



# Herding cats – Roman to Late Antique glass groups from Bubastis, northern Egypt



D. Rosenow<sup>a,\*</sup>, Th. Rehren<sup>b</sup>

<sup>a</sup>UCL Institute of Archaeology, UK

<sup>b</sup>UCL Qatar, Qatar

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## ABSTRACT

Eighty-seven glass fragments from Roman and Late Antique layers at Tell Basta/Bubastis in the Eastern Nile Delta were typologically evaluated and chemically analysed to determine chronological and compositional patterns of glass use at this important Egyptian city, and how this relates to larger pattern of glass production and consumption in the first half of the first millennium AD. Bubastis is situated in geographical proximity to Alexandria, an important seaport, and at the same time close to the raw glass production areas in the Wadi Natrun and Sinai peninsula. This paper reports the first substantial set of compositional data of Roman to Late Antique glass from a settlement in northern Egypt, filling an important gap in our knowledge of glass consumption pattern in the first half of the first millennium AD. The glass from Bubastis falls into several compositional groups known already from elsewhere in the Roman and Late Antique world, including antimony- and manganese-decoloured glass and two varieties of HIMT glass. Changes in glass composition over more than 500 years are in line with earlier observations concerning changes in prevalence of these glass groups. However, compositional groups known to dominate archaeological glass assemblages elsewhere, such as Roman blue/green during the earlier part of the period under study, or Levantine I in the later period, are notably absent. For the later period, this is probably due to the proximity of Tell Basta to the suspected production region of HIMT glass in northern Sinai/Egypt. By analogy, this might indicate that the earlier Roman blue/green glass has a production origin further away from the Delta than the decolourised glasses prevailing in Bubastis. A particular vessel type, small-volume thick-walled dark green *unguentaria*, is made of probably Egyptian plant ash glass, indicating the existence of a specialised glassmaker during the early first millennium AD.

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## 1. Introduction

The composition of Hellenistic to Byzantine glass is characterised by a surprising degree of fundamental similarity and consistency over more than a thousand years (Sayre and Smith, 1961), which may be explained at least in part by a combination of faithfully maintained traditional recipes using tightly controlled raw materials, and partly by the self-governing behaviour of the melt-forming soda-lime-silica system (Rehren, 2000; Tanimoto and Rehren, 2008). Within this broad homogeneity, however, there are well-developed and long recognized specific compositional groups, characterised by their minor oxide and trace element contents. It is generally assumed that the minor oxide and trace element contents of ancient glass reflect the composition of the sand used in its

production (e.g., Freestone, 2006), while the soda levels are determined by batch recipes. For the first four centuries AD several 'Roman' glass groups have been established, mostly through the analysis of samples from Italy and the Northern provinces (e.g. Jackson, 2005; Silvestri et al., 2008; Foy et al., 2003). The most common glass there is naturally blue/green coloured, with no intentional additives to manipulate its colour; this natural colour is due to the iron impurities in the sand and the prevailing redox conditions in the glassmaking furnace. It is often referred to as 'aqua', to distinguish it from glass intentionally coloured blue or green through the addition of metal oxides. Colourless Roman glass is characterised by the addition either of antimony or manganese oxide to counter-act the colouring effect of iron oxide, or a combination of both oxides (Jackson, 2005; Silvestri et al., 2008; Foster and Jackson, 2010). Antimony-decoloured glass is typically dated earlier than manganese-decoloured glass; substantial data sets have been published, among others, by Paynter (2006) for glass from Britain and Silvestri et al. (2008) from a ship wreck in the

\* Corresponding author.

E-mail address: [d.rosenow@ucl.ac.uk](mailto:d.rosenow@ucl.ac.uk) (D. Rosenow).



**Fig. 1.** The Egyptian Nile Delta showing the position of Bubastis, the Wadi Natrun, Alexandria, Cairo and Sinai peninsula.

northern Adria. Roman blue/green glass is generally considered to be of Levantine origin (Nenna et al., 1997), while decoloured glass is linked to a production in northern Egypt (Nenna, 2007).

For the mid to late first millennium AD, five main compositional glass groups have been identified, mostly through analysis of glasses from the eastern Mediterranean region. These include Egyptian I and II, Levantine I and II and HIMT glass (Freestone et al., 2005). The first four groups can be associated with raw glass production centres in Egypt (Wadi Natrun and Ashmunein; Nenna, 2007) and the Levant (bay of Haifa and Bet Eli'ezer; Gorin-Rosen, 2000), respectively. The production region of HIMT glass cannot be located precisely, but is thought to be in northern Egypt, possibly the northern coast of the Sinai (Foy et al., 2003; Freestone et al., 2005). Levantine and HIMT glass has been discovered at numerous sites and regions throughout the Roman Empire, while published evidence for Egyptian I glass is relatively rare outside Egypt.

Significantly, the major compositional groups have distinct chronological ranges, indicating that each production site only had a limited period of activity, spanning a few centuries. According to Freestone et al. (2000) and Freestone et al. (2005), HIMT was mostly in circulation from the late fourth to the sixth centuries AD, Levantine I during the fourth to seventh centuries AD, Levantine II during the seventh to eighth centuries AD. Egyptian I was in use from an as yet unknown start date up to the eighth century AD, while Egyptian II was the predominant glass in the Levant during the eighth and ninth centuries AD (Freestone et al., 2000). Very little is known, however, about the relative proportions of these various glass groups in northern Egypt, the heartland of early glass making, restricting our ability to discuss the organisation of 1st millennium AD glass making and consumption.

The link between regionally different sand compositions and the minor oxide and trace element content of ancient glass provides a promising tool to explore the relationship between production origin and regions of glass consumption. Two competing models

have been put forward, supporting either a more localised or dispersed system of raw glass production (Wedepohl and Baumann, 2000; Baxter et al., 2005; Degryse and Schneider, 2008; Silvestri et al., 2008; Foster and Jackson, 2010) or a more centralised one (Foy and Jezegou, 1997; Foy et al., 2000; Freestone et al., 2000; Picon and Vichy, 2003; Paynter, 2006; Nenna, 2007). The first model assumes the existence of a range of regional primary glass production centres, not exclusive to the Levant or Egypt, but also including sites in e.g. Italy (Silvestri et al., 2008) or the northern provinces (Wedepohl and Baumann, 2000; Jackson, 2005). The centralised system on the other hand supports the idea of raw glass production on a large scale at only a small number of locations at any one time. From the 4th century AD onward there is good archaeological and compositional evidence for a strongly centralised production of glass in large scale factories on the Eastern Mediterranean shores, both in Egypt and the Levant (Gorin-Rosen, 2000; Freestone et al., 2000; Picon and Vichy, 2003; Nenna, 2007), from where the raw glass would then have been sent as chunks to secondary glass working furnaces across the Empire for artefact production serving local or regional markets. It is less clear, however, whether this system also holds for the first three centuries AD, and this study aims to throw some light on this issue.

## 2. Introduction to the site

The ancient city of Bubastis (Tell Basta) is an Egyptian site of major historical and cultural significance, with continuous occupation ranging from the Old Kingdom (2686–2160 BC) to Late Antiquity (6th century AD). It is situated on the south-eastern edge of Zagazig in the Eastern Nile Delta (Fig. 1), and is best known for its temple dedicated to the Egyptian cat goddess Bastet. Its visible remains date to the Third Intermediate Period (1069–664 BC) and Late Period (664–343 BC) (all dates following Shaw, 2003). Bubastis still played a significant cultic role during Early Ptolemaic times, but at some point after the late 3rd century BC the temple collapsed,



Fig. 2. The ancient site of Bubastis.

probably due to an earthquake. In the aftermath, and certainly during Late Roman times, it was used as a quarry, and its significance as a cultic centre seems to have waned. However, the city continued to be well integrated into the Roman world, as indicated by the presence of numerous imported ceramic vessels.

The Tell Basta Project<sup>1</sup> spent the last six years exploring the area east of the temple, where – following Herodotus' description of the ancient city – the settlement of Bubastis was situated. This area of approximately 40 ha remains completely unexcavated. A survey in 2008 revealed a large number of objects dating to the Graeco-Roman Period, including numerous glass fragments of the Roman and Late Antique periods. Earlier excavations in the zone connecting the temple and the settlement (so-called *Area A*) brought to light remains of a Roman monument (Habachi, 1957, 93–94). To the east and south, remains of domestic and semi-official buildings of red bricks were unearthed, clearly connected to the Roman edifice. These building remains can be ascribed to a period when the temple, after its collapse, had not been in use anymore as a cult place. Only the contexts closest to the Roman limestone monument revealed glass finds, probably belonging to a period of subsequent use or reuse of the temple. The amount of glass discovered in deposits further away is negligible, and probably represents finds that have been accidentally moved during the last centuries; due to their uncertain archaeological origin these are not included in this study.

### 2.1. Glass at Bubastis

About 2500 glass fragments have so far been recorded at Tell Basta. The pieces studied here originate primarily from three

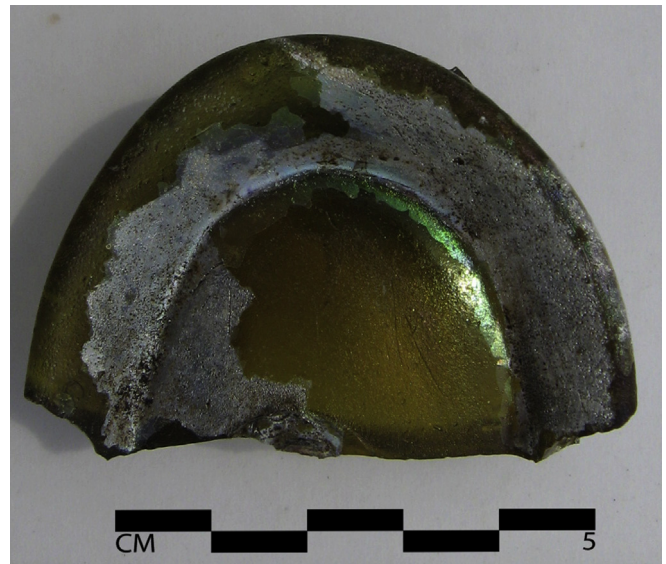


Fig. 3. Base fragment of an oval dish demonstrating the average colour of HIMT glass from Bubastis.

<sup>1</sup> The Tell Basta Project is a German-British-Egyptian Joint Mission and directed by Eva Lange.



Fig. 4. Rim fragment demonstrating the average colour of Sb decol glass from Bubastis.

contexts: the unexplored area east of the temple, the area connecting the temple and the settlement (*Area A*), and the entrance court of the sanctuary (Fig. 2). All glass fragments discovered during the 2008 survey are surface finds and have no specific archaeological contexts.

