

**An Investigation of Production
Technologies of Byzantine Glazed
Pottery from Corinth, Greece in the
eleventh to thirteenth centuries
Volume 1: Text**

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Thesis submitted for PhD

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February 2009

ABSTRACT

The century of archaeological excavations carried out at Corinth, Greece have resulted in the accumulation of a collection of Byzantine glazed pottery unparalleled in the Aegean. The site is set apart from others as being one of only a few sites in the Byzantine world where glazed pottery manufacture has been confirmed. The glazed pottery assemblage demonstrates a changing industry there. During the eleventh century local production consisted of brown glazed, unslipped vessels in a conservative range of forms that were in use alongside the imported, fine Constantinopolitan slip painted and polychrome White Wares. By the end of the eleventh century the local industry had established itself and these imports had ceased as a competitor. At this time local pottery production went through a major revolution in terms of decorative techniques and vessel morphology. Instead of the earlier plain glazed products slips and green and brown glazes were used in combination to produce a range of decorative styles each lasting only a generation or so.

In this thesis, the development of production technologies of Byzantine glazed pottery manufactured at Corinth between the eleventh and thirteenth centuries are examined using a number of archaeometric techniques: pottery fabrics are examined using ceramic petrography and inductively coupled plasma-atomic emission spectroscopy and their corresponding glazes are investigated using electron probe microanalysis. The data collected were used to establish patterns of pottery production and trade, and in particular explore developments in methods of glazing. A period of transition in glazing technologies is identified, while certain technological practices are shown to be more sophisticated than has previously been acknowledged for the period in question.

ACKNOWLEDGEMENTS

I would like to thank the following people for their help and support: in particular, my supervisor Dr Caroline Jackson, Department of Archaeology, University of Sheffield and my advisor Dr Guy Sanders, Director of the Corinth Excavations, American School of Classical Studies at Athens.

Also: Dr Sherry Fox, Director of the Wiener Laboratory, American School of Classical Studies at Athens; Dr Evangelia Kiriati, Director of the British School of Classical Studies at Athens; Dr Miguel Cau Ontiveros, Departament de Prehistòria, Universitat de Barcelona; Dr Yona Waksman, Maison de l'Orient et de la Méditerranée, Lyon; Dr Joanita Vroom, Leiden University; Mr Dave Plant, Manchester Electron Microprobe Facility; Dr Nick Walsh, NERC ICP-AES Facility, University of London; Drs Justine Bailey, David Dungworth, Sarah Paynter and Mr Roger Wilkes, English Heritage, Centre for Archaeology; Dr Patrick Quinn, Department of Archaeology, University of Sheffield; Dr Christina Tsoraki, Department of Archaeology, University of Sheffield; Dr Vasilis Roubos, Department of Civil Engineering, University of Sheffield; Mrs Apostolos Koulouvatos and Constantinos Koulouvatos.

The funding bodies: Wiener Laboratory, American School of Classical Studies at Athens (Wiener Associateship); Centre for Aegean Archaeology, University of Sheffield.

And for keeping me going: my family (Mum, Dad, Grandparents, Tom and Kay), Andy and Laura Hammon, Pat Wagner, Jamie Twycross, Gianna Ayala, Paul Mitchell, Jerry Tattershal, Naomi and Adam Nathan-Thomas, Tim Allen, Sarah Clark, Jodie Whyte, James Hope, Kim Mitchell, Faith Burns, Gwyneth Barton, Kieran Williams, Linda Howie and Maurizio Guadanini.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The application of material analytical techniques to investigate compositions and production technologies of archaeological glazes has been a growing concern during the last decade in the field of archaeometry. Much of the work carried out in this area has focussed on glazed pottery from the Islamic world (for example Mason and Tite 1997, al-Saad 2002 and Chapoulie *et al.* 2005) and more recently on medieval glazed pottery from Italy (Fabbri *et al.* 2000, Comodi *et al.* 2004 and Fortina and Memmi Turbanti 2007). Despite the increasing interest in archaeological glazing technologies in recent years Byzantine glazed pottery has received scant attention.

1.2 The Present Situation

Byzantine pottery studies have gradually been moving away from the traditional realm of stylistic and chronological analyses (Morgan 1942, Stevenson 1947, Hayes 1992, Sanders 1995; 2000) and art historical perspectives (Talbot-Rice 1965, Piltz 1996, Armstrong 1997). Over the last two decades there has been a growing interest in provenance questions using chemical analysis in an effort to understand networks of production and exchange in the eastern Mediterranean (for example Megaw and Jones 1983; Megaw, Armstrong and Hatcher 2003) (see Chapter 3). Reflecting the different priorities in ceramic studies in general, there has been a change in emphasis that has brought in work on technological aspects. A number of papers in edited volumes approach these aspects (see Maguire 1997, Papanikola-Bakirtzi 1999), while Joyner (1997; 2007) has carried out petrographic analysis of Byzantine Cooking Wares from Corinth, linking pottery technology and morphology to eating habits. Where glazing technology is concerned the traditional view is that Byzantine potters made use of lead glazes to decorate pottery, and this technology was widespread across the Empire and unchanging from its earliest use in the seventh century AD to the late Byzantine period (thirteenth to fourteenth centuries AD) (for example Dark 2001, 87; Vroom 2003, 266). This view appears to be supported by the few analytical studies of Byzantine glazes which have been undertaken to date (for example Armstrong *et al.* 1997, Wisseman *et al.* 1997) (Chapter 3). These previous studies, however, have relied upon limited sample numbers from geographically diverse areas and so potentially miss details in technological trends (for instance Armstrong *et al.* 1997). Since this time, methods of

interpreting glaze compositional data have successfully demonstrated it is possible to obtain higher levels of information regarding technological practices, especially where lead glazing technologies are concerned (for example De Benedetto 2004, Walton 2004) (Chapter 2). Very recently researchers have recognized the need to increase our understanding of Byzantine glazing technologies, and the first steps to achieve this goal have been undertaken by Waksman and her colleagues (Waksman *et al.* 2007; 2008). These important works, however, have focussed solely on the technological developments of the earliest Byzantine glazed White Wares dating to the seventh century from the region of Constantinople, leaving the large class of later Byzantine Red Wares untouched. This thesis attempts to redress the balance by providing an in-depth investigation Byzantine glazing techniques and their developments through time at a single site. This was achieved through the multiple sampling of glazed pottery from a known production centre and applying an integrated analytical methodology that takes into account compositional data of both ceramic bodies and their glazes. The production centre selected for this study is Corinth, Greece. The reasons why are explained in Section 1.3 below.

1.3 The Middle to Late Byzantine/Frankish Ceramic Assemblage at Corinth

The American School of Classical Studies in Athens (ASCSA) has a long tradition of archaeological intervention at Corinth, with the first permit for excavation granted in 1896 (Langridge-Noti 1996). The emphasis of early work was biased towards discovering monuments of the Classical city. In the process of clearing the Central Area of Corinth, the Byzantine levels were exposed. Under the auspices of Carpenter in the late 1920s, who subscribed to the notion that to ‘dig a site is to destroy it’, the Byzantine levels, rather than being removed wholesale and without documentation, were carefully excavated and recorded. Material, including pottery, coins, sculpture and metalwork, were collected and stored in the museum (Kourelis 2007). The 1940s and 1950s saw the publication of two important works detailing the Byzantine pottery (Morgan 1942, see below) and medieval architecture of Corinth (Scranton 1957). The Late Byzantine/Frankish period has also commanded attention following the discovery in 1990 of a small Byzantine-style church and associated material culture in the area southeast of Temple E. This became the focus of the ASCSA’s excavations in following years (Langridge-Noti 1996). In the view of some, Corinth stands out as being the subject of the most methodical exploration of any Byzantine urban centre in Greece (Kourelis 2007, 399), and certainly, as the result of this long history of

excavation and attention to Byzantine archaeology, the extensive reference collection of glazed pottery of Byzantine date held at the Museum of Ancient Corinth is unparalleled in its size and quality.

The existence of major pottery production at Byzantine Corinth is to be expected, due to the significance of the site at that time and with the long tradition of pottery production in the locality (for example Stillwell 1948, Merker 2005) (Chapter 4). In order to examine development of technologies at a local level, it was of importance to this thesis that the excavations of the 1930s proved conclusively the existence of pottery production in the area of Corinth. Primary amongst this evidence are a number of kiln structures of Byzantine date, and debris associated with production. These include slipped, unglazed biscuit-fired sherds, dunted wasters and kiln furniture. Where possible wasters were sampled to help characterise and confirm local productions.

The Byzantine glazed ceramic assemblage from Corinth has been the focus of a number of studies. Morgan examined the pottery stylistically in his *Corinth XI* volume (Morgan 1942) and Sanders (1995; 2002; 2003) built upon that work, focussing particularly on pottery of the ninth to twelfth centuries. The Late Byzantine/Frankish pottery has been treated in a series of articles published in *Hesperia* (for example Williams and Zervos 1990; 1992; 1995 and Williams *et al.* 1998) and by Mackay (2003). A tight relative chronological and typological framework now exists for the pottery under study (Chapter 6). This crucial resource means that the glazing practices identified can be linked to the chronological sequence.

In addition to the work carried out upon the Byzantine glazed ceramic assemblage, a number of researchers have investigated raw material resources for ceramic production at Corinth. The studies date back to the 1960s with Farnsworth's pioneering work on clays and tempering materials in the Corinthia (Farnsworth 1970, Farnsworth *et al.* 1977) and this was extended by Jones (1986) and Whitbread (1995), amongst others, who undertook additional regional studies of Corinthian clays. Consequently, there is a body of information available detailing the physico-chemical properties of clays from the region (Chapter 5). Since, previously, glazed pottery types from Corinth have been classified according to local and non-local sources based upon macroscopic analysis of fabrics and the criterion of abundance (Morgan 1942, Sanders 1995) it was necessary to refine provenance assumptions by examining the ceramic fabrics chemically and

microscopically. The data provided by Farnsworth (1970), Jones (1986) and Whitbread (1995) proved instrumental in assessing origin of the pottery.

1.4 Scope of the Thesis

This thesis attempts to expand our knowledge of Byzantine glazing technologies and explore questions of technological transfer by presenting new analytical data of Byzantine glazes from pottery manufactured at and imported into Corinth during the eleventh to thirteenth centuries. The questions investigated in this thesis are based on the broad themes of provenance and technology. They are:

1. Can categories of pottery be confirmed as local and non-local based upon chemical and petrographic characteristics of the ceramic fabrics? And hence,
2. Do raw material use and production technologies of the pottery vessels change during the eleventh to thirteenth centuries?
3. Can changes in glazing technologies be detected during the eleventh to thirteenth centuries in locally produced pottery?
4. Are there differences in glazing technologies between locally manufactured and imported glazed wares?

Throughout this study, 'Middle Byzantine' refers to pottery produced and used during the eleventh to late twelfth/early thirteenth century. Following Vroom (2003, 28) the combined term 'Late Byzantine/Frankish' refers to pottery produced and used during the thirteenth century, where the word 'Frankish' refers to the period of Frankish domination in Central Greece from 1204, while the term 'Late Byzantine' is more an art-historical term employed to describe the material culture in Greece during the Frankish Period.

The date range of this study (eleventh to thirteenth century) has been selected with good reason. The previous stylistic and chronological studies of the Byzantine glazed pottery assemblage from Corinth reveal that the types of glazed pottery being made at Corinth underwent a number of changes during these centuries. In addition, given the changing nature of the assemblage in terms of pottery both produced in and imported into Corinth

during the three centuries, it was considered there was great potential to detect developments in glazing technologies during this period at the site and identify links between technologies which are local and non-local.

An analytical methodology was selected to optimize the range and depth of information that could be obtained from the glazed ceramics under study (Chapter 7). Using a combination of inductively coupled plasma-atomic emission spectrometry (ICP-AES) and ceramic petrography fabric groups were investigated in order to establish which fabrics were produced at Corinth and which were imported, and make observations concerning ceramic technological practices (Chapter 8.1). The glazes were chemically characterised using electron probe microanalysis (EMPA), while supplementary analysis of glaze microstructures was undertaken using scanning electron microscopy with attached energy dispersive X-ray analytical facilities (SEM-EDS).

1.5 Structure of the Thesis

The background chapters of this thesis are structured in a way which best draws together the information that informs and supports this research, and moves from a general to site specific level. Chapter 2 defines ceramic glazes, presents the approaches in which archaeological glazes have previously been studied, and justifies the analytical methodology selected for this study. Chapter 3 deals with previous analytical studies of Middle to Late Byzantine/Frankish pottery. It serves to explain the current state of knowledge and highlights the gaps in that knowledge. Chapter 4 provides a historical overview of Middle to Late Byzantine/Frankish Corinth, and presents the physical evidence for glazed pottery manufacture at the site during this period. Chapter 5 presents a geological overview of Corinthia and brings together previous research on raw material resources for pottery manufacture in the locality. The final background chapter is Chapter 6 which details the chronology and typology of the Middle to Late Byzantine/Frankish glazed pottery from Corinth. The methodology is presented in Chapter 7 where the rationale for the chosen sampling system is discussed and the analytical methodology, instrument protocols, data interrogation and quantification methods are detailed. The results of the analyses are given in Chapter 8, and are presented under the headings of 'Ceramic Fabrics', where the petrographic and chemical results are given, and 'Glazes', which considers glaze microstructures and compositions. Where relevant the data are presented in order of the chronological sequence of the pottery. The pottery falls broadly into three chronological ranges in

terms of stylistic groupings. These are the eleventh century to early twelfth century, which accounts for White Wares and Plain Brown Glazed Red Wares (these wares disappear from the ceramic assemblage at Corinth in the first decade of the twelfth century), the late eleventh and twelfth centuries, which takes into account the glaze and slip decorated wares which were introduced in the last decades of the eleventh century and are present throughout the twelfth century, and the thirteenth century which accounts for the more roughly potted Byzantine styles and fine imported wares. Chapter 9 presents a discussion of the results of the main groups of pottery identified from the petrographic and chemical analysis, according to these chronological ranges. Chapter 10 gives the conclusions of the study and presents considerations for future research.

CHAPTER 2

CERAMIC GLAZES AND APPROACHES TO THE INVESTIGATION OF ARCHAEOLOGICAL GLAZES

2.1 Introduction

A ceramic glaze is a smooth, vitrified (glassy) coating fused to the underlying ceramic body. Glazes are applied either for functional purposes or as decorative elements. Where pottery vessels are designed to carry liquid or foodstuffs a glazed surface provides an easily cleanable coating which is impervious to the contents the vessel carries. Translucent or transparent glazes can enhance the appearance of the underlying ceramic and can be coloured with the addition of metal oxides, or in the case of opaque glazes hide the appearance of the underlying ceramic. Most glazes are true glasses (non-crystalline solids of more or less transparency or translucency made from the cooling of a melt of silicate materials) and in general the distinction between a glass and a glaze in terms of composition and physical behaviour is small (Rhodes 1973; Kerr and Wood 2004). Two properties are however crucial to the success of a glaze. These are a raised viscosity and reduced expansivity. Raised viscosity is required to hold the glaze in position and prevent it running off the vessel surface during firing. Reduced expansivity is necessary to help match the expansion and contraction of the glaze to the underlying ceramic body, and prevent crazing and cracking during cooling (Rhodes 1973; Kerr and Wood 2004). Rhodes (1973) highlights a final, important, distinction between a glass and a glaze which relates to the method of forming. The raw materials of a glaze, generally comprising silica (the network former), and other constituents, most importantly a fluxing agent or 'network modifier', necessary to reduce the melting temperature of the silica are blended together, applied to the surface of the ceramic vessel and formed or melted in place during firing. For glass, the raw materials are melted first into a bath of molten liquid material from which the glass object is fashioned.

The manufacture of glazed pottery has a long history, with the earliest pottery glazes dating to around the middle of the second millennium BC in the Middle East (Henderson 2001, 473). These glazes are defined as alkali glazes and contain primarily alkali oxides (10 to 18% Na₂O₃, 3 to 5% K₂O) and silica (Pace *et al.* 2008, 591), making them comparable to the contemporary glass technology. Transparent high lead glazes, comprising 45 to 60% PbO, silica and >2% alkali oxides (Pace *et al.* 2008, 591), were

introduced in the West in the Roman period during the first century BC, and independently, a few centuries earlier in China (Tite *et al.* 1998, 242; Henderson 2001, 473). Lead glazes have been used ubiquitously since the Roman period, appearing throughout the Islamic and Byzantine worlds and in Medieval Europe, for the decoration of both pottery and building materials. Their use has continued to the present day. A further important class of glazes, occurring from the Islamic period, and again common in Medieval Europe especially Italy and Spain, are the tin opacified lead or lead-alkali glazes (Mason 2004). The Islamic lustre-wares and European maiolicas, especially, formed the pinnacle of ceramic art and technology in each region of these two periods (Mason and Tite 1997, 41). The lead-alkali glaze class is defined compositionally as containing 20 to 40% PbO, 5 to 12% alkali oxides and silica (Pace *et al.* 2008, 591).

In general, the study of archaeological glazed pottery has for many years focussed on the art historical perspective, where the primary importance is to explore the nature and significance of decorations. Examples of such studies would include those on Byzantine and Islamic pottery carried out by Talbot Rice (1965), Piltz (1996) and Armstrong (1997). Increasingly, though, there has been a growing trend to approach pottery glazes from a scientific analytical perspective, where chemical and microscopic techniques have been applied to glazes and their ceramic bodies to investigate various aspects of their composition and production processes. This is true of Islamic glazed pottery with works by Mason and Tite (1997), Daszkiewicz and Raabe (1999) and Mason *et al.* (2001); Hispano-Moresque pottery with research carried out by Molera *et al.* (1997), and of Roman pottery with work carried out by Hatcher *et al.* (1994).

The purpose of this chapter is to introduce analytical approaches previously applied to the investigation of archaeological glazes from a range of periods, and laboratory produced glazes, and to discuss the scope and quality of information that may be gained from such studies. It rationalises the analytical methodology selected for the current study.

2.2 Investigation of Archaeological Glazes

2.2.1 Chemical Characterisation of Glazes

The simplest type of study of archaeological glazes is glaze characterization, where archaeometric techniques are applied to groups of glazes in order to investigate their

chemical compositions. Information gained is generally used to define glaze types according to their spatial or temporal contexts. Such studies would include those by Caley (1947) on Roman lead glazes, Hedges and Morey (1975) and Hedges (1976) on pre-Islamic glazes, Fitz (1982) on neo-Babylonian glazes, Sasaki *et al.* (1993) on Islamic glazes, and Demirci *et al.* (1996) who looked at Byzantine and Seljuk glazes. Each of these studies shares the theme of glaze or glaze/body characterization and in each case they have been successful in defining chemically the glaze types under investigation. Though they do little more than reconstruct the glaze compositions, and fall short of any real archaeological or cultural interpretations, studies such as these do have their value. Hedges and Moorey (1975), for example, analysed the polychrome and monochrome glazes from a number of objects (pottery and brick) from Kish and Nineveh in Iraq dating from the period *c.* 600 B.C. to A.D. 600. They were able to show that throughout the time period under study there was constancy of glazing technique, paralleled by constancy of ceramic body composition and that all of the glazes under study were alkali-lime glazes. This was a striking finding as it had generally been assumed, but until this study was untested, that monochrome pottery glazes from the pre-Islamic period in Iraq were alkali-lead glazes with a lead component of up to 30 wt% (Hedges and Moorey 1975, 38). In a similar vein, Fitz (1982) was able to demonstrate that the coloured glazes of wall facings from the Ishtar Gate, the Processional Way and the throne room façade of the palace complex of Babylon (*c.* 604-562 BC) were alkali glazes. Again there had been an incorrect supposition that the glazes included a high lead component, and were opacified by tin dioxide. The opacifying agent was in fact shown to be calcium antimonite.

Hedges and Moorey's, and Fitz's two papers demonstrate the purpose and necessity of chemical characterization studies. Glaze types can be identified and long held assumptions can be challenged. More importantly, glaze composition data sets can be built up to provide an information base against which more directed research can take place.

2.2.2 Approaches to the Investigation of Glazing Technologies

In the last decade or so there has been an increasing emphasis on the history of technology, where details of ceramic production processes and glazing technologies are explored. The materials science approach can provide a great body of data on the types of raw materials used, how they were processed, on pottery forming methods, types of

surface treatments, and the firing regimes used. Analysis of wasters and products from known production sites can enable researchers to identify and reconstruct the specifics of individual workshop practices (see for example Hurst and Freestone 1996, Daszkiewicz and Raabe 1999, Molera *et al.* 2001). In each of these studies, glaze and body analysis are combined to reconstruct the production processes involved in the manufacture of the various types of glazed pottery.

This approach to glazed pottery research can be illustrated by Pérez-Arantegui *et al.* (1999) who identified the stages involved in the *cuerda seca* decorative technique of glazed ceramics from eleventh century al Andalus, Spain. *Cuerda seca* is a decorative style of Islamic glazed ceramics that was particular to North Africa and Spain during the medieval period. It consists of designs drawn onto the body with a black slip, which are subsequently partially or totally in-filled with green, yellow, black or white coloured glazes. The discussion on the provenance of the *cuerda seca* technique is on-going, with its origin considered Eastern by some, while others argue that it is an Andalusian innovation that diffused into Northern Africa (Pérez-Arantegui *et al.* 1999, 935).

A program of analysis was carried out on *cuerda seca* decorated ceramics from the Islamic potters' quarters of Saragossa, believed to have been in production during the eleventh and twelfth centuries. The aim was to characterise the technique chemically and clarify the steps involved in *cuerda seca* decoration. Using a scanning electron microscope with an attached energy-dispersive X-ray spectrometer (SEM-EDS) they were able to establish a number of features of the pottery. They found, for instance, the pigment to be a heterogeneous layer composed of manganese and iron oxides, clay and lead oxide. Manganese oxides are coloured black or brownish black when fired above 870°C. It was considered possible that the lead component may help the pigment to adhere to the body (Pérez-Arantegui *et al.* 1999, 938). The presence of barium was recorded in relation to the manganese oxide leading the authors to suggest the use of the manganese ore psilomelane in the pigment.

The glazes of these pots were analysed and shown to be lead-silica glazes (35 to 65% PbO, 22% to 43% SiO₂). Green glazes were coloured with copper (1.5 to 4.4% CuO) and the yellow by the presence of ferric oxide (Fe³⁺) in the glaze (2.3 to 7.8% FeO). The white and black glazes were coloured by tin oxide and manganese respectively but due to the advanced alteration of these glazes the analytical data was considered

unreliable. The majority of the green and yellow glazes show similar proportions of silica, lead and alkali compounds.

The ceramic bodies were very homogenous, white and with few inclusions representing the use of calcareous clays. In looking at the glaze/body interaction zone, the presence of a 50-100 μm reaction layer with crystal formation and varying interaction indicated that the decorated ceramics were fired once only (see Section 2.3).

Using this information Pérez-Arantegui *et al.* (1999) were able to detail the production sequence of the *cuerda seca* decorated pottery from Saragossa. They determined that the black designs were drawn onto unfired, dried bodies, using a mixture of manganese oxides and clay, and in-filled with coloured glazes before being fired in an oxidizing atmosphere. Based on glaze composition and mineralogy of the body and pigment the firing temperature was considered to be around 900°C.

Pérez-Arantegui *et al.* (1999) were successful in clarifying the details of the production of *cuerda seca* decorated ceramics. As shown, they were able to identify each of the steps involved in the manufacture of this pottery type. Yet it could be argued that the study is lacking in the absence of interpretation of the data presented. More could be made of choices involved in and the organization of production processes. For example, data for glaze composition would seem to suggest the use of a standard glaze recipe, differing only in the addition of colorants. The use of different glaze recipes can usually be detected by substantial variations in the proportions of principal ingredients (Hatcher *et al.* 1994, 443). Further, the use of calcareous clays, gives the vessels a white surface, better highlighting the designs in coloured glazes. This draws attention to the careful selection and manipulation of the raw materials by the potters producing *cuerda seca* pottery, and indicates a level of sophistication in and the standardization of production.

The study presented above considers production technologies at an intra-site level. However, the information gained from chemical and microstructural characterisation can be used to explore questions relating to the origins and development of technology, the transmission of technology through the movement of the pottery through trade or by contact. A classic example to demonstrate this is the important study by Mason and Tite (1997) on Islamic glazes from Iran, Iraq, Egypt and Bahrain.

