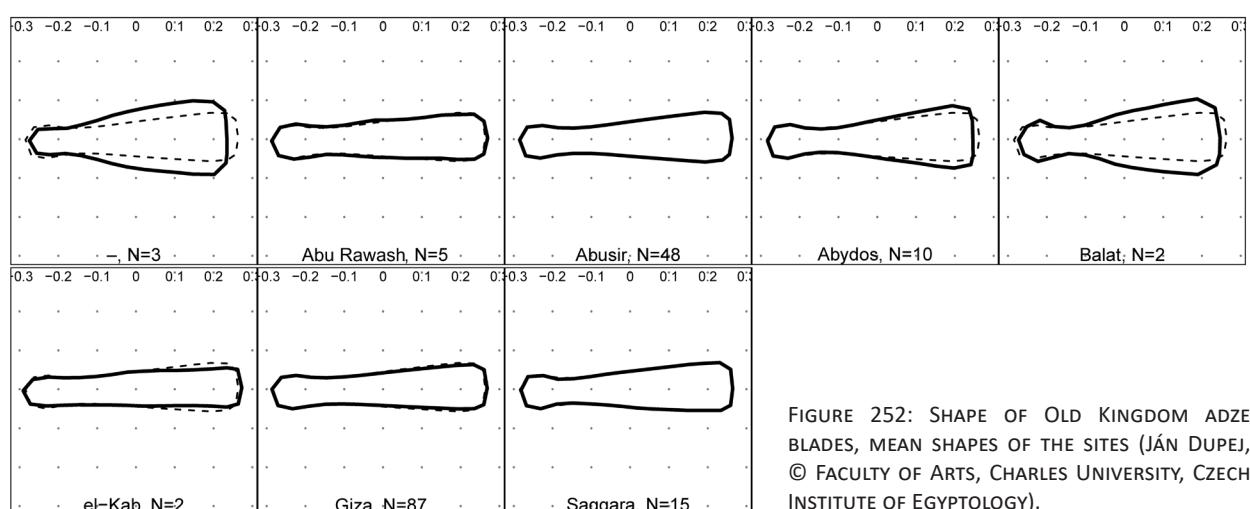


FIGURE 252: SHAPE OF OLD KINGDOM ADZE BLADES, MEAN SHAPES OF THE SITES (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

