

## **Identifying and evaluating atypical traits in Ancient Egyptian glass vessels from the New Kingdom using raw data analysis and expert assessment.**

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### **Abstract**

The descriptive data pertaining to the remaining, largely intact, glass vessels produced in ancient Egypt between the reigns of Thutmosis IV (1401-1391 BC) and Pinudjem II (959-945 BC) contained in 'Die Glasgefäße im Alten Ägypten' [The Glass Vessels in Ancient Egypt], was extracted and standardised to create a dataset that could be analysed to determine the most typical and atypical features of vessels attributed to the New Kingdom in the corpus. Seven descriptive categories were assessed based on the percentage of incidence to determine if a vessel could be defined as statistically 'atypical'. An expert's evaluation was employed as a second assessment method. The two methods identified 76 vessels from a total number of 320 vessels and agreed on 16 vessels considered as atypical, all of which had little or no provenance information. The resulting 76 vessels identified as 'atypical' by the combined methods were subsequently compared with the respective provenance information and current location to determine patterns of collection and distribution throughout the world. The data showed that the Americas held the largest number of vessels that had little or no provenance data, including those held in private collections. The combined atypical tests identified that the Americas hold the largest proportion of atypical vessels. It is not the intention of this research to undermine the authenticity of vessels but to determine if data methods can be used to identify atypical traits in archaeological collections and to encourage the application of archaeometric testing to provide supporting information on statistically rare objects.

Keywords: Glass, Vessel, Ancient Egypt, Atypical, Provenance, Stylistic, Morphology, Origin.

## Introduction

‘Die Glasgefäße im Alten Ägypten’ [The Glass Vessels in Ancient Egypt], produced by Birgit Schlick-Nolte in 1968, is a catalogue of 344 remaining, largely intact vessels from ancient Egypt produced between the eighteenth and twenty-first Dynasties (between approximately 1550 to 945 BCE). Each vessel is recorded in detail, describing the morphology, colour, decoration, and specific features, such as the handles, feet, neck, and rim. Very few vessels have been added to the corpus since this time, therefore the information contained in Schlick-Nolte’s catalogue continues to represent a relevant data set. Although many other vessels were produced in, and excavated from, ancient Egypt, these vessels cannot be reliably restored from the fragments, however, it is reasonable to expect that the corpus described in *Die Glasgefäße* represents the corpus of vessels that were created overall. Using the Schlick-Nolte catalogue, the descriptive information pertaining to the colour of the body, the shape of the vessel, opacity, colour of the neck rim, handles, pattern colour and pattern design was extracted and standardised to create a data set that could be used to quantify and assess patterns in the attributes of the vessels. The data was used to identify the number of incidences of certain characteristics, thereby distinguishing what could have been the most common usages of colours, preferred shapes, and favoured decorative patterns. Using the same data, vessels that present statistically rare attributes can be identified as ‘atypical’ and when compared with the provenance information, these vessels can be the subject of further investigation. This study also seeks to compare the current location of the post-study data set vessels with the provenance information and to use the results of the atypical study to examine the distribution of this particular subset of vessels throughout the world.

Although a novel technology in the Late Bronze Age (LBA), glass was rapidly assimilated by the ancient Egyptian elite to become an important symbol of high status. The ensuing production of glass was strictly regulated by the Egyptian royal courts and administered according to a rigid distribution model. Ingots of raw glass were exchanged between royal courts at the highest level, while glass vessels were an exclusive commodity suitable for high-level gift-giving between rulers of LBA states and preferred members of the domestic court (Na’aman, 2000, p130; Shortland, Nicholson and Jackson, 2001, p153). Early vessels were created using the ‘cold-working technique’ by which glass would be poured into a cast, and then shaped using lapidary techniques (Broschat and Rehren, 2017). The invention of core-forming represented a significant advance in glass vessel production technology (Shortland, 2001, p212), transforming how glass vessels could be created, shaped and decorated. A ‘core’ made from a mixture of clay and dung was moulded to form the interior shape of the vessel around a long pole called a ‘handling piece’. The core was heated and rolled in powdered glass, then worked in the form of a “pasty mass”, upon which layer after layer was applied to create the vessel (Nicholson, 1993, p53). The foot, handles and decoration were added before the vessel was left to slowly cool, after which the core and handling piece was removed (Nicholson and Henderson, 2000, p203).

Establishing a reliable timeline for early glass vessels has proven to be problematic: reburials, destruction and transference of goods caused by extensive looting or the actions undertaken by the priests of the necropolis administration to preserve their charges has rendered the context of items in these tombs unreliable in several instances (Reeves and Wilkinson, 2008, p125). Glassworking was undertaken by multiple glass workshops, who based their work on the modes of the time. The workshops of Malkata and Amarna represent the peak of Egyptian glass production, both in the number of vessels produced, the technical accomplishment of the craftsmen and stylistic uniformity; namely the iconic vessels of blue glass with yellow and white threads applied to create feather or garland patterns (Petrie, 1894, p25). In *Die Glasgefäße*, Schlick-Nolte assigns the vessels into groups and subgroups: The first group comprises of the vessels that can be reliably dated to a specific time of manufacture, having either come from a specific archaeological context such as the tomb of Amenhotep II, or are stylistically dated with confidence. Even though this group is comparatively small, the author emphasises the archaeological importance of having such pieces recorded from reputable investigations (Nolte 1968, p46). The second, and largest group comprising of 213 vessels, are divided into “*Werkkreis*”; this term is often used to refer to an Old Master artist and his associated assistants and followers - “circle of workshops” is perhaps the nearest translation. The vessels in the *Werkkreis* groups have been approximately dated according to the stylistic features and some are attributed to known workshop locations such as Malkata and Amarna; at the beginning of the 14th Century BCE, a more uniform approach was taken for the morphology and style of glass vessels,

however, subtle changes in features such as the diameter of the neck, the shape of a spout, handles and the shape and size of the feet provided key elements that narrow estimates for the period of production. As such, the *Werkkreis* are divided into six groups, the largest of which, *Werkkreis* 6, contains 43 vessels and dates between the reign of Tutankhamun (1333-1323 BC) and that of Pinudjem II (959-945 BC), an era of approximately 390 years, thereby making any speculation pertaining to periodical trends somewhat ineffectual as the dating of the vessels in this working group largely tentative. Of the vessels contained in the *Werkkreis* groups, only 15% are of known origin, 19% are of unknown origin, 32% are of ambiguous origin and the remaining 35% belong to private collections. The *Kohlpalmsäulchen*, or kohl palm vessels, are the largest group containing 58 vessels and are collectively dated from Amenhotep III (1391-1353 BC) to the Ramesside period (ending in 1070 BC), which spans approximately 320 years, again, making the dating for each specific piece largely speculative.