In their study they used the information obtained from chemical and microscopic analysis to construct a chronological sequence for the development of the tin opacification of glazes, and explored the evidence for the movement of potters from Iran to Egypt. The use of tin oxide as an opacifying agent in ceramic glazes had long been recognized as an important aspect of glazed pottery production in the early Islamic world (*c.* AD700-1250) and early post-medieval Europe (*c.* 1250-1700). The chronological precedence of the Islamic wares has led scholars to argue for the diffusion of technology from the Islamic world to Europe. Despite this, the relationship between pre-Islamic opaque glazes and the known Islamic tin-opacified glazed wares had received scant attention and remained little understood. Mason and Tite (1997) undertook a program of research on Islamic glazed ceramics focusing on chronology, provenance and technology. The pottery studied originated from the sites of Samarra, Nippur and Hira in Iraq; at Susa and Siraf in Iran; at Fustat in Egypt and in Bahrain. They include a range of opaque-glazed pottery types dating predominantly from the eighth to twelfth centuries AD. Microstructural information was gained using thin-section petrography and SEM, and the bulk chemical compositions of the glazes, together with the compositions of the crystalline phases within the glaze were determined using SEM-EDS or WDS (wavelength-dispersive X-ray spectrometer).

The results of the study showed that the pre-Islamic glazes of the third century BC to third century AD were of alkali-lime type containing approximately 9 to 19% soda, 4 to 6% potash, 7 to 8% lime and 2 to 3% magnesium. Their opacity was caused by the presence of acicular colourless crystals (wollastonite and diopside), gas bubbles and undissolved quartz and feldspar. The Early Islamic turquoise glazed wares from Iraq, dating from the eighth to ninth century AD, are considered to be a direct continuation of this pre-Islamic technology. While the chemical composition of this group is similar in general to the previous glazes, an important distinction is the presence of lead of up to 2% showing the introduction of new components to the glaze (Mason and Tite 1997, 49). Tin oxide as an opacifying agent was identified in Group One Blue-painted wares (dated to AD 700 to 750) from Basra. Thin-section analysis showed that like the pre-Islamic and Early Islamic glazes, crystals of wollastonite and diopside were present along with air bubbles. However, concentrated at the glaze/body interface and occasionally dispersed throughout the glaze were small particles of tin oxide, less than 5

μm across. Chemical composition of the glazes showed them to be of alkali-lime type, again with small quantities of lead (*c.* 1% PbO).

The Group Two Blue painted wares from Basra dated a little later to AD 750 to 800 show a development in the use of tin as an opacifier. Like the pre-Islamic and Early Islamic glazes, the Group Two type are alkali-lime glazes with a minor lead component (1 to 2% PbO) and, again, revealed wollastonite and diopside crystals, undissolved quartz and feldspar, and gas bubbles dispersed throughout the glaze. Tin oxide was present in a concentration of 3 to 4% SnO₂, however, the particles were coarser than those seen in the Group One glazes (at 10-20 μm across) and were distributed throughout the glaze rather than being concentrated at the glaze/body interface. The Group Two glazes then are the first to show the use of tin oxide as a true opacifying agent (Mason and Tite 1997, 51).

The glazes of Basra groups Three to Six (AD 800-975) include Blue-painted wares, but increasingly Lustre-painted wares. They show an increased reliance on tin oxide as the opacifying agent and in many cases it is the only opacifier. It is present in concentrations of 4 to 8% SnO₂ and is dispersed throughout the glaze. As well as the increased tin content, these later glazes show a higher concentration of lead, with the majority containing 6 to 8% PbO. They can therefore be classified as alkali-lead glazes.

Mason and Tite (1997, 53) also looked at samples from Samarra and Nippur, dating to the ninth century and *c.* AD 800 respectively. Based on their petrology they are tentatively ascribed to the production centre of Baghdad. Like the Basra glazes, they are inclusively reliant on tin oxide inclusions for opacification, however, they have a far higher lead component (30 to 45% PbO), and as a consequence are considered to be technologically independent from the Basra glazes.

Mason and Tite were thus able to demonstrate that the first opacified Islamic glazes developed in the context of traditional glazing in Iraq, as their chemistry and typical opacifiers (gas bubbles, quartz and wollastonite) are found in the pre-Islamic opaque glazes (Mason and Tite 1997, 55). Furthermore, they viewed the first use of tin oxide as an opacifier in the Group One Blue-painted ware as the natural result of the synthesis of existing technologies in the Islamic world. The use of tin oxide as an opacifier in glass is attested in the Mediterranean from at least the fourth century AD, so it is extremely

plausible that its use would have been known in those areas that were integrated into the Islamic world at an early date. They also argue that the use of a tin oxide coating would suggest the application of a layer of tin opacified glass, which is analogous to the contemporary use of crushed quartz as a white 'slip' by potters in Iraq (Mason and Tite 1997, 56).

Later Egyptian glazed pottery (dating from AD 975-1175) was also considered in the study. These were deemed relevant as it is generally understood that around AD 975 potters from the production centres of Basra, and possibly Baghdad moved to Egypt and set up productions in Fustat. The evidence for this is cited as being the continuation of forming and decorative techniques used at Basra, and technological transfer including the use of lustre-painting and the tin opacification of glazes (Mason and Tite 1997, 54). The Egyptian lustre wares produced between the mid tenth to late twelfth century at Fustat split typologically into four groups. The majority of Groups One and Two (*c.* AD 975-1075) are made from a Nile alluvium modified with calcareous clay, but some are made using a proto-stonepaste or stonepaste body. Groups Three and Four differ considerably in body composition, being produced from a separate, highly calcareous clay. Analysis of the glaze showed that this difference in body composition was paralleled by glaze composition. The glazes of Groups One and Two were shown to be lead-alkali glazes with a lead component of 25 to 35% PbO, an alkali content of 3 to 7% Na₂O+K₂O and tin oxide as the only opacifier present in amounts of 9 to 16% SnO over the clay bodies and 5 to 9% SnO over the proto-stonepaste and stonepaste bodies. This composition, while having a greater lead component than the later Basra glazes, overlaps with the Baghdad glazes.

The glazes of Groups Three and Four (*c.* 1075-1175) are clear rather than opaque and show lower lead contents than groups One and Two, with between 10 to 15% PbO and higher alkali contents of 11-13% Na₂O+K₂O. A thin white 'slip' was found to be present at the glaze/body interface, which was shown to be a densely packed crystal layer with a chemical composition suggestive of wollastonite.

The tin opacification of glazes was not resumed in Egypt from this point, although they continued to be used in Iran and Islamic Spain. Mason and Tite (1997, 56) looked to social and economic circumstances to explain the abandonment of tin opacification of glazes, a phenomenon that occurred at the same time in Syria. The treatise of Abū'l-

Qāsim (see below) written c. AD 1300 discusses three tin sources: Europe, the Volga region and China. Given that the period under study coincides with the beginning of the Crusades, they hypothesized that Egypt and Syria could possibly have been cut off from these tin sources, forcing a change in glazing technology, whereas Iran would have still been able to import tin from the Volga region or China.

The importance of this study from an archaeological point of view lies in the fact that Mason and Tite have effectively used the chemical and microstructural information to demonstrate the development of Islamic tin opacified glazes, setting their beginnings in the context of pre-Islamic glazing technologies. Moreover, in contrast to the previously mentioned characterization studies where few attempts are made to interpret results, Mason and Tite endeavoured to explain their findings in terms of the social and economic contexts of the Islamic World. Existing technologies were considered when looking to explain the development of opacified glazes, and historical evidence was explored to account for the later shift in glazing technology. This study therefore is a good example of how combining scientific data with wider information can broaden our understanding of the processes involved in the development of past technologies.

2.2.3 Glazes and Literary Sources

The existence of a number of historical texts detailing technical practices in pottery production and glaze decoration allow for a different avenue of research into archaeological glazes. Important and well-known texts include Abū'l-Qāsim's treatise on the manufacture of tiles and other ceramic objects, surviving in two manuscripts dating from AD 1301 and AD 1583. Here, all processes of pottery production are detailed including the preparation of clays, the mixing of glazes, pigments and lustres, and the building and firing of kilns (Allen 1973). Eraclius' *De coloribus et artibus Romanorum*, a Latin technical treatise thought to be written between the ninth and twelfth centuries, includes a short section on the lead glazing of pottery, and there is the important *Three Books of the Potter's Art* written by Piccolpasso in the sixteenth century, in which the production of Italian maiolicas and lustres are described in great technical detail (Lightbrown and Caiger-Smith 1980). These writings are useful as a source of information on the raw materials and procedures used in the production of ancient pottery.

Molera and Mesquida *et al.* (2001) were provided with a unique opportunity to study lustre glaze recipes following the discovery of the thirteenth century AD 'Les Olleries Xiques' workshop in Paterna, its furnaces and raw materials (including clays, powdered pigments, and unfired and partially fired lustre decorated wares). The production of lustre was common in the Valencia region in the medieval period. A number of ancient recipes survive detailing the manufacture of lustre of different colours and have been collected by Caiger-Smith (1985). The recipes contain sulfides, nitrides, carbonates or chlorides of silver and copper in various quantities, china clay and/or red ochre (40-80 wt%) and cinnabar (mercury sulfide) (10 to 15 wt%). The cinnabar component allows the temperature at which lustre is formed to be lowered, removing the risk of glaze discolouration by reduction (Molera and Mesquida *et al.* 2001, 455). To produce lustre pottery, a calcareous clay was generally used for the creamy colour it produces upon firing up to 950°C. Following a biscuit firing, the pottery was covered with a tin glaze (composition given as 49 wt% SiO₂, 36 wt% PbO, 5 wt% SnO₂, 6 wt% K₂O, 2 wt% Al₂O₃ and 2 wt% CaO), of thickness 100 to 200 µm, and refired under similar conditions. The lustre decorations were then applied and the pottery received a final firing under reducing conditions at approximately 600°C to create the metallic sheen.

In their study Molera and Mesquida *et al.* (2001) set out to characterise the chemical and mineralogical compositions of the raw materials used for lustre production and compare their compositions with lustre produced at the same workshop. It was also possible for them to compare the results with the ancient lustre recipes collated by Caiger-Smith (1985).

Samples were taken from two sherds that had been prepared for but had not received the final reducing firing, as well as from a red powder of similar colour and appearance to the raw lustre decoration that was recovered from the workshop. Samples of lustre produced at the same workshop were also analysed. Chemical analysis was carried out by X-ray fluorescence (XRF) and inductively coupled plasma spectroscopy (ICPS) and phase analysis by X-ray diffraction (XRD). The lustre decorations were analysed using SEM-EDS. The results showed that for the three raw material samples the main chemical compounds are the same, although they occur in different proportions. The differences in calcium could in part be explained in terms of contamination from burial, although analysis of the clay found at the workshop shows that it contains approximately 15 wt% CaO. An important difference to be noted between the prepared

lustres and the powder is the discrepancy in mercury content, with the powder showing a greater proportion at 30.46 wt% HgS. It was thought that this may indicate a partial firing of the ceramic pieces which would have the effect of lowering their mercury component (Molera and Mesquida *et al.* 2001, 457). In comparing the results of the phase analysis with the recorded lustre recipes, they were found to be compatible with those containing cinnabar and clay, copper compounds, quartz and iron oxides.

The samples of lustre produced at the workshop showed decorations composed of two different colours; a golden brown, and reddish brown. Analysis of these revealed a higher silver content for the brown lustres and a higher copper content for the red lustres. Relative percentages of copper and silver are similar to those found in the raw materials analysed for the red lustre, but the brown lustres show a much higher silver content. It was observed that the Cu/Ag ratios of the lustre decorations and of the original recipes were different. However, it was suggested that during the firing of the lustre, only part of the copper and silver is incorporated into the lustre, the rest being removed as part of a residue. Historical records document the reuse of the lustre residue, 'cosela', in the production of new lustre (Molera *et al.* 2001, 459).

This study is an excellent example of the way in which historical documentation can be used in conjunction with archaeological evidence and analytical data. Here, the main emphasis was on the evidence obtained from the archaeology, but it was compared to written sources. The analytical findings conform to the ancient recipes in general, validating the recipes and giving the results added significance. In addition, historical sources were used to provide explanation for certain findings. There is, then, in this study a sound balance between the archaeological and historical resources.

Whilst historical documents can prove advantageous in studies of ancient glazing technologies, they should be treated with some caution. The main reason for this can be given as inaccurate information. In Eraclius' *De coloribus et artibus Romanorum* (III₃), for example, it is written "but if you wish to lead-glaze the pot... take some lead well *solutum* [powdered?]. However, if you want to obtain a green colour, take some copper, or better still some brass, and mix it with the lead as follows: take the lead and melt it in a pot; when it is molten stir it by turning it with your hands (*sic*) in the pot until a powder is produced, and mix this then with 6 parts of brass filings. When the pot has been dampened with water and flour sprinkle it immediately with the lead, *i.e.* with the

filings mentioned above. If you want a yellow glaze sprinkle the pot with pure lead without brass filings” (as cited by De Boüard 1974, 69). It is known that a lead compound on its own makes a viable glaze (Tite *et al.* 1998, 248, see Section 2.2.4), and copper is a well known colorant for green glazes (Hatcher *et al.* 1994, Armstrong *et al.* 1995, Pérez *et al.* 1999). Nevertheless, the proportions are almost certainly incorrect. Several hundreds of glazed medieval sherds dating from the ninth to tenth centuries and twelfth to thirteenth centuries were analysed by De Boüard and the quantity of copper in the glazes varied from 0.3% to 4%. This quantity is comparable to other analyses of green lead glazes (Armstrong *et al.* 1995, Pérez *et al.* 1999). One explanation for this error is that the original text was corrupted in translation (De Boüard 1974, 75). However, it should also be considered that the author did not have first person knowledge of glazing processes written about leading to inaccurate descriptions of the technologies. Therefore, while it is worthwhile to compare scientific data on glaze recipes and glazing technologies with documented processes, and interesting to carry out experimental replications, it should not be assumed that they are reliable in entirety.

2.3 Investigations of Laboratory Produced Glazes

Experimental replications of glaze manufacturing methods in a laboratory setting provide an excellent resource for the understanding and interpretation of archaeological glazes. An area that has received attention in recent years is in the forming mechanisms of high lead glazes (for example Molera and Pradell *et al.* 2001 and Walton 2004). This body of work on high lead glazes is particularly relevant to Byzantine glazes and so this current research, thus it is presented here in detail. As summarized by Tite *et al.* (1998) there are a number of routes through which a lead glaze can be manufactured (Figure 2.3.1). The simplest technology is to apply a lead compound such as litharge (PbO), red lead (Pb₃O₄), white lead (2PbCO₃.Pb(OH)₂) or galena (PbS) directly to the surface of the pottery vessel, either by itself or as a suspension in water. In a second method, the lead compound is mixed with the silica (quartz sand, ground quartz or chert pebbles, or a siliceous clay) and this lead-silica mixture is applied (raw or fritted) as a suspension to the vessel surface. As is widely understood by modern potters the raw glaze components react with and decompose the underlying ceramic body, and elements from the body diffuse into the glaze melt (for example Fraser 1986). Until recently, this process of interaction and diffusion was rarely considered in studies of archaeological glazes. The important work by Molera and Pradell *et al.* (2001) was the first to

characterise lead-silicate glaze melts with earthenware ceramic bodies. They carried out a set of experiments to determine the nature and importance of the interaction between clay bodies and glazes using different firing times, temperatures and cooling rates, with glazes of differing proportions of lead and silica and different bodies (illitic, kaolinitic and calcareous clays), either raw or biscuit fired. A number of crucial findings were made, and one in particular highlights the importance of the composition of the underlying ceramic body on the resultant glaze composition. In this one aspect of the study, glazes of composition 70/30, 80/20, 90/10 wt% PbO/SiO₂ ratios were applied over an illitic, low calcareous body and fired at 1000°C for 4 hours and cooled at a rate of 100°C per hour to obtain a homogenous glaze composition. The original compositions of the raw glazes were compared with the final average composition of the vitreous phase formed (Molera and Pradell *et al.* 2001, 1123-1124). These are presented in Table 2.3.1. It is interesting to note that the final compositions of the glazes formed from 70/30 and 80/20 wt% PbO/SiO₂ are similar in composition, containing approximately 18 wt% Si and 43 wt% Pb, revealing an equilibrium with the ceramic is reached. In each case, the Si content has increased in the final glaze, showing that a proportion of the Si in vitrified glaze derives from digestion of the underlying ceramic, while the Pb content has decreased through dilution. Each of the final glazes carries significant concentrations of Al, K, Ca and Fe, again resulting from digestion and diffusion from the ceramic body.

In a second aspect of the study the progression of digestion and diffusion as a function of firing temperature was examined. In this instance a glaze mixture comprising 75 wt% PbO and 25 wt% SiO₂ was applied over an unfired kaolinitic, non-calcareous body and fired at temperatures from 600° to 1000°C every 50°C, and fast cooled by quenching in water to freeze microstructure. The vitrified layers were examined in a series of SEM photomicrographs, and by compositional analysis of points from the glaze/body contact zone to the edge of the glaze. The digestion and diffusion progression can be summed up as follows: between 600°C and 700°C the glaze is only partially melted and interaction between body and glaze is undetectable. At 750°C the glaze forms a vitreous layer and elements carried in the body can be detected in the glaze in the first 80µm of the glaze. At this temperature, an interaction zone of approximately 5µm was observed which contains crystals determined to be lead-feldspars. By 900°C the interaction zone has the same thickness, but diffusion of

elements carried in the body increases up to 200 μ m in the glaze. In contrast, a reverse profile for PbO was observed, with lead content decreasing from the glaze edge to the glaze/body contact zone (Molera and Pradell *et al.* 2001, 1121).

In a final experiment Molera and Pradell *et al.* (2001) investigated interaction of glazes (70 wt% PbO and 30 wt% SiO₂) applied over raw and biscuit fired kaolinitic bodies, since both application methods have been employed in antiquity (for example Tite *et al.* 1998). In brief, the findings show that elements diffuse from the body into the clay in both application methods; nevertheless, the concentrations are greater in the glaze applied to the raw body (see Figure 2.3.2). This demonstrates increased reactivity with the raw ceramic during firing. The lead-feldspar crystalline interface is formed with both application methods but was observed to be much thicker for the raw than fired body. Though it is acknowledged that much is dependent on body composition, firing temperature and cooling rate (for example Tite *et al.* 1998) difference in glaze/body interaction between the two methods offers a potential to elucidate whether a single or biscuit firing was used in the manufacture of archaeological glazes.

The importance of this work lies in the fact that it establishes clearly how PbO·SiO₂ glazes are formed through a process of digestion and diffusion, and that a final glaze composition differs from the composition of the raw glaze composition. As Molera and Pradell *et al.* (2001, 1128) point out, one of the general methods for classifying archaeological glazes is through their chemical composition (for example see Section 2.2.1 above), and it is commonly assumed the final composition of the glaze is the same as that originally applied. Thus elements oxides considered to have been intentionally added to a raw glaze batch (an example is Fe₂O₃ which may be added as a colorant) may have derived, in reality, from the ceramic body. This work demonstrates the limitations of such an approach and highlights the necessity of taking into account the composition of the underlying ceramic substrate in the investigation of archaeological glazing technologies.

Molera and Pradell's *et al.* (2001) work was expanded by Walton (2004) during his thesis research on archaeological lead glazes at the University of Oxford. Where Molera and Pradell considered glazes formed from PbO/SiO₂ mixtures, Walton investigated formation mechanisms of glazes using PbO on its own, or PbO and clay mixtures over a kaolin-rich unfired or biscuit fired substrate (refer to Figure 2.3.1 for

methods of lead glazing), and the resultant compositions and microstructures of the vitrified layers formed. These were compared with glazes formed using PbO/SiO₂ mixtures. His laboratory manufactured glazes included Group 1, PbO over a raw clay body; Group 2, PbO over a fired body; Group 3, 7:1 PbO:Clay over a fired body and Group 4, 3.5:1 PbO:Clay over a fired body. They were fired at temperatures of 730°C, 800°C, 900°C and 1000°C (Walton 2004, 44). To summarise his findings, there were no significant differences in composition and microstructure detected between the different glaze groups. At each temperature only minor fluctuations in chemistry were noted between the groups. Image analysis of backscatter electron images revealed that at any given temperature, crystal morphologies and layer thickness at the glaze/body contact zone were similar. In contrast to the diffusion profiles noted by Molera and Pradell *et al.* (2001) for PbO·SiO₂ glazes, (see Figure 2.3.2 for an example), Walton (2004) noted flat compositional profiles, indicating equilibrium with the ceramic is rapidly reached.

The implications of this study in relation to the understanding of archaeological lead glazes is that there is not enough chemical or microstructural resolution to distinguish between glaze forming methods using PbO or PbO·Clay over raw or fired bodies, limiting technological interpretations. Nevertheless, differences in chemistry of glazes manufactured by these methods of glaze application and glazes manufactured using PbO·SiO₂ as investigated by Molera and Pradell *et al.* (2001) may establish if a PbO / PbO·Clay mixture or a PbO·SiO₂ mixture was used.

Walton investigated the formation mechanisms of a PbO glaze and showed them to differ from those of a PbO·SiO₂ glaze. Using X-ray diffraction measurements (taken at 14 minute intervals using a high brilliance X-ray beam) of a 50/50% powdered ceramic and PbO mixture during its firing to 870°C (temperature was ramped at 5°C per minute). He was able to demonstrate that the PbO reacts first with the quartz contained in the ceramic. At around 690°C a low viscosity PbO·SiO₂ glass phase is formed, which wicks the surrounding clay minerals and begins to digest them by 700°C. By 720°C, the digestion is complete, and the vitrified layer is formed from the PbO and quartz and clay minerals contained in the ceramic body. This process is schematised in Figure 2.3.3., and compared to the glaze formation mechanism determined for the PbO·SiO₂ by Molera and Pradell *et al.* (2001) schematised in Figure 2.3.4. The

resulting glaze manufactured using PbO alone is comprised of the lead oxide and dissolved ceramic body, while that manufactured using the PbO·SiO₂ method comprises the lead oxide and silica in addition to element oxides derived from the ceramic body.

Hurst and Freestone (1996) and Tite *et al.* (1998) theorised it should be possible to resolve which method was employed in antiquity by subtracting the lead oxide content of the glaze (and element oxides such as CuO which may have been added as a colorant) and normalizing the remaining element oxides to 100%. If after renormalizing the glaze composition matches the body composition it indicates PbO on its own was applied to the body. In contrast, if after subtraction and renormalizing the glaze composition shows higher silica and lower alumina and other oxide concentrations than the body it indicates a lead oxide-silica mixture was used. This method of data reduction was employed De Benedetto *et al.* (2004) with some success to identify the glazing method of PbO·SiO₂ in the manufacture of Roman glazed ceramics from Canosa, Italy.

2.4 Summary and Conclusions

This review of analytical studies of archaeological glazes and glazed pottery has shown that there are a number of ways in which to approach the subject. The emphasis has been on glaze characterizations for purpose of defining glaze types and on the history of technology with the purpose of reconstructing the processes involved in the manufacture of glazed pottery. The earlier characterization studies, while doing little more than presenting chemical data and lacking in any real interpretation of result, are useful in that they provide rudimentary information on the composition of specific glaze types. However, analytical work can provide greater depths of information that can further our understanding of technological processes involved in glazed pottery production.

A major step in this direction came in the mid 1990s when researchers started applying an integrated analytical approach to glazed pottery studies. In a number of studies a range of techniques including thin section petrography and SEM were used to explore the chemical and microstructural character of glazes and body fabrics to reconstruct the details of production processes (for example Pérez-Arantegui *et al.* 1999, and Molera and Vendrell-Saz *et al.* 2001). In some cases this has been combined with evidence for glazing techniques procured from historical documentation (Molera and Mesquida *et al.*

2001). In this way, information on the types of raw materials used, their manipulation, decorative techniques and firing regimes of specific glazed pottery types were presented (see for example Pérez-Arantegui *et al.* (1999)). These studies have been successful in accomplishing their aims. Yet it is often the case the information is presented without archaeological interpretation and they could be taken further by setting the information in its archaeological, historical or social contexts. Mason and Tite (1997) moved in this direction in their study on the development of Islamic tin-opacified glazes, when they considered existing technologies, as well as social and economic evidence to explain their results. They demonstrated that questions concerning the origin and development of production technologies, the transfer of technology either through the movement of people or pottery, and changes in technology can be answered by combining analytical data with various other sources of information.