The overwhelming majority of glass finds, approximately 90%, are from 10 grid squares ( $10 \times 10$  m) in *Area A*, most of them coming from the uppermost layers covering or surrounding the limestone monument and red-brick buildings. They are associated with other artefacts and pottery dating from the 3rd century BC to Late Antiquity. About 10% of the finds have been excavated from the entrance court of the temple of Bastet. These fragments derive also from heavily disturbed contexts, with some associated ceramic finds in deeper deposits dating from the New Kingdom to the 5th century AD.

All glass finds from Tell Basta were studied, recorded, drawn and typologically compared to published parallels; the results of this will be published elsewhere. Fragments include pieces of lamps, beakers, bowls, plates, cups, jugs, bottles, jars, flasks, goblets, oval dishes, and small and large containers. In addition, intensively coloured bracelets, beads and counters/gaming pieces were recovered. The majority of the assemblage belongs to vessel types representing utilitarian ware for daily use. This is consistent with the ceramic evidence from *Area A*, indicating that at this time the temple of Bastet was no longer used as an active place of worship. Luxury glass is thus scarce, with just a few fragments of millefiori glass dishes, facet-cut colourless glass or indented beakers. Only very few pieces can be related to secondary production processes, such as wasters, moils or chunks.

A few fragments represent mould cast vessels such as cast ribbed bowls, plates or bowls made of millefiori glass, or rims and bases from cast bowls and plates. However, free blown glass is by far the most dominant; some vessels are mould blown. The most usual colour within the Bubastis glass is yellowish green to deep olive green to brown, in varying shades and intensities, particularly for the typologically later material (Fig. 3). Among the earlier finds, however, many sherds are pale bluish-greenish ('aqua') to colourless. Some pieces are amber, a few finds are blue, purple or red. Due to the moist environment of the Egyptian Nile delta, corrosion is affecting the majority of glasses, and more so the earlier finds (Fig. 4); the formation of dark brown or whitish crusts can obscure the original colour and transparency of the glass.

Some glass vessels are decorated by single wheel-engraved lines or bands and/or ornaments of applied blobs of blue glass, pinched elements, indents, single applied threads of the same or a different colour below the rim, or incised horizontal lines. One fragment displays facet-cut circular impressions.

The dating of the glass vessels used for this study is based on typology, since most glass was retrieved from disturbed contexts. According to parallels with dated finds from Roman and Late Antique Egypt, such as Mons Porphyrites (Bailey, 2007), Kom el-Dikka (Kucharczyk, 2004, 2006, 2010), Quseir al-Qadim/Myos Hormos (Meyer, 1992; Peacock, 2011), Bagawat (Nenna, 2010; Hill and Nenna, 2003), Ismant el-Kharab (Marchini, 1999), several sites in the Eastern Desert (Brun, 2003a,b, 2011), Karanis (Harden, 1936), Kom el-Nana (Faiers, 2013) or Tebtynis (Nenna, 2000; Foy, 2001), the Bubastis corpus roughly covers a time between the first century BC to the sixth century AD. The majority of the material dates to the second to fourth centuries AD.

### 3. Materials and methods

The main aims of this project are to learn more about the economic position of Bubastis during the Roman and Late Antique periods, and to improve our understanding of the distribution of specific glass compositions in space and time, particularly for Egypt. The project also aims to test the utility of portable XRF analysis to assign glass fragments to specific compositional groups, in order to be able to analyse large assemblages such as this one on site to quantify the relative importance of each glass group over time, while minimising the need for more invasive and time-consuming laboratory-based analyses. Detailed results of this will be presented elsewhere, as this topic is outside the remit of this paper.

#### 3.1. The analysed assemblage

Eighty-seven glass vessel fragments were selected for quantitative analysis, including mould cast, free-blown and mould blown vessels (Table 1). Due to their state of preservation, a few samples could not be typologically identified. In this case, sampling was motivated by the colour of the glass. The majority of the samples are of pale greenish colour, yellow-greenish, green or colourless. Two samples are intentionally coloured blue, four samples are light blue. There is one sample each of pale purple, red-brown, burgundy and brownish pink colour. The low capacity *unguentaria* are made of dark green or bluish-green 'emerald' glass.

Fragments selected for analysis are thought to reflect the whole range of glass vessel types, manufacturing methods and decoration techniques, over the entire period of time when glass finds are attested in Bubastis. With less than five percent of all fragments analysed, and covering a period of more than 500 years, this is necessarily only a pilot study, and the relative proportions of samples reported here are not representative of the types and compositions constituting the total glass assemblage. In particular the early glasses are over-represented in the analysed corpus, with nearly all cast glass and a significant proportion of the visually identified antimony-decoloured glass analysed. In contrast, the vast abundance of late glass, typically of olive green to brown colour, is under-represented among the analyses, even though these pieces make up about two thirds of all analysed material.

#### 3.2. Data generation and handling

EPMA was done on polished cross sections using a JEOL JXA 8100 with three spectrometers. The instrument was operated at 20 kV with a beam current of 6 nA and count times of 10 s on the

**Table 1**  
Catalogue of analysed samples.

<i>Mn decoloured</i>								
Mn 01	TB3a- -Z/3.SCH.1-G009	Skyphos	Handle	Mould cast	Colourless-light purple	1	Isings type 55	1. AD
Mn 02	TB2a-OPQ/2006-G001	Ribbed bowl	Wall	Mould cast	Aqua	7	Isings type 3a	50 BC–130 AD
Mn 03	TB1a-T/8-G001	Bowl	Rim	Mould cast	Colourless	4	Meyer, 1992, pl. 2.26	1./2. AD
Mn 04	TB2b-W/3.SCH.1-G008	Beaker	Rim	Free blown	Colourless	5	Peacock, 2011, 67, Fig. 7.7.77	1./2. AD
Mn 05	TB2b-X/3.SCH.1-G004	Bowl	Rim	Mould cast	Colourless-light green	4	Jennings 2006, 35, Fig. 2.6.5	50 BC–50 AD
Mn 06	TB3b-X/4.SCH.1-G025	Ribbed bowl	Rim	Mould cast	Dark blue	7	Isings type 3b	50 BC–130 AD
<i>Sb decoloured</i>								
Sb 01	TB2b-X/4.SCH.1-G033	Bowl or plate	Base	Technique Mould cast	Colourless-light green	48	Isings type 80	Late 1.–mid 3. AD
Sb 02	TB1a-D/12.2-G001	Flask?	Base with folded (tubular) ring	Free blown	Colourless-light green	103	Isings type 104a	Mid 1.–mid 3. AD
Sb 03	TB3a- -Z/3.SCH.1-G056	Plate	Base	Free blown	Colourless-light green	42	Bailey, 2007, 254, Fig. 8.14.15	Late 1.–late 2. AD
Sb 04	TB1b-X/2.AbH-G022	Bowl	Rim	Mould cast	Colourless	3	Peacock, 2011, 69, Fig. 7.9.106	Late 1.–175 AD
Sb 05	TB3a- -Z/3.BEF.1-G003	Bowl	Base	Free blown	Colourless	103	Brun 2003b, 384, Fig. 8.6	2. half 2. AD
Sb 06	TBXIV-OPQ-G010	Plate	Base	Mould cast	Colourless-light green	48	Bailey, 2007, 238, Fig. 8.2.19	1./2. AD?
Sb 07	TB3a-X/4.SCH.1-G023	Facet-cut beaker?	Wall	Free blown	Light green-colourless	1	Peacock, 2011, 65, Fig. 7.5.62	1./2. AD?
Sb 08	TB3a-Y/3.SCH.1-G060	Beaker?	Base	Free blown	Colourless-light green	37	Bailey, 2007, 247, Fig. 8.8.71	late 1.–2. AD
Sb 09	TB3a-X/2.TS.SCH.1-G012	Flask?	Base with folded (tubular) ring	Free blown	Colourless-light green	103	Isings type 104a	1./2. AD?
Sb 10	TB2b-X/3.SCH.1-G029	Beaker, goblet, sprinkler?	Base with pinched feet	Free blown	Colourless	15	Brun, 2011, 239, Fig. 271.136	2.–6. AD
Sb 11	TB3a- -Z/3.SCH.1-G050	Aryballos	Rim	Free blown	Colourless	5	Bailey, 2007, 256, Fig. 8.15.118	1./2. AD?
Sb 12	TB3b-Y/4.SCH.1-G042	Waster	Base	Free blown	Light green-colourless			unknown
Sb 13	TB1a-T/8-G018	Flask?	Base with folded (tubular) ring	Free blown	Colourless	103	Isings type 104a	1./2. AD
Sb 14	TBXIV-D/7-G001	Cup?	Base with folded (tubular) ring	Free blown	Colourless	103	Isings type 37	1./2. AD
Sb 15	TB2a-X/2.AbH-G007	Plate or bowl?	Base	Free blown (?)	Colourless-light green	42	Peacock, 2011, 74, Fig. 7.13.158	1.–3. AD
Sb 16	TB2a-X/3.SCH.3-G007	Bottle/flask	Rim with applied thread	Free blown	Colourless	72	Isings type 102b	3. AD
Sb 17	TB1b-W/2.SCH.1-G008	Bowl	Base	Mould cast	Colourless-light green	48	Isings type 80	1.–3. AD
Sb 18	TB2b-X/3.SCH.1-G011	Small container	Base	Free blown	Colourless-light green	10	Bailey, 2007, 259, Fig. 8.17.142	1.–4. AD
Sb 19	TB1a-Survey-G024	Small container	Rim	Free blown	Blue	33	Bailey, 2007, 258, Fig. 8.16.135	1./2. AD
<i>Plant ash</i>								
PA 01	TB3b- -Z/3.SCH.1-G001	Mid-capacity unguentarium	Base	Free blown	Green-turquoise	2	Bailey, 2007, 259, Fig. 8.17.141	1./2. AD
PA 02	TBXX-G20093	Mid-capacity unguentarium	Base	Free blown	Green	2	Bailey, 2007, 259, Fig. 8.17.138	1./2. AD
PA 03	TB1a-Survey-G017	Low-capacity unguentarium	Base and body	Free blown	Dark green	4	Bailey, 2007, 261, Fig. 8.18.155	1./2. AD
PA 04	TB1b-W/2.SCH.1-G006	Storage or transport container	Ridged handle	Free blown	Turquoise	6	Bailey, 2007, 262, Figs. 8.19, 165	1.–5. AD
<i>Weak HIMT</i>								
wH 01	TB3a-Y/3.SCH.1-G024	Beaker, jug, goblet, flask?	Base with applied rings	Free blown	Colourless	39	Sternini 1999, 99, Fig. 9.119	4./5. AD
wH 02	TB2a-X/2.SCH.2-G019	Bottle, jug, flask, beaker?	Rim with applied thread	Free blown	Wall (sampled part) light green, ring blue	72	Harden, 1936, pl. XIX, 739	ab 3. AD
wH 03	TB3a- -Z/3.SCH.1-G073	Bottle, jug, flask, beaker?	Base, pinched feet	Free blown	Colourless	15	Harden, 1936, pl. XIX, 682	2.–6. AD
wH 04	TB3a-Survey-G003	Bottle, beaker or flask?	Base, pinched feet, wall indented	Free blown	Green	15	Harden, 1936, pl. XIX, 682	1.–4. AD