### Methodology

To accurately assess the characteristics that exemplify typical and atypical features of the New Kingdom, this paper concentrates on the vessels that were attributed to between the reigns of Amenhotep II (1427-1401 BC) and Rameses III (1194-1163 BC). The 15 early vessels that are reliably dated between the reign of Thutmose III to Amenhotep II were excluded from the data set as they exhibit unusual shapes, colours and morphology that have been attributed to the experimental phase of early glassmaking<sup>1</sup> (Nolte, 1968, p5). The six vessels that are reliably dated to the 21<sup>st</sup> Dynasty and the three vessels, recorded as lost, are also excluded the data set.

The descriptive information of the remaining 320 vessels exactly as reported by Schlick-Nolte was collated into a working database using Microsoft Excel. Seven attributes were chosen to assess typical and atypical features for the purposes of the study: the colour of the body, or ‘ground colour’, the vessel shape, neck rim colour, handle colour, the pattern colour and the pattern type on the neck and body. The foot colour and foot rim colour were not included in the data as the information did not provide sufficient discrimination between the vessels; over a third of vessels were not made with a foot: the pilgrim flask, for example, is the second most common vessel shape, and the majority of the remaining vessels made with feet were created using the ground colour.

For clarity, colours are standardised into the main colour groups, rather than listing individual hues as described by the author; for example, ‘olive green’ is noted in the dataset as green. As the most prevalent colour, blue is standardised into three main groups: light blue (which contains the colours described as light blue, sky blue and turquoise), mid blue (blue, bright blue, copper blue, grey-blue and lapis lazuli blue) and dark blue (black blue, cobalt blue, dark blue, deep blue and ultramarine).

The vessels are categorised into 14 main shape types using the terminology described in *Die Glasgefäße*. The origin of these names are mainly derived from traditional ceramic vessels:

- Krateriskos refers to vessels that have a wide, cylindrical, crater-like neck with a short spherical body, usually with a foot attached.
- The thick walled krateriskoi exhibit a broader neck and have thicker, less defined handles that do not protrude far from the body of the vessel.
- The simple krateriskoi is a basic version of the krateriskos and may not contain handles, feet, or decoration.
- The pilgrim flask has a small cylindrical neck with a round, lenticular body. Pilgrim flasks can be large or small; specifically between 45mm and 145mm tall, with no, or two to three handles attached.

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<sup>1</sup>These vessels are: 24391, 47620 (British Museum), 19657 (University College London), 23.9, 26.7.1175, 26.7.1179 (Metropolitan Museum of Art), ÄS 630 (Bavarian State Collection of Egyptian Art, Munich), E 2451 (Ashmolean Museum), 24761, 24761 bis, 24768, 24804, 24808, J 33827 (Cairo Museum), E 6201 (Brussels Royal Art and History Museum).

- Kohl tubes are modelled on the Egyptian palm columns and have a rounded or flat base with a long, narrow body and an opening that is fashioned into leaves surrounding the rim.
- Amphoriskos vessels are composed of a cylindrical, narrow, or conical neck with board shoulders and a tapered base.
- Jug-shaped vessels have narrow neck with a wider, oval body with a handle attaching the neck and shoulder.
- The spherical vessel is defined by the orbicular body but can have a long or short neck with various handle types and a stand.
- The flask or bottle type is generally composed of a long and narrow neck with an oval body and rounded base without handles.
- The beaker has no handles or rim applied and tapers to a flat base.
- The pomegranate vessel exhibits a distinctive pomegranate shape with a spherical body, no handles and a narrow, cylindrical neck that opens into several small leaf shapes.
- The lotus beaker is modelled after the lotus flower and contains a small foot and no handles (Loat, 1905 pl 4-30; Nolte, 1968, p149).
- One vessel described in *Die Glasgefäße* is identified as ‘pilgrim flask and pomegranate vessel’; this vessel consists of a pilgrim flask and a pomegranate vessel which appears fused at the body, most likely accidentally, and is therefore described as one vessel throughout.
- The category of ‘special shapes’ consists of glass objects that cannot be classified into the main shape groups; these include fish-shaped vessels, curved and flat bowls and the alabastron style vessels.

The colour of the neck rim and the handles are also described in the main colour groups. Where two or more colours are used, this is described as polychrome. It should be noted that no colour combination in the polychrome group exceeds 5% of instances in the respective category, therefore all polychrome combinations of the neck, rim and handles are classified as atypical for the study.

The colours of the patterns were assessed by counting the total number of instances that a single colour occurred across the corpus of vessels overall. The specific colour combinations used for patterns for each single vessel were then determined to investigate the significance of not only the colours but also the colour combinations. The vessel patterns are described in detail to convey information about the style and aesthetic of the vessel, such as: ‘Especially generous, even garlands’ and ‘Garlands turning into a regular feather pattern, irregular feather pattern’. For clarity when comparing the data, the patterns were standardised into basic types: garland, feather, arcades, zigzag, other, unknown and none. Where multiple patterns were used on the body or neck, these were added as a separate category, for example ‘arcades merging into feather pattern’ was added to the data as ‘arcades > feather’. Where the vessel type did not comprise a neck, such as the beaker shape, the kohl tubes, and the special shapes, this was added to the data as ‘not applicable’. In some instances, more than one type of pattern was applied to the vessel on the body and neck, thereby adding another feature for trend comparison. It was noted whether the patterns on the body and neck were the same pattern, two distinctly different patterns, or had the same pattern on the body and neck with an additional pattern emerging, for example, one vessel (67.1, Toledo Museum of Art) is described as having a feather pattern applied to the body and a feather pattern, that turns into garlands on the neck (Nolte, 1968, p85).

Characteristics that represented less than 5% of the whole category were identified as an atypical trait, for example, yellow represented 3% of vessel ground colour, thereby classifying it as an atypical trait for the purposes of the study. If a vessel exhibited three or more atypical traits, the vessel as a whole was classified as atypical for the purposes of the study.