A further step forward in understanding glazing technologies and glaze compositions came in the early years of this decade with detailed investigations of forming mechanisms of laboratory produced high lead glazes. This body of work is very relevant to the current study, demonstrating the need to take in to account body compositions in order to fully understand glaze compositions. The work also further clarifies how the data reduction methods initially suggested by Hurst and Freestone (1996) and Tite *et al.* (1998) can be utilized to investigate raw glaze materials.

This current study on the development of production technologies of Byzantine glazed pottery from Corinth, utilizes a combination of techniques including petrographic analysis and inductively coupled plasma-atomic emission analysis (ICP-AES) of the ceramic bodies, and electron probe microanalysis (EPMA) and SED-EDS on their corresponding glazes, with the aim of detailing the chronological developments in production methodologies during the eleventh to thirteenth centuries.

CHAPTER 3

MATERIALS ANALYSIS OF BYZANTINE GLAZED POTTERY

3.1 Introduction

The application of material analytical techniques to archaeological ceramics to elucidate questions of production and distribution is well established in the discipline of archaeological science. This is attested to by the numerous literature available on the subject (for example, see Freestone 1982, Jones 1986, Bronitsky 1986 and Tite 1999). Despite the widespread use of analytical techniques in archaeological ceramics research in general, Byzantine glazed pottery studies have remained on the whole in the traditional realm of stylistic analyses (Morgan 1942, Stevenson 1947, Hayes 1992, Sanders 1995).

Over the last two decades there has been a growing interest in provenance questions in Byzantine pottery studies, in an effort to gain a basic understanding of spatial interrelations between sites. But the recent shift in emphasis in general in ceramic studies towards more technological aspects has remained largely neglected in this area. The aim of this chapter is to review the analytical studies carried out to date on Byzantine glazed ceramics in order to assess the current state of knowledge. It will be shown that the work is limited, and that new analytical research has great potential to dramatically alter our understanding of glazed pottery production in the Medieval Mediterranean World.

3.2 Previous Analytical Work

The earliest attempt at analysis of Byzantine glazed pottery was undertaken by Meaker and Rodman and is reported in Morgan (1942, Appendix II). Two sherds of Sgraffito pottery from Corinth (Figure 3.2.1) (see Chapter 6 for Byzantine glazed pottery typology), one of which was known to be manufactured at the site and the other believed not to be, were subjected to spectro-analysis. The results of the spectro-analysis demonstrated clear chemical differences between the two sherds, with the Corinthian sherd characterised as being calcium rich in comparison to the second sherd, indicating manufacture from two different clays. The calcareous nature of the Corinthian sherd is consistent with what is known about Corinth clays today (see Chapters 5 and 8).

Polychrome White Wares were the next Byzantine pottery type to receive attention. Fragments from two White Ware tiles held in the Louvre were selected for chemical and microscope analysis by Coche de la Ferté (1957) because of their similarity in appearance. The main inclusions noted in the fabrics were angular quartz grains and iron oxide nodules, and despite contamination of the fabrics by lead oxide from the glaze, Coche de la Ferté concluded they were chemically similar and considered they derived from the same source of production. Following Coche de la Ferté's study, Rice (1965, 197, note 4) examined two Polychrome White Ware vessel sherds using X-ray fluorescence (XRF), and considered them to have been manufactured at different places.

Frierman (1967) examined 11 glazed sherds from Athlit and Caesarea in Israel using petrographic analysis and X-ray emission spectroscopy (Figure 3.2.2). Though there are no formal descriptions or illustration of the sherds, six of the 11 (green and brown glazed) sherds are what would be considered as 'Byzantine' (Armstrong and Hatcher 1997, 4). The glazes were found to be of the high lead type (>60 % in all samples), with yellow and brown areas coloured by Fe_2O_3 , and green areas coloured by CuO .

The first major contribution to Byzantine pottery studies following these exploratory works came in 1983 with Megaw and Jones' comprehensive paper on production and distribution of Byzantine and allied ceramics. Their investigation focussed on 14 batches of ceramics, seven of which came from well-attested production sites (Corinth, Thessaloniki, Didymoteichon and Kounoupi in Greece, and Lapithos, Lemba and Dhioros on Cyprus) (See Figure 3.2.1 and 3.2.2). These were sampled to include control material such as wasters, firing tripods and so on. The remaining seven batches were unprovenanced. They included White Wares excavated at Corinth and Istanbul; Red Wares from Paphos, Cyprus; glazed (fine) and unglazed (coarse) wares from Athens; and Byzantine Sgraffito Ware from the Pelagonnisos shipwreck (White and Red Wares are the two primary classification of Byzantine ceramics, see Chapter 6). The samples were analysed using Optical Emission Spectroscopy (OES). The main conclusions can be summarised as follows: The White Wares from Corinth and Istanbul were attributed to a single source given the similarity in composition (Table 3.2.1). It was assumed at the time of Megaw and Jones' study that Byzantine White Ware pottery was manufactured at Constantinople given vast quantities of recovered from excavation in Istanbul in comparison to other Byzantine sites, (see Chapter 6 for discussion on distribution of White Wares). This theory appears to be corroborated by

their work since the composition of the sherds showed a strong match to white clay from Anadolu Hisari on the Bosphorus in use by modern potters (Table 3.2.1).

The glazed Red Ware group from Corinth formed an isolated, calcium-rich group. In comparing the two groups from Athens, Megaw and Jones (1983, 237) noted that the compositions for the Athens coarse and fine wares were markedly different, with the coarse wares having a typically 'Attic' composition (Table 3.2.2). They argued the coarse wares were produced in the Athens locale, whereas the fine wares were thought to be imported from an unidentified source. The Athens fine ware group was also considered to be fairly similar to the Istanbul and Pelagonnisos Sgraffito groups, of which a common, but unidentified, origin was proposed. Of the Pelagonnisos and Istanbul groups the only major difference to be noted is the increased value for Mg (4.0% compared to the 1.9% seen in the Istanbul group) (Table 3.2.2). If indeed the same source can be claimed for these two groups the increased magnesium content of the Pelagonnisos group could be explained given the aggressive chemical environment of the sea water burial. Bearat and Dufournier (1992) demonstrated in long-term experiments that certain ceramics will become depleted in calcium and strontium and enriched in magnesium in a sea water environment.

In the same year Calogero and Lazzarini (1983) analysed a collection of Sgraffito Ware recovered from the islands of the lagoon of Venice (Figure 3.2.2). Using an integrated approach combining X-ray fluorescence (XRF), atomic absorption (AAS), Mössbauer spectroscopy and petrographic analysis, the co-existence of imported and locally produced wares was established. It was demonstrated that whereas the Venetian Sgraffito products showed a basic similarity in the materials and manufacturing techniques employed, the Byzantine products showed a variety in the range of their clays and production methods, suggesting no single common source for the imported Sgraffito ceramics.

In a later study Lazzarini and Calogero (1989) built upon this work, their aim being to suggest some locations in Medieval Greece from where the imported Sgraffitos may have originated. To establish a possible provenance, mineralogical and chemical data (obtained using XRF) from local and imported ceramics were compared with those from the analyses of Byzantine sherds, mostly wasters of known provenance and date (from Constantinople, Athens, Corinth, Thessaloniki and Lemba), together with the

chemical data provided for those sites by Megaw and Jones (1983). The provenances of the imported wares were difficult to establish, but some tentative suggestions were made on the basis of mineralogical data. Orthorhombic pyroxene, abundant in the Thessaloniki fabrics, were noted in one of the samples (B2) and so was considered to be a possible source. In the same way, the presence of shale in a second sample (B3) linked it to Corinth as clasts of shale were characteristic of the Corinthian fabrics. However, comparison of the imported wares with the chemical data was inconclusive. At best, the general trend in the analytical data supported the distinction between the Venetian and Byzantine Sgraffitos based on the mineralo-petrographic data, but it was not possible to identify the origin of the imported ceramics. Though inconclusive, this study is a good example of how a combination of chemical and mineralogical analysis can provide complementary datasets.

A second regional study on Byzantine ceramics was published in the same year by Kuleff *et al.* (1989). In this work neutron activation analysis (NAA) and cluster analysis were used to investigate 101 monogrammed Sgraffito sherds from Shumen, Varna and Tcherven in north-eastern Bulgaria (Figure 3.2.2). The samples from Varna included a number of wasters from an earthenware workshop. Of the 101 samples, 78 formed a large cluster which included the Varna wasters, and sherds from Varna, Shumen and Tcherven, indicating their local manufacture. The remainder of the sherds derived from two unidentified, but presumed non-local sources. The importance of this study lies in the fact that it reveals patterns of manufacture and commercial contact between Varna and other towns in the region during the thirteenth and fourteenth centuries.

Waksman and her colleagues used particle induced X-ray emission (PIXE), NAA, ceramic petrography and X-ray diffraction (XRD) in a major study to characterise pottery excavated from the Byzantine levels at Pergamon, Turkey (Figure 3.2.2). This work was published in a series of articles, including Waksman *et al.* (1994), Waksman *et al.* (1996) and Waksman *et al.* (1997). The aim was to propose a new chemical and mineralogical reference point amongst the few Byzantine kiln sites that have been analysed to date. The ceramic groups selected for study included local glazed fine wares dating from the twelfth to fourteenth centuries, contemporary coarse wares, local Hellenistic ceramics and imported Byzantine glazed products (Fine Sgraffito and Green and Purple Stained Ware). In considering the local ware groups it was demonstrated

that the three groups showed no unity in either petrographic or elemental composition. The glazed wares were characterised mineralogically by the presence of volcanic and metamorphic rock fragments, quartz, potassic feldspars and plagioclases, micas (mainly biotite) amphiboles (hornblende) and opaques. The coarse wares revealed fabrics that were mainly composed of polycrystalline quartz and some plagioclase, where the Hellenistic group showed a very fine fabric, perhaps indicating that the clays went through a refining process, the few inclusions present being identified as mica-schist with muscovite and opaques. Chemically, the three were well defined and distinct. The coarse ware showed a lower Na, Ca and Sr content, higher K, Rb and Ba content and had a greater amount of Si, light rare earths (La and Ce) and U and Th than the glazed group and the Hellenistic group was differentiated by its higher (nearly 3 times as much) Cr and Ni content and low Na content. Ti, Fe and the elements Sc, Co and Rb were also found to be more abundant (Waksman *et al.* 1996).

It was suggested that in terms of the Byzantine pottery industry at Pergamon, raw materials were selected according to the function of the ceramics. That is, whether or not they were decorative or utilitarian. Further, given the chemical differentiation between the Hellenistic and Byzantine groups, different clay sources were exploited according to the date of ceramic production. An alternative may be that the differences correspond to the extraction of successive layers of the same clay deposit. This study therefore is useful in highlighting the need for care when using non-contemporary references in provenance studies (Waksman *et al.* 1996, 1997).

Of the imported groups, only the chemical data produced for the Fine Sgraffito group could be compared with analytical data on similar pottery reported by Megaw and Jones (1983) in an attempt to locate its origin (no previous compositional analysis had been carried out on the Green and Purple stained Ware). Despite the knowledge that the fine Sgraffito was produced at more than one location, this is demonstrated by the variation in the chemical compositions of those sherds analysed by Megaw and Jones from Paphos, Constantinople, Corinth and so on, Corinth was at the time the only identified production centre for this ware type (Waksman 1995, 210). The highly calcareous nature of the Corinth material (see Table 3.2.2) would rule it out as the source for the Pergamon Sgraffitos. That Waksman and her colleagues were limited to Megaw and Jones' research carried out almost 15 years prior to their own studies when searching for comparisons for chemical compatibility for their imported material highlights the

serious need for more work to be done in this area. Not only are the characterised production sites or ceramic groups available for comparison few in number, but Megaw and Jones analysed for nine elements only. Therefore, distinct features of the Sgraffito pottery imported into Pergamon, such as low Sr contents (95 ppm) and low Sr/Ca ratios, could not be exploited when searching for a possible origin. Moreover, the lack of inter-calibration between the analytical techniques employed in the different research centres meant that no definite conclusions could be drawn from observed differences between the Pergamon, Constantinople and Paphos Sgraffitos (Waksman *et al.* 1997).

In the same year as the first Pergamon paper was published, Boas (1994) published a short article on a number of Red Wares (Byzantine Sgraffito, Aegean Ware, Zeuxippus Ware, Port Saint Symeon Ware, and Cypriot Sgraffito and Slip Painted Ware) found in Israel and Cyprus. NAA was used to investigate the geographical origin of these wares. Boas concluded that all the Red Wares including Aegean, Zeuxippus and Fine Style Sgraffito were produced on Cyprus, that Cyprus exported Byzantine Sgraffito to Constantinople, Corinth, Athens and Thessaloniki amongst other towns of the Byzantine Empire and that Cyprus monopolised the trade in glazed wares to the East. These findings are somewhat suspect. For instance, it is not made clear from where or how the samples for analysis were obtained. Further, the singular evidence he presents to demonstrate manufacture of the pottery on Cyprus by comparison of the ratios of three elements only (Fe_2O_3 , Eu and Co), and even where they do differ between groups, for example Aegean Ware, Byzantine Sgraffito and Sgraffito from the Lapithos kiln site (Boas 1994, Figure 9, 114) the difference is explained in terms of period of production rather than provenance. Given these shortcomings it is suggested that this study be read with caution.

In 1995 Mason and Mango published the results of a petrographic and chemical analysis of one White Ware Polychrome vessel sherd, and one White Ware Polychrome wall tile fragment. The study is useful in that the petrographic descriptions are provided. Though the vessel sherd and wall tile fragment are similar, containing quartz, altered potassic feldspars and opaques (probably iron oxide), the frequency and size of inclusions indicate two distinct fabric types. The results of the chemical analysis (X-ray SEM) further demonstrate the two bodies are distinct, with the tile fragment having increased CaO in comparison to the vessel sherd, and the sherd having higher Fe_2O_3 than the tile. Nevertheless, they also suggested that different clay preparation

techniques and secondary calcite contamination may account for the petrographic and chemical differences observed (Mason and Mango 1995).

Polychrome White Ware tiles dating from the ninth to eleventh centuries were again the subject of investigation in a paper published by Vogt and Bouquillon (1996). In their research they analysed 35 fragments of tiles deriving from excavations in Constantinople and Preslav, Bulgaria (Figure 3.2.2) using inductively coupled plasma-mass spectrometry (ICP-MS), while their corresponding glazes were analysed using SEM-EDS. The wall tiles from both regions are very similar stylistically, indicating the importance of cultural exchange between the two regions, and according to Vogt and Bouquillon (1996, 106) although logic dictates the technological knowledge for their manufacture originates in the region of Constantinople, the inaccuracy of chronological information has in the past led Bulgarian scholars to suggest a Preslav source. They undertook the investigations in order to reconstruct the various stages of manufacturing processes of the two groups of tiles in order to determine the direction of the transmission of technological knowledge.

The results of the ICP-MS analyses of the tile bodies reveal that they fall into two distinct chemical groups (the compositional data of the Constantinople group are published in Vogt *et al.* (1997)). Though both groups are silica and alumina rich, the Preslav group was determined to have increased K₂O and Ba, Cr, Th, Zr and Ru, and depleted Co, Cu and Zn concentrations in comparison to the Constantinopolitan group. A finding of particular importance is that Preslav tiles were decorated with lead glazes only, while the Constantinople tiles were decorated with lead, lead-alkali and alkali glazes (these lead-alkali glazes are discussed more fully in Chapter 9). Two hypotheses are put forwards to explain these findings. In the first it is suggested that the range in glaze compositions observed in the Constantinopolitan group is a product of the chronology of the tiles, with the lead glaze being the earliest technology in use, and the lead-alkali and alkali glazes being the later; the Constantinopolitan tiles are manufactured from the middle of the ninth to eleventh centuries. The second is that there were various workshops in the region producing the tiles, with the different potters utilizing distinct glaze recipes. They argued if the first hypothesis were to be accepted, and technological knowledge was transferred from the Byzantine capital, it may explain the absence of lead-alkali and alkali glazes in the Preslav group; these were manufactured for less than a century between AD 893 and 972 (Vogt and Bouquillon

(1996, 112). These published results are important for this current study since, although it focused on glazed wall tiles rather than vessels, it offers insights into the range of glazing technologies known and utilized in the Constantinopolitan region.

In the following year, Armstrong and Hatcher (1997) outlined a program of analysis that was to be a continuation and extension of Megaw and Jones' (1983) 'Byzantine and Allied Pottery' work. The aim of the project was to reanalyse the kiln groups sampled by Megaw and Jones using inductively coupled plasma-atomic emission spectrometry (ICP-AES) and so provide a larger number of elements for the groups, and add material from further sites in Greece such as Sparta, sites in the Levant including Saint Symeon, and in Israel such as Acre and Tiberius, with the purpose of establishing a database, against which unprovenanced Byzantine sherds could be tested. A final goal was to publish the results of the analyses (Armstrong and Hatcher 1997, 1). In 2003, the chemical data obtained for pottery from three of the production centres included in the study (Serres, Thessaloniki and Kaffa) were utilized to test the provenance of two groups of Zeuxippus Ware (Zeuxippus Class I and Zeuxippus Class II) from the excavations of Saranda Kolones, at Paphos, Cyprus (Megaw, Armstrong and Hatcher 2003). The results of the study show that the two groups of Zeuxippus Ware from Saranda Kolones formed a single, cohesive chemical group, demonstrating their manufacture at a single source. Given the chemical differences between the Zeuxippus group and the groups of Byzantine reference material from Serres, Thessaloniki and Kaffa, these production centres were ruled out as place of production. The importance of this study lies in the fact that the chemical data (major, minor and trace elements) for the groups of pottery were published, making them available to other researchers for comparative purposes.

In a second initiative of the Byzantine and Allied project (Armstrong and Hatcher 1997, see above), the glazes from a range of Byzantine and Crusader ceramics from the ninth to thirteenth centuries were to be investigated to test for chronological developments in glazing technologies, and on a broader level investigate the eleventh century transition from the use of Constantinopolitan White Wares on Byzantine sites to the use of Red Wares (see Chapters 4 and 6 for a discussion of this). The results of the study were published in the same year (Armstrong *et al.* (1997)). The pottery types analysed, their findspots and suggested places of manufacture are presented in Table 3.2.3 (see also Figures 3.2.1 and 3.2.2). The ceramic bodies were analysed using SEM-EDS and their

corresponding glazes by SEM-WDS (wavelength dispersive spectrometry). The results can be summarised as follows: the White Ware bodies showed typical White Ware composition of high Al_2O_3 and low FeO . The remainder of the bodies (Red Wares were characterised by high FeO , but contained variable contents of CaO and Al_2O_3). The results of the glaze analyses are presented in Table 3.2.4. All glazes were found to be of the high lead type, with PbO typically in the range of 60 to 70%, and alkali ($\text{Na}_2\text{O}+\text{K}_2\text{O}$) contents less than 2%. Al_2O_3 contents were variable, ranging from 0.9 to 6.7%. The colorants were determined to be CuO for the green glazes and FeO for the yellow glazes. Armstrong *et al.* (1997) concluded that these results demonstrate there are no changes in Byzantine glazing technology from the ninth to thirteenth centuries when other aspects of ceramic production underwent changes, and that similar high lead glazes were utilised for both the White and Red Ware ceramic categories.

It might be argued that by basing this study on ten sherds only, which derive from five archaeological sites from a wide geographical setting, and a chronological range of four centuries, Armstrong *et al.* (1997) potentially, miss details in technological trends.

In the same year Wisseman *et al.* (1997) used NAA to characterise the glazed wares from Serres and Thessaloniki (Figure 3.2.1) in an attempt to answer questions regarding the production and distribution of the Serres pottery. The large amount of late thirteenth to fourteenth century Brown and Green Sgraffito and production debris recovered from excavations in Serres demonstrate that it was an important centre of glazed ware production in the Late Byzantine period (Papanikola-Bakirtzi 1997). The Serres Ware was compared with contemporary material produced at Thessaloniki, again an attested production centre, and the products of the two sites were observed to be visually distinct. For instance, the majority of the glazed pottery from Thessaloniki is plain glazed without the Brown and Green decoration characteristic of Serres productions. Further, while products from the two centres share the same common thematic repertory, there are notable stylistic differences: birds on Serres Ware have long sturdy legs with a hatched body in contrast to the Thessaloniki bird with its smaller, more uniform body that is gouged from the clay (Figure 3.2.3). The motifs on the Serres pottery are usually tightly packed giving the impression of elaborate ornamentation, particularly when they are set against a background of fine hatched lines in contrast to the Thessaloniki products that are more sparsely decorated (Papanikola-Bakirtzi 1997).

Having distinguished the pottery from the two production centres on stylistic grounds, pottery visually resembling the Serres Ware was recorded in large numbers at Thessaloniki, and in lesser amounts in locations as diverse as Philippi, Skoupje, Prilep, Abdera, Corinth and also Venice. The study was undertaken to investigate the specific questions: can the stylistically distinctive products from the two centres be distinguished chemically, and were the Serres Ware recovered from Thessaloniki and Philippi of Serres origin?

Wisseman *et al.* (1997) demonstrated the presence of two distinct compositional groups associated each with Serres and Thessaloniki and that the Philippi finds were chemically compatible to that of the Serres group. Surprisingly, however, it was observed that the Serres Ware found at Thessaloniki split consistently between the main Serres and Thessaloniki clusters, raising interesting questions regarding the transfer of technological knowledge. For example, it could be explained thus: that a Serres potter set up production in Thessaloniki, keeping to the Serres stylistic tradition but utilizing local clays, that the Serres Ware was imitated by the Thessaloniki potters, or that a Serres potter shared his knowledge in collaboration with the Thessaloniki potters (Wisseman *et al.* 1997). However, that various clay sources around Serres were utilized, perhaps one chemically similar to the Thessaloniki clay should not be discounted.

As an aside to the study the glazes from three samples were analysed to determine whether or not the expected lead, copper and iron were present, and whether there was any layering in the glaze to indicate how many times the sherds were fired. The glazes were found to be of the high lead type, and interestingly, the green glaze analysed showed that copper, the expected colorant, was not present. While it was noted that the trace amounts of nickel or chromium present could have coloured the glaze green, it was concluded that the technique used (SEM-EDS) probably would not have detected the copper component. The reason for this was not specified, but it is possible that Wisseman *et al.* (1997) was referring to the limit of detection for the EDS, the implication being that the copper content fell below the limit at which the technique could analyse for. However, depending on the count time used during analysis, representative figures for the detection limit have been given as 0.05-0.26 wt% of the element (Pollard and Heron 1996, 52). This figure falls below the amount of copper

found to be present in the Byzantine green glazes where they have been analysed (for example see Armstrong *et al.* (1997) above, and Table 3.2.4).

While this study was important in that it published the first reference set of chemical compositions for glazed wares produced at the sites of Serres and Thessaloniki (see Megaw *et al.* (2003) above for later analyses of Byzantine pottery from these locations), and discussed some of the implications the findings had on aspects such as the transfer of technological knowledge, it was disappointing in that the unexpected findings for the glaze compositions were dismissed as a the result of the analytical technique used, and were not explored in any further detail as was perhaps warranted. It would have been worthwhile extending the glaze analysis to further samples, and perhaps making recourse to WDS as a more sensitive technique to test if the absence of copper really was a product of the methodology used, or whether in fact other minerals were being exploited as colorants.