Table 1 (continued)

wH 05	TBXX-G20087a	Lamp	Base (pointed)	Free blown	Light green	6	Isings type 106d	From 4. AD
wH 06	TB1b-W/2.SCH.1-G019	Beaker, jug, goblet, flask?	Base with applied rings	Free blown	Light green-colourless	39	Tatton-Brown 1984, 206, Fig. 68.103	4/5. AD
wH 07	TB3a-Z/3.SCH.1-G002	Lamp or beaker	Base (conical hollow)	Free blown	Light green	14	Harden, 1936, pl. XVI, 457	From 4. AD
wH 08	TB3a-Y/3.SCH.1-G002	Bowl	Rim (tubular)	Free blown	Light green-colourless	25	Marchini 1999, 80, Fig. 3 b	1./2. AD
wH 09	TB1a-Survey-G012	Lamp	Base (with solid stem)	Free blown	Light olive green	9	Jennings 2006, 146, Fig. 6.20.11-13	From 4. AD
wH 10	TBXX-G20049	Lamp	Base (pointed)	Free blown	Yellowish green	6	Isings type 106d	From 4. AD
wH 11	TB2a-X/2.AbH-G037	Beaker, jug, goblet, flask?	Base with applied rings	Free blown	Unknown, corroded	39	Tatton-Brown 1984, 206, Fig. 68.103	4/5. AD
wH 12	TB3a-Z/3.SCH.1-G027	Small container	Base	Free blown	Light green	20	Harden, 1936, pl. XX, 799	1.-3. AD
wH 13	TB2a-X/3.SCH.5.BEF.1-G001	Plate or bowl	Base (high footring)	Free blown	Colourless-light green	120	Harden, 1936, pl. XII.83/130	From 4. AD
wH 14	TB2b-W/3.SCH.2-G005	Bottle, jug, flask?	Rim with applied thread	Free blown	Light green	72	Harden, 1936, pl. XIX, 712	From 3. AD
wH 15	TB2b-W/2.AbH-G010	Aryballos	Handle	Free blown	Unknown, corroded	5	Isings type 61	Late 1.-7. AD
wH 16	TB3a-Y/3.SCH.1-G008	Bottle or jug?	Base with applied rings	Free blown	Light olive green	39	Tatton-Brown 1984, 206, Fig. 68.103	4/5. AD
wH 17	TB3a-Y/3.SCH.1-G042	Bottle, flask or jug?	Base with applied ring	Free blown	Wall light green, ring blue	37	Keller 2006, Tafel 21.g	4/5. AD
wH 18	TBXIV-S/2-G013	Goblet	Base and stem	Free blown	Light green	6	Harden, 1936, pl. XVI, 482	5.-7. AD
wH 19	TB3a-Z/3.SCH.1-G001	Goblet, beaker or flask?	Base with applied ring	Free blown	wall colourless-light green, base ring blue (sampled part)	37	Bailey, 1998, pl. 93.Y72	4/5. AD
wH 20	TB1b-OPQ-G009	Oval dish	Rim, tubular	Free blown	Light blue	17	Isings type 97b	3.-5. AD
wH 21	TB1b-OPQ-G006	Bottle, flask, beaker or jug?	Base, pinched feet	Free blown	Light green	15	Harden, 1936, pl. XIX, 682	2.-6. AD
wH 22	TB3a-Z/3.SCH.1-G024	Dish made of mosaic glass	Wall	Cast	Green (sampled) and yellow	3		1.-5. AD
wH 23	TBXIV-G14011	flask/toilet bottle?	neck and rim	free blown	Colourless-light green	5	Nenna, 2010, 210, Fig. 10.34	1.-3. AD
wH 24	TBXIV-OPQ-G005	Beaker, jug, goblet?	Base with applied ring	Free blown	Wall colourless, base ring blue (sampled part)	37	Hill/Nenna, 2001, 91, Fig. 4.4	4/5. AD
wH 25	TB2a-X/2.AbH-G020	Flask/bottle	Base	Free blown	Colourless	70	Isings type 133	1.-4. AD
wH 26	TB1b-W/2.SCH.5-G006	Base indented beaker	Base	Free blown	Unknown, corroded	25	Harden, 1936, pl. XV, 376	1.-4. AD
wH 27	TB3b-X/4.Steg-G011	Jug, flask, bowl?	Base (high footring)	Free blown	Reddish brown	120	Harden, 1936, pl. XIV.274	4.-7. AD
wH 28	TB3a-X/4.SCH.1-G027	Bowl	Stem	Free blown	Purple-red	17	Harden, 1936, pl. XV, 360	4/5. AD
wH 29	TB3a-Z/3.SCH.1-G028	Cup or bowl	Rim (inturned)	Free blown	Light blue	35	Nenna, 2000, 23, Fig. 9.4	From 4. AD
<i>HIMT</i>								
H 01	TB3b-V/3.SCH.1-G159	Bowl or beaker?	Wall	Mould blown	Unknown, corroded	33	Harden, 1936, pl. XIII, 217	4/5. AD
H 02	TB2b-X/3.BEF.1-G005	Lamp	Base (pointed)	Free blown	Light green-colourless	6	Isings type 106d	From 4. AD
H 03	TB2b-X/3.BEF.1-G010	????	Wall	Mould blown	Colourless-light green	33		2.-4. AD
H 04	TB2b-X/3.SCH.1-G040	Bowl or beaker?	Wall	Mould blown	Green	25	Harden, 1936, pl. XIII, 189, pl. XV, 409	Unknown
H 05	TB2a-M/1.SCH.1-G015	???	Wall (with cut decoration)		Colourless	2		Unknown
H 06	TB2b-X/3.SCH.3-G009	Conical lamp or beaker	Rim	Free blown	Green	90	Isings type 106d	From 4. AD
H 07	TB1a-W/2.AbH-G007	Stemmed bowl	Stem	Free blown	Green	17	Harden, 1936, pl. XV, 358	4/5. AD
H 08	TB2b-X/3.SCH.1-G016	Hemispherical bowl or cup	Rim	Free blown	Light green-colourless	20	Isings type 96	From 4. AD
H 09	TBXX-G20041	Oval dish	Base	Free blown	Olive green	17	Isings type 97b	3.-5. AD
H 10	TB2b-W/3.SCH.3-G008	Bowl or drinking vessel	Base (high footring)	Free blown	Light green	120	Harden, 1936, pl. XV, 360	From 4. AD
H 11	TBXX-G20008b	Lamp	Base (with twisted blob)	Free blown	Light green	6	Kucharczyk, 2006, 48, Fig. 1.4	From 4. AD
H 12	TB2a-W/3.SCH.4-G001	Bowl or flask?	Base (high footring, wavy)	Free blown	Olive green	2	Harden, 1936, pl. XIX, 672	From 4. AD
H 13	TBXX-G20026	Lamp or beaker	Base (conical hollow)	Free blown	Green	14	Harden, 1936, pl. XVI, 457	From 4. AD

(continued on next page)

Table 1 (continued)

H 14	TB3a-Y/3.SCH.1-G039	Bowl	Rim (horizontal)	Free blown	Olive green	4	Harden, 1936, pl. XII, 130	From 4. AD
H 15	TB3a-Y/3.SCH.1-G033	Bowl	Rim (edge going up)	Free blown	Light green	10	Nenna, 2000, 23, Fig. 9.2	From 4. AD
H 16	TB1a-V/2.AbH-G189	Transport or storage container	Handle (ridged)		Light green	6		
H 17	TB2b-OPQ-G014	Bowl	Rim	Optical blown	Olive green	4	Harden 1936, pl. XXIV, 256	From 4. AD
H 18	TB3b-V/3.SCH.1-G172	Bowl	Rim	Free blown	Pinkish brown	1	See drawing	Mid 4.-mid 5. AD
H 19	TB2a-X/2.SCH.1-G054	Conical lamp or beaker	Rim	Free blown	Green	90	Isings type 106d	From 4. AD
H 20	TB3a-Y/3.SCH.1-G093	Beaker/jug/flask?	Base with applied rings	Free blown	Green	39	Tatton-Brown 1984, 206, Fig. 68.103	4./5. AD
H 21	TB3a-Y/3.SCH.1-G017	Cup or bowl	Rim (strongly everted)	Free blown	Light olive green	15	Tatton-Brown 1994, 283, Fig. 15.1.5	From 4. AD
H 22	TB1a-T/8-G003	Cup or bowl	Rim (horizontal)	Free blown	Green	4	Weinberg 1988, 52, Figs. 4-12.95	4.-6. AD
H 23	TB1b-W/2.SCH.3-G006	Flask	Neck	Free blown	Light green-yellowish	26	Isings type 133	Unknown
H 24	TBXX-G20008c	Bowl	Base with folded (tubular) ring	Free blown	Yellowish green	103	Harden, 1936, pl. XIV, 245	4. AD
H 25	TB1b-X/2.AbH-G119	Bottle	Wall	Mould blown	Olive green	25	Harden, 1936, pl. XIX, 700 and 701	4. AD
H 26	TB1a-V/2-G005	Amphora?	Handle (ridged)		Green	6		4.-5. AD
H 27	TB3a-X/2.TS.SCH.3-G001	Conical lamp or beaker?	Wall	Free blown	Wall light green (sampled part), blue blob	18	Kucharczyk, 2006, 48, Fig. 1.15	From 4. AD
H 28	TB2a-X/2.AbH-G047	Bowl	Rim (tubular)	Free blown	Olive green	7	Harden, 1936, pl. XII, 89	4.-7. AD
ukn	TB1a-D/11.SCH.3-G004	Stemmed goblet	Stem	Free blown	Aqua	6	Sternini 1999, 95, Fig. 6.67	From 4. AD

peak position and 5 s on the background positions. Soda loss during analysis was prevented by scanning the beam over the area visible at 800 times magnification. Table 2 reports the results of measurements of Corning A and B reference glasses analysed together with the Bubastis samples. For most oxides the measured values are within 5% of the published values; however, alumina and phosphorus oxide were consistently analysed lower than the published values, while antimony oxide was measured higher by about one third (20 and 40% in Corning A and B, respectively) of the published value (Brill 1999). No adjustment has been made for these systematic deviations in the reported data in Table 3. Concentrations of antimony oxide need to be treated with caution, and values below 0.3 wt% are not reported; these may well reflect analytical error rather than real presence of this compound.