Finally, the information pertaining to the provenance and the location of the vessel were reviewed with the post study data set. Four categories were given to describe the origin of each vessel: ‘Origin

known' describes a vessel that is recorded as being excavated from a specific archaeological context, i.e. a grave or tomb, whereas 'Origin ambiguous' indicates that the vessel is recorded as coming from a specific region or town, such as 'Malkata', 'Cairo' or more generally 'Egypt'. It is possible (indeed probable in many cases) that the object was bought rather than found there. 'Origin unknown' refers to the vessels that have no provenance information, or that the information refers only to the date or location of acquisition. Finally, 'Private collection' refers to those vessels where only the collection name is listed, but there is no information regarding the actual origin, and such pieces are usually bought and exchanged through the art market. During the research for this paper, it was apparent that the locations of some vessels have changed, for instance, where vessels that have been purchased by museums from private collections. While these locations were updated, no active investigation to confirm the current location of each vessel was undertaken as part of this research. For clarity, the regions of Egypt and the Levant, Europe and the Americas were used to define locations, rather than individual countries, unless pertinent to the information.

In addition to using the raw data approach, a second test method using 'connoisseurs' eye' was employed. A specialist in the area of ancient Egyptian glass, Professor Andrew Shortland, was asked to use their expert opinion to appraise each vessel using black and white images without context. The specialist was asked to categorise each vessel as typical or atypical based on shape, design, and discernible pattern type. The two methods were designed to provide virtually opposite techniques of assessment; the 'connoisseurs' eye' method was intended to assess the vessels using a minimal amount of visible data, compared with the raw data approach which presented attribute categories, but with no stylistic description. Each method was performed independently.

## Results

Blue was revered above all colours by the ancient Egyptians and utilised extensively in painted reliefs, protective amulets, and jewellery. Blue symbolised a range of significant spiritual meanings, including representing the embodiment of divine truth and justice (Birren, 1950, p37). It is unsurprising, therefore, that 80% of the vessels described in *Die Glasgefäße* were produced with a ground colour of either dark, mid, or light blue glass. Early vessels dating to the reign of Thutmosis III are primarily light to mid-blue, often described as turquoise, in colour and are generally opacified. The next most prevalent colour is black which represents a significantly smaller group of 6% of the vessels. Some 'black' vessels are actually very dark blue vessels coloured with cobalt, or very dark purple glasses coloured by manganese, however as mentioned previously the characteristics of each vessel are reported as described by Schlick-Nolte. The remaining colours used for the body in descending frequency are white, green, yellow, grey, brown, purple, unknown, polychrome, and red, comprising between 5% to less than 1% per colour of the ground colour. Also, 86% of vessels in the dataset are described as opaque, rather than translucent, making this by far the most typical trait of Ancient Egyptian vessels. However, because the incidences of translucent vessels are above 5%, they are not classified as an atypical trait for this study. It should also be noted that the classification of atypical vessels in this study is performed using the data as unrelated variables and no attempt is made to define statistical correlations that may link results of the frequency of stylistic characteristics, however, where it is appropriate, the dating of the vessel in *Die Glasgefäße* is considered in the discussion section.

The most common four vessel shapes are the krateriskos, the pilgrim flask, the kohl tube, and the amphora. The remaining vessel shapes accounted for 6% or less per vessel shape type (Figure 1). With the exception of the thick-walled krateriskos, the beaker shape, pomegranate vessels and the unusually merged pilgrim flask and pomegranate vessel, blue is the most predominant colour for all vessel types.

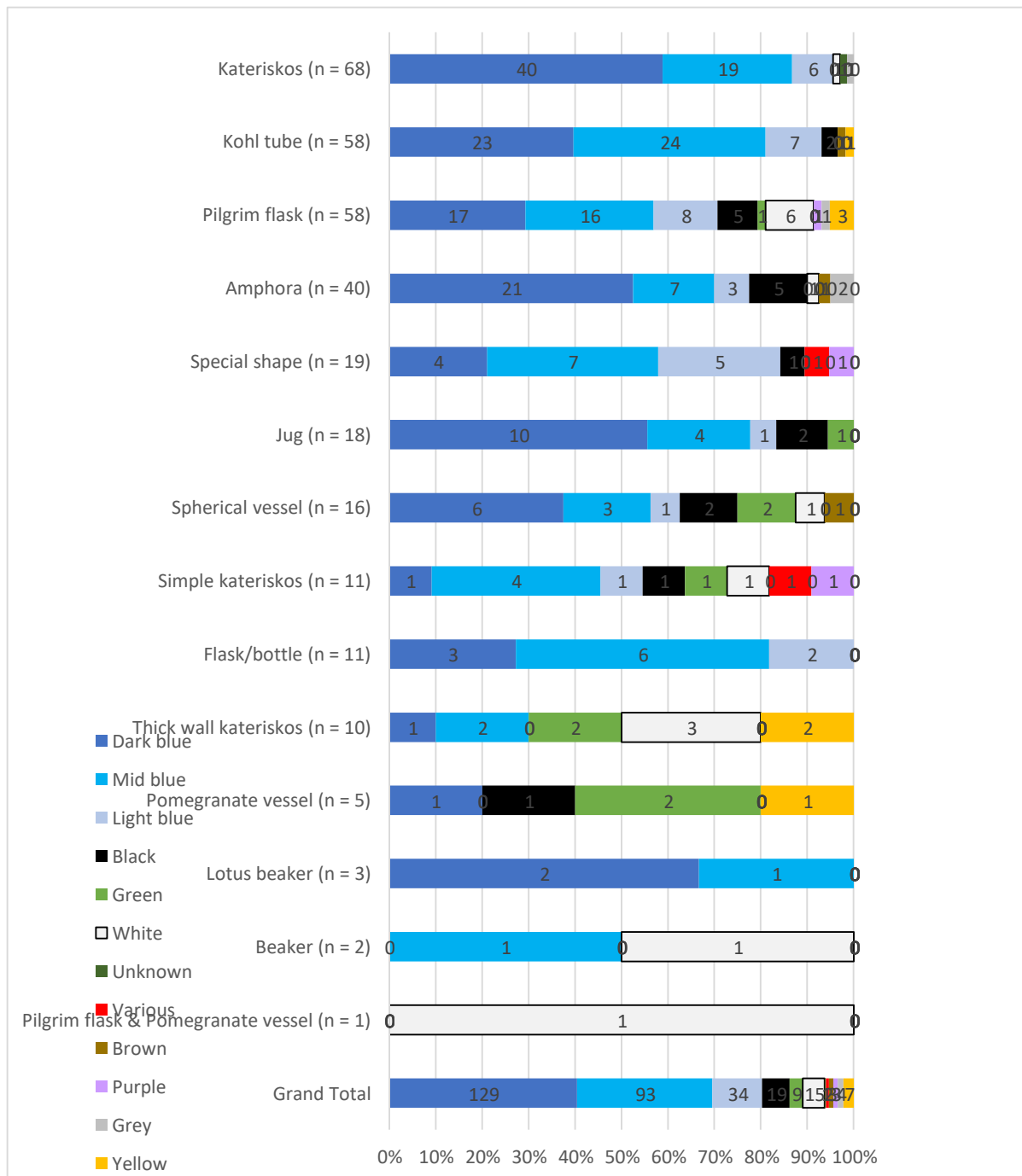


Figure 1. Chart illustrating colour prevalence in each vessel type attributed to the New Kingdom. Centre bar labels indicate number of vessels.

