'To See a World in a Grain of Sand'

Glass from Nubia and the Ancient Mediterranean

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Cover: Roman Glass Vessels (© Garstang Museum, reproduced with permission from the Garstang Museum)
SEM BEI Image showing dendritic structures in high-lead red glass from Faras (taken by author)
Back cover: Red glass from Garstang Museum of Archaeology
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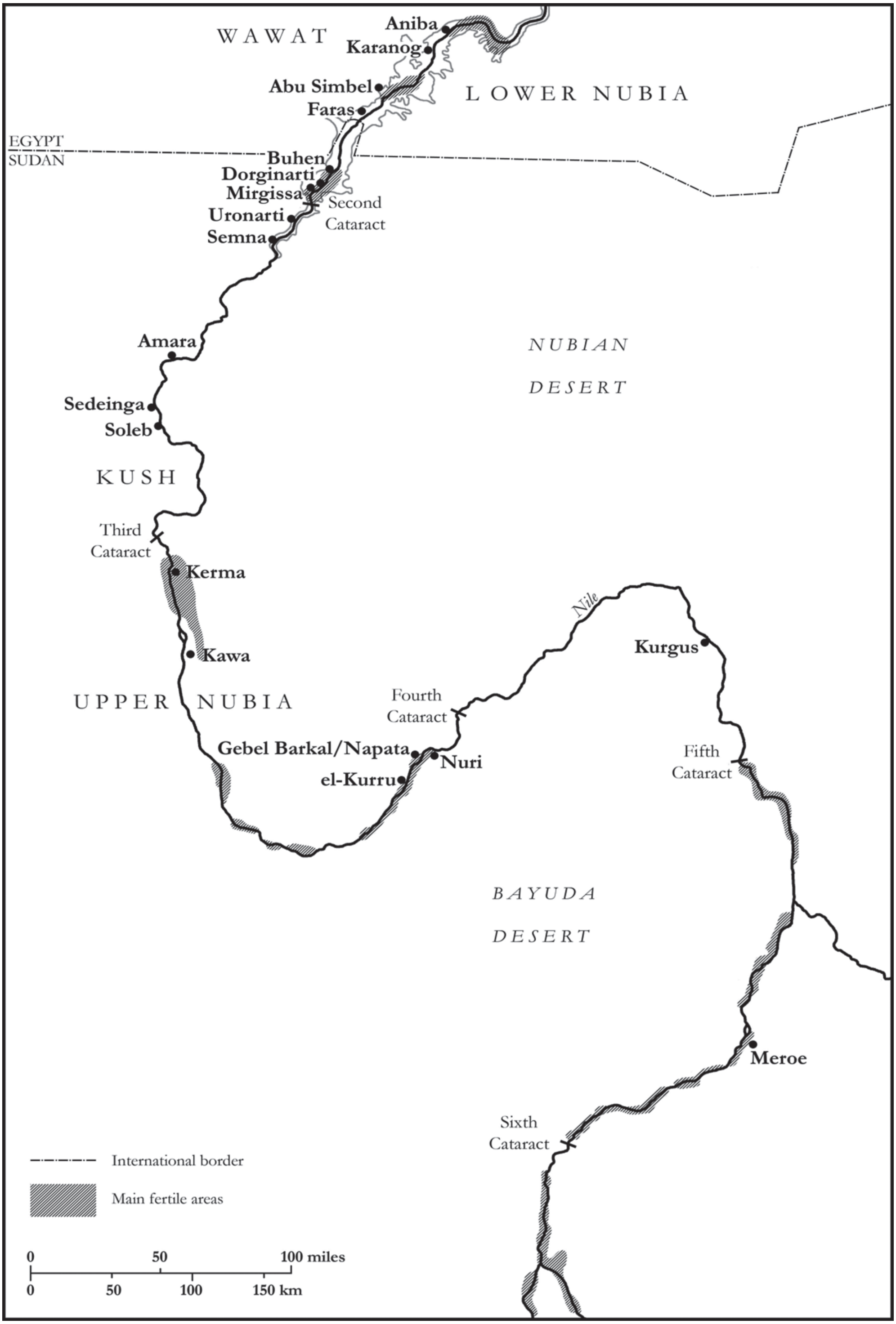
Dedicated to Duncan Probert

(1961-2016)



Nubia (all maps by D. Probert)

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Abbreviations

Ant. Jud.	Antiquities of the Jews (*Antiquitates Iudaicae*) (Flavius Josephus)
BH	Bibliotheca Historica (Diodorus)
Deipn.	The Deipnosophists (Athenaeus)
FHN III	Fontes Historiae Nubiorum. Textual Sources for the History of the Middle Nile Region Between the Eighth Century BC and the Sixth Century AD III. From the First Century BC to the Sixth Century AD.
HoR	History of Rome (*Historia Romana*) (Cassius Dio)
Id.	Idylls (Theocritus)
NH	Natural History (Pliny)
O. Leid	Ostracon Leiden
O. Thebes	Ostracon Thebes
P. Amh	Papyrus Amherst
P. Hawara	Papyrus Hawara
P. Mich. Zenon	Papyrus Michigan
P. Oxy	Papyrus Oxyrhynchos
Periplus	The Periplus Maris Erythraei

Chemical Oxides (Symbols and Meaning)

SiO_2	Silica – main glass component (network former)
Na_2O	Soda – main glass component (network modifier/flux)
CaO	Lime – main glass component (network stabiliser)
Fe_2O_3	Iron (II) oxide – natural contaminant
Al_2O_3	Alumina/aluminium oxide – natural contaminant
TiO_2	Titanium oxide – natural contaminant
K_2O	Plant ash/potassium oxide – contaminant from ash/main glass component (flux)
MgO	Magnesia/magnesium oxide – contaminant from ash or flux
P_2O_5	Phosphorous oxide – contaminant from heating
CuO	Copper oxide – colourant
CoO	Cobalt oxide – colourant
MnO	Manganese oxide – colourant and decolourant
Sb_2O_5	Antimony oxide – decolourant
PbO	Lead oxide – intentional addition, flux, contaminant
(BaO	Barium oxide – natural contaminant)

Timeline of Ancient Egypt and Nubia

	Egypt	Lower Nubia	Upper Nubia
Before 3050 BC	Predynastic Period (to Dynasty 0)	Classic A-Group Terminal A-Group	Pre-Kerma
***c.* 3050-2685 BC**	Archaic Period (Dynasties 1-2)		
***c.* 2685-2150 BC**	Old Kingdom (Dynasties 3-6)	C-Group Ia, Ib	Early Kerma
***c.* 2150-2008 BC**	First Intermediate Period (Dynasties 7-first half 11)		
***c.* 2008-1685 BC**	Middle Kingdom (2nd half of Dynasty 11-13)	C-Group IIa, IIb	Middle Kerma
***c.* 16850-1550 BC**	Second Intermediate Period (Dynasties 14-17)	C-Group III	Classic Kerma
***c.* 1550-1077 BC**	New Kingdom (Dynasties 18-20)	Egyptian occupation	Egyptian occupation
***c.* 1076-723 BC**	Third Intermediate Period (Dynasties 21-24)	Independent Nubian cultures	Independent Nubian cultures
***c.* 722-332 BC**	Late Period (Dynasties 25-30) 2nd Persian Period	Napatan	Napatan
332-30 BC	Ptolemaic Period	Meroitic Early Meroitic (*c.* 3rd-1st Centuries BC)	Meroitic Early Meroitic (*c.* 3rd-1st Centuries BC)
30 BC-AD 350	Roman Period	Meroitic Middle Meroitic (*c.* 1st Century BC-AD 1st Century) Late Meroitic (*c.* AD 1st-4th Centuries)	Meroitic Middle Meroitic (*c.* 1st Century BC-AD 1st Century) Late Meroitic (*c.* AD 1st-4th Centuries)
AD 350-641	Roman Period	Early Nobadia	Early Makuria