In a paper published in 2003, Stern and Waksman reported the results of a typological and analytical study of twelfth to thirteenth century pottery from the important Crusader port of Acre ('Akko), Israel (Figure 3.2.2). A program of petrographic and chemical analysis (using ICP-AES and ICP-MS) was undertaken to characterise a range of categories of pottery common on Levantine sites in the Crusader period. Production of pottery at Acre is evidenced by the discovery of wasters of an unglazed type of bowl termed "Acre Bowl". The findings revealed that of the various categories of pottery analysed (Sgraffito Ware, Slip Painted Ware, Reserved-Slip Ware, Acre Bowls and wasters, and glazed cooking wares) only the Acre Bowls were manufactured at the site. Included in the study were 43 sherds of imported Zeuxippus Ware that were treated separately. Of the sherds, 11 could be attributed to Zeuxippus Ware Class II as defined by Megaw (1968) (see Chapter 6 for a discussion of the Ware), two groups containing 14 and eight members were classed as "Zeuxippus influenced ware", and a final group containing 11 samples were related to the Italian ware "Spirale Chercio" (Stern and Waksman 2003, 176). The petrographic and chemical analysis demonstrated all groups were imports to Acre. Usefully, a broad petrographic description of the fabrics was included in the publication. All samples, except one were found to have similar features, including a fine micaceous matrix, with varying amounts of silt-sized quartz. They were lightly tempered with well sorted, subrounded quartz, micas, metamorphic rock fragments decomposed carbonate grains, feldspar, hornblende and clay pellets.

Hierarchical clustering of the chemical data resulted in the formation of three well-defined chemical groups, one of which included only examples of Zeuxippus Ware Class II, one included both groups of “Zeuxippus influenced ware” and the final one contained the “Spirale Chercio” related ware. These results indicate that a number of as unidentified production centres were manufacturing and exporting the Zeuxippus type pottery.

In 2007 Waksman published the results of a characterisation study of Byzantine pottery from Chersonesos (Figure 3.2.2), one of the main outposts of the Empire in the Black Sea area, and a site that had been attributed to the manufacture of Zeuxippus Ware given the quantity and quality of the ware type present at the site (Waksman 2007, 384). Ceramic production is well attested in Chersonesos given the presence of medieval kilns associated with tile and amphora manufacture. That glazed ware was also manufactured at the site is indicated by finds of firing tripods at the site. These are used to separate glazed wares in a kiln. The aim of the study was to define the chemical characteristics of local products and test these data against Zeuxippus Ware type ceramics from the site. As no local reference material “*stricto sensu*” such as kiln furniture or wasters were available, the ‘local group’ was sampled to include common glazed wares, tiles, amphora and a fishing weight. Characterisation was carried out using WD-XRF and hierarchical clustering was performed on the resultant data. The results revealed four main chemical groups could be distinguished. The first group included all but a few of the samples considered to be local (glazed wares, tiles, amphora etc), reinforcing the hypothesis of their local manufacture and providing a reference for Chersonesos productions. The second group included Zeuxippus Ware and the third and fourth comprised Zeuxippus related wares. These groups showed no chemical similarity to Group 1. Waksman (2007) concluded the results of this analysis do not support the manufacture of Zeuxippus Ware at Chersonesos, nor were potters in the locale imitating the type.

Waksman and her colleagues undertook a detailed analysis of the earliest Byzantine glazed White Wares from Constantinople in an attempt to investigate the technological relationship between these and “Eastern” and “Western” productions. The results of the study are published in two articles (Waksman *et al.* 2007, 2008). Byzantine glazed White Wares first appear in Constantinople in the seventh century AD and represent a break in the typological repertoire of Late Roman productions in Asia Minor (Waksman

et al. 2007, 129). Their investigations centred on the question of whether the (re)introduction of the glazing techniques had an Eastern influence (glazing had been continuous in the Parthian, Sasanian, then Islamic territories), or a Western influence (glazed pottery was manufactured and used in northern Italy and the Balkans in the fifth to seventh centuries). The samples included glazed wares dating to the seventh century from Constantinople (the “Byzance” batch), Caričin in Serbia (the “Balkans” batch), Saint-Blaise and Hyères in south-eastern France (the “Italy” batch) and Saint Symeon (al-Mina) in Northern Syria (the “Middle East” batch) (Figure 3.2.2) (Waksman *et al.* 2007, 2008). The ceramic bodies were characterised by WD-XRF and the glazes using SEM-EDS. In brief, the results indicate that each of the batches were compositionally distinct in terms of their ceramic bodies. The “Byzance”, “Balkans” and “Italy” batches have high concentrations of Al₂O₃ and SiO₂ (>90%) in common, indicating the use of kaolinitic clays, while the “Middle East” batch is significantly different due to high CaO, MnO and Sr concentrations. The glazes were all determined to be of the high lead type (approximately 60 to 70% PbO and 20 to 30% SiO₂), though the “Byzance”, “Balkans” and “Italy” batches also had significant concentrations of Al₂O₃ (approximately 7 to 9%), in contrast to the “Middle East” batch, which contained less than 1% Al₂O₃. In investigating glaze manufacturing method (using the data reduction technique detailed in Section 2.3), two distinct glaze technologies were identified. The “Byzance”, “Balkans” and “Italy” glazes were determined to be manufactured using PbO on its own, whereas the “Middle East” glazes were determined to be manufactured using a PbO·SiO₂ mixture. This is a significant finding, and taken together with the other evidence, suggests that the reintroduction of the glazing technique in Byzantium occurred via the Western provinces, rather than an Eastern influence (Waksman 2007, 134).

3.3 Summary and Conclusions

This review of previous analyses of Byzantine glazed pottery reveals that work to date is fairly limited. The main emphasis has been towards chemical characterisations of pottery from known production centres. For many years, Megaw and Jones’ (1983) pioneering work provided the only dataset for comparison. This is slowly being added to with productions from sites such as Pergamon (Waksman *et al.* 1994, 1996, 1997), Thessaloniki and Serres (Wisseman *et al.* 1997), and Chersonesos (Waksman 2007) now characterised and added to the published literature. This situation will improve greatly when the results of the work undertaken by Armstrong and her colleagues, and

outlined in Armstrong *et al.* (1997) are published in full. This review has also demonstrated that there is some bias towards the analysis of two classes of Byzantine pottery. These are the Constantinopolitan White Wares (both vessels and wall tiles) and Zeuxippus Ware and its derivatives. Only three studies give special emphasis to glazing technologies. These are by Vogt and Bouquillon (1996), Armstrong *et al.* (1997) and Waksman *et al.* (2007, 2008). Waksman *et al.* (2007, 2008) considered the earliest Byzantine glazed White Wares from Constantinople dating to the seventh century, and revealed them to be high lead glazes, manufactured using the simplest glazing technology, and related it to contemporary glazing technologies in the West. Vogt and Bouquillon (1996) analysed later (ninth to eleventh century) glaze decorated White Ware wall tiles from Constantinople. The results obtained from their study are significant since they demonstrate that in addition to lead glazing, lead-alkali and alkali glazing technologies were known amongst the Byzantine potters of Constantinople. Armstrong *et al.* (1997) considered the development of Byzantine glazing technologies in the context of the transition from White Ware manufacture at Constantinople to glazed Red Ware manufacture at sites across the empire. They determined that similar high lead glazing technologies were utilized for both White and Red Wares, and that no technological developments were apparent. Nevertheless, their conclusions relied upon only a small number of samples, from diverse locations, and spanning four centuries. Therefore, details in technological developments may have been missed. This thesis attempts to add to the knowledge on Byzantine glazing technologies by detailed investigations of a range of wares manufactured at and imported into Corinth during the eleventh to thirteenth centuries.

CHAPTER 4

HISTORICAL OVERVIEW OF MIDDLE TO LATE BYZANTINE/FRANKISH CORINTH

4.1 Introduction

To enable a better understanding of the changes that took place in the period under study and its associated material culture, it is necessary to place the sampled material in its historical context. Corinth's role as an economic centre and pottery producer is key to the formation of research objectives (Chapter 1) and interpretation of the resultant dataset (Chapters 8 and 9) in this thesis. This chapter presents a historical and archaeological overview of Corinth in the Middle Byzantine and Late Byzantine/Frankish periods and the physical evidence for the Byzantine pottery industry during this period. In order to fully understand Corinth's situation in the eleventh to thirteenth centuries it is necessary to trace the history of Corinth back to the early Byzantine period. The medieval archaeology of Corinth has been documented in some detail by Morgan (1942) and Scranton (1957) in their respective *Corinth* volumes. However, as highlighted by Sanders (2003, 647) these works must be treated with discretion given that historical events were used as markers with which to date excavated remains, often with misleading results. Recent reassessment of old contexts and the excavation of new ones has refined and clarified the chronology and understanding of Corinth in the period in question, and a revision is presented by Sanders (2002, 647-654, 2003, 295-297) and Williams (2003, 423-434). These current interpretations of the site are relied upon in the following section and are fully referenced where appropriate. Finally, as brought to attention by Sanders (2002, 647), only a relatively small portion of the Byzantine and Frankish levels have been excavated with work concentrating on areas in and around the Roman Forum, the Bath on the Lechaium Road, the theatre and trial trenches on Acrocorinth and in the modern village, thus they may not be considered typical of medieval Corinth as a whole. Section 4.2 presents the historical overview of the city and Section 4.3 details the physical evidence for pottery production at Corinth during the Middle Byzantine and Late Byzantine/Frankish periods.

4.2.1 Historical Overview of Corinth

The defining dates which see the decline of late Roman Corinth are given as the earthquakes in 365 and 375, and the destruction of the city by the Goths in 395/396.

Following these events structural changes to the forum area include the levelling of the shops and their replacement by a staircase bordering the Bema and the refurbishment of the west shops. The early fifth century saw the building of a new city wall thought to have reduced the defended area of Corinth by one third to approximately 1.5 km² (Scranton 1957, 7; Sanders 2002, 647-48). During these early centuries Corinth was the capital of the province of Achaia, the area corresponding to the modern day Peloponnese and was the seat of a metropolitan Bishop (Scranton 1957, 6, 9). In the fifth and sixth centuries the Christian basilicas and cemeteries were situated outside of this new city wall (Sanders 2002, 648). Further events affecting the population of Corinth are given as the great plague of 542, possibly reducing the population by half, followed by a devastating earthquake centred close to the city. Later in the sixth to seventh centuries the Slavic colonization of the Peloponnese led to the resettlement of some of the population of Corinth on Aegina (Davidson 1937, 227-228; Sanders 2002, 648). The civic and business activities once carried out in the Forum area were relocated at this time. This is evidenced by the rarity of pottery and coin evidence in excavation and by its use for burial from the late sixth to eighth centuries. Sanders (2002, 648; 2003, 396) suggests that this indicates either the imperial edicts prohibiting burial within the city had lapsed or a new city wall was built which excluded the Forum from its enclosed area.

By the late eighth to early ninth centuries, the Byzantine empire was entering a period of political recovery which saw successful campaigns under Irene and Nikephoros I against the Slavs in central Greece and the Peloponnese, and the reorganization of the themes (administrative centres) of Hellas and Macedonia and the creation of the themes of Kephalaria and the Peloponnese by Nikephorus (Laiou 2002a, 16). Following the reintegration of the Peloponnese into the empire, Corinth retained its earlier position of importance, remaining the thematic capital of the Peloponnese region until the early eleventh century. In addition to being the seat of local government and housing a number of government officials Corinth also held the seat of an archbishop and so must have had a metropolitan church of some importance (Sanders 2002, 649). Numismatic evidence from Corinth demonstrates that local remonetization of its economy occurred in the second decade of the ninth century under Leo VI, increased somewhat under Theophilos and after a short period of decline increased dramatically at the end of the ninth and first half of the tenth centuries under Leo VI and Constantine VII (see Table 4.2.1). The large volume of coins recovered from the forum area give good indication

that by the tenth century it was once again used for commercial purposes, though the lack of substantial built structures from the ninth to early eleventh century suggest the area may have functioned as an *emporopanegeireis* or open market (Sanders 2002, 650).

A review of the material evidence at this time shows that for a short period during the late eighth century glazed White Wares from Constantinople were imported in small quantities (see Chapter 6 for detailed review of chronology and typology of glazed wares from Corinth). This trade appears to have ceased almost straight away, possibly the result of raids into the Aegean by Arab colonists on Crete and southern Italy, interrupting sea travel. During the ninth century at Corinth, the glazed wares consisted predominantly of plain glazed chafing dishes, considered to be locally produced though towards the end of the century, following the reopening of the Adriatic they show stylistic links to contemporary Italian counterparts. Byzantine control of sea communications was firmly re-established only after the recapture of Crete by Nikephoros Phokas in 961 (Laiou 2002a, 22), and this is perhaps reflected in the ceramic record at Corinth with the reappearance of Constantinopolitan White Wares in the second half of the tenth century. This ceramic trade continued through the eleventh century until the imported White Wares dominated the glazed-ceramic market, with only a small portion represented by local plain glazed products (Sanders 2002, 650; 2003, 390).

During the early eleventh century, the themes of Morea and Hellas were amalgamated, with the capital established at Thebes. Scranton (1957, 35) argues that since the concept of a theme was military, providing a general and army on the scene of potential trouble, Corinth's loss of status as a thematic capital rather than leading to the loss of economic incentive that an administrative centre would provide, perhaps reflected that the Peloponnese was safe from threat, with the more stable environment being favourable to economic development and cultural life.

The forum area saw development at the end of the eleventh to twelfth centuries with the construction of domestic buildings, shops and industrial complexes (Figures 4.2.1 and 4.2.2). Industrial activity in this area included pottery production (see Section 4.3 for discussion of pottery workshops in the forum area), glass working, and gold and bronze working, while a medieval bathhouse operated southwest of the Bema church and remains of wine and olive presses were located to the east (Sanders 2002, 652-653). Its

coastal position meant that as well as functioning as a regional trade centre Corinth was involved in interregional trade, being a commercial centre regularly frequented by Venetian merchants, with major exports being silk and oil. The Venetian presence in Corinth is recorded from 1088 and trading privileges to Venice were renewed in 1126 and 1147 as well as being extended to other Italian cities. (Scranton 1957, 50; Harvey 1989, 216; Laiou 2002b, 747-748). Laiou (2002b, 751) states that the increase of trade with Italy led to the increase in attacks of piracy by the Italians during this period. The strength of Corinth's economy meant that it was target to such an attack by the fleet of Roger of Sicily in 1147 when skilled craftsmen were recorded to have been carried off to Sicily (*Nicetas Choniates*, pp. 74-5 in Harvey 1989, 215; Sanders 2002, 651). Nonetheless, in 1154 Corinth was described as 'large and flourishing' by Edrisi, Roger's court geographer while in the late twelfth century Choniates recorded Corinth as a wealthy town with two harbours, in one anchoring boats from Asia, and the other boats from Italy indicating contact with both east and west (Harvey 1989, 215; Sanders 2002, 651; 2003. 396).

The Corinthian glazed ceramic industry underwent a major change during the last two decades of the eleventh century under the reign of Alexius I with the cessation of importation of Constantinopolitan White Wares and a decline in the appearance of chafing dish and other plain glazed types in conjunction with the development of the local industry, where slip and glaze decorated vessels in forms imitating the earlier White Wares were produced in local fabrics (Sanders 2002, 651; 2003, 394). In addition to the introduction of new decorative styles and forms, the proportion of glazed wares present in the ceramic assemblage increased from less than 0.7% by weight in the tenth and eleventh centuries to 2% at the beginning of the twelfth century. By the middle of the twelfth century glazed pottery represents 6% of the ceramic assemblage and by the mid thirteenth century approximately 20% (Sanders 1995; 2002, 394; 2003, 651). Sanders (2002, 651) links this twelfth century growth in production and consumption of glazed pottery to the steady reduction in the size and values of coins during the mid eleventh century leading to the increase in the circulation of low denomination bronze coinage that could be used for petty shop transactions by a greater proportion of society throughout the twelfth century. Thus an environment was created whereby the glazed ceramic products became available to the wider society, and an increase in demand provided stimulus for the evolution of the industry. The increase in production and use of glazed pottery in this period perhaps supports the comment made

by François and Spieser (2002, 599) that there was very little distinction in status between the coarse cooking and storage wares widely used and these glaze decorated tablewares.

Maritime commerce was extensive in the Byzantine period (for example see van Doornink 2002), and glazed pottery as a trading commodity is demonstrated not only by the presence of ceramic imports such as the Constantinopolitan White Wares of the late tenth and eleventh centuries, but also by shipwreck evidence. For example, the wreck that sunk off Pelagonnisos in the Northern Sporades carried a primary cargo of fine Sgraffito tableware which dates to the mid twelfth century (Kritzas and Throckmorton 1971; Parker 1992, 306). One must surmise given the burgeoning pottery industry and increase in consumption of glazed pottery at Corinth during the twelfth century that its industry fed into the international trade network in ceramics. Thus, not only did the Corinthian pottery industry supply the requirements of the local population and produced pottery for export (see Patterson (1993) for possible examples of Corinthian Measles Ware exports to Otranto, southern Italy), but must also have been supplemented by glazed ceramic imports.

The thirteenth century at Corinth saw changing political conditions. In the year immediately following the Crusader capture of Constantinople in 1204 the Franks gained control of Thessalonika and central Greece east of the Pindos Mountains and began the subjugation of the Peloponnese. The Byzantine Empire was partitioned with the creation of new states (Lock 1995, 4-5). Acrocorinth, the fortress overlooking the city, was besieged from 1205 until it fell in 1210, putting Corinth under Frankish control. While Corinth was an important garrison for Geoffrey de Villehardouin following its capture and held the mint for the principality of Achaea, it was not one of the major baronies of the Morea (Scranton 1957, 84). Williams (2002, 425-426) reports that during the first half of the thirteenth century there was a noticeable decrease in the size of the city combined with a general decline in the standard of living until the middle of the century when this situation was reversed. Excavation shows the construction of buildings and increased activity in the area near Temple E and St John's Church from this point in time (Figure 9.2.3). It is noted, however, that any change in the values and culture of the local Greek population to those of the new rulers was neither wide-ranging nor immediate, thus material culture continued essentially unchanged until the middle of the century (Sanders 2002, 651; Williams 2003, 424).

The administrative change at Corinth following 1210 seemed to have had little adverse impact on trade and the city retained its importance in international commerce.

Ceramic evidence shows the continuation of the use of late twelfth century pottery styles well into the thirteenth century, with the presence of Champlevé and Incised Sgraffito wares. These pottery styles were found throughout Greece in this period and are considered to be imports to Corinth, possibly originating from the mainland of Asia Minor (Mackay 2003, 404). Local production of glazed wares continued with cruder, more loosely decorated versions of the twelfth century Green and Brown, and Slip Painted Styles, in addition to imitations of the Incised Sgraffito and Champlevé imports. Protomaiolica from Italy first appeared in small quantities around the second quarter of the thirteenth century along with Aegean and Zeuxippus Wares imported from as yet unidentified locations, though thought most likely to have originated in the Aegean rather than Italy (MacKay 2003, 409). By the middle of the century a new style of pottery characterised by “murky” ochre and olive glazes, along with new forms of cooking vessels, were suddenly introduced. Williams and Zervos (1994, 35-36) link this, and the increased building activity occurring at the same time, to the possible resettling in Corinth of the displaced Latin population of Constantinople following its recapture from the Franks in 1261 by Michael Palaiologos, with the effect of weakening the Byzantine traditions at Corinth. The latter decades of the thirteenth century see a marked increase in the presence of Italian imports such as Protomaiolica, Archaic Maiolica and Metallic and Veneto wares in excavated contexts at Corinth, almost certainly the effect of the late thirteenth century control of Charles II of Anjou over the Peloponnese in which already existing commercial ties with Italy were likely to have been strengthened (Sanders 1987, 192-193; Sanders 2002, 652; MacKay 2003, 419).

Although outside the scope of this study it is worth noting that Corinth faced severe decline in the fourteenth century following a series of events including a devastating earthquake in 1300, the Catalan sack in 1312, a further earthquake around 1320 and the arrival of the Black Death in 1348 (MacKay 2002, 402; Sanders 2003, 652).

4.2.2 Summary of the Historical Overview of Corinth

In order to investigate the development of glazed pottery production at a local level it is crucial to understand the environment in which the pottery at Corinth was being produced and exchanged in during the period under study. The picture of eleventh and twelfth century Corinth is, in general, one of political stability and growth. A monetary

economy was re-established there during the tenth century, and the loss of Corinth's status as thematic capital in the early eleventh century would suggest the Peloponnese was free from threat, providing a setting for the growth of economic and cultural life. Certainly, from the archaeological record it is apparent that the twelfth century was a period of expansion, with excavated areas showing development of the urban environment. Corinth's geographical position between the Corinthian and Saronic Gulfs meant that it grew as an important commercial centre during the Byzantine period, with contact both to the east and west, while historical records document an active international trade with the Venetians. The thirteenth century wrought political changes in Corinth with the Frankish takeover in 1210. Despite a reduced population in the first half of the century, Corinth stayed active in commerce, while material culture shows that any conversion of the Greek population to Frankish standards and ideals took time. The sudden upsurge in building activity in addition to the introduction of new pottery styles, both locally produced and imported that occurred around the middle of the thirteenth century perhaps reflects a demographic change, with the influx to Corinth of Latin refugees following the recapture of Constantinople by the Byzantines. Therefore the ceramic assemblage at this point possibly reflects the demand of the settlers for familiar material culture, thus diluting the upheld Byzantine traditions observed in the first half of the century.

The development of the Corinthian glazed pottery industry in the eleventh to thirteenth centuries did not occur in isolation. It was a reflection of and influenced by the political, social and economic conditions of the times. Thus, in exploring technological changes in production that may have occurred as the local industry developed it is essential to consider possible external influences, and perhaps the most important in this context is commercial contact. The glazed ceramic assemblage at Corinth is complex in nature, showing not only the products of local manufacture, but also a significant quantity of imported material. The broad trend in ceramic commerce at Corinth can be documented as so: in the eleventh century, while glazed pottery represents only a small fraction of the ceramic assemblage as a whole, the majority of it is represented by imports from Constantinople. As this trade was discontinued in the twelfth century and the local industry established itself, imports were represented by red wares, possibly originating in the Aegean. The Aegean imports continue in the ceramic record into the first half of the thirteenth century, but by the second half they were replaced Italian imports. Not only does this demonstrate extensive trade links that alter over time, but it

represents an environment of social contact which provides a route for the exchange of ideas and transfer of technological knowledge.

4.3.1 Evidence for Pottery Production in the Byzantine Period

The purpose of the previous section was to place in context the development of the Corinthian pottery industry. The aim of this section is to look in more detail at the physical evidence showing the production of glazed pottery at Corinth and consider what can be said about the organization of that industry based upon that evidence.

That glazed pottery was produced at Corinth during the period under study is conclusively demonstrated by the significant quantity of ceramic production debris that has been recovered over the years of excavation at the site. This evidence is in the form of fragments of kiln lining, unglazed, slip-decorated, biscuit fired sherds, misfired vessels and kiln furniture, including firing yokes used for hanging stemmed vessels in the kiln and firing tripods for the separation of stacked, glazed vessels (Figures 4.3.1 to 4.3.3). Much, though not all, of this material came from excavations of the forum area carried out in the 1930's. In the course of these excavations a number of structures were revealed that were identified as kilns operating in the twelfth century; they are the St John's 1937 kiln, the Agora S.C. 1938 kiln, the Agora N.E 1936 kiln, and the Agora S.C and South Stoa 1936 kilns (these features were originally dated to the eleventh and early twelfth centuries (Morgan 1942, 3-25), however, a new understanding of the development of the forum area, and the redefining of the Byzantine glazed pottery chronology places these structures well into the twelfth century (Sanders 1995, 2002)). At least four of them were considered to be pottery kilns (Morgan 1942, 7). Thus, in publication of the Byzantine pottery and production workshops, Morgan (1942, 3-25) presents a picture of an expanding industry within the city limits, specializing in the production of glazed pottery which was focussed around the forum area.

A review of these kilns today is made difficult given the length of time since their discovery and the limited detail given to their recording in both excavation notebooks and the original publications that treat these features (see Morgan 1936, 1939, 1942). In particular, they were excavated under the prevailing paradigm of the times where importance was placed upon the recovery of gross material evidence. Hence, the subtle residues and important material associations that would now be recorded and which would allow for an in-depth analysis of the function of the various kilns and their

complexes were often not considered significant. To enable a more complete picture of pottery production at Corinth in the Byzantine period Sanders has provided information on three further unexcavated and unpublished potential pottery production sites. While two of them (the Hadji Mustapha site and the Acrocorinth kiln site) appear to have produced coarse wares and amphorae it is necessary to include them in this section as they provide evidence of the pottery types produced during the timescale under study. The kilns and kiln sites are treated in broad chronological order and their locations shown in Figures 4.3.4 and 4.3.5).