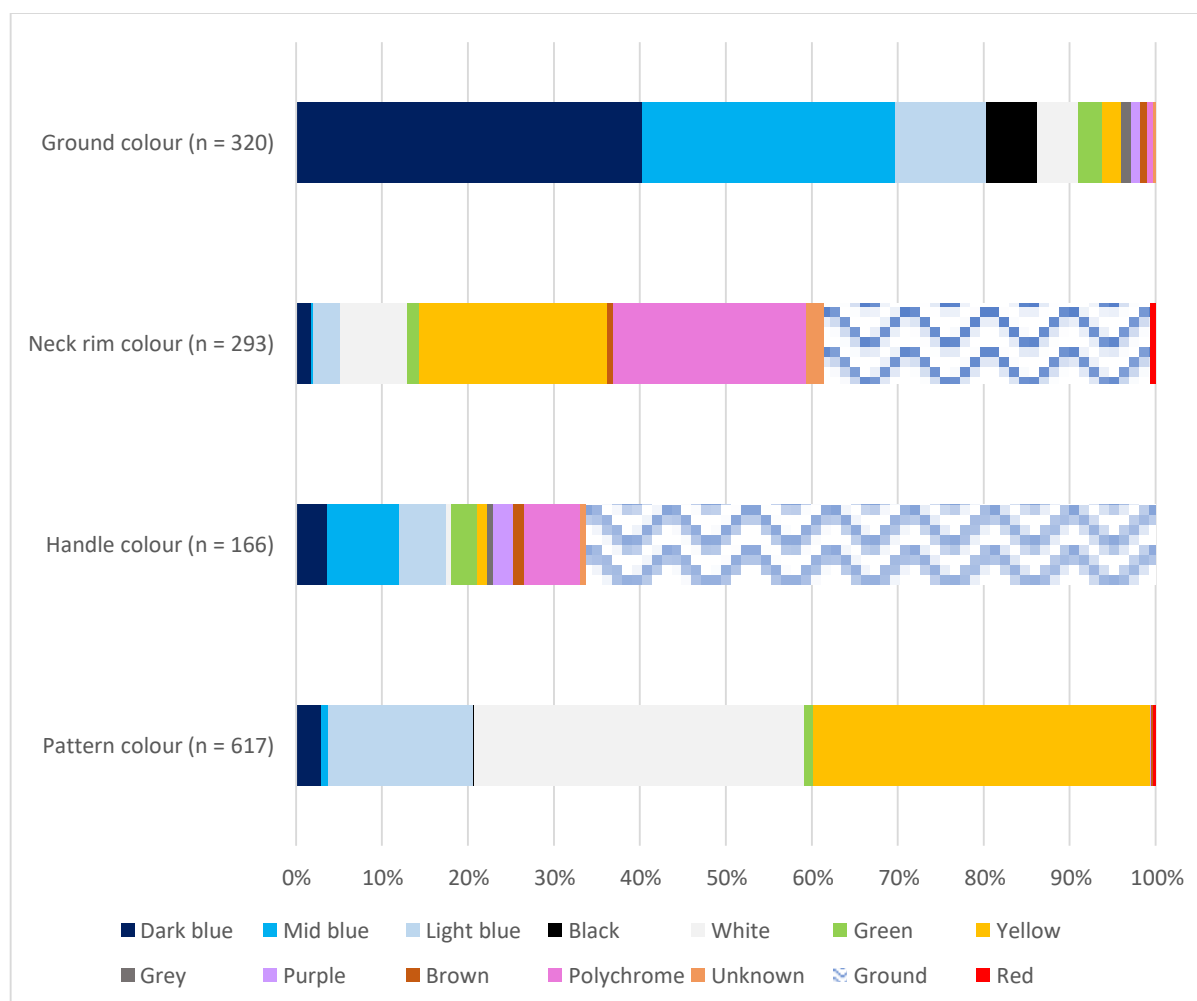


Figure 2. Distribution of colours used in ancient Egyptian New Kingdom vessels to create patterns, handles, neck rim and the vessel body. Where vessels do not contain a neck rim or handles, or are recorded as not present, these have been removed from the figure.

Of the 320 vessels observed, 92% of vessels have a rim which is still preserved. 35% of these vessels presented rims created from the same tone as the ground colour, 20% of vessels using yellow and 21% of vessels were recorded as polychrome, exhibiting 22 different colour combinations of two or more colours (Figure 2). The most common polychrome combination being black and white, occurring in 4% of instances. 8% of vessels were observed as having no rim, broken from the body of the vessel.

34% of ancient Egyptian vessels were produced without handles, with the same percentage of vessels exhibiting handles made from the same tone as the ground colour used for the body of the vessel. 14% of vessels are recorded as once having had handles, however, these have been broken and are missing from the vessel thereby preventing colour determination. The remaining 18% of handles equate to 29 different colour combinations; therefore, classified as atypical. 11 handles are described as translucent and appear to be made in a different colour to the vessel ground colour, making this an unusual trait. However, it should be noted that the translucency of a vessel may be more difficult to discern due to the thickness of the glass used for the body, any weathering of the vessel and any core remaining inside the vessel. The hue of the handles, therefore, may look distinct from the vessel body. For the purposes of the study, the colours are reported as stated in *Glasgefäße*.

The three most used colours for pattern application across the corpus of 320 glass vessels examined are yellow, white, and light blue. 76% of vessels had a yellow pattern applied, and 74% of vessels had a white pattern applied; light blue is the third most common pattern colour, used on 33% of vessels. However, it is the combination of colours which were the most statistically significant when identifying atypical pattern traits. Patterns applied using yellow and white combined comprised of the 35% vessels in the dataset, with the second most common combination of pattern colours being

yellow, white, and light blue at 28%. The third-largest group totalling 20% of vessels have no decoration applied to the body. The remaining pattern colours were mid or dark blue with yellow or white, and the use of green, red, purple, or black in various colour combinations. 13% of vessels exhibited combinations of yellow or white with one or multiple other colours such as green, red, or purple. These ‘atypical’ colours and combinations presented 18 separate incidences of single and polychrome combinations, comprising the remaining 17% of vessels, hence less than 1% per incidence.