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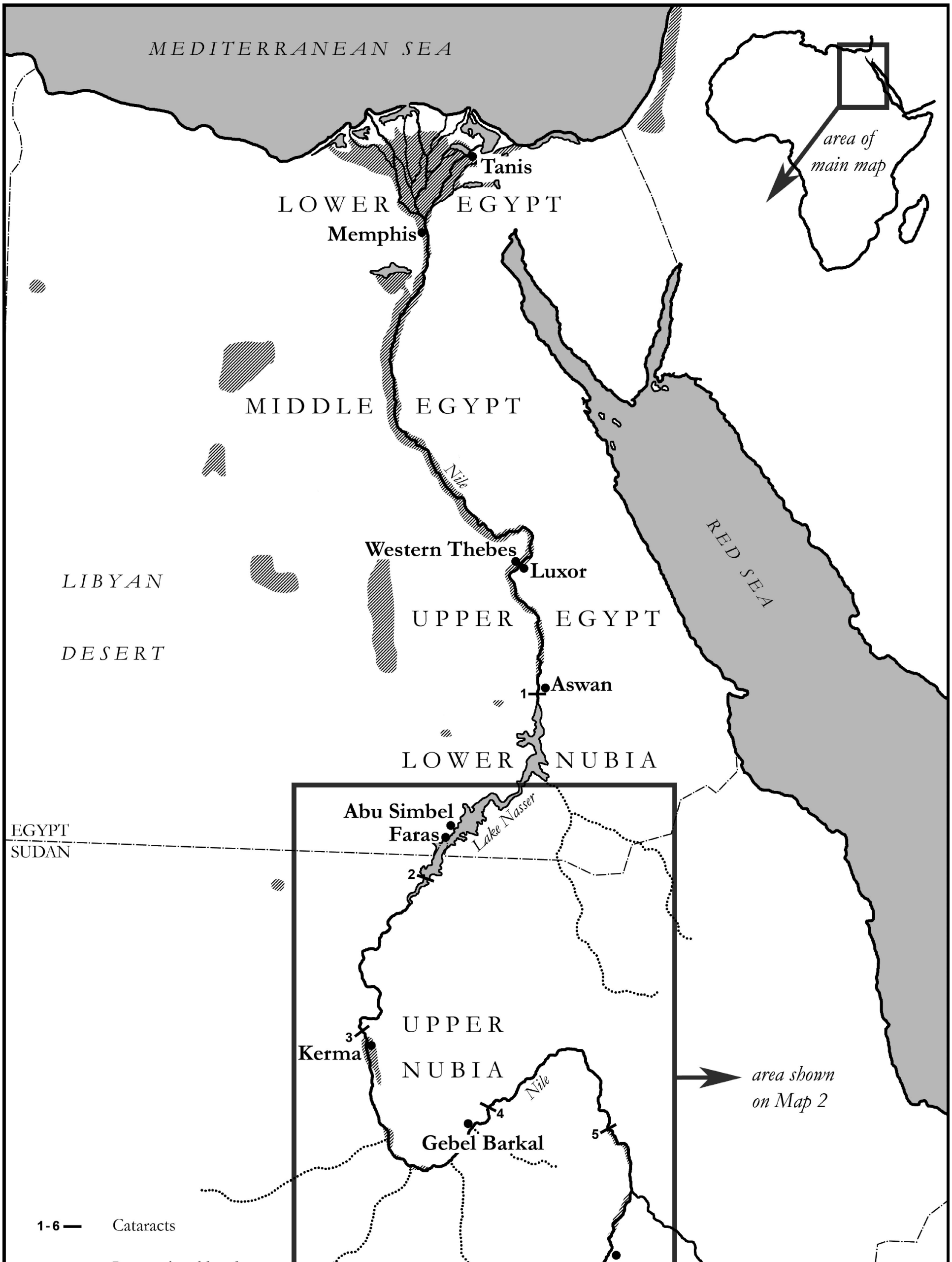
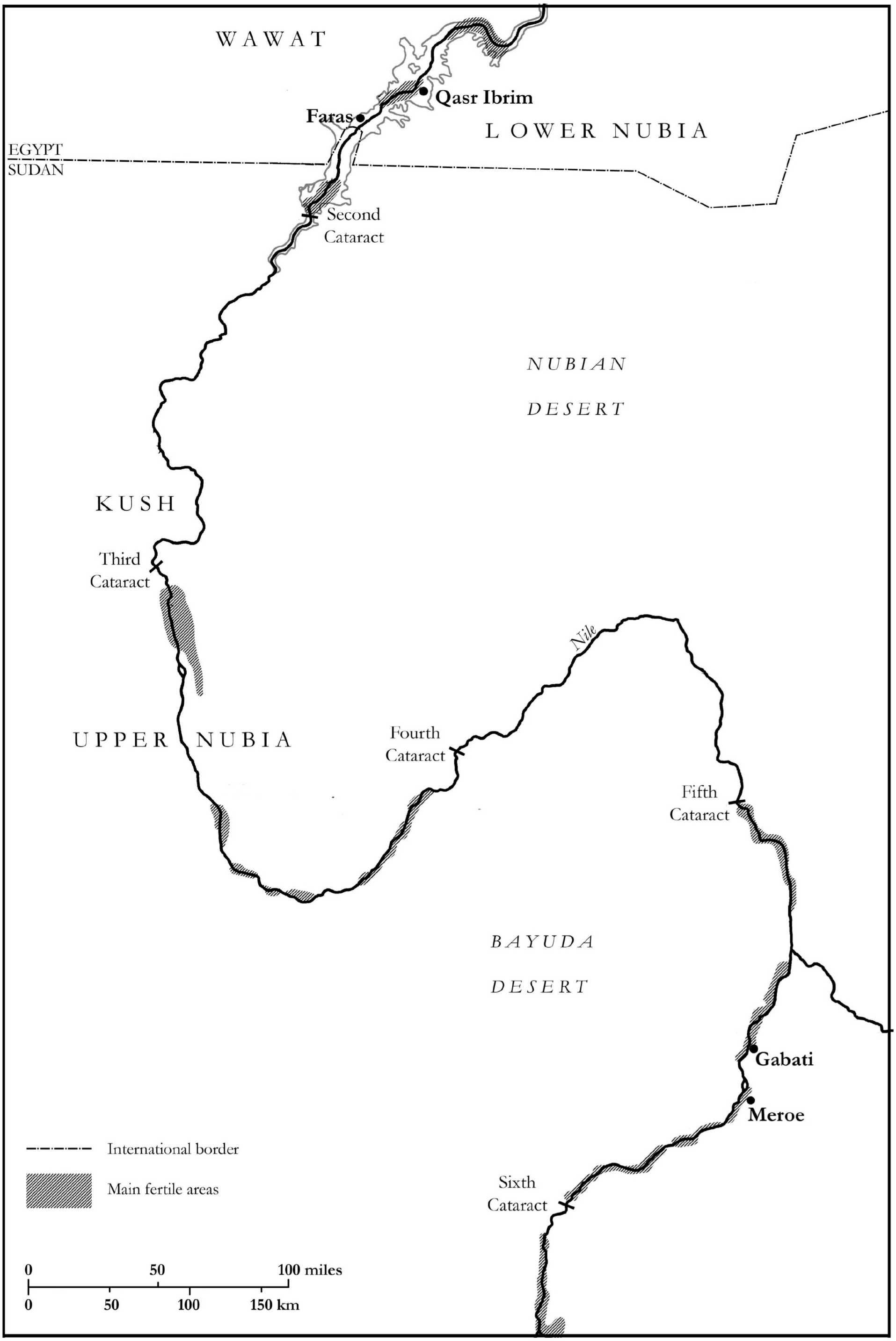
To See a World in a Grain of Sand
And a Heaven in a Wild Flower,
Hold Infinity in the palm of your hand
And Eternity in an hour.

From ‘Auguries of Innocence’

William Blake



MAP OF EGYPT AND NUBIA



MAP OF NUBIA SHOWING THE PRINCIPAL SITES MENTIONED IN THE TEXT

Chapter 1

Nubian History, Glass, and Mediterranean Trade

Aim and Scope

The production of glass was one of many industries in the ancient Mediterranean world, all of which inevitably occurred in the context of the political, social, and economic events peculiar to the numerous interconnected cultures of the region. These influences would have forced diversification in sources of supply during times of unrest or facilitated the introduction of new artistic ideas, technologies, and trading links during periods of diplomatic accord. The aim of this study is to undertake a chemical examination of glass from Nubian contexts—Faras, Gabati, Meroe, and Qasr Ibrim—dating to the Meroitic Period (*c.* 350 BC-AD 350) and X-Group/Ballana Culture/Early Nobadia (*c.* AD 350-600) in order to better understand its composition.[1] The results of this compositional analysis are then examined alongside each other and alongside published material from sites around the Mediterranean in order to identify any similarities present. This will enable the identification of links between all these sites based on the chemical makeup of the glass found there. The samples from the four Nubian sites will also be considered in the context of the social and historical relations between Meroitic Nubia and Egypt, and—via Egypt—to the wider ancient Mediterranean world. This is a new area of research that begins to shed light on how glass from Nubian contexts fits into the wider context of the glassmaking, glass working, and trade of the ancient world. This first chapter will survey trade between Nubia and Egypt from the 7th century BC onwards, and show how that interaction around the Mediterranean helped to disseminate Hellenistic influences on technology and creativity. Against this background glassmaking flourished and developed. Not only was glass made from scratch, it was recycled and there is also evidence from the Roman Period for an international trade in coloured and colourless glasses, whether new or cullet (broken pieces).

The Nubian Historical Context

Before discussing glassmaking a brief history of Nubia before, during, and after the Meroitic Period is necessary in order to establish the historical context. At this time—the waning of the Late Bronze Age and of Egypt's importance on the world stage—new powers emerged as key international players. These new powers included Kush and the Assyrians, which would both rise to prominence in the mid-8th century BC, ultimately resulting in clashes between these civilisations (Morkot 1993: 294).[2] While these clashes brought about a shift in the dominant powers, there is evidence that Nubia was still trading with Egypt even during times of political

[1] The term 'X-Group' (*c.* AD 350-600) is a slightly problematic one in Nubian archaeology, with this period also more recently previously referred to as the 'Ballana Culture in Lower Nubia' (Adams 2013a: 7). The name Ballana comes from the site where many of the rulers were buried (Adams 2013b: 35). The preferred term for referring to Lower Nubia following the end of the Meroitic Period is now the 'Early Nobadia'. Hereafter the term used will be 'Early Nobadia'. For Upper Nubia following the collapse of the Meroitic Kingdom the preferred term is Early Makuria.

[2] The terms 'Kush' and 'Nubia' in this context refer to the area under the control of the Kushite kings who were the ancestors and the founders of the 25th Dynasty. The term Kush will be used to refer to the royal court and rulers; the term Nubia will be used to refer to the geographical region to the south of Egypt.

unrest (Morkot 1993: 294) with archaeological evidence showing that Nubia's commercial activity remained dominated by trade with Egypt (Shinnie 1991).