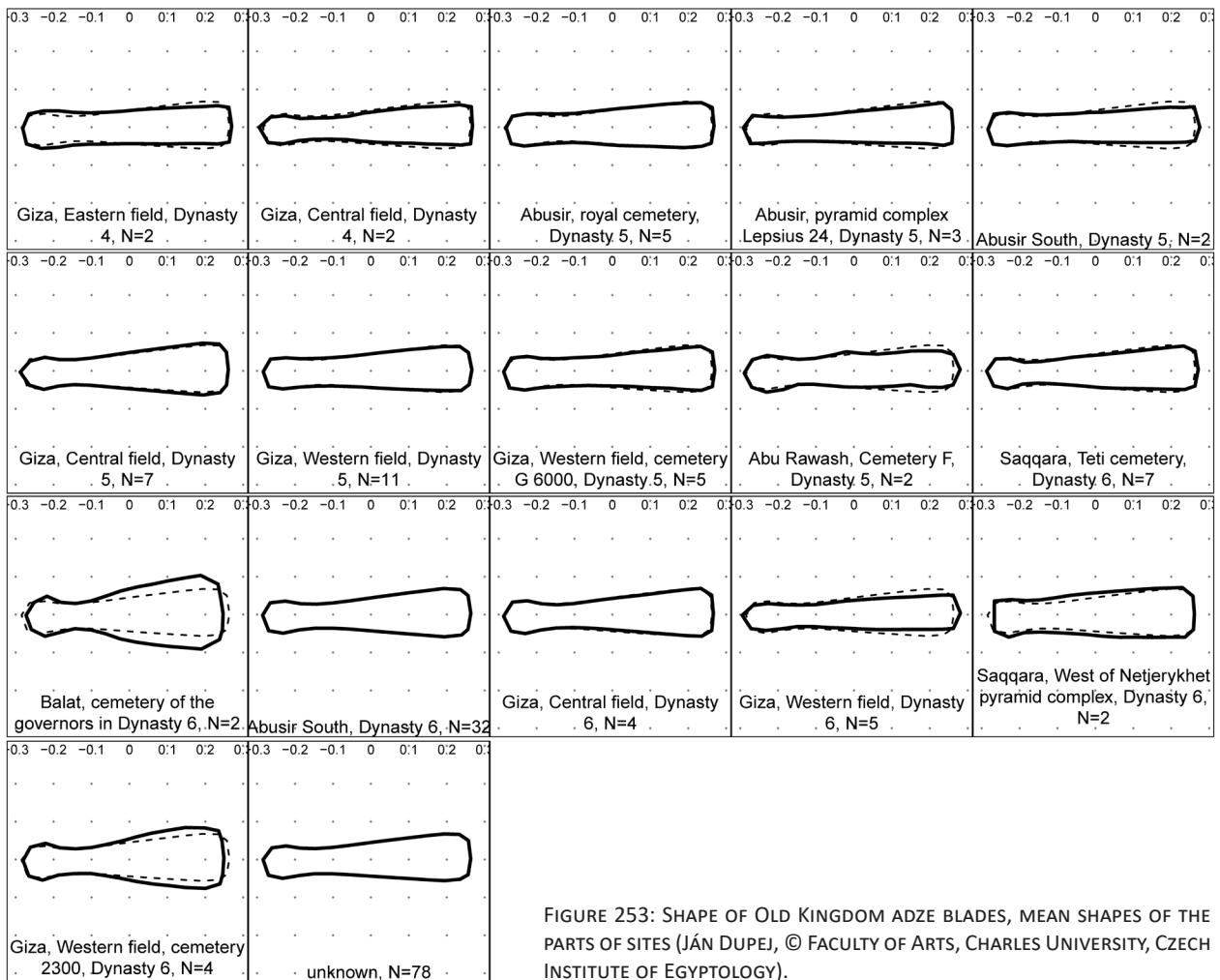


FIGURE 253: SHAPE OF OLD KINGDOM ADZE BLADES, MEAN SHAPES OF THE PARTS OF SITES (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

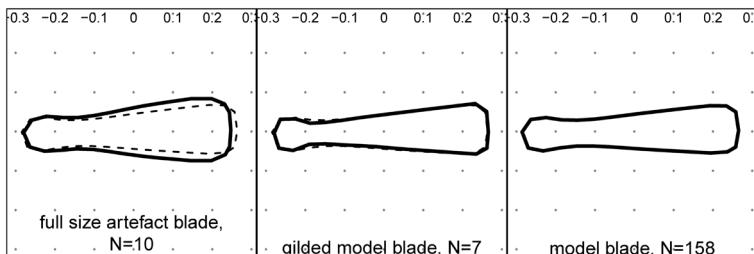


FIGURE 254: SHAPE OF OLD KINGDOM ADZE BLADES, MEAN SHAPES OF FULL-SIZE BLADES AND MODEL BLADES (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

Kingdom. An increase in the size and width of blades is observable on the corpus, while significant differences among the sites indicate different approaches of the craftsmen in the production of model and full-size blades. The next phase of the research needs to be focused on the chemical composition of the artefacts and the supposedly differing Old Kingdom craft traditions.

If the material culture found would be presented in comparable way (which is not always the case in excavation reports) and certain rules of the publication of artefacts are applied to material culture (not only in the case of metal artefacts), it will be possible to do morphometrical and statistical studies not only on the intra-site but also on the inter-site level.