The garland pattern followed by the feather pattern are the two most likely patterns to be applied to both the body and neck of a vessel; the third most common pattern attribute is no pattern applied. Combinations and fusions of feather, garland, and arcade patterns, zigzag, or other patterns occur in 5% or less of vessels per pattern type. Although not assessed as part of the atypical traits, it was noted that 61% of vessels that are created with the garland pattern have the same pattern on the neck and body, and 63% of vessels created with the feather pattern have the same pattern on the neck and body. 8% of vessels showed a combination of patterns that merged on the neck or body, for example, a vessel that is described as having a feather pattern on the body and a neck pattern that showed both a garland and feather pattern. 22% of vessels from the dataset do not comprise necks and were excluded from this interrogation. 35% of vessel rims were created using the ground colour, followed by 20% of vessels using yellow. 8% of vessels are recorded as the rim not being present, either from damage or because of the vessel design, for example, fish-shaped vessels in the ‘special shapes’ category, white composed 7% of rim colours. The remaining 30% of vessels exhibit multiple different single colour or polychrome combinations, less than 1% per incidence.

### Provenance review

From the corpus, 17% of vessels are of known origin, having been excavated from a specific archaeological context such as a tomb or grave. 34% are described as ‘Origin ambiguous’, 18% are ‘Origin unknown’ and finally, 32% have been or are still part of a private collection where virtually no information is known about the origin of the vessel (Figure 3). The distribution of vessels by individual country was assessed by comparing the region with the provenance category; the vessels of known origin in the post-study group equate to 53 vessels; the country with the largest number of known vessels is the United Kingdom with 15 vessels. Egypt holds the second largest number equating to 13 vessels, followed by Israel with 6 vessels of known origin. The remaining 19 vessels of known origin are distributed throughout 9 different countries.

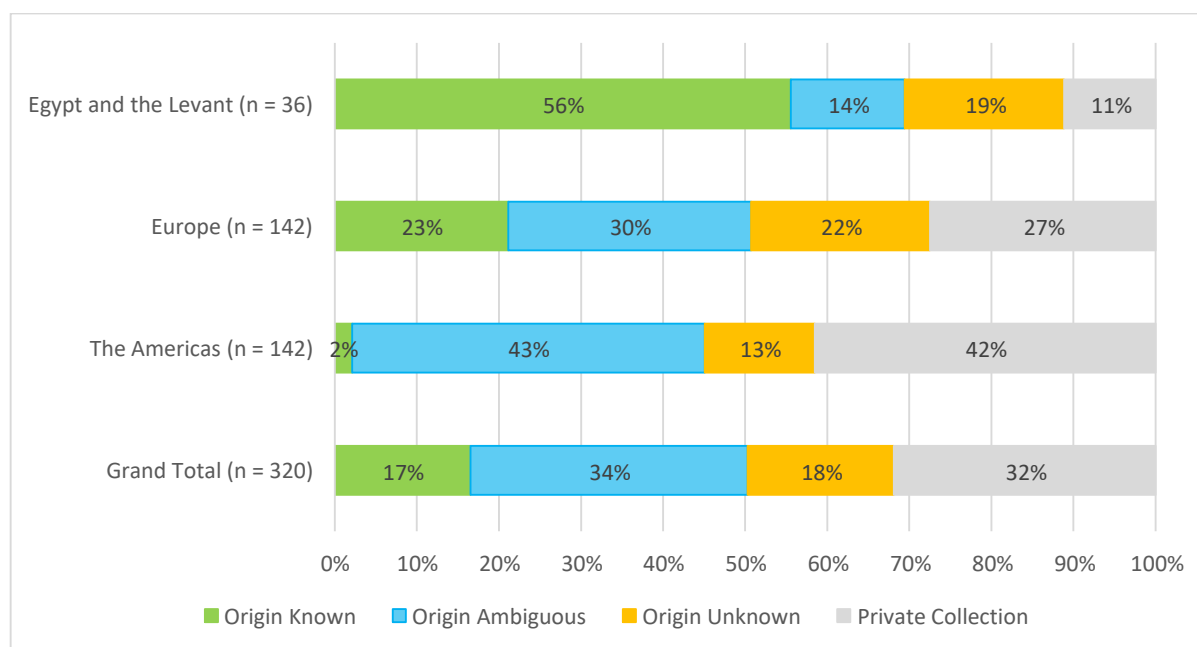


Figure 3. Vessel provenance category by current regional location.



The data also showed that although the Americas contained the same number of ancient Egyptian glass vessels as Europe, 142 vessels each in total, only 3 vessels are of known origin with the remaining 139 vessels having very little or no recorded information about the provenance. Of the vessels located in the Americas, 42%, equating to 59 vessels, are recorded as belonging to private collections meaning that the Americas have the largest number of privately owned ancient Egyptian glass vessels in the world. The number of privately own vessels in the Americas represents 18% of the total number of vessels in the world. By comparison, the number of vessels in private collections in Egypt and the Levant is 4, equating to 10% of the total number of vessels in this region. Europe has 39 vessels in private collections, equating to 27% of the total number of vessels in Europe.

## Discussion

Using the raw data approach, 44 vessels were identified as having three or more atypical traits according to the test criteria, thereby classifying them as atypical vessels. The expert identification method distinguished 48 vessels as atypical. Both methods combined identified 76 vessels in total, with 16 vessels being identified as atypical by both methods.

The largest group of shape type distinguished in the raw data atypical test is the pilgrim flask, formerly the third most frequent vessel type in the corpus; the frequency of this vessel increased from 18% to constitute 27% of the atypical vessels. The second most prevalent shape in the atypical group is the spherical vessel, composing 16%, previously it occurred in only 5% of the corpus. The third most frequent is the thick-walled krateriskos, that comprises 11% in the atypical group, but only 3% in the corpus. The amphora shape was the fourth most common vessel shape in the corpus at 13% and occurs in 9% of the raw data atypical group. The most prevalent vessels from the corpus, the krateriskos and the kohl tube represented 21% and 18% respectively, however, in the atypical group they represented 7% and 5% of the vessels identified as atypical. Therefore, the krateriskos and the kohl tube show the largest decreases in frequency in the atypical raw data group, and the pilgrim flask and the spherical vessel show the largest increases in frequency in the atypical raw data group. The only two vessels not detected in the atypical group are the merged pilgrim flask & pomegranate vessel and the lotus beaker shape. The expert assessment differed to the raw data test by identifying the amphora shape, krateriskos, kohl tube and pilgrim flask as being the four most prevalent atypical vessel types (in this order), but did not identify any thick-walled krateriskos shape or beaker shaped vessels as being atypical.