With the end of the 25th Dynasty (656 BC), Kushite rule in Egypt came to an end.[3] The installation of Amenirdis I (the Kushite king's daughter) as God's Wife Elect had been used by the kings of the early 25th Dynasty as a device to consolidate their power and legitimacy in Thebes, and through this their control over all Egypt (cf., Kahn 2005: 151; Török 2009: 321). Similarity, Psamtik I, who would become the first king of the 26th (Saite) Dynasty, had his daughter Neith-iqeret (Nitocris) adopted as Divine Adoratrice Elect in 656 BC, in imitation of the Kushites (Török 2009: 357-358; this is recorded on the Nitocris Adoption stela (Cairo JE 36327), see Caminos 1964). This extended Psamtik I's legitimacy over Egypt while simultaneously removing any last lingering threads of Kushite control over Thebes. Despite the hostilities between the successors of the last king of the 25th Dynasty (Tanutamun) and those of Psamtik I, relations between Nubia and Egypt were still structured in the interests of international trade (Diodorus *BH* 1.66.8, 67-9; Lloyd 1983; Török 2009: 360). The continuing exchange of goods between Saite Egypt and Nubia is indicated by imports, or by 'diplomatic gifts' from Egypt found in tombs at Nuri and both Begarawiya West and South (Török 2009: 361). These finds include objects made of metal (e.g. Dunham 1963: figs 18/e (Beg. W. 832), 1955: Fig. 55; Wenig 1978: Cat. 111 (gold vase inscribed for Aspelta's funerary equipment from Nu. 8)), calcite (e.g. Dunham 1963; Griffith 1923: Pl. XVI), and faience vessels (e.g. Dunham 1963: Pls XXXI-XXXII) and amulets (e.g. the *pataikos* types associated with the cult of Horus-the-Saviour and the Memphite Cult of Ptah-Sokaris in Andrews 1994: 38f; Dunham 1955; Dunham 1963: Figs 18/e (Beg. W. 832); Griffith 1923: Pl. XXVI/33). The assemblages of pottery and other artefacts from Saite Egypt found at the fortress of Dorginarti at the Second Cataract, and at Gabal Abu Ahmed in the Lower Wadi Howar (Török 2009: 362), have been used to identify Dorginarti as the southernmost outpost of the Persian empire (Heidorn 1991: 205, 206; Török 2009: 362). In contrast, the presence of the kiosk in Temple T at Kawa (Macadam 1955: Pl. LI; Török 2002: 124ff) of the Napatan Period king Aspelta (593-568 BC) and the votive cartouche of Malanaqene (553-538 BC) (Aspelta's second successor) from the same shrine (Macadam 1949: 89 No. XLIII), indicates Kushite control between the Third and Fourth Cataracts (Török 2009: 362). With Egypt controlling trade to the north and the Kushites controlling trade to the south, the Lower Nubian communities were prevented from participating in and profiting from long-distance trade between Egypt, Nubia, and the interior of Africa (Török 2009: 363).

Later conflicts in Egypt following the death of Cambyses (522 BC) and anti-Persian revolts during the reigns of Xerxes I (486-465 BC), Artaxerxes I (465-424 BC), and Darius II (423-404 BC) permitted Kushite reoccupation of the region between the First and Second Cataracts (Török 2009: 365). This pattern of the First and Second Cataract region appearing to 'change hands' between Egyptian and Kushite control would continue (see Török 2009: 369-376), and arguably could have had an influence on which ideas and innovations in technology and production were able to reach Lower Nubia. This may in turn have affected the vitreous technology of Qasr Ibrim and Faras that will be examined in this study.

In 275/274 BC the Egyptian ruler Ptolemy II undertook a military campaign as a result of Kushite incursions into Upper Egypt (Török 2009: 377-378. For the great triumphal procession

[3] For a study of the ethnic dynamics of Egyptian-Nubian relations see Smith 2003.

displaying the exotic animals and other booty from Kush see Athenaeus, *Deipn*. 197ff and Foertmeyer 1988. For the dating of this expedition, see Theocritus, *Id.* 17.87; and Athenaeus, *Deipn.* 197ff). This conflict resulted in the region between the First and Second Cataracts (in Greek sources known as the Triakontaschoinos) being annexed to Egypt (cf., Locher 1999: 252ff; Török 2009: 384). Peace on the Egyptian/Nubian frontier was maintained by the annexation of Lower Nubia as far south as the Second Cataract. (For Theocritus, *Id.,* 17.86f on Ptolemy II 'cutting off a part of Black Aithiopia' see Burstein 1993: 42.) This conquest of Lower Nubia is indirectly commemorated in the list of Lower and Upper Nubian nomes who brought tribute to Isis, inscribed after *c.*275-274 BC in the temple at Philae (Török, 2009: 386). Egypt's action against Nubia would enable the establishment of large-scale trade contacts between Egypt and the Middle Nile region (Török 2009: 389) and as a result Lower Nubia was victim of the competing interests of these two great powers. Egyptian occupation of Lower Nubia and subsequent organisation of trade routes contributed to the development of a settlement chain both north and south of the Second Cataract. It has been suggested that the interest of these locations (sites around the Dal Cataract, Semna-tila, and the Second Cataract, Argin, Faras-Jebel Adda, Toshka-Arminna, Aniba-tomas, and perhaps Shablul and Wadi el Arab) were related to managing and protecting the traffic through Lower Nubia (Edwards 1996: 86). Further south, the trade in or acquisition of exotic animals and goods from lands to the south brought about the rapid development of the political and socioeconomic structure of the Butana and Gezira region in the south of Nubia (cf., Török 1997a: 420-453; Török 2009: 389). An example of the procurement of exotic animals is the acquisition of African war elephants and ivory (Török 2009: 385). The great triumphal procession in Alexandria after the Nubian campaign shows Nubian gift bearers carrying 600 elephant tusks (Athenaeus, *Deipn* 197ff; Kallixeinos 3C 627 F 2.32; Rice 1983).

The maintenance of relations between Nubia and Egypt necessitated a restructuring of relations between the central Kushite power at Meroe and provincial elites, resulting in an increased home production of prestige goods such as faience and fine pottery (Török 2009: 389). (For the significance of gift exchange between the king and the provincial elite cf., Edwards 1996: 86 ff.) Maintenance of Nubian-Egyptian relations also brought connections through new allegiances with areas to the south of Nubia, shown by Hellenistic prestige goods found at Sennar-Makwar, 200km south of Khartoum (Török 2009: 389). (For the goods at Sennar-Makwar see Dixon 1963, for dating see Török 1989: Appendix No. 53.) The distribution of such goods was important in forging relations between the Meroitic rulers and the elite of the provincial centres, leading to David Edwards's (1996: 87) assertion that the Meroitic Period settlement history of Lower Nubia was closely linked to this distributive aspect of Meroitic royal power.

Ultimately, the 3rd century BC would see the emergence of a new Meroitic Kushite dynasty, with a reformulation of the Kushite myth of state and a re-emergence of the cults of Nubian deities. The direct contacts between the courts in Ptolemaic Egypt and Meroe resulted in Meroitic interpretations of Hellenistic architectural types and artistic styles. A prime example of this was the sculptural decoration of the water sanctuary at Meroe itself (Török 2009: 390). This ornamentation dates from two successive decorative programmes, the first during the late 3rd- and early 2nd-centuries BC and the second during the second half of the 1st century BC and early 1st century AD (Török 2009: 509, for the dating see Török 1997a: 70f). It is the statues from the first decorative programme that show a Hellenistic influence, for example figures of Dionysos as a child, the *kithara*-playing Dionysos, figures of Silenos, a double pipe player, a syrinx player, a standing philosopher, and two seated philosophers or poets (see Török 1997b: figs 75-80, Pls 16, 34-36-38, 41, 42, 45-49 for more statues).

During the late 3rd century BC (207/206 BC) the revolt in the Thebaid saw the brief establishment of the Upper Egyptian kingdom of Hor-Wennofer (Török 2009: 391; Zauzich 1978: 157-158). Under his son Ankh-Wennofer this kingdom would extend from Syene (Aswan) to Lykonpolis (Török 2009: 392). It is considered that the Kushite building activities in Lower Nubia to indicate that the region south of the First Cataract was annexed from Egypt as a result of an agreement that the Kushite king would offer armed support to Hor-Wennofer (Török 2009: 392). The two decades of Kushite supremacy that followed saw extensive building activity in Lower Nubia under the ruler Arqamani (Ergamenes II) and his successor Adikhalamani (Török 2009: 393). That the Kushite control led to building activity in Lower Nubia is clearly shown in the founding of the temple of Debob, which was dedicated to a newly created form of Amun, revered as the Meroitic king's divine father, something inspired by Taharqa's foundation of the cult of Amun of Takompso (Török 2009: 395).