The glasses were sorted into compositional groups based on minor oxide concentrations. Typical values for published glass groups of the oxides of aluminium, calcium, titanium, manganese and antimony informed a first allocation of the newly-analysed

samples to the known groups; this was then further refined by checking the levels of the remaining minor oxides for consistency with those typically found in the established compositional groups, re-allocating samples as necessary to obtain a subjective best fit. All but one sample were thus allocated to specific compositional groups.

#### 4. Results

Eighty-three of the eighty-seven samples are mineral-natron based soda-lime-silica glasses (Table 3), while four fragments appear to be made from plant ash glass. Among the mineral natron glasses, four main groups dominate: Manganese-decoloured (6), antimony-decoloured (19, including one coloured blue by cobalt), weak HIMT (29) and strong HIMT (28). A single pale-coloured stemmed goblet cannot be attributed to any of these groups, but stands compositionally alone. The main groups are presented below in chronological order as listed in Table 1, with the plant-ash

**Table 2**  
Comparison of published compositions for Corning A and B (Brill 1999: 544) and the average values of 7 measurements of Corning A and B during the course of the analysis of the Tell Basta samples. The precision of the analyses is indicated by the standard deviation among the seven individual analyses for each of the Corning glasses, while the accuracy is expressed by the deviation of the analysed value  $C_a$  from the published composition  $C_p$ . This  $\delta$  rel% value is calculated using the formula  $(C_a - C_p)/C_p * 100$ .

	SiO <sub>2</sub>	Na <sub>2</sub> O	CaO	K <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	Sb <sub>2</sub> O <sub>5</sub>	MnO	CuO	P <sub>2</sub> O <sub>5</sub>	Cl	SO <sub>3</sub>	Analytical total
Cor A published	66.56	14.30	5.03	2.87	2.66	1.00	1.09	0.79	1.76	1.00	1.17	0.13			99.53
Cor A aver (n = 7)	67.08	14.16	4.92	2.78	2.59	0.91	1.03	0.78	2.12	0.97	1.19	0.09	0.09	0.15	99.87
StdDev	0.61	0.11	0.03	0.03	0.03	0.02	0.02	0.01	0.04	0.00	0.04	0.01	0.01	0.01	0.67
$\delta$ rel%	0.8	-1.0	-2.2	-3.1	-2.6	-9.0	-5.5	-1.3	20.5	-3.0	1.7	-30.8			
Cor B published	61.55	17.00	8.56	1.00	1.03	4.36	0.34	0.09	0.46	0.25	2.66	0.82	0.20	0.54	99.98
Cor B aver (n = 7)	62.18	17.08	8.43	0.99	1.00	4.15	0.33	0.09	0.64	0.21	2.70	0.69	0.17	0.54	100.04
StdDev	0.47	0.29	0.07	0.03	0.01	0.10	0.03	0.01	0.01	0.03	0.05	0.03	0.01	0.02	0.83
$\delta$ rel%	1.0	0.5	-1.5	-1.0	-2.9	-4.8	-2.9	1.1	39.1	-16.0	1.5	-15.9	-15.0	0.0	

**Table 3**

EPMA analyses of glass samples from Bubastis, data in weight percent. Cobalt, tin and lead were analysed for, but not found at levels above 300 mg/g (500 mg/g for lead).

	SiO <sub>2</sub>	Na <sub>2</sub> O	CaO	K <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	FeO	TiO <sub>2</sub>	Sb <sub>2</sub> O <sub>5</sub>	MnO	CuO	P <sub>2</sub> O <sub>5</sub>	Cl	SO <sub>3</sub>	Analytical total
Mn 01	66.6	16.4	8.10	0.52	0.53	2.03	0.27	0.05	<0.3	0.86	<0.03	0.08	0.68	0.32	96.7
Mn 02	69.2	15.1	7.28	0.65	0.42	2.13	0.28	0.04	<0.3	0.46	0.03	0.11	0.96	0.14	96.8
Mn 03	66.8	16.6	8.68	0.53	0.65	2.13	0.33	0.05	<0.3	1.13	0.03	0.07	1.13	0.18	98.4
Mn 04	68.5	14.5	7.62	0.45	0.60	2.49	0.32	0.06	<0.3	1.30	<0.03	0.06	0.92	0.21	97.0
Mn 05	67.7	15.6	7.43	0.87	0.94	2.25	0.34	0.05	<0.3	1.14	<0.03	0.09	0.82	0.19	97.7
Mn 06	67.6	17.8	9.21	0.59	0.55	2.44	1.17	0.04	<0.3	1.11	0.07	0.10	0.83	0.29	100.9
Average	<b>67.7</b>	<b>16.0</b>	<b>8.05</b>	<b>0.60</b>	<b>0.62</b>	<b>2.25</b>	<b>0.31</b>	<b>0.05</b>	<b>&lt;0.03</b>	<b>1.00</b>	<b>0.02</b>	<b>0.08</b>	<b>0.89</b>	<b>0.22</b>	<b>97.9</b>
StDev	<b>1.0</b>	<b>1.2</b>	<b>0.76</b>	<b>0.15</b>	<b>0.18</b>	<b>0.18</b>	<b>0.35</b>	<b>0.00</b>	<b>0.30</b>	<b>0.03</b>	<b>0.02</b>	<b>0.02</b>	<b>0.15</b>	<b>0.07</b>	<b>1.6</b>
Sb 01	71.3	17.9	5.11	0.42	0.48	1.91	0.33	0.04	0.8	<0.03	<0.03	0.03	1.23	0.24	99.7
Sb 02	69.1	17.6	5.96	0.45	0.44	1.81	0.31	0.06	0.5	<0.03	<0.03	0.03	1.11	0.26	97.6
Sb 03	69.9	16.5	5.67	0.41	0.48	1.88	0.34	0.07	0.5	<0.03	<0.03	0.03	1.06	0.21	97.0
Sb 04	69.2	17.3	6.44	0.46	0.50	1.77	0.37	0.08	0.8	0.04	<0.03	0.03	0.96	0.27	98.2
Sb 05	70.8	16.0	5.67	0.46	0.43	1.86	0.36	0.08	0.6	<0.03	<0.03	0.02	1.01	0.20	97.4
Sb 06	68.5	18.1	5.90	0.68	0.50	1.87	0.40	0.07	0.7	0.03	<0.03	0.04	1.04	0.24	98.1
Sb 07	69.5	17.7	6.92	0.55	0.49	1.97	0.41	0.06	0.9	<0.03	0.05	0.04	1.08	0.33	99.9
Sb 08	67.7	17.1	6.23	0.65	0.60	1.98	0.52	0.06	0.7	0.07	<0.03	0.07	1.02	0.25	96.9
Sb 09	66.1	17.5	6.58	0.54	0.59	1.98	0.49	0.07	0.7	<0.03	<0.03	0.05	1.05	0.31	95.9
Sb 10	65.9	18.0	8.27	0.39	0.60	1.91	0.48	0.09	0.4	<0.03	<0.03	0.03	0.93	0.35	97.3
Sb 11	68.6	18.5	6.47	0.51	0.58	2.08	0.50	0.10	0.8	0.03	<0.03	0.05	1.03	0.30	99.5
Sb 12	66.1	17.6	6.87	0.54	0.61	2.04	0.53	0.10	0.7	0.03	<0.03	0.06	1.07	0.33	96.6
Sb 13	68.1	16.8	7.83	0.54	0.67	2.15	0.51	0.10	0.7	<0.03	<0.03	0.04	0.98	0.32	98.8
Sb 14	68.3	16.9	7.34	0.68	0.58	2.21	0.64	0.10	1.1	<0.03	<0.03	0.04	0.87	0.29	99.1
Sb 15	66.3	17.4	8.55	0.53	0.79	2.09	0.62	0.10	0.5	<0.03	<0.03	0.05	0.83	0.34	98.2
Sb 16	66.0	18.4	8.42	0.58	0.76	2.23	0.58	0.11	0.5	<0.03	<0.03	0.05	0.89	0.34	98.9
Sb 17	65.9	17.1	8.22	0.51	0.71	2.31	0.62	0.11	0.6	<0.03	<0.03	0.04	1.02	0.31	97.4
Sb 18	71.5	16.0	5.81	0.46	1.05	2.30	0.61	0.12	0.8	0.03	0.03	0.03	0.97	0.21	99.8
Sb 19	71.3	14.2	7.67	0.61	0.43	2.50	1.31	0.06	0.8	0.05	0.21	0.06	0.46	0.38	100.2
Average	<b>68.4</b>	<b>17.2</b>	<b>6.84</b>	<b>0.53</b>	<b>0.59</b>	<b>2.0</b>	<b>0.48</b>	<b>0.08</b>	<b>0.7</b>	<b>0.02</b>	<b>0.01</b>	<b>0.04</b>	<b>0.98</b>	<b>0.29</b>	<b>98.2</b>
StDev	<b>2.0</b>	<b>1.0</b>	<b>1.07</b>	<b>0.09</b>	<b>0.15</b>	<b>0.20</b>	<b>0.22</b>	<b>0.02</b>	<b>0.2</b>	<b>0.02</b>	<b>0.05</b>	<b>0.01</b>	<b>0.16</b>	<b>0.05</b>	<b>1.26</b>
PA 01	63.4	18.5	6.59	1.15	1.44	2.09	0.81	0.12	0.6	0.47	<0.03	0.37	0.99	0.29	96.8
PA 02	65.2	16.9	6.05	1.49	3.39	1.76	1.05	0.16	<0.3	1.55	<0.03	1.10	1.07	0.21	100.2
PA 03	62.3	18.2	7.00	1.34	2.53	1.97	1.17	0.16	0.5	1.05	<0.03	0.73	1.10	0.26	98.3
PA 04	64.7	14.3	8.85	1.75	2.30	1.85	1.09	0.11	0.5	0.22	0.03	0.59	1.00	0.20	97.4
Average	<b>63.9</b>	<b>17.0</b>	<b>7.12</b>	<b>1.43</b>	<b>2.41</b>	<b>1.92</b>	<b>1.03</b>	<b>0.14</b>	<b>0.5</b>	<b>0.82</b>	<b>0.01</b>	<b>0.70</b>	<b>1.04</b>	<b>0.24</b>	<b>98.15</b>
StDev	<b>1.3</b>	<b>1.9</b>	<b>1.22</b>	<b>0.25</b>	<b>0.80</b>	<b>0.14</b>	<b>0.15</b>	<b>0.03</b>	<b>0.2</b>	<b>0.60</b>	<b>0.01</b>	<b>0.31</b>	<b>0.05</b>	<b>0.04</b>	<b>1.47</b>
wH 01	70.7	17.0	5.77	0.42	0.54	1.77	0.49	0.09	<0.3	1.16	<0.03	0.02	1.01	0.24	99.2
wH 02	69.1	17.9	5.32	0.41	0.68	1.99	0.66	0.12	<0.3	1.26	<0.03	0.02	1.20	0.17	98.8
wH 03	69.4	18.2	6.04	0.38	0.86	2.10	0.56	0.09	0.3	0.54	0.03	0.02	1.07	0.23	99.7
wH 04	68.3	18.2	7.45	0.40	0.82	2.04	0.60	0.09	<0.3	0.45	0.03	0.07	1.27	0.21	99.9
wH 05	67.0	20.0	6.86	0.46	0.76	1.97	0.58	0.10	<0.3	1.15	<0.03	0.04	0.97	0.40	100.3
wH 06	65.2	18.8	7.57	0.52	0.81	2.32	0.76	0.11	<0.3	0.49	<0.03	0.05	1.27	0.30	98.2
wH 07	68.3	18.8	6.25	0.50	0.87	2.23	0.81	0.11	<0.3	0.94	<0.03	0.05	1.23	0.27	100.4
wH 08	65.2	17.2	7.93	0.57	0.86	2.11	0.76	0.11	<0.3	1.36	<0.03	0.10	0.84	0.42	97.5
wH 09	65.6	18.4	7.47	0.51	0.97	2.01	0.70	0.12	<0.3	1.28	<0.03	0.07	1.04	0.32	98.6
wH 10	66.3	17.6	8.79	0.71	1.13	2.44	0.98	0.12	<0.3	1.42	0.04	0.14	0.89	0.38	101.1
wH 11	66.3	16.9	7.26	0.55	0.98	2.24	0.81	0.12	<0.3	1.25	0.51	0.10	1.08	0.20	98.3
wH 12	65.9	18.7	5.93	0.49	0.82	2.20	0.74	0.12	<0.3	0.98	<0.03	0.07	1.11	0.28	97.4
wH 13	65.4	17.6	7.25	0.52	0.84	1.96	0.61	0.13	<0.3	1.77	<0.03	0.07	0.86	0.33	97.4
wH 14	68.7	17.9	5.62	0.49	0.68	2.19	0.77	0.13	<0.3	1.65	<0.03	0.13	1.12	0.24	99.7
wH 15	67.2	16.9	7.57	0.68	0.98	2.40	0.91	0.14	<0.3	1.69	<0.03	0.07	0.80	0.35	99.8
wH 16	65.8	17.1	8.28	0.65	1.02	2.30	0.73	0.14	<0.3	1.59	0.03	0.07	0.78	0.32	99.0
wH 17	66.0	16.7	7.19	0.43	1.14	2.66	1.08	0.15	0.3	0.27	2.78	0.06	1.00	0.26	100.1
wH 18	65.0	17.9	7.56	0.69	1.04	2.38	0.95	0.15	<0.3	1.33	<0.03	0.09	0.84	0.36	98.5
wH 19	62.4	17.1	5.88	0.52	0.98	2.20	0.88	0.15	0.3	0.83	5.88	0.08	0.95	0.34	98.6
wH 20	66.4	17.6	8.52	0.81	1.02	2.39	0.81	0.16	<0.3	0.92	<0.03	0.16	0.74	0.36	100.2
wH 21	66.6	18.0	6.50	0.57	0.79	2.53	0.92	0.17	0.4	0.23	<0.03	0.09	0.99	0.37	98.0
wH 22	61.3	18.0	8.06	0.69	1.37	2.62	1.15	0.17	0.4	0.14	2.40	0.20	1.14	0.31	99.3
wH 23	66.1	17.8	7.48	0.54	0.85	2.53	0.74	0.18	0.8	0.01	<0.03	0.03	1.03	0.29	98.4
wH 24	67.9	17.4	4.63	0.47	0.97	2.96	1.00	0.18	<0.3	1.17	0.55	0.04	1.02	0.15	98.5
wH 25	64.2	17.9	8.88	0.55	1.17	2.82	0.88	0.19	0.6	0.58	0.03	0.08	0.99	0.28	99.1
wH 26	63.2	17.4	9.73	0.61	1.20	2.82	1.00	0.20	0.6	0.60	<0.03	0.11	1.05	0.32	98.8
wH 27	66.0	18.2	6.55	0.41	0.95	2.26	0.91	0.22	<0.3	2.01	0.03	0.04	1.04	0.22	99.0
wH 28	63.1	17.7	7.01	0.65	1.01	2.43	1.11	0.25	<0.3	2.43	<0.03	0.07	0.95	0.28	97.2
wH 29	64.7	19.7	7.04	0.56	0.85	2.34	1.14	0.26	<0.3	0.89	<0.03	0.10	0.89	0.40	98.9
Average	<b>66.1</b>	<b>17.9</b>	<b>7.12</b>	<b>0.54</b>	<b>0.93</b>	<b>2.32</b>	<b>0.83</b>	<b>0.15</b>		<b>1.05</b>		<b>0.08</b>	<b>1.01</b>	<b>0.30</b>	<b>99.00</b>
StDev	<b>2.1</b>	<b>0.8</b>	<b>1.16</b>	<b>0.11</b>	<b>0.17</b>	<b>0.28</b>	<b>0.18</b>	<b>0.04</b>		<b>0.58</b>		<b>0.04</b>	<b>0.14</b>	<b>0.07</b>	<b>0.99</b>
H 01	66.1	19.3	5.95	0.44	1.04	2.34	1.07	0.30	<0.3	1.85	0.05	0.05	1.17	0.25	100.0
H 02	63.9	18.5	6.05	0.41	0.99	2.33	1.12	0.33	<0.3	1.80	<0.03	0.04	1.11	0.24	96.9
H 03	64.9	19.7	6.08	0.42	1.04	2.40	1.15	0.32	<0.3	1.91	<0.03	0.05	1.14	0.28	99.4