The most prevalent ground colour distinguished by the raw data atypical test is dark blue comprising 27%, compared with the pre-test corpus which comprises 40%. The remaining ground colours distinguished in the atypical test differ in frequency to the corpus order; the second most prevalent ground colour is green, which represents 14% of the ground colour, the third most prevalent being white and light blue at 11% each. Therefore, the incidences of green more than triple in the raw data atypical group, white more than doubles in the atypical test, whereas light blue represents almost the same percentage in the atypical group. Mid blue, the second most prevalent corpus ground colour at 29% is seen in only 5% of atypical vessels. The remaining colours ranged from 9% to 2% which included two polychrome vessels and one vessel of unknown colour, meaning that at least one of each colour category is seen in the raw data atypical test. The expert test identified atypical vessels which were primarily dark blue vessels at 54%. The remaining vessels were light blue, mid blue, black, white, green, and yellow: almost identical to the order of prevalence seen in the corpus.

The polychromatic combinations in the raw data test were most prevalent at 61% of the neck rim colour distinguished in the raw data atypical test, whereas it accounted for 21% in the corpus; the two most prevalent colour combinations in the polychromatic group being black and white and blue and white in both the corpus, the raw data test and the expert test. By comparison, the ground colour accounted for 11% of the neck rim colour of the raw data atypical test but accounted for 35% in the corpus. Yellow accounted for 20% in the whole corpus but only accounts for 11% in the raw data atypical group. The expert test also identified vessels that had polychrome neck rims (31%), ground colour (27%), yellow (21%) and white (13%) and respectively as the most prevalent groups in the neck rim category.

27% of handles in the atypical raw data group are made from the ground colour and are therefore the most prevalent. No handles in the atypical group represented the second largest group at 20%. In the corpus, the no handle group and the ground colour group were the most frequent in the corpus at 34% each. Vessels which were recorded as handles 'not present', i.e. vessels which showed evidence of comprising handles, but were no longer surviving on the vessel, was the third largest group at 14% in the corpus, however, in the raw data atypical group, only 5% of vessels are recorded as having handles 'not present'. Dark blue represented 11% in the raw data atypical group, while only comprising 2% in the corpus. The polychrome group represented 18% of the handle occurrence in the raw data test, the most prevalent colour combination was blue and white, comprising of 5% of the handle colour. The most prevalent handle colour of atypical vessels indicated in the expert assessment were made from the ground colour then no handles at 35% and 31% respectively, but the remaining nine categories were seen at 6% or less.

The most common pattern colours in the atypical group were the combinations of white, yellow, and light blue occurring in 25% of the atypical vessels, compared with 28% in the corpus. Vessels that were reported with no pattern applied were noted at 23% in the raw data atypical group and 20% in the corpus. The most prevalent colour combination of pattern in the corpus is the combination of white and yellow, which occurred in 35% of the corpus compared with 18% in the raw data atypical group. Patterns applied singly in white or yellow occur in 5% and 2% of the atypical vessels respectively but each occurred in 2% of the whole corpus. The remaining colours and combinations are noted at 6% or below in the atypical group. In the expert assessment, the two most prevalent patterns were yellow and white at 38% and yellow, white, and light blue at 31%. 'No decoration' and yellow, white, and dark blue both accounted for 8% each of the expert pattern identification, the remaining six categories accounted for 4% or less.

The most prevalent body pattern in the raw data atypical group was the feather pattern at 23%, 'other' and 'no pattern' are the second most common representing 18% of the atypical vessels each, with the garland pattern comprising 17% of the atypical group. In comparison the most common three pattern types in the main corpus were garlands (35%), feather (33%) and none (19%); all other pattern types represented 5% or less. Patterns described as 'other' represented 5% in the vessel corpus. The expert test indicated a total of seven body pattern categories in contrast to the raw data method that indicated nine; the three most prevalent patterns in the expert test were garland, feather, and 'other' at 40%, 27% and 13% respectively, with the remaining four categories accounting for 8% or less per pattern type.

The most common neck decoration group in the raw data atypical vessels group was 'no pattern' and garlands at 20% each, and 'other' at 16%. Zigzag represented 14% of the atypical vessels, with the feather pattern appearing on 11% of atypical vessels. The corpus by comparison showed that the neck pattern fell into four major categories; garlands were most prevalent at 27%, feather 23%, now neck at 22% and no pattern at 19% all others occurred in under 3% of incidents, including 'merged' patterns. The expert assessment for the neck decoration was similar to the body decoration: garlands and feather being the most prevalent respectively at 31% and 27%, with 'no neck' accounting for 21% and 'no pattern' accounting for 10%. Only two other pattern types, 'zig-zag' and 'other', were identified by the expert assessment.

The raw data approach identified four vessels of known origin as atypical whereas the connoisseur's eye method identified only one, equating to a total of five vessels identified of known origin. Overall, the raw data approach identified more atypical vessels as being from the 'origin ambiguous' category, whereas the connoisseur's eye method indicated more atypical vessels as being from private collections (Figure 4 and Figure 5).