The Philae Stela (Cairo 9295) of 29 BC records the crushing of yet another revolt in the Thebaid. It was after the subsequent reoccupation and political reorganisation of Lower Nubia by the Romans—also recorded on the Philae Stela—that a Roman protectorate was established (Török 2009: 431-434). Roman forces would attempt to conquer all of the Meroitic kingdom in 25-24 BC but could only take and hold the region between the First and Second Cataracts (Cassius Dio *HoR* 54.5.4-6; Flavius Josephus, *Ant. Jud.* 15.199, 307; Pliny, *NH* 6.181; Török 2009: 442). Soldiers were recruited from the occupied territory and the assimilation of these Nubian forces would contribute greatly to a mutual acculturation of the different ethnic groups who lived in the Roman Dodekaschoinos: the Egyptian priests and officials, soldiers from what Török (2009: 444) refers to as other remote parts of the Roman empire, and the inhabitants of Lower Nubia. (For the concept of 'Romanisation' see MacMullen 2004.) The soldiers in Lower Nubia would turn to the Nubian gods, worshiping alongside the native population (Török 2009: 446). New temples and sanctuaries were founded in the Dodekaschoinos during the Augustus temple-building activity of 29-25 BC, 25-21/20 BC and after 21/20 BC (Török 2009: 448). The first period (29-25 BC) saw work at Elephantine and Philae, after Cornelius Gallus's campaign of 29 BC, which was mentioned in the hieroglyphic text of Gallus's trilingual stela of which no remains are preserved (cf. Hölbl 2004: 32ff.), and the temenos gate of the Ptolemaic Mandulis chapel at Kalabsha being replaced by a monumental gateway (Török 2009: 448; Winter 2003). The next stage (25-21/20 BC) was at Kalabsha, which saw the chapel and temenos wall pulled down and the building of a new temple started, and—in connection with Roman forces in the Triakontaschoinos—the building of a temple ('Temple 5'). A cult temple was also started at the fortress of Primis/Qasr Ibrim (Frend 1974; Horton 1991; Török 2009: 448). After 21/20 BC there were large construction works at Elephantine, Philae, Kertassi, Tafis/Taifa, Talmis/Kalabsha, Ajuala (Abu Hor East), Tutzis/Dendur, Pselkis/Dakka, and Hiera Sycaminos/Maharraqa (Török 2009: 448). These works were part of a carefully designed program of acculturation extending over the entire population of the Roman Dodekaschoinos, with the iconographic programme of the temples of the Dodekaschoinos designed to display an equality between the Nubian and Egyptian deities in the northern (Egyptian) and southern (Nubian) halves of the temples (Török 2009: 447). These associations through theology and cult were designed to neutralise the ever-present political, ethnic, and cultural differences and tensions resulting from the Roman conquest (Török 2009: 446). Following the Meroitic-Roman war (25-21 BC), the province of *Akine* was organised between the Egyptian frontier and the Secord Cataract (Török 2009: 511). In the three-and-a-half centuries that followed, the elite of *Akine* would act as officials and dignitaries of a centralised Roman government and while there were regional authorities in Lower Nubia these individuals were successfully kept under the control of the Meroitic ruler far to the south (Török 2009: 511).

Following the collapse of the Meroitic kingdom, the Early Nobadia—a small remnant of the Kushite kingdom that Adams describes as a 'post-imperial splinter state'—survived in the north thanks to continued trade with Egypt. The Early Nobadia shows a mix of Kushite, Hellenistic, and Roman influences, for example the jewelled crowns worn by the rulers were of Byzantine design and topped with both Egyptian and Kushite royal symbols. They continued to worship Isis, with some Kushite temples remaining in use and the principal cult centre being on the Island of Philae, within the territory of Christian Egypt (Adams 2013b: 35). Despite this, Adams (2013a: 17) considers the Early Nobadia to show some 'cultural retrogress' with the loss of, for example, an indigenous written language, monumental architecture, and the highest Kushite artistic traditions. The Early Nobadia will be discussed further in Chapter 5.

Having looked briefly at the history of Nubia from the pre- to post-Meroitic Period, the processes involved in ancient glassmaking—raw materials, production, recycling, and an insight into an aspect of the Roman glass trade—will now be discussed.

Ancient Glassmaking

Since there is no contemporary documentation concerning ancient Nubian glass and therefore any findings must be related to what is known about Roman glassmaking and compared to the published analytical data concerning Mediterranean glass of the same period (see Chapter 4). The basis for much of the modern understanding of Roman glassmaking materials comes from Pliny's *Natural History*, in particular the use of Egyptian soda (natron) and the use of Levantine coastal sands (Freestone 2008: 77). Freestone (2008: 77) combined Pliny's descriptions with archaeological and archaeometric work, highlighting ambiguities in Pliny's account. Freestone also emphasised how perceptions of ancient glassmaking models have changed following archaeological discoveries of large workshops in Egypt and the Levant where the prime function was making glass from raw materials but not working it into objects. The 'large-batch' melting is typified by the discovery of an 8-tonne slab of failed glass at Bet She'arim, Israel, although evidence for large-scale melting does exist from earlier periods (Freestone 2008: 79-80; Nenna *et al.* 2000).

Raw Materials

There is a consensus that the deliberate production of glass in Egypt began in about 1500 BC (see for example Lucas 1962: 179; Nicholson and Henderson 2009: 195; Shortland 2001: 211). The principle of glassmaking has not changed since these earliest times. Manufactured glass has always been a mixture of a network former (silica) and a network modifier (flux) (Sagui 2007: 212). Sand would have been the common source of the silica, and because sufficiently pure sand was difficult to come by the natural impurities present were transferred into the glass (Henderson 1985: 270). As achieving the high temperature of 1720°C necessary to melt the silica was beyond the capabilities of ancient pyrotechnology the addition of a flux was required. This has the effect of reducing the melting temperature to 1000-1300°C (Sagui 2007: 212). The chosen flux, either mineral soda or plant ash, can be used to categorise the glass according to modern terminology, although there is little evidence that the ancient craftsmen made such a distinction (Rehren and Freestone 2015: 234).

Plant ash would have been made by burning plants that grow in salt-rich environments (the desert or around the coast) leading to it accumulating small quantities of sodium and potassium. When burned, the sodium and potassium form a considerable part of the resulting ash (up to 25 wt%). On the other hand, ancient mineral soda glass, instead of using burnt plant matter, used naturally occurring evaporate minerals, the most well-known being the natron from the Wadi Natrun in Lower Egypt, although other natron sources such as that in Western Turkey, are known to have been exploited in antiquity (Rehren and Freestone 2015: 234).

To this silica-soda mix was added the network stabiliser (lime) which would reduce the weathering of the glass (Henderson 1985: 277). It is the presence of these three main components and the resulting natural contaminants, in particular alumina, lime, and iron oxide, that enables modern scholarship to classify the different glass groups that dominate the archaeological record in the Mediterranean and Europe for most of the 1st millennium AD (Schibille *et al.* 2016: 1).

Superficially, glass production appears to be a relatively static process as certain raw materials are necessary. That there was little scope for variation gives the impression of little development over time. Ann Aerts *et al.* (2003) examined how the source of silica in North-European Roman glass from the 1st-4th century AD is not as certain as the soda source, concluding that glass was produced at a site away from the soda source. Sand compositions could have varied as a result and the authors consider the dependable consistency of the glass analysed from the Middle East and Europe over the time period of their study to indicate raw glass production was undertaken in stable economic and political structures (Aerts *et al.* 2003: 666).

Shortland (2004; see also Shortland *et al.* 2011) has also examined another of the raw materials: natrun. Looking at natrun and the formation process of the evaporate deposits of the different lakes and the Wadi Natrun he found that the soda present is trona but only in certain lakes at certain times of the year. Thus he made the important observation that the deposits in the lakes have changed over time. This, as Shortland discusses, would have had implications for the glass, since potentially unpredictable amounts of chlorides and sulphates would have a negative effect on the glass manufacture, even preventing it from forming. There is also the seasonality of natrun production since it would not have been a year-round occupation and the potential for the lakes to vary even year-by-year making the process uncertain. Shortland (2004: 514) states that this could potentially have resulted in production ceasing altogether at times.

Shortland (2006) also examined the changes in the composition of Egyptian glass during the New Kingdom using scanning electron microscopy with wave dispersive spectrometry (SEM-WDS) analysis to suggest that glass from the time of Thutmosis III/Amenhotep II shows the widest stylistic variations and is therefore evidence for experimentation in design, something not seen in the more uniform styles and procedures of later periods (Shortland 2006: 593). This contrasts with the earlier belief that Egyptian glassmaking technology never went through any period of experimentation. More specifically, Shortland (2006: 597) identifies the lack of cobalt in glass from the site of Lisht, something that is different to earlier blue glasses in which cobalt and antimony were common. Shortland's (2006: 598) analysis shows the similarity between glasses found at Malkata and Amarna, two sites that were closely contemporary with each other albeit geographically distant, implying a use of the same raw materials. (The use of the same raw materials across geographically distant sites in relation to Nubian glass will be examined in Chapter 4.) By comparison, the Lisht glass is compositionally closer to that from Mesopotamia than to samples from Malkata and Amarna, which may suggest a change in the raw materials used or the influence of methods from Mesopotamia (Shortland 2006: 599). Again, Chapter 4 of this study looks at whether something similar was happening in Nubia.

Shortland *et al.* (2006) undertook a further study of the use of natrun, considering whether the Wadi Natrun was the only source used in conjunction with ancient glassmaking. They conclude that the Egyptian sites of the Wadi Natrun and al-Barnuj were the primary natrun sources used in glass production, a conclusion reinforced by the observation that most glass production was in Egypt and the Levant within reasonable proximity of these natrun sources (Shortland *et al.* 2006: 526-527).

Caroline Jackson *et al.* (2005) also examined the alkali to understand the composition of the raw materials and also discussed the choices and decisions made by the glassmakers. The authors identify two factors that affect the finished glass: the natural variability of the materials used, and what they term 'behavioral variability', that is the changes to the raw materials brought about by the actions of the glassmaker. They define natural variability as an 'understanding of the variability in inorganic and organic raw materials that is central to the formulation of criteria for the interpretation of archaeological glasses' (Jackson *et al.* 2005: 782). The authors state that this type of variability can be used to attribute difference in the raw materials and thus to imply the location of production. 'Behavioral variability' is recognised as being of equal importance in understanding compositional data (Jackson *et al.* 2005: 782). An example of this would be the glassmaker's choice of raw materials. It is the natural variability that needs to be better understood so that the contribution of the behavioral variability can be estimated to assess the effect that the choices made by glassmakers had on the finished product (Jackson *et al.* 2005: 793-794).

Shortland *et al's* (2007) analysis of trace elements to examine both raw materials and the manufacturing processes showed differences in glass produced in Egypt and Mesopotamia, demonstrates the link between compositional variations and local geographical and geological features, thus possibly permitting identification of differences between ancient glasses from different provenances. This, as Shortland *et al* observe, would imply different manufacturing sites. While Shortland *et al's* (2007) study looks at Egypt and Mesopotamia well before the Meroitic Period, the observations and conclusions are still valid to the study of Nubian glass. Was glass found in Nubia coming from one or more glassmaking centres?