(continued on next page)



Table 3 (continued)

	SiO <sub>2</sub>	Na <sub>2</sub> O	CaO	K <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	FeO	TiO <sub>2</sub>	Sb <sub>2</sub> O <sub>5</sub>	MnO	CuO	P <sub>2</sub> O <sub>5</sub>	Cl	SO <sub>3</sub>	Analytical total
H 04	64.4	18.2	5.60	0.28	1.07	2.45	1.16	0.41	<0.3	2.07	<0.03	0.04	1.23	0.15	97.1
H 05	68.4	17.6	5.32	0.40	0.83	2.57	1.31	0.40	<0.3	1.98	<0.03	0.05	1.03	0.19	100.1
H 06	67.8	17.4	5.40	0.39	0.81	2.53	1.37	0.37	<0.3	1.52	<0.03	0.05	1.06	0.22	98.9
H 07	63.8	19.0	5.50	0.36	0.99	2.69	1.37	0.51	<0.3	2.30	<0.03	0.03	1.08	0.25	97.8
H 08	63.0	19.8	4.89	0.33	0.97	2.65	1.43	0.54	<0.3	2.25	<0.03	0.05	1.07	0.27	97.3
H 09	64.8	18.2	5.43	0.34	0.78	2.61	1.49	0.47	<0.3	2.25	0.03	0.04	1.07	0.25	98.3
H 10	65.8	16.0	5.51	0.44	1.18	2.69	1.50	0.46	<0.3	2.45	<0.03	0.03	0.92	0.21	97.4
H 11	62.9	18.5	5.56	0.42	1.06	2.69	1.51	0.45	<0.3	2.05	<0.03	0.05	1.03	0.22	96.5
H 12	64.8	17.0	6.05	0.43	1.01	2.57	1.55	0.64	<0.3	2.54	<0.03	0.04	0.84	0.26	97.9
H 13	63.3	19.6	5.74	0.36	1.06	2.67	1.56	0.53	<0.3	2.17	0.03	0.06	1.14	0.23	98.5
H 14	62.4	18.4	6.65	0.37	1.11	2.64	1.58	0.41	<0.3	2.41	<0.03	0.06	0.97	0.24	97.2
H 15	65.6	17.8	5.60	0.43	1.00	3.00	1.58	0.62	<0.3	2.01	0.03	0.04	0.81	0.27	98.9
H 16	63.7	17.8	6.48	0.55	1.08	2.63	1.71	0.43	<0.3	1.95	0.04	0.09	0.87	0.31	97.9
H 17	66.1	16.8	6.34	0.45	1.02	2.62	1.71	0.53	<0.3	2.74	0.03	0.05	0.87	0.24	99.5
H 18	66.2	18.9	5.29	0.49	0.71	2.45	1.73	0.31	<0.3	2.13	0.04	0.08	0.98	0.32	99.6
H 19	66.6	16.6	4.97	0.42	1.20	3.13	1.77	0.72	<0.3	2.77	<0.03	0.04	1.00	0.18	99.5
H 20	63.9	17.5	6.00	0.51	1.07	2.70	1.78	0.78	<0.3	1.86	<0.03	0.05	0.86	0.29	97.3
H 21	62.9	19.9	5.91	0.40	1.12	2.77	1.78	0.60	<0.3	1.96	<0.03	0.06	1.06	0.23	98.7
H 22	64.7	18.4	5.57	0.47	1.17	2.97	1.79	0.53	<0.3	2.13	<0.03	0.05	0.99	0.23	99.1
H 23	63.3	19.0	5.94	0.49	1.19	3.01	2.56	0.52	<0.3	1.49	<0.03	0.09	0.83	0.45	98.9
H 24	62.7	18.1	6.26	0.40	1.18	2.78	2.87	0.58	<0.3	2.05	<0.03	0.09	0.86	0.29	98.4
H 25	66.2	18.0	4.93	0.44	1.02	2.82	3.01	0.31	<0.3	0.90	<0.03	0.11	1.07	0.26	99.1
H 26	63.4	18.5	5.79	0.41	1.27	2.96	3.01	0.55	<0.3	1.50	0.03	0.08	1.01	0.24	98.7
H 27	65.7	18.0	5.37	0.45	0.96	2.98	3.27	0.67	<0.3	0.96	<0.03	0.14	0.91	0.26	99.7
H 28	65.9	15.8	5.46	0.39	0.95	2.88	3.76	0.61	<0.3	2.18	<0.03	0.19	0.89	0.18	99.4
Average	<b>64.8</b>	<b>18.1</b>	<b>5.70</b>	<b>0.42</b>	<b>1.03</b>	<b>2.70</b>	<b>1.84</b>	<b>0.50</b>	<b>&lt;0.3</b>	<b>2.01</b>	<b>0.02</b>	<b>0.06</b>	<b>0.99</b>	<b>0.25</b>	<b>98.50</b>
StDev	<b>1.6</b>	<b>1.1</b>	<b>0.45</b>	<b>0.06</b>	<b>0.13</b>	<b>0.21</b>	<b>0.71</b>	<b>0.13</b>	<b>0.44</b>	<b>0.01</b>	<b>0.01</b>	<b>0.04</b>	<b>0.11</b>	<b>0.06</b>	<b>1.02</b>
Ukn	72.0	16.3	4.95	0.60	0.55	2.82	0.47	0.07	<0.3	0.01	0.02	0.06	0.90	0.13	98.9

based glass group set between the antimony- and manganese-decoloured and the two HIMT groups, respectively.