4.3.1.1 The Hadji Mustapha Kiln Site

The earliest of the unexcavated Byzantine kiln sites is located approximately 100m north of the Hadji Mustapha fountain on the edge of Acrocorinth (Figure 4.3.4), and is characterised by a substantial deposit over a meter deep of misfired pottery and distorted wasters. The area was exposed during exploratory excavation of a building site by the Greek Archaeological Service carried out in the late 1980's. Analysis of the material washed from the baulks and collected from the site was predominantly wave-decorated transport amphorae, with lesser quantities of plain wares, cooking pots and tiles, though no examples of the coarse plain brown glazed wares are reported. The deposit is dated to the ninth and possibly tenth centuries. While no kiln structure has been located, it is considered very likely to represent the production debris from a pottery workshop located within the area (Sanders pers. com.).

4.3.1.2 The Acrocorinth Kiln site

The unexcavated Acrocorinth production site is situated on a small mound west southwest of the first gate of Acrocorinth (Figure 4.3.4). It is represented by a dense scatter of bloated wasters and fragments of dunted vessels and a significant quantity of fragments of kiln lining at the top and western slopes of the mound, while a thinner scatter extends approximately 100m down the steeper southern slope. In addition, one firing tripod has been found. An examination of the surface material indicates a greater variety of shapes than those produced at the Hadji Mustapha kiln. Forms include amphorae and amphorae stands, stew pots, basins, pithos lids and jars, and chafing dishes, though this last group are more rarely represented. Pottery styles suggest production occurred during the tenth and eleventh centuries (Sanders pers. com.). The presence of chafing dish forms and a firing tripod, while scarce, give indication that the manufacture of glazed coarse wares was carried out in conjunction with the production

of the more common unglazed forms. This argument may be strengthened by the presence of glazed patches on unglazed cooking wares of this period (Figure 4.3.6) suggesting in these instances that either glazed and unglazed vessels were prepared in the same workshop allowing transfer of raw glaze materials onto unglazed forms, or that both glazed and unglazed wares were stacked together in the kiln during firing.

Sanders comments that this site was ideally situated for pottery production, with all the raw materials required located within close distance. Useable clays are available within the immediate environs, whilst an outcrop of mudstone, a common tempering material characteristic of ceramics produced at Corinth, is situated less than 500m to the east (see Chapter 5 for geology of the area). Water sources are present outside the inner gate of Acrocorinth and from Klephtovrisi 300m to the northwest, and gariga scrub on the mountain slopes could have supplied a source of fuel (Sanders pers. com.).

Consequently, given both location, and quantity and spread of debris it is safe to assume that a pottery kiln operated in close proximity.

4.3.1.3 Roumelioteika Waster Dump

This site at Roumelioteika by the Asklepieion (Figure 4.3.4) is represented by surface finds of unglazed wasters of Green and Brown Painted and Slip Painted Dark on Light wares, and numerous firing yokes. The styles of pottery represented date the material to first half of the twelfth century. The occurrence of quantities of wasters here may indicate the presence of a kiln within the vicinity; however, without knowing the scale of waste, it may simply represent the dumping of production debris from another site (Sanders pers. com.).

4.3.1.4 St John's 1937 Kiln

The St John's 1937 kiln was situated under the north aisle of St John's church to the northeast of the market place (Figure 4.3.5, Kiln A). Little can now be said regarding its setting as much of it and its surrounding buildings were destroyed by the construction of the St John's church and monastic complex in the early thirteenth century. The remains of the kiln itself show that it was circular in plan with a chamber floor 1.60m in diameter, and walls 0.60m thick constructed out of brick and tile fragments held together with mortar. Some of its wall was preserved to over a meter in height, retaining the lower courses of its roof showing it was domed in form. The floor was supported by a surviving thick central circular pier. The firing chamber was

thought to have been located on the northern side of the kiln which was completely destroyed by the church foundations. Surrounding the kiln was a 0.20m black soil deposit underlying a red earth layer containing tiles thought to have originated from the collapsed kiln dome (Morgan 1942, 14; Sanders pers. com.). Biscuit fired sherds comprising Green and Brown Painted, Sgraffito, Measles, Slip Painted and Plain Glazed styles, bloated amphorae, wasters, firing yokes and two tripods were among the production debris in the immediate vicinity of the kiln. While the volume of waste in the area was relatively small, possibly reflecting that the production debris was removed and dumped elsewhere, the remains provide convincing evidence that this site was indeed used for the manufacture of glazed pottery. Morgan (1942, 14) considered this to be the earliest kiln in the series dating it to the eleventh century. However, the styles of pottery represented among the production waste (see Chapter 6) indicate it was operating for approximately 25 years from the first half to the third quarter of the twelfth century.

4.3.1.5 Agora S.C. 1938 Kiln

The mid twelfth century Agora S.C. 1938 complex, Morgan's "Pottery Factory", is situated at the southwest corner of the Market Place (Figures 4.3.5 Kiln B), and fronted by a colonnaded street, with an alley running along its western boundary. To the east it adjoins a set of buildings identified as a glass factory, initially thought to be contemporary but a recent reassessment of glass fragments suggest a date of the thirteenth or fourteenth century (Davidson 1938, 299; Morgan 1939, 257; Francoise and Spieser 2002, 579). The "Pottery" consists of an irregular rectangular court, roughly 16 by 33 meters containing two wells. A number of rooms are situated on the northern, western and southern walls which are variously ascribed the functions of display rooms for finished pots, potting rooms, quarters for the potters, storage rooms and so on. The smallest room on the western wall is perhaps the only one which contained evidence of purpose, housing four small vats and four large pithoi set into the floor, three of which were closed with circular stone covers when unearthed. While no traces of the contents of the vats were discovered to identify their use Morgan believed they were employed for the preparation of special clays or slips. (Morgan 1942, 12-13). Outside this room adjoining the southwest corner was a rectangular feature measuring only 0.53 by 0.80m constructed of brick and tile set in strong plaster described by Morgan as the firing hole of a pottery kiln, of which the chamber had been completely destroyed due to later intrusions (Morgan 1939, 257; 1942, 12).

Morgan (1942) draws on similarities of layout with a small pottery situated on the outskirts of Amarousi operating in his day to support his identification of this complex of buildings as a pottery factory. In particular, he notes the Amarousi pottery consisted of a large court containing a well, mounds of red and white clay, vats sunk into the ground for the preparation of unworked clay, drying areas for washed clay and unfired vessels and small basins for the preparation of slips. Around the court are various rooms used for throwing, slipping, glazing and firing the pots, as well as the proprietor's house, rooms for the workers and a storage cellar for maturing clay (Morgan 1942, 8-9). It has to be acknowledged that the general plan of the Agora S.C. 1938 complex is close to that of the Amarousi pottery in that a number of rooms surround a court containing a well, however, this organization of buildings around a central court would be convenient for any number of activities, while the absence of a number of features cast doubt on Morgan's interpretation. For example, Morgan reports that during excavation of the courtyard fill there were no traces of anticipated features such as cleaning vats, drying floors or residues of clay deposits. He explains this by suggesting these may have been located at the southern end of the enclosure where later intrusions cut across and demolished the twelfth century levels, destroying any evidence of these features or alternatively, the clay that was used by the potters was cleaned, matured and stored outside the town. He uses the absence of any cellar which he considers essential for storing maturing clay may support this second supposition (Morgan 1942, 12). Biscuit fired sherds of Dark on Light Slip Painted, Light on Dark Slip Painted, Sgraffito and Plain Glazed wares were recovered from the courtyard area and fill of the rooms (Morgan 1942, 175). Nevertheless, the lack of other associated production debris such as the firing yokes and tripods typical of the St John's 1937 kiln, or any bloated wasters or ashy deposits again make Morgan's identification of this unit as a pottery factory less secure. It is possible the unglazed sherds represent production debris deposited in this area from elsewhere, quite possibly from the St John's kiln just 80 meters to the northwest, rather than being products from this unit (Sanders pers. com.), and therefore Morgan's identification of this complex being a "Pottery Factory" cannot today be upheld.

4.3.1.6 Agora S.C. and South Stoa 1936 Kiln

Close to the Agora S.C. 1938 complex abutting the street on the southeast corner of the market place are the remains of two fairly small independent units each with a court (the

northernmost, Agora S.C. 1936, roughly 13 by 20 meters and the southernmost, South Stoa 1936, 15 by 17 meters) containing a kiln, a well and a number of pithoi and surrounded by several rooms (Figure 4.3.5, Kilns C and D, and Figure 4.3.7). The most interesting of these is the South Stoa unit. Morgan (1942, 20) describes the kiln situated in the north eastern corner as being rectangular in plan and cut down into the hardpan with walls of small stone blocks and bits of tile set into strong plaster lining the cut. The interior measured approximately 1.80 by 1.30m and the walls about 0.50m thick. The lowest level featured a firing pit and a lower chamber while the upper walls of the kiln no longer survived. He supposed, however, they would have been vaulted with vents in the top as was common with rectangular pottery kilns of his day. Sanders examined the excavation notebooks which recorded these features and noted that some evidence of burning was found in the general vicinity of the kiln as well as some tiles, and little pottery while a coin of Alexius I was found in the deposits around the foundations of the structure providing a *terminus post quem* of at least the end of the eleventh century (Sanders pers. com.). Nevertheless, excavation notebooks covering the kiln and adjacent area reveal no reference to wasters or kiln furniture leading him to question its function as a pottery kiln.

Of interest is a deposit of unfinished pottery buried in a small pit approximately eight meters away against the northern wall of the court. The pottery included two complete and numerous fragmentary vessels which were slip decorated and biscuit fired but without the final glaze decoration and include examples of Sgraffito, Measles, Slip Painted Dark on Light and Slip Painted Light on Dark Spotted (Figure 4.3.8) (Morgan 1936, 475; Morgan 1942, 175). If this deposit of biscuit fired pottery is indeed associated with the kiln structure then it may provide evidence that the unit was involved at least in some aspect of the production process of the pottery, perhaps the glazing of pottery produced at another location. It is therefore suggested here that this unit should not be dismissed entirely as a workshop associated with the production of glazed pottery.

The kiln of the adjoining Agora S.C. 1936 complex is different in form from the South Stoa kiln comprising of a roughly rectangular firing pit and circular chamber dug in to the hardpan and which are joined together by a tunnel. The circular chamber was encircled by a 0.2 meter wide ledge 0.5 meters from the base of the kiln which sloped downwards away from the tunnel mouth. This was thought to support the floor

separating the lower and upper chambers of which no trace was detected during excavation (Morgan 1942, 19). Morgan could find no real convincing evidence to fix the function this kiln as a pottery kiln as both metal slag and a few pottery wasters were found in its vicinity, thus its purpose must today remain undetermined.

4.3.1.7 Agora N.E. 1936

The Agora N.E. kiln, located to the northeast of the market place is the best preserved kiln excavated (Figure 4.3.5, Kiln E). Little information is given about its situation other than it is constructed at a relatively high level in sand and gravel deposits over a Roman pavement amongst a number of Byzantine walls (Morgan 1936, 467). The kiln chamber was circular in plan with a small rectangular fire pit lined with smallish stones in regular courses while the lower kiln chamber was lined with tough plaster (Figures 4.3.9 and 10). As with the St John's kiln a cylindrical pier of brick and tile set in mortar supported a vault of the same material over which a plaster floor was laid. This floor to the upper kiln was perforated with twenty six holes. A small section of the upper chamber wall survived to show that chamber wall, constructed of brick and tile curved inwards to form a dome (Morgan 1936, 70; 1942, 17). According to Morgan (1936, 70), this kiln dates to the end of the Byzantine/beginning of the Turkish period based upon associated pottery finds, however, given the poor understanding of pottery chronology in his day this date is in need of reassessment. Unfortunately no further information regarding associated deposits or material with which to support Morgan's identification of this structure as a pottery kiln was published, therefore, at present it is injudicious to make further comment.

Later (thirteenth century) production sites are currently unknown at Corinth, but this may change with time given the continuing program of excavation of Ancient Corinth by the American School of Classical Studies at Athens.

4.3.2 Summary and Discussion

It is very difficult to build a detailed picture of the organization of glazed ceramic production at Corinth based upon the physical evidence available. Attempts are hampered by the time elapsed since excavation of the forum area structures and the limited detail given to their recording in both excavation notebooks and the original publications that treat these features, and by the lack of excavation of the remaining sites. In addition to this, there is an absence of historical literature referring to the

Byzantine pottery industry that might aid in the interpretation of organization and scale of glazed pottery production at Corinth. Nonetheless, two points can be drawn from the evidence presented above.

In the first instance, it appears that during the tenth and eleventh century, the manufacture of glazed pottery was carried out at production sites in conjunction with unglazed coarse and cooking wares (for example, the Acrocorinth site). The scale of demand for glazed wares during these years was relatively low, and much of it was met by the Constantinople industry. Thus, local production consisted of the manufacture of coarse glazed wares such as chafing dishes, pitchers and pilgrim flask on a scale small enough not to require a separate, specialized industry. With the cessation of White Ware imports and a new demand for glaze decorated wares by a wider section of society at the end of the eleventh/beginning of the twelfth century it appears that the organization of production underwent a transformation. The presence of waster dumps (such as at Roumelioteika) and the production debris recovered from the St John's site, where the pottery is predominantly glazed styles, indicate some separation of the production of coarse wares and fine (glazed) wares, showing a move towards the specialization of the industry. Thus, production units were set up following the twelfth century transition whose primary products were glazed wares. The absence of any kiln assemblages dating to the thirteenth century mean that no comment can be made regarding the pottery industry during the Late Byzantine/Frankish period at Corinth.

The second point to be drawn from this assessment of the physical evidence for the production of glazed pottery at Corinth during the period in question is that Sanders' (1999) opinion that Morgan overestimated the number of production units operating in the forum area in the Byzantine period is here considered accurate. Of the structures discussed by Morgan (1942), only the St John's kiln can be considered a potters' kiln with any degree of certainty, nevertheless, it is also here believed that the South Stoa unit should not be dismissed out of hand. In addition to Morgan's kilns, two other Byzantine pottery production sites can be counted. They are the Hadji Mustapha and Acrocorinth sites. Finally, while the spread of wasters at Roumelioteika near the Asklepieion may indicate a further pottery kiln in the vicinity it is equally feasible that they represent the dump of production debris from another site.

To conclude, the physical evidence at Corinth demonstrates an active and changing industry in the production of glazed pottery making it an ideal location to investigate the development of Byzantine and Frankish glazed pottery production technologies on a micro-scale.

CHAPTER 5

GEOLOGICAL OVERVIEW OF THE CORINTHIA

5.1 Introduction

In order to make an assessment of provenance and technology of the pottery under study it is necessary to understand the nature of parent geology and clay deposits of the region. By studying local geology it is possible to establish the range of rock fragments and minerals that may be found in pottery produced in the locality. Conversely, if the ceramic fabrics are found to contain inclusions that prove to be inconsistent with local geology and there is no other physical evidence to connect them to the area, it may be taken as evidence that they were produced elsewhere and imported to the site.

Moreover, since all aspects of pottery manufacture are dependant on the nature of raw materials available conclusions on technological practices must be drawn not only from the analysis of ceramic fabrics themselves but also from information concerning the raw materials where possible (Whitbread 2003, 1)

The Chapter sets Corinth in its geological context and presents a précis of the research to date on the clays of the Corinthia. It concludes with a summary of characteristics of local clays which will be drawn upon in the interpretation of provenance and technology. It needs to be emphasised at this point that Corinth geology and clay studies have already been published in detail by Whitbread (1995, 261-263 and 308-344, and 2003) in relation to the production of archaeological ceramics at Corinth. This must therefore rely heavily upon Whitbread's work, which will be referenced at each point.

5.2 Regional Geology of the Corinthia

The site of Ancient Corinth lies to the southwest of the Isthmus of Corinth, the land bridge that connects the Peloponnese to Mainland Greece, with the Corinthian Gulf to the west and the Saronic Gulf to the East (see Figure 3.2.1 for location). It is situated on two terraces that run broadly parallel to the Gulf of Corinth, part of the series of terraces that descend down to the coastal plain lying to the north of the city. The acropolis of Acrocorinth is located immediately to the south (Salmon 1984, 21; Whitbread 1995, 261; Higgins and Higgins 1996, 43; Hayward 2004, 386). The high ground surrounding Ancient Corinth including Acrocorinth, and Penteskouphi to the southwest, the Oneia mountains to the east and the Geranea mountains to the north consist of Triassic to

Jurassic limestone masses (Bornovas *et al.* 1972; Whitbread 1995, 261; 2003, 2; Hayward 2003, 16), with ophiolitic rocks, predominantly peridotite, occurring between the middle and western parts of the Geraneia mountains (Collier 1990, 301; Whitbread 1995, 261) (Figure 5.2.1). Associated with the limestone and ophiolites are outcrops of the Upper Jurassic Shale-Sandstone-Radiolarite Formation occurring in the Geraneia Mountains, Acrocorinth, Penteskouphi, near Aghioi Theodori and in the mountains of south-central Corinthia (Merki 1965, 27; Bornovas *et al.* 1972; Whitbread 1995, 261; 2003, 3). In addition to shale, sandstone and radiolarite, this formation contains siltstones, tuffite, serpentinite and volcanic lava (Merki 1965, 27; Whitbread 1995, 261; 2003, 3-4).

The Gulf of Corinth is a graben, sinking as the result of normal faulting. The resultant trough has been filled gradually with Pliocene marls, sandstones and conglomerates with inter-beds of lignites (Hotz 1965, 52; Collier 1990, 201; Whitbread 1995, 261). The sedimentation occurred during alternating marine and lacustrine environments (Collier 1990, 314).

The series of terraces that rise from the coastal plain are the consequence of a complex history of regional uplift, faulting, together with deltaic sedimentation and changes in relative sea-level, with the youngest terraces only identified as being of normal marine origin (Doutsos and Piper 1990, 829; Whitbread 1995, 262; Hayward 2003, 16). While lithological units vary in their exact nature and thickness between terraces, and within sequences of single terraces, they generally consist of a basal conglomerate with overlying inter-bedded sandstones and coarse clastics that grade upwards into fine sandstones and are capped by impure or relatively pure limestone (Hayward 2004, 385).

The terraces are cut by valleys and gulleys that run perpendicular to the sea. These features are formed by erosion from fast-flowing water as the result of regional uplift. The Holocene sediments of coarse breccias and conglomerates that cover the northern slopes of the high limestone hills and parts of the terraces were water-transported from the high ground to the south of the Corinthian peninsula (Hayward 2003, 17).

The sedimentation processes and formation of the marine and tectonic-faulted terraces would have had significant impact on the availability of suitable raw materials for ceramic production by the ancient potter. The conditions of sedimentation mean that separate clay deposits are commonly limited in extent, both vertically and horizontally.

Furthermore, the formation of the raised marine terraces cause the exposure of different clay beds throughout the sequence, while through faulting, the same clay bed may be exposed in successive terraces (Whitbread 2003, 3).

5.3 Clays of Corinth

The interest in the raw material resources for ceramic production at Corinth date back to the 1960's with Farnsworth's pioneering study of clays and tempering materials in the Corinthia (Farnsworth 1970). These were built upon successively by Jones (1986) and Whitbread (1995), amongst others, who in the 1980's undertook additional regional studies of Corinthian clays. Consequently, there is a body of information available detailing the physico-chemical properties of clays from the region to aid in the study of ancient ceramic production at Corinth.

Using a combination of petrography, X-ray diffraction and neutron activation analysis (NAA), Farnsworth (1970) characterised three broad clays from the region; Acrocorinth red, Acrocorinth white and the white clay of the Corinthian plain (see Table 5.3.1 for summary of clays, and Figure 4.3.4 for overview of the site of Ancient Corinth). These were seemingly distinguished by the colour of the fired clay, hardness and feel in hand specimen, and by the presence or absence of mineral inclusions. Samples of the Acrocorinth red and white clays were taken from the banks of the road running from Acrocorinth to Ancient Corinth. The red clay bed was found to be crossed by bands of limestone. The white clay of the plain was sampled from within the immediate environs of Ancient Corinth, and is noted to be intimately mixed with lime. The three clays were found to be mineralogically similar, composed largely of montmorillonite (smectite), with some chlorite. In addition, the two white clays were found to contain appreciable amounts of illite. Non-clay mineral inclusions of the white clays were found to be calcium carbonate, quartz and feldspar, with the addition of dolomite in the Acrocorinth white clay. The Acrocorinth red clay contained only quartz in any appreciable amount.

In comparing the fabrics of the fired clays with those of a range of archaeological ceramics, Farnsworth believed them to be formed from either the red or white Acrocorinth clays or from a mixture of the two, with the Acrocorinth white clay being the most compatible in terms of mineral content. She was however, unable to reconcile the chemical compositions, finding the clays to have greater calcium contents than the ancient pottery. Two samples of classical Corinthian pottery analysed showed values of

12.16% and 14.90%, with all modern clay samples showing around 75% lime, thus identifying them as marls. Following further qualitative tests of clays from a wider area she found them all to have very high lime contents and so proposed that the clays have been enriched in calcium since the Classical period, most likely as the consequence of climatic changes (Farnsworth 1970, 20).

In addition to the analysis of clays in this study, Farnsworth identified for the first time the use of hornfels (mudstone) as a temper commonly used in ancient pottery produced at Corinth, and sourced the raw material to the outcrops of Shale-Sandstone-Radiolarite Formation on Acrocorinth (Figure 5.3.1).

Farnsworth *et al.* (1977) extended the survey of Corinthian clays in an attempt to source the raw materials used for ancient pottery production in a further study. Analysing seventeen samples from the vicinity of Ancient Corinth and one from Solomos by NAA, it was once again found that the majority were unusable, having too high a lime content. Two, however, were of interest. These were sampled from the west bank of the ravine below the Potters Quarter and from a clay bed east of the Tile Works (see Figure 4.3.4 for their locations). Chemically they were compatible to each other and showed similarities to the Corinthian pottery analysed in the same study. Nevertheless, as previously found, the calcium content was higher at 20% Ca in the clay as opposed to approximately 10% Ca in the pottery (Farnsworth *et al.* 1977, 457, 460).

It is today recognized that the matching of clays to archaeological ceramics is complicated by a variety of factors. For instance, the manipulation and mixing of raw materials, the history of use of the pottery and burial environments all have the capacity to introduce compositional changes in the pottery so that the chemical and mineral compositions may not correspond to the composition of a distinct raw material (Hein *et al.* 2004, 357-8). Farnsworth's research was nonetheless groundbreaking in its day. Most importantly, it had long been held that Corinth had an unlimited supply of usable pottery clay. Payne (1931, cited in Farnsworth 1977, 459-460) states, for example, that "... the fine pale clay of which Corinthian vases are made is a distinctive feature of the landscape in the neighbourhood of Corinth; it marks the country westward, towards Sicyon and south along the gorges that run down to the coast of the Corinthian gulf from the watershed at Nemea. The several industries that depend upon a supply of fine clay must have been greatly facilitated by this abundant supply of raw material". That

was the view still held by archaeologists working at Corinth during the period of Farnsworth's studies (Farnsworth 1977, 460). Farnsworth was able to demonstrate that this was not in fact the case and the majority of what one sees are actually marls, with the high calcium content making them unsuitable for pottery production. She was consequently impressed by the ability of the ancient potters to recognise and exploit usable clays from the area.

Jones (1986, 176-179) continued the work on raw materials available for pottery production at Corinth, with particular reference to Corinthian amphora. In addition to Corinthian amphora, fourth century pottery, Roman pottery and Blister Ware, a number of modern clays, an ancient mudbrick and fragments of ancient kiln linings were analysed using optical emission spectrometry (OES). The location and description of the clays sampled are given as a pale clay from Solomos, a pale clay from north east of Ancient Corinth near the Roman tileworks, a pale clay from the west bank opposite the Potters' Quarter, a pale, fine clay from near the National Road, and a red clay near the Sanctuary of Demeter and Kore below Acrocorinth (this last and the Potters' Quarter and tileworks clays duplicating the clays examined by Farnsworth (1970)). Jones was able to confirm Farnsworth's earlier observations regarding the calcareous nature of most modern clays. Perhaps of greater importance, he demonstrated the variable nature of compositions, not only between the different clay and marl beds in the region, but also within them. In the case of the Potters' Quarters and Roman tileworks clays, for example, he sampled from the thick surface layer of marl whereas Farnsworth sampled from below this layer. Comparison of the results showed an appreciable decrease in calcium content with depth. It was further found that whilst his and Farnsworth's Acrocorinth red clay samples were characteristically non-calcareous in comparison with the typical pale Corinthian clay, they were non-uniform in composition (Jones 1986, 179).