Ancient Glass Production

The glassmaking process requires a combination of particular chemical skills; access to specific, sometimes exotic or ill-defined, raw materials; and large quantities of fuel (Rehren and Freestone 2015: 236). It is known that during the Bronze Age, once the appropriate raw materials had been procured, they would be ground as finely as possible before being mixed together. Any extraneous material such as incompletely burned plant ash would then be removed. Once mixed, the ingredients were heated in a process known as 'fritting', a process mentioned by several early scholars including Pliny, the monk Theophilus (10th century AD), and the alchemist Antonio Neri (AD 1612) (Nicholson and Henderson 2009: 199). The ingredients would be stirred continually so as to facilitate mixing, while the gas that was produced would be lost to the atmosphere. The viscosity of the glass meant that it had to be stirred in order to allow the bubbles to escape (Nicholson and Henderson 2009: 199; Vandiver *et al.* 1991: 609). Once the product had cooled it would be ground up, allowing the removal of any large unreacted particles (Nicholson and Henderson 2009: 199). It is at this point, before a final melt, when decolourisers (for example manganese and/or antimony), opacifiers (for example antimony), and colourants (copper, cobalt, manganese, antimony, lead, tin, iron) could be added (Henderson 1985: 270). Such colours were used to imitate precious stones, such as lapis lazuli, turquoise, amethyst, obsidian, jade, alabaster, carnelian, rock crystal, and emerald (Rehren and Freestone 2015: 235). It is Late Bronze Age glass production debris in Egypt that has shown this two-stage firing method and that it used different temperatures. This contrasts with the single-stage firing of the larger scale Roman to early Islamic glass production in the eastern Mediterranean. At this later date raw materials in quantities of 10 tonnes to more than 30 tonnes at a time were being melted in large tanks and fired for weeks (Rehren and Freestone 2015: 236).

Ancient glassmaking methods have continued to be the subject of scholarly debate, projecting back from an initial model based on post-Medieval European glassmaking and a 17th century account by Neri. For Bronze Age production, the model proposed by Rehren incorporated textual and archaeological evidence for the long-distance exchange of coloured glass from Egypt and Mesopotamia to the Levant and Greece. It consisted of several 'elite-attached' studios processing different coloured glass from different producers (Rehren and Freestone 2015: 236). For the Roman Period, Freestone *et al.* (2002a) examined an accepted model for glassmaking and used recent archaeological discoveries to suggest an alternative to the assumption that because ancient glass was made at local or provincial level the product of each of these workshops would have had their own distinct composition. Archaeological finds of large primary glassmaking installations from the Graeco-Roman Period in Egypt and from Byzantine to early Islamic date in Israel, e.g. the eight-tonne slab at Bet She'arim, provide evidence of sites producing large batches of raw glass without necessarily working it. The authors note the abundance of evidence from Israel, while other sources of glass produced in competition with the Levantine factories are not fully understood (Freestone *et al.* 2002a: 258-259). It is hoped that the current study of Nubian glass will help to fill in such gaps by ascertaining the composition of Nubian glass samples from four different sites, three of which will be examined in Chapter 4 with the remaining one looked at in Chapter 5. In Chapter 4 comparison will be made with published data in order to ascertain similarities of composition and this may enable the identification of possible trade links, both direct and indirect. Freestone *et al* (2002a: 270) do suggest caution when looking at correlations between glass typology and composition since many different glassmaking houses are likely to have used raw glass made from the same materials. Should individual workshops in a region use raw glass from different primary sources, however, then this enables improved possibilities for detecting such a correlation. The current study also has the potential to identify whether the revised model of glassmaking needs to be examined further, and this is noted in Chapters 4 and 5. Is it solely a case of there being large primary production sites or does analysis of chemical composition and the technological knowledge associated with production mean that a more nuanced view needs to be taken? The potential reuse of glass as well as a more local level of production also needs to be considered and will be examined briefly in the context of Nubian glass in Chapter 5.

In the late Roman and Byzantine empires, Freestone *et al*'s (2002a: 270) model is based on spatial separation of what they term the 'primary production' of glass in very few but large-scale production centres. These provided glass to countless secondary working sites that processed this primary (raw) glass, as well as cullet for recycling, into new artefacts. This link between production centres is indicated by finds of irregular fist- to hand-sized chunks of fresh glass found across the Roman Empire (Freestone *et al.* 2002a: 270).

As Freestone *et al*'s (2002a) model shows, glassmaking and working were two separate processes. The working of glass included lamp-work, cold casting, moulding, and core forming (Nicholson and Henderson 2009: 202-203). In discussing glass it is generally necessary to be specific about the distinction between raw glass and manufactured glassware since these are different stages in the manufacturing process, so the terms used in this current study reflect this. The second half of the 1st century AD would see the spread of the technique of glassblowing, although bowls and plates could still be cast, and in this form represent a key product of the 1st-2nd (or 3rd) centuries AD (Gliozzo 2017: 455).

Experimental archaeology, such as that undertaken by Sarah Paynter (2008), describes the various types of waste produced in glassmaking, including their characteristics and formation processes. Paynter (2008: 277) also gives physical observations of the glass, for example that the glass gathered in the earlier stages of production had more visible imperfections than glass heated for longer periods. Similarly, the observation that glass gathered at 14 and 29 hours of heating contained occasional undissolved particles, in particular grains of quartz, potassium, feldspar, zircon, spinel, and numerous bubbles, can provide a better insight into the length of the firing process (Paynter 2008: 277, see also 280). Glass heated for more than 50 hours was shown to contain occasional bubbles, few inclusions, and was compositionally more homogenous. Observations from the experimental material indicated that the alkali-rich waste gases from wood-fired furnaces affected the composition of the glass when it was heated over prolonged periods, resulting in increased concentrations of alkali, particularly plant ash (Paynter 2008: 280-281). Observations of this sort have significance for archaeological interpretation of glass analysis, especially if it is suspected that the glass had been recycled (Paynter 2008: 290).

Recycling

Glass is extremely well suited to recycling, since it is easily breakable and it can be remelted for shaping into new objects. Glass recycling is attested in Roman literature and suggested by passages in the writings of Martial and Statius (Freestone 2015: 29). Unfortunately, recycling is very difficult to detect archaeologically but there has been evidence recovered from caches of broken glass from workshops, ecclesiastical contexts, and domestic dwellings that demonstrates that glass recycling was widespread (Freestone 2015: 29). Furthermore, since the chemistry of glass can retain the evidence of recycling it enables the detection of this process, for example the mixing of two different types of glass to produce intermediate compositions. Colourant elements, such as cobalt, can also appear at trace levels too high to be natural, indicating the incorporation (accidental or not) of coloured glass (Freestone 2015: 30). A further effect of recycling is more subtle but still detectable. This involves the incorporation of dust and dirt from the environment, the loss of alkali fluxes (particularly sodium) suggesting reheating, the incorporation of contaminants such as iron (from the blowpipe and pontil and absorbed from the clay melting pot), and elements derived from the fuel ash, most notably magnesium, potassium, and phosphorous. All these factors can result in a deterioration in the colour of the glass and an increase in viscosity, making it more difficult to work, something that will eventually render the glass unusable unless 'fresh' glass is added to the recycled batch (Freestone 2015: 30). The discovery of the 3rd century AD shipwreck the *Iulia Felix* (Silvestri *et al.* 2008: 331) and its cargo of 140kg of broken glass vessels, which when analysed indicated previous recycling, also shows the effects and extent of the process (Freestone 2015: 31). Chloë Duckworth (2020a: 319), however, points out that such problems could be reversed.

Duckworth (2020a: 346) notes that should recycling be considered a possibility when the long-term and large-scale glass production models are re-examined, then the chemical patterning will permit its observation. As a result, she considers that recycling was more widespread in Roman glass production practices than is detectable in the current archaeological evidence, an example of this being the small pits discussed by Hodgkinson and Bertram (2020). Patrick Degryse (2020: 296) has estimated that over a quarter of all glass circulating in the Roman and Early Byzantine economy may have been recycled.

On the practical side of glass recycling, Degryse (2020) observes that the benefits of recycling include being able to avoid sourcing raw materials, instead using, for example, cullet of locally available broken items, which results in waste management and a lower expenditure of energy (see also Duckworth 2020b). It therefore has the potential to have been 'a small-scale process', i.e. at individual workshop level (Degryse 2020: 296).

Experimental work looking at practicalities of glass recycling, in particular the potential to mix different alkali types, has highlighted logistical matters that need consideration (Scott *et al.* 2017: 10). Scott *et al*'s study (2017: 10-11) observed that it is the composition of the glass melt and the temperature of the furnace that affects this process. They suggest that, as a result, it was not until the appearance in the 1st century BC of horizontal heating chambers used for glass blowing that a melt could stay hotter for longer, thus making it possible to completely remelt glass (Scott *et al.* 2017: 11). But therein lies a potentially important distinction. This suggestion by Scott *et al.* that recycling, or rather a complete remelt of glass, did not occur till the 1st century AD highlights the potential need to distinguish between the process of fully remelting to recycle objects like vessels, and reheating to soften glass sufficiently to produce beads. Such a distinction has the potential to highlight a longer history of glass reuse. Additionally, Duckworth (2020b) has highlighted that even a less advanced knowledge of pyrotechnology could still permit glass recycling and therefore this could suggest not only a longer history of glass recycling but also the potential for reuse of glass through the working of imported cullet or from broken objects at site level. Therefore, as Duckworth (2020b: 353) has highlighted, the terms recycling and reheating must be considered carefully so as not to impose any modern preconceptions that might mean we miss the nuances and intricacies of interactions with ancient glass as technological knowhow and resources permitted.