The six manganese-decoloured glasses are all but one from cast vessels. They have between 0.5 and 1.3 wt% manganese oxide. Compared to the antimony-decoloured glass, they have higher calcium oxide, alumina and phosphorus, and significantly lower levels of iron oxide and titania.

The antimony-decoloured glass has between half and one percent antimony oxide, and relatively low levels of calcium oxide (5–8.5 wt%) and alumina (typically around 2 wt%, reaching up to 2.5 wt%). Potash, magnesia and iron oxide are all around half of a percent, and titania from 0.05 to 0.11 wt%. This closely matches data

published by Paynter (2006), Silvestri (2008) and Schibille (2011) for contemporary antimony-decoloured glass found in Britain, northern Italy and Albania.

Four glasses have higher potash (1.2–1.8 wt% K<sub>2</sub>O), magnesia (1.4–3.4 wt% MgO), and very high phosphorus oxide (0.4–1.1 wt% P<sub>2</sub>O<sub>5</sub>) compared to both the early and later glasses. These elevated values are the reason for interpreting the glass as plant-ash based, in line with arguments developed first by Brill (1970) for Egyptian Late Bronze Age glass. Alternatively, the elevated levels could originate from contamination by fuel ash during extended periods of heating (Paynter, 2008; Rehren et al., 2010: 75–76, Schibille, 2011: 2940); further research is necessary to understand this issue better.

The 'weak HIMT' group has from 0.5 to 1.1 wt% iron oxide, from 0.1 to 0.2 wt% titania, and typically between 0.5 and 2 wt% manganese oxide. Its calcium oxide content ranges from about 6 to about 9 wt%, and alumina ranges from 2 to 3 wt%. Potash concentrations are around one half of a percent, while magnesia is as high as iron oxide – around one percent by weight. This compositional pattern clearly differs from typical HIMT glass; in particular, the calcium oxide levels are too high by comparison, and show a slight positive correlation with alumina (Fig. 5) not normally seen in HIMT glass. Despite a basic similarity in composition, the colour of some of these samples does not always match the olive green tint of typical HIMT glass.

The final large group among the analysed samples is made from unambiguous HIMT glass. Iron oxide in this 'strong' HIMT group ranges from 1 to more than 3 wt%, manganese oxide from 1.5 to 2.5 wt%, and titania from 0.3 to nearly 0.8 wt%. Calcium oxide levels are relatively narrowly set between 5 and 6.5 wt%, while alumina ranges from 2.3 to more than 3 wt%. Potash is present at just under half a percent, while magnesia levels fall closely around 1 percent; all these values are fully compatible with published HIMT analyses from other assemblages elsewhere (Mirti et al., 1993; Freestone, 1994; see particularly the discussion of weak and strong HIMT glass from Britain and France in Foster and Jackson, 2009: 193–4).

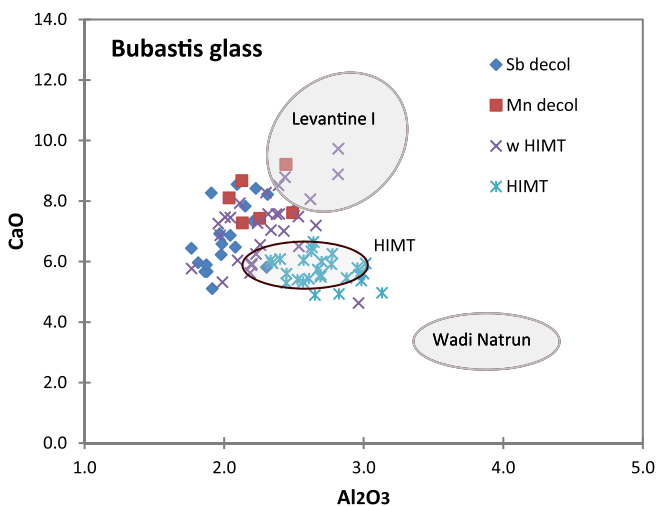


Fig. 5. Plot of the four natron groups from Bubastis. Note the good match of HIMT glass from Bubastis with published HIMT analyses, and the absence of glass with a Wadi Natrun signature. Levantine I glass is also not represented. Graph based on Freestone et al. (2005).

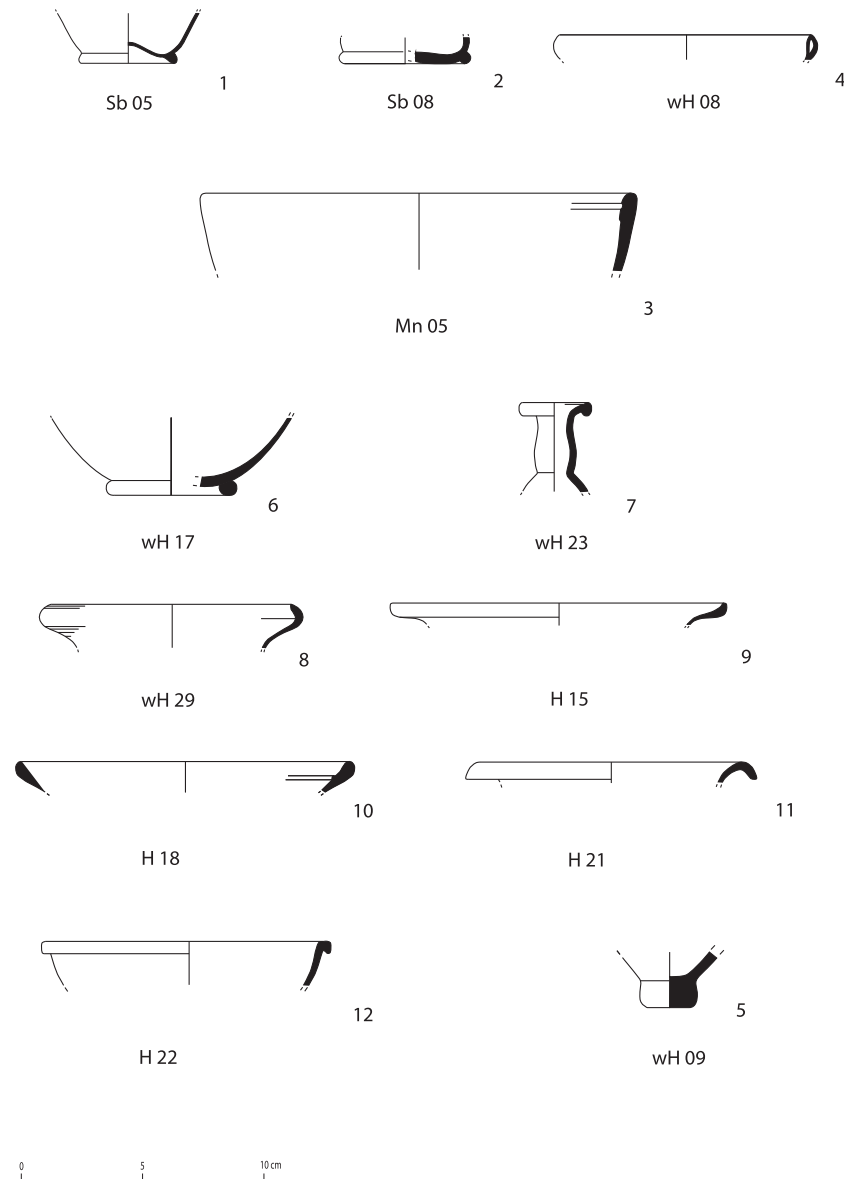


Fig. 6. Glass vessel fragments from Bubastis. Scale 1:2 (Drawings: Daniela Rosenow, digitalisation: Mandy Mamedow).

One sample did not meet our criteria to be allocated to one of the groups above; it is compositionally closest to the Sb-decoloured glass, but has no antimony above the detection limit, and deviates also in its content in lime (too low) and alumina (too high). We therefore left it unassigned and labelled it *ukn* for unknown.

## 5. Discussion

The compositional groups identified among the Tell Basta samples are discussed below in chronological order. The manganese-decoloured, antimony-decoloured and the plant-ash based glasses fall almost all into the first to third centuries AD. The weak HIMT glasses potentially overlap with these early groups and continue into the fifth century AD, while the strong HIMT glasses are all from the fourth century or later. It has to be stressed here that the dating of individual samples is done purely on typological grounds, often with rather long run times of some types

stretching over several centuries, and not on stratigraphic or other evidence that would date specific finds more narrowly.