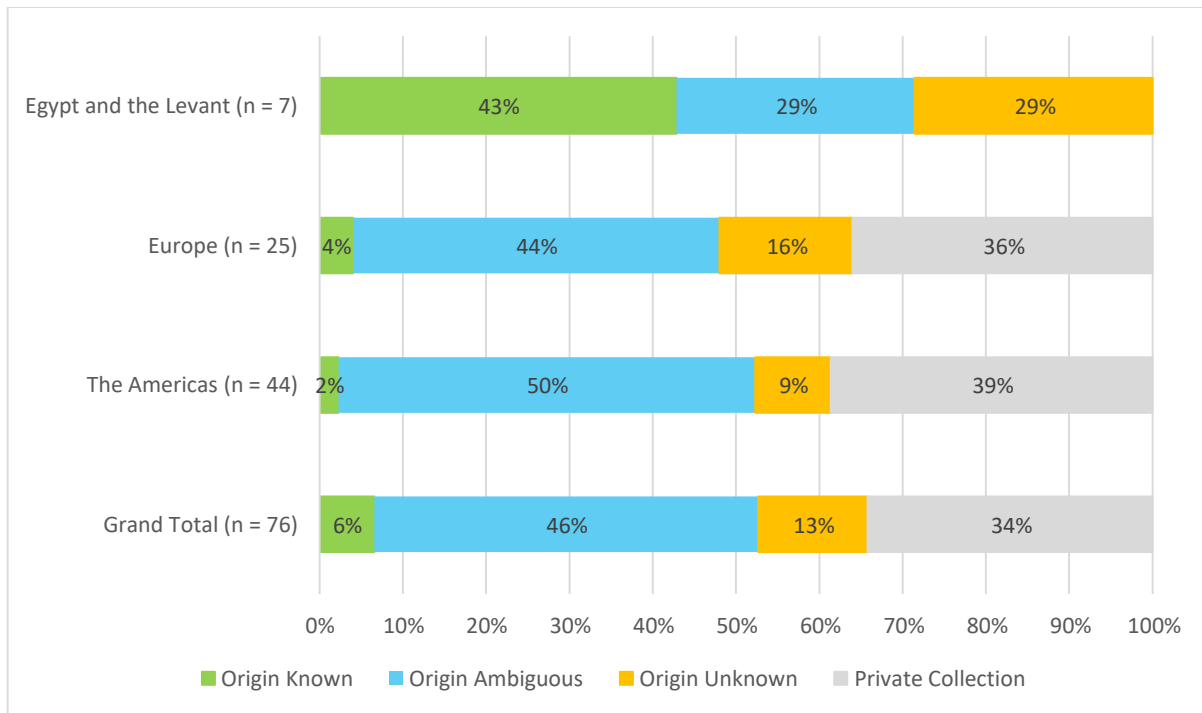


Figure 4. Combined percentages of provenance type by region of atypical vessels using both the raw data method and the connoisseur's eye method.

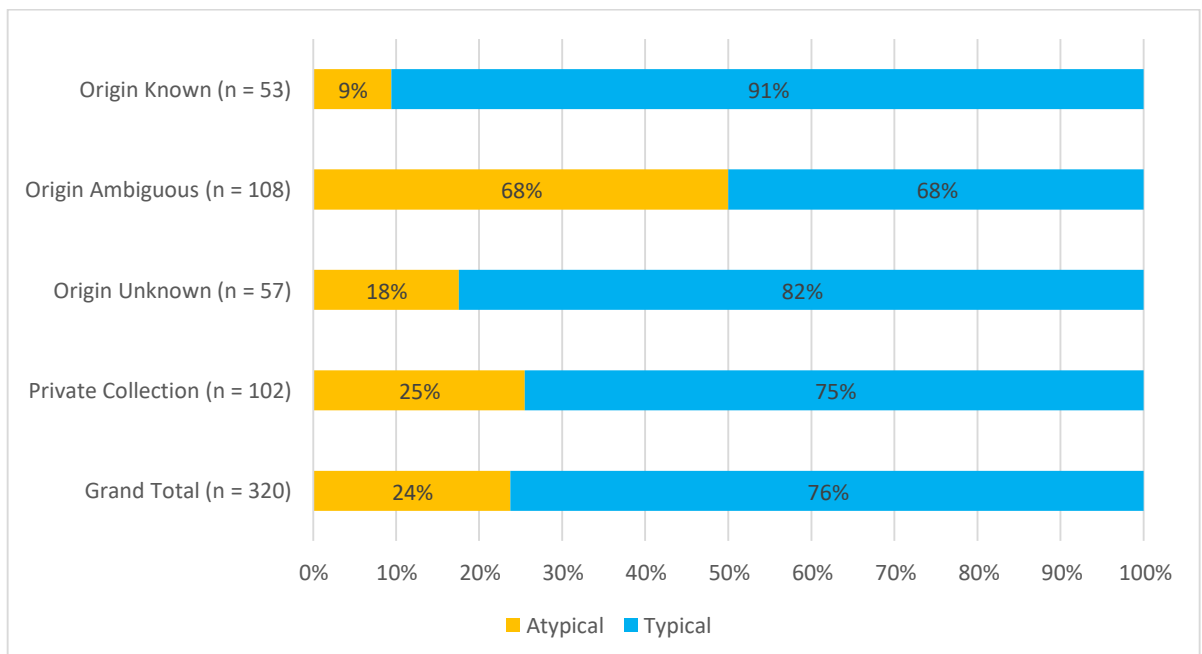


Figure 5. Percentage of provenance category: typical, atypical, and total number of vessels in the experimental group using the connoisseur's eye and raw data methods combined.

Using the combined methods, it was observed that 31% of the total number of vessels currently located in the Americas were identified as atypical, constituting 56% of the total number of atypical vessels in the world. Also, 33% of the atypical vessels are located in the Americas and are of ambiguous or unknown origin. Only 1% of the vessels identified as atypical located in the Americas (constituting one kohlr tube vessel), was of known origin, and this was indicated by the connoisseur's eye method. The Americas also has the largest percentage of atypical vessels held in private collections at 22%. compared with the private collections in Europe that hold 10%, and Egypt and the Levant that have only 1% of atypical vessels (Figure 6).