How glass beads could be produced from (imported) cullet or as a result of (imported) glass at site level is shown by experimental work by Hodgkinson and Bertram (2020). They also suggest how this could have been happening towards the beginning of the appearance of manufactured glass in the ancient world. Their study, based at the New Kingdom site of Amarna, showed that small pits could achieve the high temperatures needed to produce glass beads, the absence of these pits from the archaeological record being due to their insubstantial and superficial nature and, in the case at Amarna, not being recorded by early excavators. Then-Obluska and Dussubieux (2021b) also suggest the use of Levantine glass sources during the Late Antique at a local level in Nubia. This highlights the potential for local glass working of imported material and is something that needs to be examined further.

The Wreck of the Iulia Felix: Glass Cullet and Recycling

The discovery of the wreck of the *Iulia Felix* provides a means for us to examine the movement of glass during the Roman period. (For publications that examine the wreck see Beltrame and Gaddi 2007; Dell'Amico, 1997; Dell'Amico 2001; Silvestri *et al.* 2008; Silvestri 2008; Toniolo 2005). The ship was discovered at a depth of 15m, six miles off the coast of Grado in the northern Adriatic in 1986, with underwater exploration of the site beginning in 1987 and ending in 1999 (Beltrame and Gaddi 2007: 138; Silvestri *et al.* 2008: 331). The ship was a small cargo vessel, 15-18m long and 5-6m wide, referred to in ancient sources as a 'corbita' (Dell'Amico 2001; Silvestri *et al.* 2008: 331). The majority of the cargo was *c.*600 amphorae, weighing at least 22tons in total. These containers and the ship's equipment permit the dating of the wreck to between the middle of the 2nd century to the first half of the 3rd century AD. Of particular interest to this study is the wooden barrel of glass fragments found in the bow (Beltrame and Gaddi 2007: 138; Silvestri *et al.* 2008: 331). This barrel, originally 1.4m high, was filled with more than 11,000 fragments of glass vessels totalling 140kg (Silvestri *et al.* 2008: 331). These glass vessels were identified as having been goblets, cups, *hydriai* (the most frequent shape being very thick-walled, square bottles), trays, plates, bottles, small jars, and containers of various sizes, shapes, and decorative types. The most common glass colours were blue-green (this colour was in the majority, in excess of 100kg), pale blue, and pale green, with yellow and dark-green fragments being rare. There were also colourless fragments. Silvestri *et al.* (2008: 331) state that these fragments represent examples of glass that was broken accidentally and then traded to be recycled. So far the *Iulia Felix* is the only Mediterranean wreck found to have been carrying recycling glass, with the majority being coloured glass. This is because, the authors explain, it was cheaper to produce coloured glass than colourless glass (Silvestri *et al.* 2008: 331).[4] Silvestri *et al*'s aim when examining the composition of the *Iulia Felix* glass was to research colourless glass, investigating similarities within and between established glass types in order to compare the chemical compositions of the *Iulia Felix* glass samples

[4] Diocletians's Price Edict mentions that raw glass was sold at 24 and 13 denarii per pound, depending on whether the glass was colourless (*vitri alexandrine*) or blue-green (*vitri indaicis virdis*).

with colourless glass groups documented elsewhere, and to clarify Roman glass-production technology (Silvestri *et al.* 2008: 332; Silvestri 2008: 1492).

Roman glass-production technology has been defined by modern scholarship according to two competing models: 'centralised production' and 'local production' (Silvestri 2008: 1492). The argument for centralised production is based on the relatively stable chemical composition of Roman glass over time, indicating the use of a small number of large primary production sites located near the raw materials (Freestone *et al.* 2002a). Those found in Egypt and Israel dating to the Greaco-Roman, Byzantine, and early Islamic Periods provide the evidence for this model (see Freestone *et al.* 2000; Freestone *et al.,* 2002a for full details on this model of glass production). The opposing model states that glass was made on a small scale at a large number of local or regional workshops. This argument is sustained by the chemical analysis of *Iulia Felix* colourless glass and British Roman glass (Baxter *et al.* 2005; Silvestri *et al.* 2008), Roman, Byzantine, and Islamic glasses (Degryse *et al.* 2006; Freestone *et al.* 2003a; Henderson *et al.* 2003; Leslie *et al.* 2006; Wedepohl and Baumann 2000), as well as ancient texts (Pliny's *Naturalis Historia*), and analysis of the probable sand sources mentioned by Pliny (Brill 1988, 1999b; Vallotto and Veritá 2002; Silvestri *et al.* 2006; Turner 1954).

In order to provide information on Roman glass production for the identification of possible primary production locations, Silvestri *et al.* (2008: 332) and Silvestri (2008: 1493) took a combined approach, using both statistical analysis and archaeological evidence. Their analysis revealed that the *Iulia Felix* glass samples were all of the soda-lime-silica type and used natron as the flux (Silvestri *et al.* 2008: 340; Silvestri 2008: 1499). Additionally, comparing the coloured *Iulia Felix* glasses with the colourless glasses revealed that the production technology of the colourless vessels 'constitute two well-defined technological end-members, also related to group type, which included those of the coloured glass samples' (Silvestri 2008: 1499). According to the findings, the composition of the first 'end-member' implies the use of high-purity sand (being particularly rich in silica and poor in feldspar, calcite, and iron) with antimony as the decolouriser for the colourless glass. The second 'end-member' was glass produced with a quartz-feldspar-carbonate sand composition, making it rich in alkali feldspar and low in iron, with manganese as the decolourising agent (Silvestri *et al.* 2008: 340; Silvestri 2008: 1499). From this the authors identify two types of glass. High-quality vessels (for example cups and plates) had been made from the first type, with less elaborate, lower status items such as bottles showing a mixture of both the first and second types (Silvestri *et al.* 2008: 340; Silvestri 2008: 1499). The analysis of trace elements, particularly zirconium, strontium, and barium, proved diagnostic in revealing the different sands used for the *Iulia Felix* colourless glasses (Silvestri *et al.* 2008: 340). It was the high concentrations of strontium and generally low levels of zirconium in most of these colourless samples that suggest that beach sand was predominantly used as the silica source. The coloured objects (all bottles and low status vessels) were produced using mainly beach siliceous-feldspar-calcareous sand but there was not the same need to exert strict control over the raw materials, and decolourising agents were not used. The authors suggest, therefore, that the use of sands from different sources may relate to the type of glass vessel being made, either high-quality plates and cups or low-status bottles (Silvestri *et al.* 2008: 340). The compositional variability present in all the *Iulia Felix* glass samples does support, in their view, the idea of the multiple sand sources mentioned by Pliny. This variability was also detectable in the colourless glass samples, exemplified by the barium and alumina content (Silvestri *et al.* 2008: 340). With regard to the coloured glasses, Silvestri *et al.* (2008: 340) state that their complex compositional signatures reveal that, as the Flavian poets reported, during the Roman period recycling was common, particularly for lower-status glassware.

The Embiez Shipwreck: Movement of Raw Glass

In the *Iulia Felix* glass was being moved in the form of cullet whilst a wreck discovered near the island of Embiez off the coast of southern France is an example of a ship carrying raw glass (Fontaine and Foy 2007; Ganio *et al.* 2012b). The Embiez wreck dates from the end of the 2nd century to the start of the 3rd century AD (contemporary with or slightly after that of the *Iulia Felix* therefore), with the majority of its cargo being 15-18 tons of raw glass, but is also included finished objects that numbered 1800 vessels as well as two types of window glass (Fontaine *et al.* 2007: 235).

A sample of the glass from the Embiez wreck was analysed, revealing that—like the *Iulia Felix* material—it was soda-lime-silica glass and that two compositional groups could be identified within the sample (Ganio *et al.* 2012b: 219). When the samples from the Embiez wreck and those identified by Silverstri *et al.* (2008) are compared, however, the results show a clear difference (Ganio *et al.* 2012b: 221, Fig. 1). This difference indicates to Ganio *et al.* (2012b: 221) that different raw materials were used and even suggests production at two separate centres. Ganio *et al*. (2012b: 224) consider that these results present the possibility that there were different centres producing colourless glass at around the same time, especially in view of the close dating of the *Iulia Felix* and Embiez wrecks, even if the trade routes used cannot be identified.

What is of great interest with these wrecks is that there is an apparent differentiation in glass as a raw material between 'fresh' raw glass and the recycling cullet. This gives an insight into how glass as a material, rather than the finished product, was viewed and may hint at the possibility of different destinations for the cargoes based on whether it was fresh glass in the form of ingots or recycled glass from cullet.

Having examined a specific part of Roman trade as it pertains to glass, a broader overview of the movement of goods through Roman Egypt will now be discussed. This highlights the wider context of the trade links in which glass of the Mediterranean world (as a raw material and/or finished objects) played a part.

The Movement of Goods in Roman Egypt

In the Mediterranean shipping has permitted cultural exchanges between regions otherwise separated by thousands of kilometres. These exchanges reached their peak during the Roman empire (1st to 3rd centuries AD) (Rubio-Campillo *et al.* 2017: 1241), with the sea route between Alexandria and Puteoli (Italy) being the most important in the Roman world for the export of Egyptian grain to Rome, and the movement of money for the luxury products of eastern trade (Tchemia 2016: 48). As a side effect of this trade through Alexandria, and the resulting shipping this generated between Italy and the Eastern Mediterranean, there was also the circulation of many different types of goods, for example Baetician oil, Cretan wines, and Egyptian chickpeas (Tchemia 2016: 275). Alexandria's prominence in this trade network and its status as a port could have enabled material traded with Nubia to cross the Mediterranean. The nature of movement across the Eastern and Western deserts should also be considered. It is therefore necessary to look briefly at what mechanisms could have been used to move all sorts of materials through Roman Egypt.