### 5.1. Early decoloured glass

The early date of the six manganese-decoloured glasses is noteworthy, as is the fact that five of the six are from mould-cast vessels (see Table 1, Mn 01–06, with primary typological reference). Two fragments belong to cast ribbed bowls, one represents the handle of a skyphos and two fragments are rims of cast hemispherical grooved bowls (see Fig. 6.3). The blown fragment belongs to a beaker with wheel-cut horizontal grooves. The early use of manganese-decoloured glass is consistent with the occurrence of the same glass among Hellenistic assemblages in the eastern Mediterranean (e.g. Connolly et al., 2012), while elsewhere in Europe, manganese-decoloured glass only appears much later, as in Southern France (Foy et al., 2000: 54–56, corresponding *groupe* 3) or Italy (Silvestri et al., 2008), where manganese seems to have

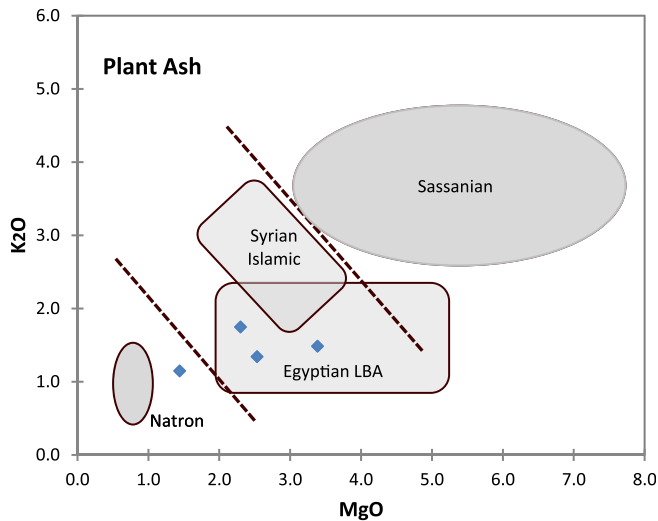


Fig. 7. Comparison of the four plant ash glasses from Bubastis to typical compositional fields of other glasses. The best match is with Egyptian LBA glasses (data from Smirniou and Rehren, 2013, and references therein). Graph based on Freestone (2006).

replaced antimony as a decolourant only at the end of the second/start of the third century AD, or in Roman Britain, where the use of manganese as a decolourant also does not seem to start before the fourth century AD (Foster and Jackson, 2010). One of the six analysed fragments (Mn 06) is dark blue coloured by cobalt (0.05 wt%) and copper oxides; this sample has also much higher iron oxide content than the others in this group. This is consistent with the observation from contemporary Pergamon (Rehren et al., 2014), where dark blue glasses are also coloured by a combination of cobalt, copper and iron oxides. This colorant has some similarity with the cobalt-blue colorant used earlier in New Kingdom Egypt (Smirniou and Rehren, 2013), and may indicate a continuity of its exploration well into the first millennium AD.

Antimony-decoloured glass predominates at Roman Bubastis. It has been used for mould cast vessels, vessels with a folded/tubular base ring (see Fig. 6.1), an applied foot ring (see Fig. 6.2) or pinched feet elements, a wall fragment with cut circular facettes, the rim of an aryballos, possibly an indented beaker with a thick base, a small container and a bottle or flask with flaring rim and applied thread, all of which – apart from one waster (Sb 12) – have typological parallels in the first three centuries AD (see Table 1, Sb 01–19, with primary typological reference). Comparable analytical data exists from the eastern Mediterranean, e.g. from Petra (Schibille et al., 2012) or Pergamon (Rehren et al., 2014) where the majority of glass decoloured by antimony can be dated to the first and second centuries AD. Elsewhere, as in Thamusida (Morocco: Gliozzo et al., 2013) and Roman Britain, these glasses are dating to the first to third (Jackson, 2005; Paynter, 2006), or even to the fourth centuries AD (Foster and Jackson, 2010). Significantly, antimony-decoloured glass has been identified by Picon et al. (2008) at the Wadi Natrun primary production installations in Zakik, Beni Salame and Bir Hooker, which date to the first and second centuries AD. In particular their group *wnc* has close similarities to the Bubastis glass; it has, however, significantly higher amount of soda compared to the Bubastis material which can therefore not be linked directly to the Wadi Natrun production sites.

Elsewhere in the Roman world, decoloured glass, particularly by antimony, is often seen in more high-class products, and being made of purer raw materials and the presumably expensive antimony (Jackson, 2005; Paynter, 2006; Nenna, 2007; Silvestri et al.,

2008; Foster and Jackson, 2010). This does not apply for the Bubastis material, where antimony-decoloured glass seems to predominate heavily over manganese-decoloured glass. It is remarkable that the analysed assemblage does not contain any naturally-coloured aqua or blue-green glass, despite the fact that during the first three centuries AD in many parts of the Roman Empire this 'Roman blue/green' glass was most commonly used for vessels (Paynter, 2006; Silvestri, 2008).

## 5.2. Plant-ash glass

Particular mention has to be made of the plant-ash based glasses (see Table 1, PA 01–04, with primary typological reference). All dark green-turquoise translucent low-capacity, thick walled *unguentaria* fall into this group; three of these are reported here, while one sherd represents a ridged handle, probably from a relatively large and also thick walled transport or storage container. Large quantities of such *unguentaria* are also known from other Roman-period sites in Egypt (such as in Tuna, M. Flossmann pers. com.), and we hope to analyse these in the near future. The only published comparable contemporary glass vessels from Egypt and apparently made of plant ash glass are those deriving from Wadi Natrun (Picon et al., 2008) and several kohl flacons and *unguentaria*, dating to the second and third centuries AD, mentioned among the glass finds in the Louvre collection (Arveiller-Dulong and Nenna, 2005; Nenna et al., 2005). Further examples of this composition have been published from Britain and France (Jackson et al., 2009) as well as Italy (Gallo et al., 2013) and Albania (Schibille, 2011).

Plant ash glass is very rare in the eastern Mediterranean during the first millennium BC and the first half of the first millennium AD. Having dominated Egyptian and Mesopotamian glassmaking during the second millennium BC, it is replaced in Egypt and the eastern Mediterranean around 1000 BC by mineral-natron based glass (Schlick-Nolte and Werthmann, 2003). However, plant-ash based glassmaking persisted in the Sasanian Empire, to the east of the Euphrates, from where it may have found its way back into the west following the collapse of natron supply in the eighth or ninth century AD (Whitehouse, 2002; Shortland et al., 2006). Islamic-period glassmaking appears to be concentrated in Syro-Palestine, with little if any Egyptian plant-ash glass making known from this period (Freestone et al., 2009). Against this traditional narrative, Picon et al. (2008) in their study of Roman glass from the Wadi Natrun report four plant-ash glass finds which they link to a local Egyptian production. A comparison of their analyses with ours, however, shows significant differences. The Wadi Natrun plant ash glasses are very rich in lime (10–16 wt%), alumina (4–7 wt%) and iron oxide (2–3 wt%), and very low in soda (9.5–12.5 wt%). This composition is very unusual and does not resemble the plant ash glass analyses from Bubastis, or elsewhere. We therefore do not link the Bubastis samples to a production from Wadi Natrun.

The geographical origin of the glass used to produce these vessels is of considerable interest, as the presence of several such vessels in Tell Basta could imply that the Roman town was still engaged in long-distance trade if the glass were indeed coming from east of the Euphrates. To discuss this, we can look at both the composition of the flux and that of the sand used to make this glass. There appears to be a tendency that the levels of potash and magnesia in plant ash glasses follow a broad trend of increasing levels from Syria eastwards (Freestone, 2006). Using this criterion suggests that the relevant values found in the Tell Basta assemblage are far too low to assume an import of these vessels from the Sasanian Empire; they are also lower than the levels found in most Islamic glass from Syria (Fig. 7). The closest match in their alkali composition for PA 02–04 is with the relatively low-potash New Kingdom cobalt-blue glasses found both in Egypt and Mycenaean

Greece (Smirniou and Rehren, 2013) for which production evidence has been found in Amarna (Smirniou and Rehren, 2011). This suggests that these Roman-period plant ash glasses might also have been made in Egypt. The elevated concentrations of sand-derived components in these glasses, particularly iron oxide, titania and manganese oxide, are also more consistent with glasses typically linked to an Egyptian origin than a Levantine one. However, the phosphorus content of these glasses exceeds that of most other glasses from the Bronze Age and Classical Antiquity, reaching more than one percent by weight in one sample. It is hoped that our ongoing research on vessels of this type across Egypt will shed more light on the chemical composition and geographic and chronological distribution of this intriguing glass group.

For now, we note that only these particular vessels were made consistently using plant ash glass rather than mineral-natron based glass. Their existence strongly indicates that production of plant-ash glass persisted in Egypt a millennium after the introduction of mineral-natron based glassmaking, and at least half a millennium before the re-introduction of plant ash-based glassmaking in the Islamic period, as already observed by Picon and co-workers (2008). It may be significant that particularly low-capacity *unguentaria* and kohl flacons seem to fall into this glass category, raising the question whether plant ash glass was produced specifically for vessels carrying low-volume high-value goods.

### 5.3. HIMT glass

HIMT glass is widespread between the fourth and sixth centuries AD throughout the whole Mediterranean and Europe. After its introduction it soon dominated the Roman and Late Antique glass industry, and at least outside the Levant became more popular than the contemporary Levantine glasses (Freestone et al., 2002b). It is therefore not surprising that almost two thirds of the samples reported in Table 1 are HIMT glass, divided equally between a 'weak HIMT' and a 'strong HIMT' group. The weak HIMT group (see Table 1, wH 01–29, with primary typological reference) consists of an oval dish, a wall fragment of an mosaic glass vessel, an aryballos, a stemmed goblet, a stemmed bowl, an indented beaker, fragments of flasks (see Fig. 6.7), base fragments of vessels with pinched feet, base fragments of vessels with single applied base rings (see Fig. 6.6) and multiple applied base rings, lamps with a pointed base, a conical hollow base or manufactured with a solid stem (see Fig. 6.5), vessel bases with a high footring, flaring rims of bottles or jugs with an applied thread and rims of cups with tubular or up-going rims (see Fig. 6.4 and 6.8). Some of these are only faintly-coloured, appearing almost colourless when thin-walled, and at least one third of the analysed objects in this group can be dated by typology to the first three centuries AD. However, the majority of this group, and all of the strong HIMT glasses, are later finds, starting mostly in the fourth century AD, and are of dark green to brown colour (see Table 1, H 01–28, with primary typological reference). Identifiable objects include conical lamps or hemispherical bowls with cracked-off rims and pointed bases or a solid blob, a vessel base with multiple applied base rings, cups or bowls with various rim shapes (see Figs. 6.9, 6.10, 6.11 and 6.12), one oval dish, vessel bases with a high footring or a folded/tubular base, a stemmed bowl, four wall fragments of mould blown vessels, one wall fragment of a lamp with an applied blue blob, two fragments of ridged handles, possibly deriving from transport or storage containers and the neck of a flask.