OLD KINGDOM COPPER TOOLS AND MODEL TOOLS

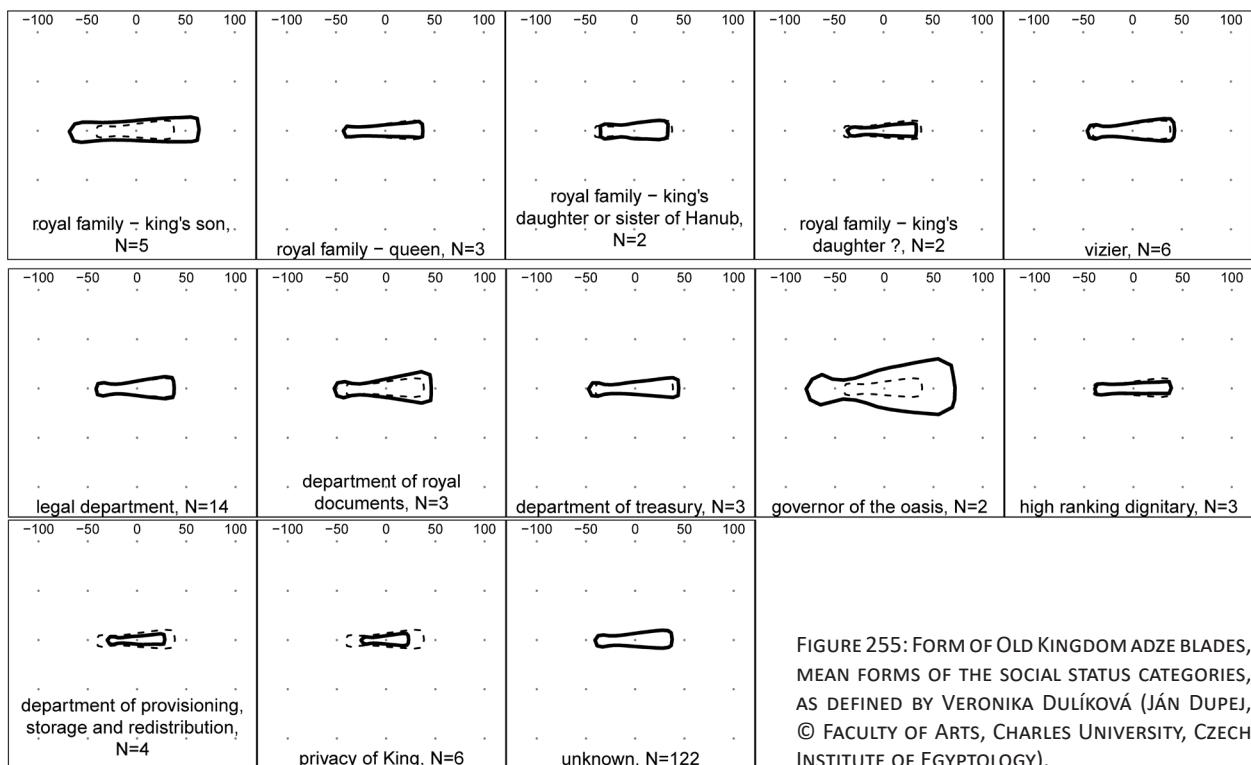


FIGURE 255: FORM OF OLD KINGDOM ADZE BLADES, MEAN FORMS OF THE SOCIAL STATUS CATEGORIES, AS DEFINED BY VERONIKA DULÍKOVÁ (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

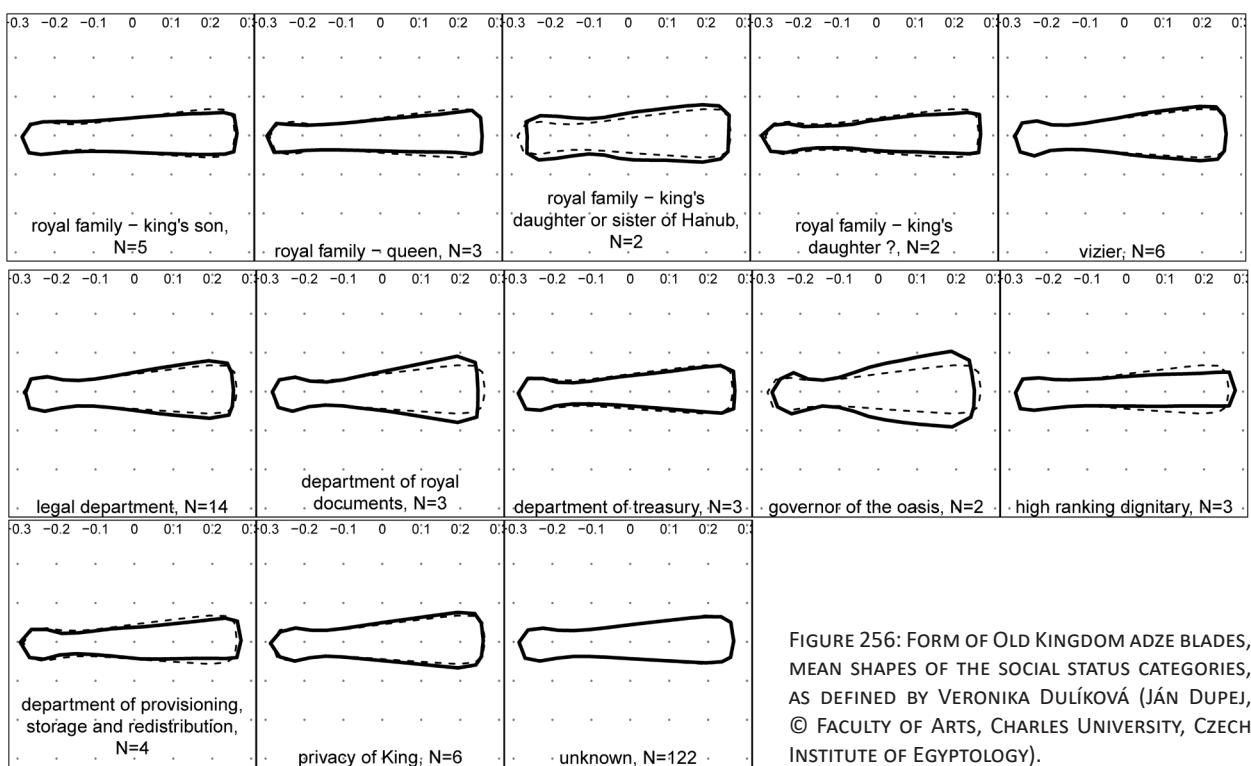


FIGURE 256: FORM OF OLD KINGDOM ADZE BLADES, MEAN SHAPES OF THE SOCIAL STATUS CATEGORIES, AS DEFINED BY VERONIKA DULÍKOVÁ (JÁN DUPEJ, © FACULTY OF ARTS, CHARLES UNIVERSITY, CZECH INSTITUTE OF EGYPTOLOGY).

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