When looking at the transport of goods by land and water, Egypt's geography and topography must first be examined. It is the movement of grain that best illustrates the effect that the Nile flood, which lasted from June to September, had on river transport just before the inundation was due (Adams 2007: 19). (On the hazards of travel in Egypt see Adams 2001; Nachtergael 1988. See P. Oxy. LIX 4003 (4th or 5th century) and 4004 (5th century) for river transport affected by the flood.) This is seen in P. Oxy XVIII 2182 (AD 165), where Heliodorus, the strategos of the Themistos and Polemon divisions of the Arsinoite nome, writes to the royal scribe of the Oxyrhynchite nome urging him to send more transport animals to assist with the movement of grain in the Arsinoite, 'while the river is still navigable' (Oxy. XVIII 2182 (AD 165); Konkordanz, BL. 153, see Hoogendijk *et al.* 2007 on the date BL VIII 254). The verb used is ὑπονοστέω which normally has the meaning 'to retire' (Youtie 1944: 163-5 1/4 Scriptiunculae ii 869-72), with ὑπο- acting as a 'minimizing' prefix. The text may therefore mean 'as the water is imperceptibly falling' (Adams 2007: 19). Transport upstream would therefore not have been possible 'since the force of the river overcomes every human device' (Diodorus *BH* 1.33.1). The Nile flood also had an effect on land transport, with neighbouring roads being rendered impassable (Adams 2007: 20). This is seen in the 2nd/3rd century AD in a private letter from Oxyrhynchos (P. Oxy XXXIII 2680) in which a woman named Arsinoe writes to Sarapis, referring to the roads not yet being firm, possibly due to the inundation. Similarly a papyrus from the archive of Zenon shows that transport animals were unable to travel between Nechthenibis in the Saite nome to Hermopolis Parva in the Delta because the flood had covered the roads (P. Mich. Zenon 103, col. 1, 2-8 (first half of 3rd century BC)). The use of the verb καταγωγειν in line 6 of P. Mich. Zenon 103 must, according to Adams (2007: 20), indicate the caravan's intention to travel north, 'down to' the Delta, and thus Hermopolis Parva is the probable destination. Recorded evidence of the movement of grain shows that this transport was more concentrated in the periods immediately after the harvest and before the flood (Adams 2007: 19-20). In addition to the use of the river Nile for convenient transport, evidence from a 1st century AD papyrus from Oxyrhynchos (P. Oxy. XLII 3052) details not only the stopping points for travellers on the Nile but also the available canals (Adams 2007: 21). (On the canal at Schedia see Strabo 17.1.16, who mentions the presence of a customs station.) Glass and glass products could have taken advantage of the routes that facilitated the large-scale movement of grain and people. This could also include the trade in oils and in unguents contained in glass vessels, such as the fragments seen at Meroe, or the more 'accidental' movement of more everyday personal objects like beads found at such places as Faras, Gabati, and Qasr Ibrim.

While the Nile dominated life in Egypt and was crucial to transport and commerce (Adams 2007: 8), land transport in Egypt has been regarded as being of lesser importance. But for transport of goods from the Red Sea ports, such as Berenike, to the Nile land routes would have been a vital part of the wider transport network. The major road networks ran the full length of Egypt from the Mediterranean to Syene (e.g. P. Oxy. I 112 (3rd or 4th century)) but due to the annual flood and related changes in the course of the river any trace of them has been lost (Adams 2007: 22). Milestones are now almost entirely absent from Egypt. While the lack of them in the Nile valley is explicable because of the flooding and depredation over time, it is more surprising in connection with the well-attested routes in the Eastern Desert (Adams 2007: 22). Strabo mentions marker-stones, probably predating the Roman period, on the road from Syene and Philae (Strabo 17. 1. 50.), while from the Roman Period only two milestones survive from the whole of Nubia, one Trajanic, the other tetrarchic. The first of these records the distance to Philae (32 miles), the second is unclear (Adams 2007: 22 (CIL III Suppl. 141482 and 141483)). Only one milestone survives elsewhere in Egypt. This one is Constantinian in date, and relates to the road connecting Babylon with Clysma, via Heroonopolis (Adams 2007: 22 (CIL III 6633)). Nevertheless, the road system was used for the transport of produce over land since not everywhere in Egypt was accessible by the river, prime examples being the Faiyum and the Eastern and Western deserts (Adams 2007: 8).

The Eastern Desert was connected to the Red Sea, which was where the trade in luxuries between Rome and the East entered the Mediterranean. Textual and archaeological evidence shows that glass (as both raw material and finished product) was traded from the Mediterranean, via the Red Sea, to India. The *Periplus Maris Erythraei* of the 1st century AD, describes two major lines of trade from the Red Sea ports of Egypt, one that followed the coast of Africa, the other heading eastward to India, with Egypt being specifically mentioned as the point of departure (see *Periplus* 6:3.5, 14:5.7, 49:16.31, 58:18.28-29 Casson 1989: 15). Opinion, however, is divided on the dating of the *Periplus,* ranging from AD 40 to AD 120 (see Casson 1984: 39 who favors AD 60-120, while Fitzpatrick 2011 gives a date of AD 40-70, as does Millar 1998: 529). The *Periplus* includes details of Egypt's trade in glass to India, in particular to the ports of Barbarikon (near the modern city of Karachi) and Barygaza (the Graeco-Roman name given to the city of Bharuch), two of the major ports serving the northwest of India's west coast (Casson 1989: 22). Barbarikon is mentioned as only importing finished 'ὑαλᾶ σχενη' 'glassware' (*Periplus* 39:13.9) (Casson 1989: 75), while Barygaza imported only 'ϋελος ἀργὴ' 'raw glass' (*Periplus* 49:16.23) (Casson 1989: 81).[5] The use of different words in the *Periplus* indicates that there was a market for both the finished objects and glass as a raw material, as in the Mediterranean. Archaeological evidence for this trade in glass is provided by a diagnostic type of Mediterranean glass vessel: the ribbed bowl. Upriver from the site of Barbarikon, mentioned in the *Periplus*, ribbed bowls have been found in Taxila and Begram contexts (Borell 2010: 127). Additionally, from the port site of Arikamedu (Podouke in ancient written sources) on the south-eastern coast of India, a fragment of mould-made dish characteristic of Hellenistic glassware, and three ribbed bowls were found. When this fragment was analysed Brill found it to be made of a natron type of soda-lime glass, a characteristically Mediterranean glass recipe. These types of vessels have a similar date range to the *Periplus*: 1st century BC to 1st century AD (Borell 2010). The mechanisms for trade with India (also with Africa and Arabia) involved using Nile boats to take goods upriver to Coptos, where they were then transferred to donkey and camel trains (Casson 1980: 22). The *Periplus* describes crossing the Eastern Desert to Myos Hormos and then down the Red Sea coast to Berenike (*Periplus* 1:1.2-4) (Casson 1989: 13). (Pliny *NH* 6.102-103 gives in detail the route to Berenike; for Myos Hormos see Strabo 2.5.12 (118); Casson 1980: 22.)

[5] A third form was also imported, millefiori and mosaic wares, described as 'numerous types of glass tones and also of millefiori glass of the kind produced in Diospolis', (*Periplus* 6) (Botan 2014: 159). This third form is not discussed in this study.

Work by a Polish team at the Red Sea port site of Berenike, in particular the excavation of 2000 beads and pendants during the 2009-2012 seasons, found in early- and late-phase occupation contexts, has shown the extent of this trade coming from India into Egypt. The early phase of the site corresponds to the 3rd century BC to the 3rd century AD (contemporary with the Nubian Meroitic Period) and the late phase dating from the 4th century AD to the beginning of the 6th century AD (post-Meroitic Period) shows the potential for glass material to enter Egypt via this Red Sea port (Then-Obluska 2015: 736).

Once these beads entered Berenike they could have moved from the port to the Nile Valley along the road that linked the port to Coptos. This road was approximately 380km long and, according to Pliny (*NH* 6.26.103), involved a twelve-day trip (Sidebotham 2011: 128). While there was a road linking Berenike with Apollonopolis Magna (Edfu), a survey by Steven Sidebotham has revealed that this route fell out of use in the Late Ptolemaic or Early Roman Period. By comparison, the road from Berenike to Coptos rose to prominence, particularly in the mid to late 1st century AD (Sidebotham 2011: 160). Another route, revealed by Sidebotham's survey (2011: 128), linked Berenike to Syene.

Along with the Egyptian Red Sea ports mentioned in the *Periplus*, is a Nubian Red Sea port, Adulis, which is described as being 'about 3000 stades beyond Ptolemaic Thêrôn' (*Periplus* 4) (Casson 1989: 51). The *Periplus* describes Adulis as 'a legally limited port of trade' (*Periplus* 4:2.6), with Lionel Casson calling it 'a modest village' (Casson 1989: 20). The *Periplus* states that Adulis is 'a journey of three days to Koloê', (*Periplus* 4) (Casson 1989: 53). Ivory was exported from Adulis and traded into the Roman Empire (Haaland 2014: 656). Pliny the Elder (*NH* 6.34.173) also describes the port.

Recent surveys at the site of Adulis have discovered a port (although not necessarily the same one). More of the site from the 4th century AD has also been revealed, Sidebotham believing this to imply that there were two ports at Adulis, one early, the other of late Roman date (Geresus *et al.* 2005; Habtemichael *et al.* 2004; Munro-Hay 1982: 107; Peacock and Blue 2007; Peacock *et al.* 2007: 2-5, 7-9, 31-32, 37, 57-64, 79-86, 95-96, 103-104, 112, 125-134; Sidebotham 2011: 187). Glass finds have been recovered from the site (Zazzaro 2013: 5). Finds now in the National Museum of Eritrea include 400 glass objects with the wide date range of the 1st millennium BC to the 6th-7th century AD (Zazzario 2013: 32). Unfortunately, there is not yet the same wealth of evidence, or even precise dating, possible for this material.