Despite its importance, HIMT glass has not been well defined compositionally (Foster and Jackson, 2009: 193). It is generally accepted that in addition to the eponymous higher concentrations in iron, manganese and titania it also has elevated levels of magnesia as well as zirconium, chromium, barium and other trace

elements, and typically a good positive correlation between alumina, iron oxide, and most of the other characteristic elements. In contrast, lime levels are normally relatively constant and scatter around 6 wt% CaO, regardless of alumina concentrations (e.g. Fig. 5 in Freestone et al., 2002a,b). The increase in recent years in published data for HIMT glasses has resulted in the identification of considerable compositional variability within this group (see e.g. Gallo et al., 2014; Schibille, 2011: group WD2), including the presence of HIMT glass without manganese (dubbed HIT glass: Rehren and Cholakov, 2010), and of ever more extreme concentrations of some of the characteristic elements. On the other hand, considerable uncertainty exists regarding the lower end of acceptable HIMT compositions or, in other words, how little iron, manganese and titania can a glass have and still be called HIMT? Here is not the place to discuss this, but suffice it to say that Foster and Jackson (2009) consider a group of glass with an average of 0.6 wt% FeO, 0.1 wt% TiO<sub>2</sub> and 1 wt% MnO still as (weak) HIMT.

We adopt the concept of weak HIMT here, even though Foster and Jackson's (2009) weak HIMT group is compositionally different from the Tell Basta weak HIMT. In some aspects, the weak HIMT glass from Tell Basta forms a continuum with the strong HIMT group (Figs. 8 and 9). However, it differs from typical HIMT glass in its higher calcium oxide content (Fig. 5). We interpret the existence of weak and strong HIMT glass to indicate the use of two only broadly similar sand sources, possibly in geographical proximity, but probably producing glass independently of each other as indicated by the chronological and compositional differences between the two groups. Compositionally closest to the weak HIMT group, including the higher lime levels and despite some subtle differences in the alumina and iron oxide ratios, is a set of glasses from northern Europe (Saxon I: Freestone et al., 2008), dating from 400 to 550 AD. Our identification of glass of this composition as a major group in Egypt supports Freestone's assumption that the Saxon glass was an import, and that its elevated levels of HIMT indicators did not result from the repeated recycling of earlier Roman glass following the end of Roman rule in northern Europe. On current evidence one can suspect that it is of Egyptian rather than Levantine origin; however, more work is clearly needed to better understand the HIMT glass family in all its compositional complexity.

Types found among this glass group include vessels made of mosaic glass, indented beakers, vessels with pinched feet, oval dishes, stemmed goblets, and an *aryballos*. Their dating covers a relatively wide time span, ranging from the first to the seventh

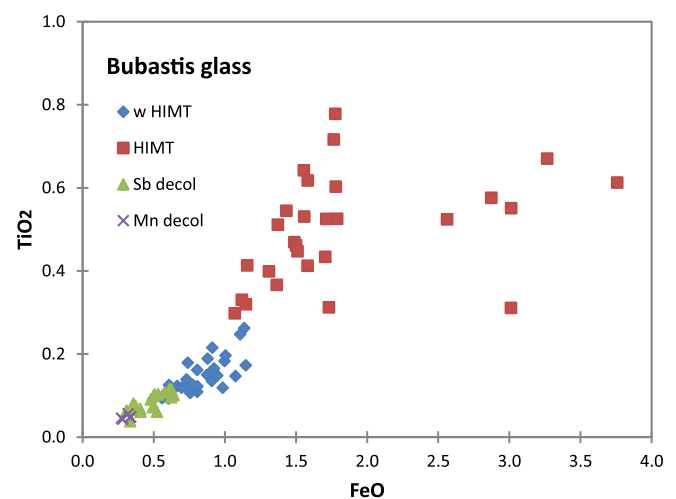
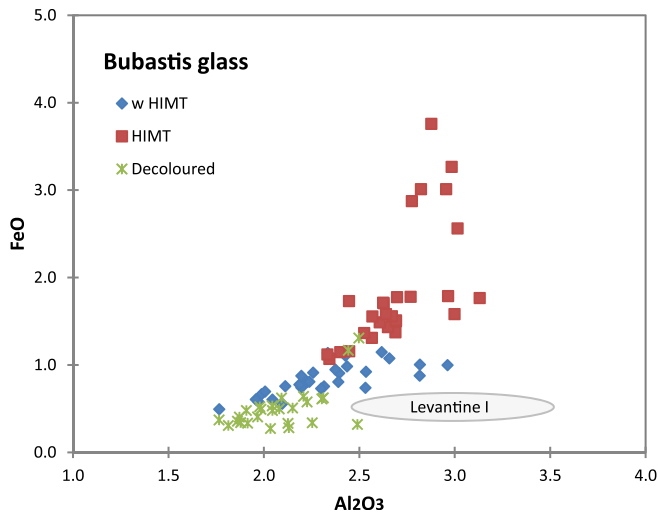


Fig. 8. Weak HIMT glass plots between the decoloured glasses and HIMT glass. HIMT glass is split into two groups, with six samples having higher iron oxide relative to titania than the majority of the HIMT glass.



**Fig. 9.** Both weak HIMT and HIMT show a positive correlation between alumina and iron oxide, in contrast to Levantine I glass. The correlation is more pronounced for HIMT glass. Note also the group of six HIMT samples with excess iron oxide. The two decoloured glasses with high iron oxide content are coloured by cobalt, which is associated with increased iron oxide.

centuries AD, and includes a number of intentionally coloured samples.

The strong HIMT group matches compositionally published data for HIMT glass; noteworthy here is the emergence of a small subgroup characterised by excess iron oxide relative to titania and alumina compared to the bulk of this group (Figs. 8 and 9); this has been observed elsewhere before (Rehren and Cholakov, 2010) and again underlines the compositional complexity of this glass group, as well as its super-regional importance for much of Late Antiquity.

#### 5.4. Absence of Egypt I and II glass compositions

In the introduction we mentioned the glass groups Egypt I and II; Egypt II is chronologically outside the frame of our study, and its absence from our data hence not surprising. In contrast, the absence of Egypt I glass was unexpected. It is linked to production in the Wadi Natrun since it shares some characteristics with the composition of glass finds from primary glassmaking installations there published by Picon et al. (2008), such as very low levels of lime and rather high soda levels. These primary glassmaking furnaces are dated to the first two centuries of the first millennium AD, contemporary with much of the glass from Bubastis. It is remarkable then that none of the glasses analysed to date from Tell Basta show this very characteristic Wadi Natrun signature, despite the relative proximity of the two sites.

## 6. Conclusion

The aim of this paper was to provide a first insight into glass supply and consumption at an Egyptian town between the first century BC and the end of the sixth century AD. Situated in the Eastern Nile Delta, Bubastis can be expected to have been well integrated into the Roman trade – as indicated by the contemporary ceramic finds from the city. On the basis of compositional analysis, the glass discovered here falls into five main groups, four of which are well known from elsewhere. In the first three centuries of the first millennium AD, manganese and antimony-decoloured glass compositions dominate, while a previously little known high-phosphorus plant-ash glass was used for *unguentaria*. The later part of the assemblage consists of two different HIMT glass groups,

one relatively low and one rather high in iron, manganese and titanium oxides. With the exception possibly of the manganese-decoloured glass, contributing less than 10% of the analysed sample and certainly even less of the entire assemblage, none of the material appears to be imported from outside Egypt, painting a picture in contrast to what the ceramic indicates.

Three observations are of particular interest and underscore the wider significance of this data set.

First: Manganese-decoloured and antimony-decoloured glass is evident here as elsewhere, with nearly identical base glass compositions and levels of additives as seen elsewhere in the Roman Empire. For Bubastis, this confirms that the town was integrated into the wider trade network of the Roman and Late Antique world. The data is consistent with a model of a limited number of primary glass producers serving super-regional markets, spanning the entire Roman world, and beyond, from Britain and France to Turkey and Egypt. There is, however, no evidence so far for the presence of the faintly-coloured Roman blue/green glass, which during this time is so wide-spread in the Northern Provinces. In contrast, in Bubastis the antimony-decoloured glass is not a glass chosen only for high-status objects, but appears during the early period to be the predominant glass type, apart from a few possibly imported and relatively early samples of manganese-decoloured glass. The absence of Roman b/g glass could indicate that this particular group was not produced in Egypt, while the Syro-Palestine area has been mentioned repeatedly in this context (e.g. Nenna, 2000; Foy et al., 2003; Gliozzo et al., 2013). The existence of plant-ash glass in this early period, probably made regionally, is intriguing, particularly with its close association to a particular vessel type.

Second: Only HIMT glasses were used at Bubastis from the fourth century AD onward, with two co-existing sub-groups recognisable by their different levels of diagnostic elements. No evidence for the use of Levantine glass has been found, despite those glasses dominating archaeological assemblages in current-day Israel and Jordan, where in turn HIMT glass is rather rare (Kato et al., 2009; Rehren et al., 2010). This suggests a strong element of regional preference in glass consumption, most likely based on proximity to the primary producer. This, in turn, could indicate that the earlier Roman blue/green glass was also made in the Levant, and hence not used in Bubastis. The chronological and compositional difference between the two HIMT groups, and the difference in composition between these two and some other HIMT assemblages reported elsewhere, indicates that there is significant systematic variation within the HIMT group. This could indicate that there were a number of contemporary and consecutive glass-making installations active using similar but different sand sources, within the broader HIMT definitions. Also, weak HIMT glass is compositionally very close to Anglo-Saxon I (Freestone et al., 2008), Frankish German (Wedepohl et al., 1997) and Merovingian French (Velde, 1990) glass dating to the 5th and 6th centuries AD, confirming that fresh raw glass from Egypt was still reaching Europe after the collapse following the departure of the Roman army. It is hoped that a comprehensive study of the HIMT glass family and its sub-groups will shed more light on this, even though trying to order the increasing numbers of analyses seem to make the picture more complex rather than clearer – a bit like herding cats.

Third: The complete absence at Bubastis of low-lime glass compositions typically linked to the Wadi Natrun, such as the primary production remains reported by Picon et al. (2008) or Freestone's Egyptian I glass based on analyses by Gratuze and Barrandon (1990) is remarkable, given that the city is located relatively close to the Wadi Natrun. This underscores how little we really know about this glass group, and its significance relative to the other, better-known groups.

The material presented here currently comprises the only available substantial data set for glass compositions from Roman and late Antique Egypt, making it difficult to generalise our observations beyond the statements just made. Clearly, more analytical data is required to support a more refined discussion about glass supply and consumption in Roman and Late Antique Egypt; some of this is currently underway as part of the Marie Curie project Glass in Late Antiquity – Science and Society, of which this is the first outcome.

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