Whitbread (1995) made a major contribution to the understanding of raw material resources for the production of ceramics at Ancient Corinth. In conjunction with his petrographic study of Corinthian transport amphora, he carried out XRD and petrographic analysis of a wide range of pale and red clays from the region (see Table 5.3.1 and Figure 5.3.2). The pale clays were: four samples from the terraces immediately to the southwest of the village of Anaploga, above and to the southeast of the Potters' Quarter, fifteen samples from the terraces in the vicinity of Ancient Corinth

(corresponding to Farnsworth's 'white clay of the Corinthian plain') and seven samples of clays associated with lignite deposits (from the Nikoleta lignite quarry near Penteskouphi, from the Solomos lignite quarry, unfired bricks containing black lignite inclusions from the Corinth Brick Factory at Aghios Charalambos and from the lignite quarry at Kokkinarea north of the Geraneia mountains). The red clays were: one sample from the second terrace of Anaploga, one from the track from Anaploga to Penteskouphi village and three samples from the soils north of Penteskouphi, from east of Ancient Corinth and from the plain south of the road from Loutraki to Perachora (Whitbread 1995, 314-333). These *terra rossa* soils, named for their reddish brown colour, are iron rich, residual soils formed on limestone and limestone conglomerates which contain a clay component that is easily settled out of the soil by levigation (Jones 1984, 23; Whitbread 1995, 330, 342).

To summarize the results of this study, Whitbread found that while the Anaploga clays had a range of natural colours (pale brown, light grey and white), they all fired to a pale yellow. XRD showed them to contain kaolinite, illite, chlorite and smectite, and petrographic analysis showed the presence of red and white micas, monocrystalline quartz and moderately altered micritic limestone. These clays also contain distinctive dark reddish brown textural concentration features (tcfs) or clay pellets. He concluded that the Anaploga clays from above the Potters' Quarter are a potential source for ceramic raw materials.

In contrast, the majority of the clays from the terraces in the vicinity of Ancient Corinth were found to be relatively low in clay minerals and highly calcareous. Many samples could not be fired beyond 700°C without falling apart and crumbling to a fine powder upon cooling. In the temperature range of 700-950°C the calcium carbonate in calcareous clays decompose to calcium oxide. Following firing, rehydration of the calcium oxide to calcium hydroxide causes volumetric changes that can result in the disintegration of ceramic fabrics (Shepard 1956, 22; Whitbread 2003, 7). The samples that did survive had a smooth, powdery feel, fired to a pale yellow, white or light grey colour, and were shown to contain very rare to rare inclusions of monocrystalline quartz (more rarely polycrystalline quartz), calcite and white mica. It was considered that none of the clays in this group were particularly suitable for ceramic production, although a class of ancient Corinthian ceramics which are a pale greenish colour and have a powdery feel could have been manufactured from similar clays (Whitbread 1995, 318).

XRD analysis of lignite associated clays showed them to have moderate clay mineral contents and relatively little calcium in comparison to the clays from the vicinity of Ancient Corinth. In the case of those from Nikoleta and Solomos the clays contained kaolinite, illite and chlorite. The two unfired brick fragments from the Corinth Brick factory contained kaolinite, illite and chlorite, and kaolinite illite, chlorite and smectite. One clay sample from the Kokkinarea contained kaolinite, illite, chlorite and smectite, while the second was found to be almost entirely calcite.

Refiring experiments on one sample from the Nikoleta quarry showed it fired to pink (700 and 900°C) and pale yellow (1100°C) from its natural light grey colour. In thin section the clay which had not been levigated contained only silt-sized inclusions of monocrySTALLINE quartz and red-brown mica. A single dark reddish brown tcf was noted which contained monocrySTALLINE quartz silt. The processed clay of the brick wasters from the Corinth Brick Factory were found to be coarser grained, with less well-sorted inclusions of monocrySTALLINE quartz than the Nikoleta clay, while brick wasters collected at the Solomos quarry were similar in thin section to those from the brick factory. Brick wasters from the Kokkinarea quarry differed in having coarser inclusions (medium to fine sand-sized and rarely coarse sand-sized) of mono and polycrySTALLINE quartz, and red and white mica schist. The fact that these lignite associated clays were used in the production of brick-making, and by their transportation to a number of ceramic factories southwest of Athens attest to their suitability for ceramic production (Whitbread 1995, 327).

With regard to the red clays, the sample from the second terrace of Anaploga fired well up to 900°C, but crumbled on cooling when fired up to 1100°C. In thin section it was found to be coarse grained with poorly sorted inclusions of mudstone with radiolarian, quartz and white mica silt, mono and polycrySTALLINE quartz, micritic limestone, chert and rare to very rare orthopyroxene, plagioclase and serpentinite.

The clay from the track from Anaploga to Penteskouphi village, included in this group due to its natural light red colour, actually fired to a pale yellow at 1100°C. In thin section it was found to contain inclusions of micritic limestone, monocrySTALLINE quartz, radiolarian chert, mudstone and polycrySTALLINE quartz, with very rare quartz-biotite schist, plagioclase, white mica and serpentinite.

The *terra rossa* clays fired to a dark reddish brown to reddish brown colour at 1100°C, but were found to distort above 700°C and become bloated at 1100°C. Inclusions present (their fine sand to silt-sized and well-sorted character being a function of the levigation process) were found to be to be mono and polycrystalline quartz, chert, rare plagioclase and very rare yellowish micas. No clay pellets were observed. XRD analysis of these samples showed the *terra rossa* clays from north of Penteskouphi and east of Ancient Corinth to have relatively low clay mineral contents, with the first containing kaolinite and illite, and the second kaolinite and smectite. The clay from the plain south of the road from Loutraki to Perachora was shown to contain a moderate amount of kaolinite and smectite.

Whitbread (1995, 331) considered the clays from the second terrace of Anaploga and the track from Anaploga to Penteskouphi village to be sources of raw material for ceramic production. But because of the tendency of the *terra rossa* clays to distort upon firing above 700°C he proposed they could be used only if mixed with other clays.

As cited in Whitbread (2003, 5), a tantalizing glimpse of the practice of mixing raw materials by ancient potters in the region is provided by Pliny (*Natural History* 35.43) who refers to the potter Butades from Sikyon who worked in Corinth modelling portraits out of clay. It is said that Butades first invented the method of colouring the plastic compositions through the addition of red earth or else of modelling the portraits from a red chalk. A second reference to the mixing of clays by ancient potters can be found in *Geoponica* (V1.3) where it is stated that ‘not all clay is suitable for pottery, but with regard to potters’ clay, some prefer the yellowish red, some prefer the white and others mix the two’ (cited in Jones 1984, 22). This was still found to be the case in a study of the potting practices of traditional workshops in Greece and Cyprus, where out of some sixty workshops over half use mixtures of clays, with the majority following the classic recipe of mixing a red clay with a pale calcareous clay (Jones 1984, 25).

Given that Farnsworth (1970) and Whitbread (1995) have now identified a number of usable sources of red and pale clays from the Corinth region, the possibility of Byzantine potters using a mixture of the clays needs to be considered in the context of this current study.

Studies on Corinthian clays are ongoing with new field prospection and experimental firings carried out by Sanders, Joyner and Whitbread. This work, which has brought to light further usable clays, is at this point unpublished and cannot be included in the current review.

5.4 Summary and Conclusions

In summary, a number of points can be drawn from the review presented above which have direct relevance for the assessment and interpretation of the chemical and petrographic results produced in this study with regard to both identifying local and non-local products and understanding possible production technologies employed by the Byzantine potters. These are listed below.

1. It is currently the situation with the Byzantine glazed ceramic assemblage at Corinth that assumptions of provenance are formed on the archaeological criterion of morphological and decorative traits, the macroscopic assessment of ceramic fabrics and the criterion of abundance. Thus, it is assumed that members of a certain appearance occurring at the site in abundance are of local origin, while those showing scarcity must be imported. These assumptions are tested by comparing the petrographic results with the local geology. Typical minerals shown to be present in the Corinthian clays include mono and polycrystalline quartz, radiolarian chert, mudstone containing radiolarian, micritic limestone, and more rarely plagioclase, orthopyroxene, serpentinite and quartz-biotite schist
2. Chemical variability has been shown to exist within as well as between clay deposits in the region. This will have relevance in the interpretation of multivariate statistical analysis (in particular cluster analysis) of the chemical data generated in this study. In brief, local wares may show separate clusters due to the presence of clays of differing composition in the region. Further, variability within clusters may be explained by chemical inhomogeneity within single clay deposits.
3. The practice of mixing red and pale clays in Greece is documented both historically and in ethnographic research. Clay prospection has identified a number of viable pale and red clay sources in the area. Moreover, *terra rossa* soils have been identified as potential sources for red-firing clays. Therefore, the use of clay-mixing by the Byzantine potters at Corinth must be a consideration.

4. The presence of clay pellets in ceramic fabrics can be indicative of the practice of clay mixing. However, it is not always easy to distinguish between clay temper and naturally occurring clay pellets in a fabric (see for instance Whitbread's (1986) discussion on the subject). Whitbread's (1995) study demonstrated that naturally occurring clay pellets are a feature of some of the clays in the region. Therefore, all evidence needs to be taken into account before determining whether or not clay mixtures were being used.

5. Fine grained fabrics with well sorted non-plastic inclusions may be taken to be suggestive of clay preparation processes such as levigation or sieving. However, certain clays in the region have been shown to be naturally very fine grained with well sorted inclusions. Therefore, fabrics that show such microstructures cannot automatically be assumed to be the products of clays processed in such a manner.

CHAPTER 6

CHRONOLOGY OF THE MIDDLE TO LATE BYZANTINE/FRANKISH GLAZED POTTERY ASSEMBLAGE AT CORINTH

6.1 Introduction

Over a century of archaeological excavation at Corinth has resulted in the accumulation of an unparalleled collection of Middle to Late Byzantine/ Frankish pottery in Greece. The large majority of it is thought to be locally produced, although importation of glazed pottery to Corinth is evidenced by the presence of Constantinopolitan White Wares, Italian imports such as Protomaiolica or Veneto Ware, as well as a number of pottery classes such as Zeuxippus and Aegean Wares of unknown provenance. This collection of local and imported glazed wares spanning the ninth to thirteenth centuries lends itself for the current study which investigates the development of production technologies of eleventh to thirteenth century glazed pottery at Corinth.

For a diachronic study of this nature to be successful it is essential to have confidence in the date ranges for the production and use of the various glazed wares in order to fully investigate the technological relationships between the different styles of locally produced wares and between local and imported wares. Charles Morgan's volume *Corinth XI* published in 1942 was the first major study on the typology and chronology of Byzantine and later glazed pottery at Corinth, and has remained for some the standard reference for pottery of this period (for example Dark 2001). While this work was seminal in its time his chronology of the glazed wares can no longer be relied upon. There are two main areas that make his dating questionable. In the first instance, Morgan's dating of deposits and thus the pottery they contained was based in part upon the accepted historical formulae of the time as presented by Finley (1932). It was believed that Corinth was abandoned following the Slavic invasion of the sixth century, and repopulated again only in the early ninth century. Therefore, the earliest strata above the post-Roman levels were believed to be early ninth century in date and any pottery recovered from these and overlying levels were dated accordingly. Following decades of further excavations at Corinth, it is now known that this was not the case and there was, in fact, continued occupation from the sixth century through to the ninth century (see for example Sanders 1999, Chapter 4). Secondly, Morgan's use of numismatic evidence can be brought into question. At the time of his study there was poor understanding of the chronological sequence of the Anonymous Folles series.

Anonymous Folles were large copper coins with an image of Christ on the obverse and a formulaic inscription on the reverse, and with no information with which to identify the emperor or empress in whose reign they were minted. Studies in the intervening years have resolved this issue to a great extent so that it is now known that the Anonymous Folles series was initiated in the reign of John I Tzimisces, probably around 970. They continued in use until monetary reforms were introduced in the reign of Alexius I (1092-1118) (Grierson 1984, 204-210, Sanders 1995; 11). In conjunction with the poor understanding of coin issues, Morgan did not question the significance of coins in archaeological contexts. That is whether or not coins were survivors, contaminants, or were in circulation with the pottery. Furthermore, he dated contexts using the commonest and not the latest associated coins. Since Morgan's time there has been great progress in methods of archaeological excavation and in the reading of relationships between archaeological contexts and associated material as well as in the understanding of history of Byzantine Corinth and in the identification of Byzantine coinage (for example Sanders 2003). In addition, there is now a greater awareness of post-depositional processes that may disturb archaeological deposits. Morgan's Chronology has therefore been superseded by more recent work. These works include studies by Sanders (1995; 2002; 2003), who treats in detail tenth to twelfth century glazed wares, while the chronology of thirteenth and later glazed pottery from Corinth is discussed by MacKay (1967, 2003), and highlighted in the series of excavation reports published yearly in *Hesperia* since the 1980's, the most important of which being Williams and Zervos (1995) and Williams *et al.* (1998). These latter works are used here as a primary dating tool.

Each of the glazed ware decorative types selected for this research are described in this chapter and a summary of the currently accepted chronological ranges for the wares is presented. It is divided into two sections headed 'White Wares' and 'Red Wares', which are the two primary categories in the classification of Byzantine ceramics. Maps showing the locations of findspots of the various wares discussed are given in Figures 6.1 and 6.2.

6.2 *White Wares*

The Byzantine White Wares form the major component of glazed ceramic assemblages from Byzantine sites from the ninth to early twelfth century (for example Sanders 2003, 390). They are characterised by ceramics with white, pale pink or buff, gritty and

coarse through to very fine pure white fabrics. The coarse fabric tended to be used for utilitarian vessels including lamps, chafing dishes, bowls and jugs, while the finer fabrics were reserved for architectural ceramics such as revetment plaques and tiles, and fine tablewares including thin walled bowls and cups (Armstrong *et al.* 1997, 225). The tablewares are covered with plain green or yellow lead glazes. Yellow glaze was commonly applied to the interior only of open forms where green glazed vessels tended to be glazed on both interior and exterior surfaces (Sanders 1995, 70).

As well as these Plain Glazed Wares, White Wares were decorated using slip painting (Slip Painted Ware), with moulded relief (Impressed Ware), or with three or more coloured glazes (Polychrome Ware). Slip Painted White Ware is characterised by the use of a thin red slip applied in bands of radiating curved lines or vertical lines on the upper interior of open forms, and is often used in conjunction with a central relief motif (Sanders 1995, 75). The slip decoration is almost always used with a yellow glaze, but examples do exist of green glazed Slip Painted Ware (for example C-37-1656, *Corinth XI*; no.130 (Morgan 1942, 190)) (see Figure 6.3).

The Impressed Ware group is characterised by plain glazed or slip painted vessels decorated with low relief motifs usually confined to the centre of large open forms, but which can also cover the entire surface. The motifs include simple designs such as crosses or webs through to complex depictions of mythical beasts, heraldic birds or occasionally human figures (Morgan 1942, 46; Sanders 1995, 77; Armstrong 2001, 62), (Figure 6.4).

Of the decorated White Wares, Polychrome is the class that has received the most attention (for example Talbot Rice (1930), Morgan (1942, 64-70), Stevenson (1947, 33-63) Hayes (1992) and Sanders (2001)). Sanders (1995, 72) found the typologies of the many different styles of Polychrome Ware presented in these studies problematic, commenting that they were based on too small and unrepresentative samples of pottery to be definitive. Further, the great variety of colour use and design presented within each category made the typologies difficult to use. He therefore proposed a new typology based on the Polychrome Ware recovered at Corinth. In brief, Sanders' Type 1 is limited in colour to blue-green, manganese and yellow-brown. Decoration includes geometric patterns and figural designs (human and animal). The main characteristic of Sanders' Type 2 (Morgan's Group I) is the use of a red dotted background for a variety

of designs including vegetal motifs, crosses or figural designs in blue-green, yellow, manganese, red or azure (Figure 6.5). Type 3 (Morgan's Group III) makes use of black and white as well as blue glazes in kufesque, floral or abstract designs, and Type 4 is characterised by the use of thick opaque glazes (Sanders 1995, 72-74, 2001, 91-97).

The White Wares, both polychrome and plain glazed, show a wide geographical distribution and occur at every major and minor site throughout the Byzantine World. Examples of find-spots include Preslav, in Bulgaria, Chersonesos, Otranto in southern Italy, numerous sites in Greece, for example, Athens, Thebes and Sparta, on Crete and on Melos, as well as Paphos and Salamis on Cyprus, (Morgan 1942; Talbot Rice 1965; Zaleskaja 1984; Armstrong *et al.* 1997; Armstrong 2001, 57) (see Figures 6.1 and 6.2). In contrast to Constantinople where large quantities of the glazed wares were present, they occurred in relatively small numbers at other sites, forming a small proportion of their overall pottery assemblages. It is generally held, given the large amounts recovered from the excavations of Constantinople, that the Byzantine capital was the producer of this ware, from where it was exported throughout the Byzantine World (Talbot Rice 1965; Armstrong *et al.* 1997, 225). Analytical studies seem to support this view (for example Megaw and Jones 1983, see Chapter 3).

Morgan and Sanders encountered problems in the dating of the imported White Wares. Both cite the fragmentary nature and small proportion of glazed pottery in the earlier levels of Byzantine Corinth as a major factor. Further, Sanders notes that apart from the Polychrome group the decoration on early pottery is limited to small areas. It was therefore difficult to assign the sherds to ware types, and impractical to quantify and seriate the samples from early deposits by decoration (see Morgan 1942, 69, Sanders 1995, 205).

In an attempt to date the White Wares, Morgan argued that since Impressed and Slip Painted Ware occurred in the lowest post-Roman levels, they must have been in use in Corinth from the ninth century. It was erroneously believed that Corinth was abandoned from the sixth and resettled only in the ninth century (see Chapter 4 and Section 6.1). Nevertheless, it was not until the tenth and eleventh centuries that they were really in vogue, and it was thought probable that they were imported into the twelfth century (Morgan 1942, 49; 86).

Morgan divided Plain Glazed Ware into two groups based on fabric type, with Group I being related to the Impressed and Slip Painted Wares and Group II related to Polychrome Ware. Group I was therefore given the same ninth to twelfth century chronological range, but he found no evidence for the existence of Group II before the tenth century, nor any after the eleventh century (Morgan 1942, 57).

Polychrome Ware proved even more difficult for Morgan to date. There were no examples from closed deposits, and stratification was unclear. Coin evidence was poor or lacking and the number of fragments too few to give anything more than a tentative suggestion of date. At best he was able to say Polychrome Ware Group I was in use at Corinth from the early ninth century, Groups IV from the eleventh century, Group II, the twelfth and Group III the thirteenth. It therefore spanned a period of four to five centuries in its various forms (Morgan 1942, 67-70).

Sanders encountered similar problems with the dating of White Wares. However, he was able to make use of Hayes' (1992) published parallels from Saraçhane to guide him. He dated the first appearance of imported White Wares in Corinth to the late eighth century, although this trade was short-lived, and their importation had ceased by the ninth century. It was not until the mid tenth century that commerce in glazed pottery resumed (Sanders 2002, 650). Plain Glazed Ware is recorded as present at Corinth from then until the early twelfth century, with the amount increasing from the mid eleventh century, but by the end of the eleventh century decreasing to negligible quantities (Sanders 1995, 251), (see Table 6.1 for a summary of the date ranges for each pottery group).

While Slip Painted Ware is known from Saraçhane from the mid tenth century it was more common in late tenth century contexts. The style started to decline in popularity in the mid eleventh century, and by the end of the eleventh century it was very rare (Sanders 1995, 258). Sanders observed that while a number of Corinth examples are of tenth century shape the majority date to the eleventh century. The chronological range was thus given as mid tenth to eleventh centuries.

No date range was given for the use of Impressed Ware at Corinth. However, based on Stevenson's (1947) Great Palace sequence, Sanders noted examples from Corinth that showed the shallow and indistinct designs limited to a single central medallion that was

common in the late tenth century at Constantinople. There were also a number of examples from Corinth in which the relief covered the interior of open forms with large figural or compound designs. This style was common to the second half of the eleventh century (Sanders 1995, 260). The minimum range for Impressed Ware at Corinth can then be said to span the late tenth to eleventh centuries.

Sanders (1995, 255) dated Polychrome Ware with more confidence. Several inventoried examples of Type 1 Polychrome were recovered from early to mid eleventh century contexts. These include C-37-62, which was found with an Anonymous Class C Folles (1042-50), and C-37-1953 was found in a deposit stratified above a deposit containing an Anonymous Class A1 Folles (969-76). Type 2 was dated to the late eleventh century at Corinth. Evidence to support this date includes the forms of Type 2, and especially cups, which have close parallels with locally produced red ware of this date. Further, the forms of the Type 2 Polychrome from Corinth have strong affinities with vessels from Saraçhane recovered from deposits that are dated from the mid to late eleventh century (Sanders 1995, 255). Sanders' Type 3 Polychrome has been repeatedly found at Corinth in association with Dark on Light slip painted ware, Measles and Sgraffito (see below) which strongly suggest use if not production in the early twelfth century (Sanders 1995, 256). The final category, Type 4, is very rare at Corinth, with no examples coming from quantified deposits. However, a late eleventh century date is suggested by its parallels with pottery of this date recorded at Saraçhane (Sanders 1995, 256-257).

6.3 Red Wares

6.3.1 Plain Brown Glazed Wares

Local production of glazed pottery at Corinth began in the late ninth century with the manufacture of plain brown glazed vessels, where a thick plain yellow to amber glaze was applied directly onto the coarse red fabric giving it a rich brown to olive-brown colour. Despite being produced locally from the ninth to eleventh centuries its presence at Corinth is uncommon. Nevertheless, its volume did increase with time so that by the mid-eleventh century it is far more prevalent than in preceding years (Sanders 1995, 236). Morgan (1942, 37) and Sanders (2002, 651) agree that initially glaze use was primarily functional, being applied only to the surface of a vessel that came into contact with liquid. A conservative range of forms were glazed in this way, including pitchers,

cups and flasks, but the most characteristic form of Brown Glazed Ware from the ninth to eleventh centuries is the chafing dish.

The chafing dish is a compound dish and brazier, with the dish sitting within or upon a hollow stand into which vents and a stoking hole was cut (Figure 6.6). Morgan (1942, 37-38) recognized an evolution of form of the chafing dish whereby the bowl was initially deep sided and flat bottomed during the ninth and tenth centuries, becoming more shallow and conical in the first half of the eleventh century. During the second half of the eleventh century it reverted back to its original flat-bottomed type. However, Sanders' re-evaluation of stratigraphy and contents of Morgan's contexts showed that Morgan started his series with examples derived from contexts once thought to date to the ninth century, but which, with a better understanding of coin evidence, are now placed firmly in the mid-eleventh century (Sanders 1995, 261). Sanders proposed his own series for the development of form, with the changes being noted in rim treatment and method of assembly. Using coin evidence and seriated contexts, Sanders (1995, 262) dated Form I (dish inserted into stand, rim of dish upturned, rim of stand everted to form flange) from the late ninth century to the late tenth century. Associated coins included Basil I (869-879), Leo VI and Alexander (886-912) and Anonymous Folles AI (969-976). Form II, the most common form at Corinth (dish sits upon stand), and echoing contemporary White Ware types dates from the late tenth to eleventh centuries. Form III (dish again inserted into stand, but stand tubular in profile) is dated to the late eleventh to early twelfth century by associated pottery and coins, by its closeness in form to contemporary White Wares, and by the occasional use of Green and Brown I style decoration (see below).

Plain Brown Glazed Wares have been recorded at other sites in Greece including Athens (Frantz 1938, 457, Fig. 19), among others in Boeotia; Thebes, Askra, Thespieae, and Ipsilantis (Vroom 2003, 147) as well as at Otranto in southern Italy where they are considered Byzantine imports (Patterson 1993, 104) (Figures 6.1 and 6.2).