By contrast, the Western Desert, while not being the focus of the same level of trade as the Eastern Desert, was still linked to the Nile Valley with a considerable amount of wealth being generated through these connections (Adams 2007: 8). As the Western Desert relied on supplies from the Nile Valley, the difficulties in reaching these regions meant there was heavy state involvement in maintaining connections (Adams 2007: 196). Unfortunately, there is much less actual evidence for trade in the Western Desert (Adams 2007: 235). (For scholarly work on the Western Desert see Wagner 1987.) It is known, however, that routes would have connected the oases in the Western Desert with the Nile Valley, principally at Oxyrhynchos, and the Fayum, with routes also existing between the oases themselves. (On the routes see Adams 2007: 235; Fahkry 1973: 14-15; Fahkry 1974: 22-6; Wagner 1987: 140–54.) Because military units were based in the oases, communication with the Nile Valley was vital, as they required considerable quantities of supplies, with the presence of soldiers encouraging further trade.

The oases of the Western Desert would also export goods. They were producers and exporters of wine, dates, and olives, but despite their fertile lands the oases could not support their populations and so imports from the Valley and Fayum were essential (Adams 2007: 235). The evidence for this trade with the oases comes mostly from customs receipts, an example being one that was probably issued in the Small Oasis detailing payment for the 1% tax on a donkey load of barley and garlic (P. Oxy. XII 1439 1/4 P. Customs 8 (AD 70)) – the text does not record whether the goods were exported from the oasis, but this seems likely, as the papyrus was found in Oxyrhynchos. (On the production of garlic, see Adams 2007: 235; Crawford 1973.) As well as customs receipts, additional evidence for transport and communication in the Western Desert comes from letters. Two letters from Oxyrhynchos, acknowledging the return of a deposit, provide evidence of a network of individuals who were engaged in transport and possibly also in trade (P. Oxy. XLI 2983-4 (late 2nd/early 3rd century AD), and P. Oxy. XLI 2975 (AD 198); Adams 2007: 237). (On administrative links between the Small Oasis and the Oxyrhynchite nome see Lewis 1964: 27-30, esp. text 2, with P. Merton III 106.) The Great Oasis was similarly linked to the Heptanomia (see Hagedorn 1967, with P. Amh. II 137 (AD 289)). A good example of such a landowner is Claudia Isidora alias Apia (see P. Oxy. XIV 1630 (AD 222), Rowlandson 1996: 114). The first letter deals with financial matters and trade, with Harpalus writing to his brother Hera to tell him he had received a consignment of fish-paste and he had paid the river and land freightage. Other details were also recorded such as the receipt of wine from Herakleides, trade in animal skins, and the receipt of a letter of credit (Adams 2007: 237). Adams suggests that this second letter indicates regular communication, since it is the acknowledgement of the receipt for the deposit on a loan. This was also taken by Adams to show regular financial transactions between different parties.

Our best evidence for trade and transport in Egypt comes from a large collection of customs receipts, almost all of which come from the Fayum, the earliest dating to March of AD 18, and the latest attested by seals and regnal years to AD 214 although the latest receipt to bear an imperial title is P. Grenf. II 50(e) (AD 175). (On seals see Adams 2007: 239-240; Vandorpe 1995, 1997: 253.) About 300 cases full of receipts are preserved covering 16 custom registers amounting to nearly 1000 individual documents (Adams and Gonis 1999). It is possible that P. Hawara 208 (AD 24/5) is also a customs register, although it does not conform in type (Adams 2007: 239; see van Minnen 1992, see also P. Oxy. LXIX 4740–4). Villages in the north of the Fayum (Soknopaious Nesos and Karanais) are shown to be linked to the oases and also to lands to the north, with routes to the Wadi Natrun, Siwa, nomes in the western Delta, and even as far as Alexandria (Adams 2007: 241). The goods transported were varied, including a great variety of agricultural produce such as staples (wheat and barley) and more desirable commodities (honey, aromatic nuts, fenugreek and dates); furniture and clothing (linen, cloaks, purple for dying) but the most common items recorded in the customs receipts were wheat, wine, and oil (Adams 2007: 241). (For a statistical analysis of the foodstuffs taken through the customs houses, see Habermann 1989.) Additionally, the tax paid on the transported wheat Adams (2007: 247) suggests it was intended for private consumption, perhaps for the supply of a city like Alexandria or Memphis. Adams states that it was transported to Philadelphia indicating its destination was Kaine, the closest harbour to the north-east Fayum which was ideally placed for transport by river to Memphis or Alexandria. A papyrus dating to AD 319 provides further information about how goods moved about (UG I 20, with PUG II Appendix I. The text was re-edited by Wagner 1987: 327-8. Wagner does not take into account the new edition in PUG II, nor the remarks and re-edition of Gofas 1982: 499–505, see also Adams 2007:

238; Amelotti and Migliardi 1969; Gofas 1992). While details of the trading ventures or the commodities purchased are unclear, this papyrus does state that both parties will bear the cost of the transport charges 'up to Egypt and to the Oasis' (PUG I 20 ll. 9-10 αχρι Αιγνπτον και εις ̈Οασιν, Adams 2007: 238). Gofas suggested that the goods might have come from one of the Red Sea ports, the phrase 'up to Egypt' often being used to describe the route from the desert to the Valley, but it may also Adams (2007: 238) suggests refer to goods coming into Egypt via Alexandria.

The documents from Oxyrhynchus also present the opportunity to assess the communication networks that might have been relevant to the trade in glass, whether as a raw material or as a finished product. Of the 201 texts that attest to communications with communities outside the Oxyrhynchite, more than half show links to the north, with 25% of the total showing communication with Alexandria (Paterson 1998: 189). The urban centres such as Oxyrhynchus and Alexandria function as retailing and production hubs, with each city serving as the economic centre for its nome. The city's trading relations extended beyond the region, to Egypt (and potentially to Nubia), and then to the rest of the Roman Empire. The archaeological, papyrological, and numismatic evidence attests to trade beyond the frontiers of the province, the majority of contact being within Middle Egypt and with Alexandria. It is likely, as Paterson (1998: 192) states, that the majority of non-Egyptian goods (including coinage) passed to these Middle Egyptian communities via the markets of Alexandria. Alexandria was described as the place where 'all the races of the world met and traded' (Dio Chrysostom, *Oratio* 32. 36) with the city not only controlling the trade from India and the East that passed through Egypt as well as the trade in Egyptian goods, but also acting as the port of call for ships heading between the west and the Palestinian area (Paterson 1998: 195).

Cities in Egypt, as described in contemporary texts, provide us with evidence for retail outlets and trade. The building programs initiated by the city elites in the late 1st and early 2nd centuries also provided trading facilities throughout much of Egypt. *Stoae* erected along major thoroughfares were ideal for shops and stalls, with cities able to collect income from renting these spaces. Any of these retail facilities could have been involved in the trade in glass either as a commodity in its own right (jewellery, ornamental, domestic items) or as vessels such as those for perfumes or similar liquids. *Agorai* were also provided by cities, with at least three being present in Oxyrhynchus: one by the Seraphim along or beside the processional avenue between the two main temples of the city; a vegetable market in the southeast of the city (P. Oxy I 43 v.) near a gate; and one specialist '*agora* of the shoemakers' (P. Oxy. VII 1037) (Paterson 1998: 184-185). Thebes had at least two (Palme 1989), a north market (O. Leid, 79, 98, 105, 106; O. Thebes 49) possibly outside the main pylon of Karnak, where a tariff of charges and taxes have been found; and a south market (O. Thebes 77) (Paterson 1998: 185). At Hermopolis there was a covered area that may have been used for retailing (*Stud. Pal. Pap.* V = *CPH* 119). Such markets were rigorously controlled with the *agoranomoi* probably having responsibly for the registration of sales and for supervision (Paterson 1998: 185). Markets near the temples were dominated by buildings representing the urban authority in Pharaonic and Ptolemaic periods, with the market square at Elephantine being enlarged in the Augustan period, a large tribunal being placed in the centre where officials could survey the market and those present (Jaritz 1980; Paterson 1998: 185; Smith 1976).

In Roman Egypt there was both regional and inter-regional trade. The *metropoleis* of the *chora* were not only the focus of local trade and supply from the nome territories they depended on, but were also important for traders outside their nomes who were looking for good prices at their markets, with Alexandria and Memphis being the focus of vigorous trade (Adams 2007: 252). Egypt was a great exporter of products, for example cloth, medicines, and—notably for the current study—glass. In turn a lot of wine and other commodities were imported, this happening separately from the state-driven economies of the grain supplied to Rome or clothing supplied to the army (Adams 2007: 252). Records of transport and travel in Egypt show a high level of mobility and 'connectivity', with the Nile uniting the routes that traversed the desert and those criss-crossing the Valley with the *metropoleis* and with Alexandria, and through this major trading hub to the wider Roman empire (Adams 2007: 283).

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This opening chapter has surveyed trade between Nubia and Egypt from the 7th century BC onwards, and noted that interaction around the Mediterranean resulted in Hellenistic influences on technology and creativity. It has also looked at the details of Roman trade in Egypt. Against this background glassmaking flourished and developed. Not only was glass made from scratch, it was also recycled and, furthermore, there is evidence from the Roman Period for international trade in both coloured and colourless glasses, whether new or cullet. The remaining chapters will present the dataset and methodology (Chapter 2), results of the chemical analysis (Chapter 3), then provide a discussion of these results (Chapter 4). Finally in Chapter 5, there will be an examination of a less usual glass type (that with a high lead content) found in Nubia. Glassy faience will also be discussed and the potential for local production/imitation of glass assessed.