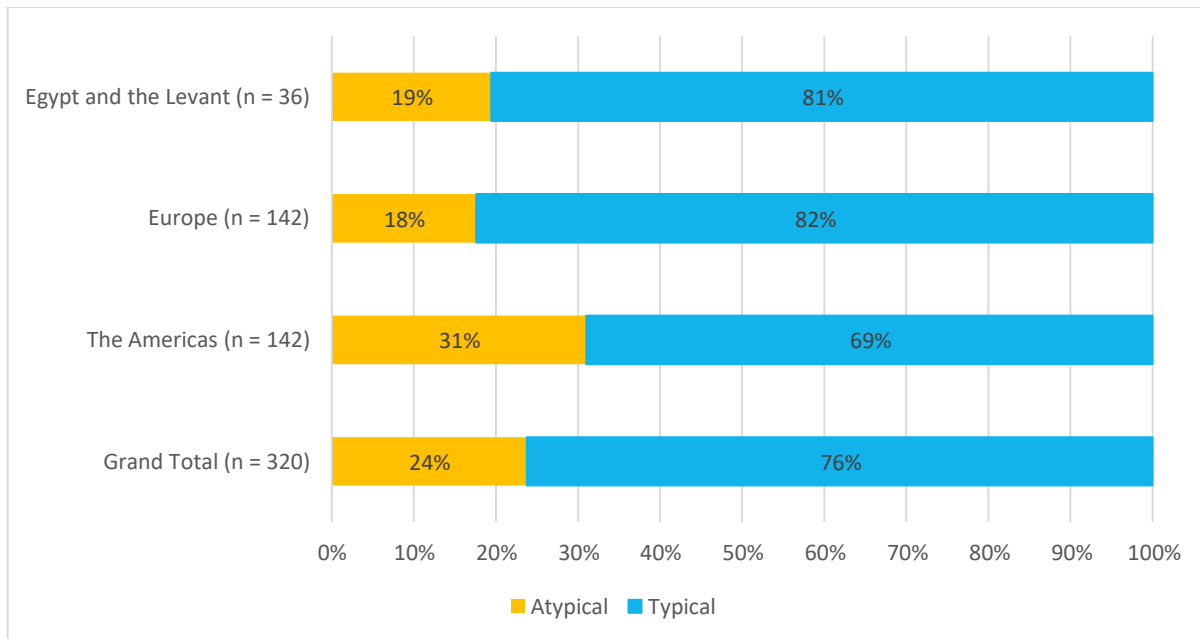


Figure 6. Percentage of atypical and typical vessels by region. Atypical vessels identified by the raw data method and connoisseur's eye method combined.

Egypt has the smallest number of vessels identified as atypical, although three vessels of known origin were indicated by the raw data method. The raw data method identified four vessels of known origin in total: the remaining vessel being located in the United Kingdom, Europe. Three of these vessels have been dated approximately, and are described as having white, brown and polychrome ground colour respectively with two additional atypical features. The remaining vessel of known origin (Cairo museum, 46955) was excavated from the main site of the city of Amarna is arguably a typical 18<sup>th</sup> Dynasty style vessel: described as a dark blue jug with trailed decoration in the feather/garland pattern applied in yellow and white. Dated to the reign of Amenhotep IV (Cairo Museum, 46955), this vessel was noted as atypical from the three 'atypical' features: the colour combination of yellow, white and blue on the rim and handles and the pattern merging from feather to garlands on the body.

The 16 vessels that were indicated as atypical by both methods were all from groups with little or no provenance information: nine vessels being from the origin ambiguous group, four vessels from origin unknown and three vessels from private collections. No vessels from the known origin group were identified from the combined methods. By country, 11 of the atypical vessels indicated by the combined methods are located in the Americas, four in Europe and one in Egypt and the Levant.

### Dating and stylistic trends

This paper focuses primarily on the viability of using complete datasets for the detection and observation of atypical characteristics and the consideration of the respective provenance of vessels attributed to the New Kingdom period. Taking the example of the thick-walled krateriskos (n = 10) and the pomegranate vessel (n = 5) the most prevalent colours are white and green, respectively. Two of these vessels were reliably dated to between the 19<sup>th</sup> dynasty and the 20<sup>th</sup> dynasty, with 13 assigned to *Werkkreis* 4 to 6, spanning a total reign of Tutankhamun to Pinudjem II, therefore it cannot be said if these represent a link between a colour preference for these specific vessel types. Likewise, vessels that exhibit multiple colours in patterns may denote a trend for polychromatic vessels, however, these vessels are relatively evenly distributed over the known reigns of production and *Werkkreis* 1 to 5. The largest group of polychrome patterned vessels belongs to *Werkkreis* 4 that spans the reigns of Tutankhamun (1333-1323 BC) - Ramses II (1290-1224 BC), therefore showing no real statistical significance. Hence, it can be claimed that these epochs are too broad and span considerable periods of political and social change to reliably assign trends to specific reigns or even Dynasties, and may not recognise periods of experimentation as seen in early glass vessel production, of which some vessels are of known origin and can be reliably dated. Therefore, assessing a dataset that spans discrete periods of glassworking institutions and styles, where dating is largely equivocal,

is challenging. Including all data prevents cognitive bias that could be introduced by attempting to refine the dataset, however, this presents limitations which should be considered for future study design.

The composition of ancient glass and associated colourants are well documented and analytical techniques have proven extremely effective in determining the period of glass production from their raw materials. Establishing the period of production would help narrow dating epochs of ancient Egyptian glass vessels, specifically the vessels which are categorised in the broader *Werkkreis* groups that span both the Late Bronze Age (LBA) and Iron Age. Where vessels are of known origin and date, elemental analysis could offer new insights regarding raw material trading including colourants and variances in composition, which would be particularly valuable when examining translucent vessels and those with statistically rare colours. Although non-destructive techniques, such as X-ray fluorescence, are currently used, this is not sensitive enough to detect trace elements which are used to determine provenance in LBA vessels, however, as non-destructive analysis techniques develop to provide greater sensitivity, compositional data can be obtained with little sample preparation and with no risk to the vessel. However, analytical analysis may not be a pragmatic solution for items located in countries with strict legislation, such as Egypt, which prohibits the export of any samples.

### Conclusion

Using the information from *Die Glasgefäße* and applying the raw data test, an ancient Egyptian vessel is statistically more likely to present characteristics typified by vessels produced during the height of the glassmaking industry in the 18<sup>th</sup> dynasty. However, some vessels of known origin do not conform to this ‘statistical ideal’ and should be highlighted and investigated as particularly rare stylistic pieces. Overall, the ‘connoisseurs’ eye’ method appeared to be more discriminatory, identifying fewer attributes per category than the raw data atypical test. This was apparent in the higher percentages (>30%) seen in the top two to three most prevalent attributes per vessel, rather than the raw data atypical test that showed a lower percentage (<30%) in the top four to five categories. Therefore, raw data extracted from detailed descriptions can be useful to help define typical and atypical traits but it does not take into account the aesthetic properties of each vessel or any potential trends throughout the ancient Egyptian glassmaking and glassworking era, therefore, an expert visual analysis should be also be used for appraisal. However, the combined methods were by no means conclusive, only ‘agreeing’ on 16 vessels of the 78 vessels identified as atypical and identifying five vessels of known origin. Therefore, any vessels to be examined should also be subjected to compositional analysis, where appropriate. The Americas were identified as containing the largest number of atypical vessels and the largest proportion of vessels with little or no provenance information, including those vessels that are contained within private collections. Finally, it is not the intention of this research to undermine the authenticity of the vessels identified in this study as atypical, but to articulate the value of the information that has been lost during as a result of poor documentation during historical excavations, and how important information may be gained by subjecting these pieces to archaeometric study.

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