6.3.2 Green and Brown Painted I, Spatter Ware and Slip Painted Light on Dark I

As discussed in Chapter 4, the glazed ceramic industry at Corinth underwent a major change at the end of the eleventh century, with introduction of slip and glaze decorated tablewares in forms previously only seen in the White Wares, and a decline in the appearance of chafing dishes and other Plain Brown Glazed forms. The earliest types to

show this move away from Plain Brown Glazed pottery is found in the last decade of the eleventh century with the introduction of Green and Brown Painted I, Spatter Painted Ware and Slip Painted Light on Dark I. These types represent the first in a series of slipped background and slip painted techniques of decoration. In Green and Brown Painted I, the vessel was given a white slipped background that was decorated with dabs and streaks of green and brown glaze. The coloured glazes bled into the greenish over-glaze leading Morgan (1942, 73) and Sanders (1995, 65) to suggest they were applied to the still liquid over-glaze (Figure 6.7). Spatter Painted Ware also utilized a wet over-glaze to produce the decoration. In this case, however, a dark brown colorant was dusted onto the liquid glaze to give a speckled and streaked effect over the white slipped background (Figure 6.8).

The technique of Slip Painted Light on Dark I is defined by a limited series of motives (concentric lozenges and triangles, zigzag bands and other geometric designs) painted onto the untreated vessel surface in a white slip with a yellow or green over-glaze (Figure 6.9). The forms now seen include plates, deep and shallow bowls, jugs, cups and only rarely chafing dishes. Morgan (1942, 75) placed Green and Brown Painted I between the reigns of John I Tzinecus (969-976) and Alexius I (1092-1118) while admitting to uncertainty in the identification of these coins, and placed Slip Painted Light on Dark I in the last quarter of the eleventh century. These two types are now known to be contemporary with each other, evidenced by their frequent association in closed deposits (for example Lots 89-16 and 5117 (Sanders 1995, 149 and 171), while a new understanding of Byzantine coins suggest the styles were fairly short-lived and dated from approximately 1090 to 1120 (Sanders 1995, 244).

A contemporary of these wares is the variation of Slip Painted Light on Dark Dotted or Spotted Ware (Figure 6.10). Here, the slip painted decoration consists of a covering of small dots or larger spots over an untreated background, over which a yellow or brown glaze and more rarely green glaze, is applied. The decoration is either applied in rows (for example C-36-505, Plate XXIXa (Morgan 1942)) or randomly applied (see 00/63, Appendix II.14 sampled for this study, and Vroom 2003, 197, Fig. 6.17, W9.1 for an example from Boeotia). Morgan (1942, 98) dated this style to the first half of the eleventh century. However, its occurrence with Slip Painted Light on Dark I and coins of Nicophorus III (1078 – 1081) and Alexius I in recently excavated deposits (Lots

1989-16, 1989-63) would indicate a date no earlier than the 1080's to 1090's (Williams and Zervos 1990, 343, 364, Pl 65c, Pl 66a; Sanders 1995, 241).

Spatter Painted Ware, rare at Corinth, is considered by Sanders to be an import following macroscopic analysis of the fabrics (Sanders 1995; 247). This style is known from other sites in Greece, for example at Panagia near the village of Kalapodi, Eastern Phokis (Armstrong 1989, 8-9, Plate 4 nos. 38-39) (Figure 6.1), while Dark (2001, 127) suggests its distribution extends beyond Greece to Anatolia, the Balkans, Italy and the Crusader sites in Palestine. The initial occurrence of Spatter Painted Ware can be dated with the previous types to the last two decades of the eleventh century (Morgan 1942, 85, Sanders 1995, 247). However, it outlived Green and Brown Painted I and Slip Painted Light on Dark I, evidenced by its occurrence with the later Slip Painted Dark on Light Ware (see below) in sealed deposits.

6.3.3 Developed Green and Brown and Slip Painted Styles and Sgraffito

The first half of the twelfth century saw the introduction of new decorative techniques such as Dark on Light (Morgan's Imitation Lustre) slip painting and Sgraffito styles, as well as the development of existing styles seen with Green and Brown Painted II and III, and Green and Brown Painted Spiral, and Slip Painted Light on Dark II. In Green and Brown Painted II, green and brown glazes are used for more geometric designs than Green and Brown Painted I, and for vegetal motifs not previously seen. An important distinction though is that rather than applying the coloured glazes to a still wet over-glaze, they were apparently allowed to set, before being covered with an over-glaze. They therefore give more defined lines, without bleeding into the over-glaze (Figure 6.11). As noted by Sanders (1995, 66) there is some overlap between the decorations of Green and Brown Painted I and II, and between II and the later Green and Brown Painted III. Green and Brown Painted III makes use of linear, spiral and vegetal motifs, and for the first time figural motifs (Figure 6.12). The main distinction, however, is the substitution of the brown glaze for a matt brown pigment. It is also common for the over-glaze to be omitted entirely (Morgan 1945, 80; Sanders 1995, 65). The Green and Brown Painted Spiral style is characterised by intricate geometric designs, combining large spirals either alone or filling pointed ovals or triangles, hatched triangles or circles and more rarely rinceaux designs. The compositions are painted either in brown glaze alone or a combination of green and brown (Sanders 1995, 66) (Figure 6.13). The Green and Brown style of decoration is widespread in Greece and elsewhere in the

Mediterranean. Vroom (2003, 151) lists known find spots as Nichoria, Kythera, Sparta, Nemea, Kenchreai, Athens, Thebes, Chalkis, Eastern Phokis, Larissa, Thessaloniki and Pella, in addition to Keos, Cyprus, Chersonesos, Constantinople, the Balkans and Italy (Figure 6.1 and 2).

The slip painted style of Slip Painted Light on Dark II, as with Light on Dark I, consists of a white slip painted directly on to the untreated vessel surface, with a preference for designs radiating from the centre to cover the entire interior. It is easily distinguished from Light on Dark I by the difference in pattern (Figure 6.14). Slip Painted Light on Dark II shows stylized radiating kufesque, radiating triangles with vegetal or geometric fillers, or vine scroll rinceaux, by the thinness in slip and the colour of the glaze, usually a murky green (Morgan 1942, 100; Sanders 1995, 64). In addition to its occurrence at Corinth, Light on Dark II is represented at a number of sites in Boeotia (Vroom 2003, 150) and rural Eastern Phokis (Armstrong 1989), as well being reported at Athens (Waagé 1933, 324, Fig. 18 a-f; Frantz 1938, 444, Fig. 4), Constantinople (Stevenson 1947, 50, Plate 25, no.12), Thessaloniki, Sikyon, Sparta and Chalkis (Vroom 2003, 151) (Figure 6.1 and 6.2).

The new style of Slip Painted Dark on Light is characterised by red slip designs painted onto a white slipped background and covered with a yellowish over-glaze (Figure 6.15). Two separate styles can be observed at Corinth. In the first vegetal, figural or abstract designs are used to create a central medallion, with a band of interlace designs, commonly pseudo-kufic writing or rinceaux designs between the rim and tondo. The second involves motifs such as stylized flowers or birds, guilloche bands or bands of pendant circles and lozenges that are commonly outlined or the spaces created in-filled with dots (Morgan 1942, 86; Sanders 1995, 67). The use of dots to outline or in-fill designs of Slip Painted Dark on Light suggests a close relationship with the decorative technique Sgraffito Measles. Measles Ware combines the sgraffito technique, incising through a white slipped background to reveal the red clay beneath, with Dark on Light slip painting (Figure 6.16). Designs including large figural or vegetal motifs covering the entire surface of open shapes are incised, and outlined or in-filled with red slip spots. The over-glaze is predominantly yellowish, but on occasion a green glaze was used (Morgan 1942, 90; Sanders 1995, 69). Measles Ware is considered a Peloponnesian style, reported from other sites in the region such as at Sparta (Sanders 1993, 267). In contrast it is absent from material collected from Boeotia (Vroom 2006, pers. com.), and

is not listed as present in Eastern Phokis (see Armstrong 1989). It has however been recorded on sites outside of Greece in southern Italy at Otranto (Patterson 1993, 108-109, Fig 4), in northern Italy at Venice and Padua (Sanders 1993, 267), and at Butrint, Albania (Vroom 2006, pers. com.) (Figures 6.1 and 6.2).

The sgraffito technique was also used on its own with wares such as Sander's Style I Duochrome (Morgan's Group III Duochrome (1942, 123)) and Sanders Style II (Morgan's Group II Spiral Style (1942, 120)). Other variations include Freestyle and Painted Sgraffito (Sanders 1995, 68). Sgraffito decorated ware is probably the most recognizable of Byzantine glazed pottery, and its appearance is widespread in the Aegean, found in addition to Corinth at Athens, Sparta, Samos, Chalkis and Thebes. It has further been found in locations in Italy, Rumania, Turkey, Cyprus, Lebanon, Syria and Palestine (Vroom 2003,152), while it formed the main cargo of a ship wrecked off Pelagonnisos in the North Sporades (Kritzas and Throckmorton (1971), see Chapter 4) (Figure 6.1).

Style I Duochrome Sgraffito (though not sampled for this current study) consists of interlocking compass drawn circles filled with vegetal scrollwork covering the entire interior of open shapes (Figure 6.17). The white slip can cover the entire biscuit, but is more commonly confined to the interior and upper part of the exterior. The over-glaze is either green or yellow, a distinguishing characteristic being the use of a lighter tone of glaze on the interior than the exterior (Morgan 1942, 123, Sanders 1995, 68). Style II typically consists of a central medallion in-filled with split-palmette or figural designs, and with concentric bands of decoration in rinceaux, spiral detail or zigzags between the tondo and rim (Figure 6.18). The over-glaze was commonly yellow to yellowish green, but occasionally a green glaze was used. The white slip background extended to the upper part of the exterior, with the glaze applied only to the slipped area (Morgan 1942, 120, Sanders 1995, 69). Free-Style Sgraffito (Figure 6.19), a variation of Morgan's Developed Style (1942, 130 Figure 104), is characterised by figural subjects including birds, fish, animals and occasionally mythical beasts freely drawn to cover the whole interior. Finally, Painted Sgraffito is essentially the Style II style, but with coloured glaze, predominantly brown, or occasionally green and brown, used to highlight areas free from the sgraffito decoration (Figure 6.20).

The forms most commonly decorated in these glaze painted, slip painted and sgraffito styles are open forms, with bowls and plates dominating, and with the same shapes commonly seen across the decorative groups (see Morgan 1942, Figs. 55, 65, 68 and 95). Despite this, Morgan gives different date ranges, although sometimes overlapping, for Green and Brown Painted II and III, Slip Painted Dark on Light and the Sgraffito styles. For example, Slip Painted Dark on Light is thought to have been in use from the mid eleventh century, but is argued to have been absorbed entirely into the Measles style by the end of the reign of Alexius I (1118). Morgan dates Measles Ware by its association with coins of Alexius I and a few of Manuel I (1143-1180) from the early to mid twelfth century. Morgan (1945, 95) acknowledged that Measles Ware and Slip Painted Dark on Light occur together in a number of contexts, which would suggest they were contemporary. Nevertheless, this and their match in form were disregarded during their dating. Finally the predominance of Green and Brown Painted II and Green and Brown Painted Spiral Style occurring with coins of Alexius I, again, led Morgan to give a date range from the late eleventh century to the first quarter of the twelfth century (Morgan 1942, 77).

Re-evaluation of contexts and form led Sanders to argue for a later date for Green and Brown Painted II. Its affinity with early Slip Painted Dark on Light forms suggests a date range of 1110+ to 1130+ (Sanders 1995, 245). The later Green and Brown Painted II, overlapping with Green and Brown Painted III is dated by Sanders to 1130+ to 1155+, and is in agreement with Morgan's second quarter of the twelfth century date for Green and Brown Painted III. Deposits such as 89-73 (Williams and Zervos 1990, 342, Pl. 62 c, d) containing Green and Brown Painted II/III and Measles with coins of Manuel I corroborate a second quarter to mid twelfth century date, while Green and Brown Painted Spiral is also dated to the same period (Sanders 1995, 246). Further, the accompaniment of Slip Painted Dark on Light and Measles in a number of deposits indicate that they were in use at the same time, and that Measles did not develop out of Dark on Light as suggested by Morgan.

The slip painted style of Light on Dark II is found in quantity at Corinth. Morgan dated it to the first half of the twelfth century (Morgan 1942, 100). However, as Sanders (1995, 242) points out, it is conspicuous by its absence from uncontaminated deposits of that period. He suggests, rather, that it is a mid twelfth century style, given that where it

does occur, it is generally associated with coins of Manuel I. This is also the case of examples found at Athens (Frantz 1938, 432).

Of the sgraffito styles, Morgan argues that the Style I Duochrome is the earliest of the local Sgraffito Wares, its association with late eleventh century coins indicating its use then, but that it had gone out of fashion by the reign of Alexius I (Morgan 1942, 124). He suggests that Style II Spiral developed out of Duochrome Sgraffito, dating it to the first half of the twelfth century by its frequent association with coins of Alexius I and John II (1118-1143). Painted Sgraffito was given the same date range again by association with coins of Alexius I and John II (Morgan 1942, 142).

Sanders agreed with Morgan that Style I (Duochrome) originated in the late eleventh to early twelfth century date. It has been recovered from deposits containing Light on Dark I and Green and Brown I/II (for example Lots 1990-11 and 1990-54 (Sanders 1995, 153, 156)). However, it is also common to deposits belonging to the second quarter to mid twelfth century (see for example Pit 1936-6 (Sanders 1995, 180)). The amount found in these later contexts counter arguments that they may be residual.

Style II developed in the second quarter of the twelfth century, and is a frequent companion to Measles and Slip Painted Dark on Light, for example Lots 1989-5 and 1992-87 (Sanders 1995, 146,159). As with Style I it is longer lasting than that argued by Morgan. Evidence demonstrates that the style continued throughout the second half of the century (for example Context 41, Sanders (1995, 387) where mid to late twelfth century Sgraffito occurs with coins of John II and Manuel I (1143-1187). Finally, Painted Sgraffito, uncommon at Corinth and thought by Morgan to date to the first half of the twelfth century is again a contemporary of Slip Painted Dark on Light slip painted ware, so can be given a date range of about 1125 to 1150 (Sanders 1995, 249).

From the mid twelfth century it is the sgraffito style of decoration that dominated the glazed pottery at Corinth, with a drop in the production of glaze and slip painted wares that were so common in the first half of the century. However there was a resurgence of debased local slip painted and glaze painted styles, existing along side of incised-sgraffito wares at the end of the twelfth to the first half of the thirteenth centuries.

6.3.4 Incised Sgraffito, Champlevé, Green and Brown Painted V(I-V) and Slip Painted Light on Dark III

Incised-Sgraffito was a term coined by Morgan (1942, 159) to describe sgraffito in which more heavy, broad incisions were made into the slip with a gouge, rather than the delicate stylus incisions seen in the twelfth century (Figure 6.21). One variant of note is Painted Incised Sgraffito, in which the decoration consists largely of incised circles, interlaces, pendant triangles, areas of cross-hatchings, and more rarely figural decorations. A dirty yellow over-glaze is used and the incisions are decorated with patches or thick lines of brown paint (Figure 6.22). Champlevé, (Morgan's Incised Ware (Morgan 1942, 162)), is also a technique that utilized the contrast in colours between the white slip and red under-clay to produce decoration. Here, though, whole fields of slip are scraped away revealing areas of the underlying clay to highlight complex incised decorations. These include geometric patterns, figural designs (animal and human), and mythical scenes (Figure 6.23). The over-glaze is yellow, green or transparent and is commonly confined to the interior. Where the exterior of a vessel is glazed it is usually of a different colour to the interior (Morgan 1942, 162, Williams and Zervos 1995, 16; Dark 2001, 134). The Champlevé style of decoration was widespread in Greece, occurring on sites such as Thessaloniki, Thebes, Chalkis, Sikyon and Sparta (MacKay 2003, 404, n. 9) (Figure 6.1), while Vroom, preferring to group Incised Sgraffito and Champlevé in a single category, notes in addition to their extensive distribution throughout Greece their presence on sites in Italy, Albania, the Crimea, Cyprus, Lebanon, Syria and Palestine (Vroom 2003, 163).

The accompanying late Green and Brown glazed styles consists of Morgan's Green and Brown Painted V, Categories I to V. While this group is termed 'Green and Brown', they are generally monochromic, with designs executed either in green or brown glaze. However, in most divisions there are examples that combine both colours. The coloured glaze is applied to a buff coloured slipped background. Green and Brown Painted V(I) is characterised by the use of large green or brown spots that cover the entire interior, with stripes around the rim (Figure 6.24). Green and Brown Painted V(II) makes use of a background of green spots, but has radiating lines of orange-brown glaze. The over-glaze of this variation is often yellowish (Figure 6.25). In Green and Brown Painted V(III), the decoration consists of narrow triangles pendant from the rim, most commonly in green glaze, but can combine both colours (Figure 6.26). In Green and Brown Painted V(IV) large, loose spirals are used, again common in green, but also

in brown. In this group, the two colours rarely occur together (Figure 6.27). The final category of Green and Brown Painted V(V) differs in that the slipped background is white rather than buff, and is characterised by the use of haphazard loops and swirls painted in two tones of green or of orange and brown, the darker of the two tones over the lighter. The over-glaze is always absent in this category (Morgan 1942, 80-83; MacKay 2003, 413) (Figure 6.28). It is interesting to note that the Green and Brown V variants were not recorded from material collected in the region of Boeotia (Vroom 2006, pers. com.), though close parallels to examples from Corinth have been recorded at Sparta (Sanders 1993, 258, compare Sanders 1993, Pl. 23, no.2 and Williams 1978, Pl. 6, C-1977-2).

The second style that revives an earlier technique at Corinth is Slip Painted Light on Dark III. Here, the interiors of open forms are decorated with randomly applied loops and circles in a white slip covered by a yellowish over-glaze, commonly accompanied with splashes of green or brown glaze (Figure 6.29). Like Green and Brown Painted V, parallels of Slip Painted Light on Dark III have been recorded at Sparta (Sanders 1993, 261-262, Pl. 24, nos. 12 and 13). The forms common to Green and Brown Painted V and Slip Painted Light on Dark III are deep bowls and plates that are coarsely thrown in an unrefined salmon to buff fabric, with heavier feet and walls than previously seen with local Corinth products. Further, no attempts are made by the potters to smooth wheel marks or pairing on the exterior of vessels. In contrast, the open forms of Incised Sgraffito and Champlévé are well potted, with fine fabric and thin walls (Morgan 1942, 83; Williams and Zervos 1995, 18; Williams and Zervos 1998, 261).

Giving a chronological range to these wares with the same detail as the earlier glazed pottery is more difficult since no comprehensive study has been carried out to the same scale as that seen with Sanders' work on ninth to twelfth century material. However, a review of the Corinth excavation reports and an assessment of what the small amount of literature there is does give a sense of the changing nature of the thirteenth century ceramic assemblage.

Morgan (1942, 165) argued that Champlévé was a style of decoration that was established in the second half of the twelfth century, in the reign of Manuel I and continued into the thirteenth and possibly the fourteenth centuries. The closed deposits available to Mackay enabled her to refine the period of use of Champlévé to late twelfth

century and continuing to the mid thirteenth century (Lots 1, 3 and 4, associated coins Manuel I, Isaac II (1185-1195), William Villehardouin (1245-1250) (Mackay 1967, 263, 310, 315)). This is in agreement with a date for inception of the style provided by Williams *et al.* (1998, 261), who noted its concentration in deposits transitional between the twelfth and thirteenth centuries. However Williams and Zervos argue for its continued use into the third quarter of the thirteenth century, evidenced by its association with later coins (for example Alphonse II, Count of Toulouse (1249-1271) Lot 1994-27) and Frankish Sgraffito (Williams and Zervos 1995, 18)).

Without numismatic evidence to supply date ranges for Painted Incised Sgraffito Morgan (1942, 160) suggested a mid to late thirteenth century date on the basis of shape and style. MacKay's evaluation of material recovered from more datable fills led her to argue that the style was much earlier. It commonly occurs with Champlévé as well as Slip Painted Light on Dark III (see below) and associated coins include Manuel I, Isaac II (1185-1195) and William Villehardouin Corinth Issue (1245-1250) (for example Lots 85, 90, and 356). This demonstrates a late twelfth century date with continued use throughout the first half of the thirteenth century (MacKay 1967, 262, 310, 317; MacKay 2003, 404).

Of the late Green and Brown V, Categories I to V Morgan argued that Green and Brown Painted V(I) and (II) first occurred in the late twelfth century and continued through the thirteenth century. Green and Brown Painted V(III) and (IV) were thirteenth century products and Green and Brown Painted V(V) appeared in the thirteenth century and continued into the fourteenth century. MacKay (1967, 262) initially agreed with Morgan that Green and Brown Painted V(I) and (II) came into fashion in the late twelfth century and continued into the thirteenth. Nevertheless, she later revised this opinion following discoveries in 1976 and 1977, and 1989-1997 which clarified the chronology of the first half of the thirteenth century and suggested a date beginning in the first third of the thirteenth century for the Green and Brown Painted V(1-IV) styles (MacKay 2003, 405; 412). Williams and Zervos (1995) were able to confirm the thirteenth century date for Green and Brown Painted V(I) with its presence in Lot 1994-27 and argued these locally made "murky-glazed" bowls (Green and Brown Painted V(I-IV)) went out of production sometime in the late in third quarter of the thirteenth century since associated coins are minted no later than the 1270's (for illustrative assemblage see Lot 1977-11 containing two large parts of Green and Brown Painted V(IV), and where none of the twenty two associated coins were minted after 1261 (Williams 1978,

34)). The Green and Brown Painted V(V) style is thought to have replaced these earlier products by their common association with Veneto Ware, a late thirteenth century import, and coins of William Villehardouin (1262-1278) and Louis VIII or XI (1270) in a number of sealed deposits (for example Deposit 3, Pit 1992-1, Lot 1992-46, Williams and Zervos 1993, 17-18). It should be noted here that Veneto Ware was not included in this study and so is not discussed further.

The late Slip Painted Light on Dark III was dated by Morgan (1942, 101,103) to the thirteenth and possibly the fourteenth centuries although no pottery of this type had been found in sealed deposits from this period. This chronological range was tentatively given for Light on Dark III because of its affinity with other wares of the period. For instance, as with the Green and Brown Painted V group the fabric is coarse and the forms heavy with thick walls and feet (see Morgan 1942, 91,102, figs. 68 and 79). MacKay (1967, 261) confirms a thirteenth century date for this style as it commonly occurred in deposits containing Protomaiolica I and later Green and Brown with coins of the thirteenth century (for example Lot 303, William Villehardouin, Genoa Gate issue). A thirteenth century date is also given by Sanders (2003, Table 23.3, 392-393).

6.3.5 Aegean and Zeuxippus Wares

It is generally considered that the thirteenth century Corinthian glazed pottery was debased, being progressively more crudely potted than twelfth century Byzantine wares, and with less care taken over glaze decorations. The formal designs popular in the earlier Sgraffitos and Slip Painted Wares were replaced by more haphazard slip and glaze applications (Mackay 1967, 261, Williams and Zervos 1995, 18). While the local ceramic industry went into decline imported wares began to appear once more in Corinth from around the beginning of the second quarter of the thirteenth century. These include Aegean and Zeuxippus Wares. A third important group is Protomaiolica, a tin-glazed ware from southern Italy, which first occurred in Corinth before the middle of the century, though this pottery class was not sampled for the current study.

Aegean Ware, first defined by Megaw (1975) based upon material excavated from the castle of Saranda Kolones at Paphos, is a variant of Incised Sgraffito, characterised by standardized bowl forms that are covered internally only with a white slip and yellow glaze (Figure 6.30). In some examples green glaze is added in symmetrical dabs around

the rim or interior. The decoration includes multiple concentric gouged lines cut by a series of oblique incisions, sometimes with a central roundel containing animals in relief, or with wavy lines or geometric designs covering the centre (Megaw 1975, 38-39). It has a wide geographical distribution and is known from sites such as Constantinople, Anamurium in Rough Cilicia, Chersonesos, Antioch-on-the-Orontes, Pergamon, Athens, Thessaloniki, Thebes, rural sites in Eastern Phokis and Boeotia, in addition to being identified on a shipwreck near the island of Kastellorizo (Armstrong 1989, 45-46 and n.64, 1991, 345; Vroom 2003, 163, Fig. 6.28) (Figures 6.1 and 6.2). Sanders (1987, 179) recorded its occurrence at Corinth in contexts belonging to the first half of the thirteenth century, and a thirteenth century date was confirmed by Williams *et al.* (1998, 256-258) from its common association with Protomaiolica and Zeuxippus Ware (see for example Lots 1997-5 and 1997-12 (Williams *et al.* 1998, 257)).

Megaw (1968) also described a class of late Byzantine glazed pottery which he named Zeuxippus Ware after the Baths of Zeuxippus, Constantinople where it first came to light. The derivatives or sub-types of this ware have been given an array of names including 'Shiny Olive Incised Ware', 'Imitation Zeuxippus', 'Zeuxippus Derivatives', 'Glossy Ware' and 'Spirale Cherchio' (for example MacKay 1967, Lazzarini 1989, Armstrong 1992), while Sanders (1993) opted for the more general term of 'Late Sgraffito' (Figure 6.31).

Megaw subdivided the ware into two classes. Class I describes a group of related products encompassing slipped monochrome bowls almost exclusively decorated with incised circles or spirals in the base of the interior, and covered with colourless (Class IA), yellow-brown (IB) or green (IC) glaze. Class II is characterised by a thick white or cream slip on the interior and upper exterior covered with a characteristic thick glossy yellow or olive green glaze. Here the incised designs include S-shaped motifs on the sides or centre, and ovals or triangles on the rim. Elaborate figural, geometric or floral designs are also used, and the incised designs may be touched up with a yellow-brown colorant (Megaw 1968; Berti and Gelichi 1995; Papanikola-Bakirtzi 2001). It is agreed today that Zeuxippus Ware does not comprise a homogenous group of productions from a unique point of origin, but rather represents a complex 'family' of related styles from a number of production centres across the Mediterranean (Sanders 1993, 157; Berti and Gelichi 1995, 85; Vroom 2003, 164).

Megaw (1968, 87) was unable to fix the chronology of Zeuxippus Ware since no closely dated deposits had been available to him. However, he suggested its initial production occurred in the last decades of the twelfth century and the first years of the thirteenth century. It appeared at Corinth in various examples of the two classes. With only a few pieces recovered by 1942 and those from updateable upper deposits Morgan assigned Zeuxippus Ware to the Turkish period (fourteenth century) (Morgan 1942, 171). In MacKay's discussion of the ware she considered it to be in use at Corinth between the late twelfth century and mid thirteenth centuries since it commonly appeared in contexts containing Late Painted Sgraffito and Protomaiolica, with Zeuxippus Ware apparently appearing at the same time as Protomaiolica. At that time of writing it was generally understood that Protomaiolica first appeared at Corinth before the Fourth Crusade (1202-1204) (Morgan 1942, 107; MacKay 1967, 258). A re-evaluation of deposits that once suggested a pre-Frankish date now indicates that the introduction of Protomaiolica and therefore Zeuxippus Ware to Corinth occurred well into the first third to second quarter of the thirteenth century and that its use continued throughout the century (Williams and Zervos 1995, 19-20, MacKay 2003, 405).

6.4 Summary and Conclusions

This review of Byzantine glazed pottery types and their periods of use reveals that the glazed ceramic assemblage from Corinth was varied and changing in its character in terms of the types of pottery manufactured and used, and trends in decorative style. Morgan was the first to describe and date the decorative types, and though his work was seminal in its time, it has been superseded by studies undertaken since by Sanders, Williams and MacKay. The glazed pottery types are now well defined and each type can be tied into a tight relative chronological sequence. This stylistic and chronological information is crucial to the interpretation of the analytical results in this thesis.

CHAPTER 7

METHODOLOGY

7.1 Introduction

This chapter describes the rationale for the chosen sampling system and analytical methodology, and details instrument protocols, data interrogation and quantification methods. The three themes covered are sample selection, ceramic analysis (petrography, chemistry,) and glaze analysis (chemistry, microstructure). To summarize the main aim of this thesis is to investigate the development of Byzantine glazing technologies at Corinth and investigate questions of technological transfer (see Chapter 1). In order to do this not only did the ceramic glazes themselves need to be understood, but also the ceramic bodies required characterization.

7.2 Sample Selection

Sample selection was carried out in collaboration with Dr G.D.R. Sanders, Director of the ASCSA excavations at Ancient Corinth following a two week field trip undertaken to study the Ancient Corinth glazed ceramic assemblage. In order to meet the requirements of the research aim, a minimum of five samples were taken from each of the main decorative groups present at Corinth during the eleventh to thirteenth centuries. The main focus was material thought to be locally produced based upon prior macroscopic analysis (Morgan 1942; Sanders 1995), though some of the main, known, imported groups, for example Constantinopolitan White Wares, Aegean Ware and Zeuxippus Ware, were also sampled for comparison of technologies. Where possible wasters from production were included in order to characterise beyond doubt locally produced ware. Sherds that could be assigned easily to decorative categories were sought out in order that results could be tied to the chronological sequence at Corinth. The majority of sherds derived from unregistered discard contexts, though a small number were selected from registered contexts (Lot 418, Agora SW excavation, 1960; Lot 5117, Roman Bath excavation, 1968). A total of 170 sherds were selected for analysis. For completeness of record the sherd catalogue is given in Appendix I, photographs of the sherds are presented in Appendix II and profiles of the diagnostic sherds are presented in Appendix III.

7.3 Ceramic analysis

The petrographic and chemical analyses of the ceramic fabrics was undertaken in order to test previous assumptions of provenance and identify where possible products from individual workshops.

7.3.1 Petrographic analysis of ceramics

The fabrics were characterised using Whitbread's (1989; 1995, 379-388) thin section descriptive system, developed out of techniques of sedimentary petrology and soil micromorphology. Rather than being concerned solely with the characteristics of the aplastic inclusions in relation to issues of provenance, this method of ceramic analysis treats the ceramic fabric as a whole. The ceramic fabric is defined as the arrangement, size, shape, frequency and composition of components of the ceramic material (Whitbread 1989, 127), and so places emphasis on the 'plastic' component of the ceramic fabric as well as the aplastic mineral content.

The importance of this approach lies in its underlying principle, summed up succinctly by Day *et al.* (1999, 1028) who state that ceramic fabrics not only reflect the geological reality of a specific area but also human habit/choice in the selection and preparation of raw materials, the forming and firing techniques. Therefore, by considering the appearance of a ceramic fabric as a whole it is possible to explore its origin and significance with respect to the technological processes involved in its production in addition to examining questions of provenance.

Thin sections of the 170 ceramic samples were prepared according to the standard method of mounting a section onto a glass slide and polishing down to a thickness of 30µm and examined using a Leica polarizing light microscope. The principal criteria for fabric grouping following Whitbread's system are:

1. The colour and optical activity of the micromass.
2. Void type and orientation.
3. The mineral and rock types comprising the non-plastic inclusions.
4. The quantity, shape, size and grain-size distribution of the non-plastic inclusions.
5. The textural, amorphous and crystalline concentration (depletion) features.

It should be noted that grain-size distribution (modality) was determined by visual assessment rather than point count analysis.

A hierarchy of classification was used. A 'Fabric Class' brings together Fabric Groups that are related by general geological characteristics. A 'Fabric Group' contains related samples that are made from the same raw materials and use the same paste preparation techniques. Individual samples within the group may show variations in terms of the frequency and/or size of the main inclusions, colour difference due to firing atmosphere and extent of optical activity resulting from firing temperature. A 'Fabric Sub-group' is a well-defined variant of a Fabric Group. It may represent the use of the same raw materials, but reflect a slightly different and definable paste recipe such as finer or coarser version. A 'Fabric' is a lone sample representing a discrete fabric type. Summary descriptions of the fabric groups are presented in Chapter 8 while full thin section descriptions which may be used for comparative purposes are reserved for Appendix IV.

7.3.2 Chemical Analysis of the ceramic bodies

Neutron Activation Analysis (NAA) has until recently been the most frequently used technique in the chemical characterization of archaeological ceramics because of its capability to determine large numbers of major, minor and especially trace elements simultaneously and with accuracy (for example, see papers presented in collections such as Hughes *et al.* 1991, Neff 1992 and von Zelst 2003). Increasingly, however, the potential of inductively coupled plasma spectrometry (ICPS) is recognized as a powerful tool for the characterization of archaeological ceramics following its successful application in the multi-elemental analysis of geological samples (Tsolakidou *et al.* 2002, 177).

Inductively coupled plasma-atomic emission spectrometry ICP-AES has been selected as the technique of choice in this study not only because of its ability to analyse large numbers of major, minor and trace elements simultaneously but because of its application in the chemical analysis of other Byzantine glazed pottery (for example the Oxford Byzantine Ceramics Project, University of Oxford) and so to ensure compatibility of results.

7.3.2.1 ICPS-AES Method

The instrument used for analysis was a Perkin Elmer Optima 3300RL ICP-AES with Winlab 32 software and AS91 Autosampler located at Royal Holloway, University of London. The following major, minor (in terms of oxides) and trace elements were analysed for: Al₂O₃, Fe₂O₃, MgO, CaO, Na₂O, K₂O, TiO₂, P₂O₅, MnO, and Ba, Co, Cr, Cu, Li, Ni, Sc, Sr, V, Y, Zn, Zr, La. The pottery samples were prepared using the hydrofluoric/perchloric acid dissolution method (Thompson and Walsh 1989, 122-124) with 0.1 ± 0.0005 mg dried, powdered sample (see Appendix V for full description of procedure), and all samples were analysed in a single batch. The system was calibrated using the internal rock standards: KC10, KC11, KC12, KC14 and RH21, and a blank solution. After each ten samples analysed the standard RH21 was run to calibrate for instrumental drift. The precision and accuracy of the system were tested by comparing replicate samples of the soil standards SL-1 (IAEA) and Soil-7 (IAEA), analysed at various points within the run. Soil standards are employed as reference materials in the chemical analysis of archaeological ceramics since currently fired ceramic reference materials with certified values for element concentrations do not exist (Tsolakidou *et al.* 2002).

7.3.2.2 Minimum Detection Levels

For the successful determination of an analyte the concentration present in the sample needs to be greater than the minimum amount detectable by the system. Thompson and Walsh (1989, 132) state that the analyte should have a background concentration of at least three times its detection limit. The minimum detection limit (MDL) is calculated using the following equation:

$$Ex(2.8\sqrt{B})/C$$

where E = analyte concentration, B = blank int(net) and C = sample int(net)

Table 7.3.1 shows that all elements analysed for were present in the archaeological samples in concentrations greater than three times their background concentrations.

7.3.2.3 Precision and Accuracy of the ICPS results

The precision and accuracy of the analytical system needs to be assessed when analyzing samples of unknown composition (in this case archaeological ceramics) in order to appraise the quality of the analytical results. Precision measures the reliability

of the analytical procedure by looking at the degree of agreement between repeated results, and is characterised by the standard deviation of a set of replicate analyses of the same standard material. It is often expressed as the coefficient of (%) variation using the equation:

$$(Sdev / \bar{X}) \times 100$$

(Jones 1986, 23; Hatcher *et al.* 1980, 135)

Accuracy signifies the extent to which an average or final analytical result differs from the true value and is estimated from the correspondence between the ICP-AES results of the standards and their certified values (where provided) using the equation:

$$((\bar{X} / CertValue) \times 100) - 100$$

(Jones 1986, 23; Hatcher *et al.* 1980, 135)

The values for the precision and accuracy for the major and minor element oxides and trace elements are presented in Table 7.3.2 (see Appendix VI for calculation of precision and accuracy).

The major and minor elements of the two standards show good within-batch precision and accuracy, with the majority of elements falling within a $\pm 10\%$ error. The only exception to this is found with K_2O in standard SL-1 which shows an error of $\pm 12.50\%$. This is in contrast to that seen for K_2O in Soil-7 which shows good accuracy with a range in error of $\pm 1.90\%$.

The trace elements of each of the standards show good within-batch precision, with the error ranging from $\pm 0.00\%$ to 11.98% . The trace elements also show good accuracy with only Co, Cu, Ni and Zr show greater than 15% accuracy. With the exception of Cu which shows good accuracy for Soil-7 ($\pm 11.36\%$) these elements were not included in the subsequent statistical treatment.

The following element oxides and trace elements were thus considered the most precise and accurate, and occurred in concentrations high enough for successful analysis have been selected for further statistical treatment: Al_2O_3 , Fe_2O_3 , MgO, CaO, Na_2O , K_2O , TiO_2 , MnO, and Ba, Cr, Cu, Li, Sc, Sr, V, Zn and La.

7.3.3 Statistical Analysis of the Ceramic Compositional Data

The ceramic compositional data obtained using ICP-AES was explored using multivariate statistical analysis to determine whether or not there are distinct groups present in the data set that have significance with respect to raw material selection, technological processes or provenance. Multivariate statistical analysis identifies and quantifies (dis)similarities between individual samples and groups of samples. According to Glascock *et al.* (2004, 98) the pottery groups formed by statistical analysis can be thought of as “centres of mass” in the compositional hyperspace defined by their measured element concentrations. The individual groups are characterised by the location of their centre and the unique correlations between their measured elements to one another.

Two methods of multivariate statistical analysis commonly applied to the study of ceramic compositional data in archaeology are Agglomerative Hierarchical Cluster Analysis (HCA) and Principal Components Analysis (PCA). Both methods were utilized to explore the data produced in this study. The statistical analysis was carried out using the software packages S-Plus Professional 6.2 for Windows.

7.3.3.1 Data Treatment

Where a dataset contains major and minor elements measured in weight percent (wt%) and trace elements measured in parts per million (ppm), the data is traditionally treated in one of two ways. The data can be transformed to their logarithms; or the subcomposition can be normalised so that the total sum of determined components equals 100. The main purpose for data transformation is to achieve better intercomparability of the element concentrations (Buxeda 1999, 297). The chemical data were logratio transformed as it is considered by many as the most robust method (for example Aitchison 1986; Buxeda 1999; Aitchison *et al.* 2002). Fe₂O₃ was used as the divisor since according to the variation matrix of the dataset it made the smallest contribution to chemical variability (Buxeda 1999; Buxeda and Kilikoglou 2003).

7.3.3.2 Agglomerative Hierarchical Cluster Analysis

In agglomerative hierarchical clustering methods each individual case is considered as a separate cluster, so that the clustering process starts with n clusters. These are successively joined to form $(n-1)$, $(n-2)$ clusters and so on until eventually, all individuals form a single cluster (Baxter 1994, 141). It makes use of (a) a measure of

(dis)similarity between pairs of cases and (b) an algorithm for grouping individuals on the basis of that defined measure (Baxter 2003, 90; Glascock *et al.* 2004, 98). There are a number of measures of (dis)similarity and clustering algorithms that may be applied to perform the analysis (these are discussed in Shennan 1988, 198-219; Baxter 1994, 140-145 and Baxter 2003, 91-93). The most commonly used in HCA of archaeological ceramic compositional data are Euclidean distance or squared Euclidean distance as the measure of (dis)similarity (though Glascock *et al.* (2004, 100) highlight the usefulness of Mahalanobis distance), and single linkage (nearest neighbour), complete linkage (furthest neighbour), average linkage (unweighted pair groups), Wards method (error sum of squares) and centroid linkage as the clustering algorithms.

Since there is no rule as to which measure of distance and clustering algorithm should be applied to a given data-set, the data were initially explored using each of the clustering algorithms together with the Euclidean distance and squared Euclidean distance as the measure of (dis)similarity. While each method produced similar results the method that best represented the data was centroid clustering using squared Euclidean distance as the measure of (dis)similarity.

The results are presented in the form of a dendrogram. A dendrogram is a two-dimensional representation of the three-dimensional structure, with the horizontal showing the extent of separation, and the vertical links showing the degree of (dis)similarity between individuals. It is important to highlight that adjacency of individuals on the dendrogram does not indicate chemical similarity, it is the level at which the cases or clusters combine that is significant (Baxter 1994, 144). Therefore, where the link between two cases is small, chemical similarity can be concluded, but where the link is tall chemical dissimilarity can be inferred.

It should be noted at this point that interpretation of a dendrogram is to a certain degree subjective. That is, a decision must be made as to which links on the dendrogram should be cut to form clusters that are 'real'. For the purpose of this study, the decision was informed by comparing the results with the petrographic data set. Once group membership had been determined using cluster analysis, principal components analysis was used to explore the structure of the groups in more detail.

7.3.3.3 *Principal Components Analysis*

Principal Components Analysis is commonly used in archaeological ceramic compositional studies as a means of identifying which variables (elements) are responsible for differences between groups of individuals. It functions by transforming the data set based on eigenvector methods to reveal the extent and direction of maximum variance of the data set in hyperspace (Glascock 1992, 17; Glascock *et al.* 2004, 98-99). The first principal component is a linear combination of the original variables and is plotted along the direction of the maximum variance. The second principal component captures the maximum remaining variance and is plotted orthogonal to the first principal component. This process continues until the all maximum remaining variance is subsumed (Glascock 1992, 18).

The advantage of this technique is that biplots showing the relationships between cases (normally based on the first two principal component scores) can be combined with biplots showing the relationship between the elements as vectors. The cosines of the angles between the vectors indicate the extent of correlation between them, while the length of the vectors indicates the variances of the elements. In presenting the results of the PCA in this manner it is possible to observe which elements are most responsible for the differences between the groups of cases (Baxter 2003, 78; Glascock *et al.* 2004, 100).

The multivariate statistical analysis was successful in establishing archaeologically meaningful groups by HCA which could be characterised using PCA.

7.4 *Analysis of Glazes*

It is the standard today to use X-ray microanalytical techniques such as scanning electron microscopy (SEM) and electron probe microanalysis (EPMA) with wavelength dispersive spectrometry (WDS) or energy dispersive spectrometry (EDS) in the study of archaeological glazes (for example Molera *et al.* 1997; Mason and Tite 1997; Perez-Arantegui *et al.* 1999 and De Benedetto *et al.* 2004). The main advantage of these techniques lies in the ability to analyse specific points on a polished section allowing the collection of quantitative bulk compositional data while avoiding areas of surface weathering, inclusions and opacifiers, or indeed to distinguish and analyse these features. In this study, both an EPMA and SEM-EDS were made available for use, though analytical time on each was limited. It is known that EPMA is a superior

analytical system than SEM-EDS, in particular with regard to better resolution of overlapped peaks, lowered detection limits and more accurate quantitative analysis. Therefore, to maximize the information gained from analysis, it was felt that the EPMA should be used exclusively to obtain compositional information on a set of 53 glaze samples, while the SEM-EDS should be used to investigate the microstructures of 15 of those samples in more detail.

Analysis was carried out on sections of samples including body and glaze of the interior and exterior of the vessels, polished down to $\frac{1}{4}\mu\text{m}$ (see Appendix VII for sample preparation method)

7.4.1 EPMA analysis of Glazes

The compositional analyses of the glazes were carried out at the Manchester Electron Microprobe Facility, University of Manchester on a Cameca SX 100 with five attached wavelength dispersive spectrometers (WDS). The system was set to operate at 15 kV with an incident beam current of 20 nA and using a beam defocused to $8\mu\text{m}$ in diameter. WD X-ray spectrometry provides no direct information on the valence states of the elements present in the analysed material. For each element the appropriate valance state was selected based upon those observed in previous compositional analyses of archaeological glazes (for example Pérez-Arantegui *et al.* 1996, Molera *et al.* 1997 and Molera *et al.* 2001). The oxide weight percents were calculated stoichiometrically for each element. The elements analysed for were SiO_2 , Al_2O_3 , Fe_2O_3 , MgO , CaO , Na_2O , K_2O , TiO_2 , MnO , PbO , SnO , As_2O_3 , CoO , NiO , CuO and Cr_2O_3 . This selection was based on the typical composition of medieval and Islamic high lead glazes observed in the archaeological literature. A 20 second count time was used for all elements with the exception of the volatiles Na_2O and K_2O which were given a 10 second count time in order to reduce loss under the electron beam. The samples were analysed in two separate batches.

7.4.1.1 Minimum Detection Levels

The Minimum Detection Levels were calculated internally by the system for each analysis. In examining the data it was found that the MDLs for each analysis were very consistent. The mean MDL for ten samples are given in Table 7.4.1. The element oxides As_2O_3 , Cr_2O_3 , NiO and CoO were found to be at or below the MDL and so are not reported.

7.4.1.2 Precision and Accuracy

The precision and accuracy of the system were checked by comparing repeat analyses of the glass standards NIST 620 (soda-lime flat glass) and SGT Glass 8 (lead oxide-potassium oxide-silica glass) and were calculated using the formulae given in Section 7.3.1.4. The results are presented for NIST 620 and SGT Glass 8 in Tables 7.4.2 and 7.4.3 (see Appendix VIII for full calculations).

The analysis of the glass standards show good analytical precision with better than $\pm 0.63\%$ for element oxides in concentrations over 1 wt% for Run 1, and up to $\pm 1.26\%$ for the same elements during Run 2. Where element oxides occur in concentrations of 0.3-0.5 wt% the precision is approximately 4%, with no real differences in the values between the two runs. Where Na₂O is present in amounts of 0.23 wt% (Glass 8, Table 4) the range in error for precision increases to approximately $\pm 10\%$. As expected, the analytical precision is poor when element oxides occur in concentrations around the MDLs with the error ranging from $\pm 17.85 - 244.94\%$.

The accuracy is better than $\pm 10.5\%$ for all element oxides present in concentrations above 0.23 wt% in Run 1. The same element oxides show a similar level of accuracy in Run 2 with the exception of Na₂O which has a range in error of $\pm 18.91\%$ (Glass 8), and K₂O which has a range in error of $\pm 13.17\%$ (NIST 620) and $\pm 16.82\%$ (Glass 8). Where element oxides are present in concentrations close to the MDLs the accuracy is generally poor, ranging in error from $\pm 17.82 - 97.67\%$. Exceptions to this can be seen with TiO₂ (NIST ± 20 , Run 1) and Fe₂O₃ (NIST ± 20 , Run 2) which have good levels of accuracy with $\pm 6.48\%$ and $\pm 5.11\%$ respectively.

The analysis of the glass standards demonstrate that there is a high level of precision and accuracy where element oxides occur in concentrations above the detection limits of the system. This allows confidence in the results of the analyses of the archaeological glazes. Nevertheless, not all elements analysed for were represented by the glass standards.

7.4.1.3 Analysis of the Archaeological Samples

The aim of analysis by EPMA was to collect bulk compositional information on the archaeological glazes. Therefore, spectra were collected from the middle of the glaze layers to reduce effects of contamination from surface weathering and diffusion of

elements from the ceramic bodies. Between four and six spectra were collected from each sample and the results averaged. Analytical totals, typically in the range of 95-99%, were normalized to 100%.

7.4.2 SEM-EDS analysis of Glazes

Supplementary analysis was carried out using SEM-EDS to investigate glaze microstructure. This was undertaken at the English Heritage Technology Research Department, Fort Cumberland, Portsmouth. The instrument used was a Zeiss-Stereoscan 440i SEM with a tungsten filament, and attached Oxford Instruments germanium ED X-ray detector, and ISIS software. The germanium detector allows for the simultaneous detection of all elements from boron to uranium providing they are present in concentrations above the detection limits of the system. The operating conditions of the SEM were 25 kV accelerating potential with a probe current of 1 nA, and each spectrum for 100 s livetime. The spectra were calibrated using a cobalt standard, and deconvoluted with the phi-rho-z correction procedure using the Oxford Instruments SEMQuant software. This utilizes element profiles derived from single element or simple compound standards (e.g. pure iron, jadeite, wollastonite etc.). As with WDS, ED X-ray spectrometry provides no direct information on the valence states of the elements present in the analysed material. The same valence states selected for analysis by EPMA were chosen and the oxide weight percents were calculated stoichiometrically. Where observed, crystal formations, undissolved grains and inhomogeneities within the glazes were investigated by spot analysis. A minimum of three spectra were collected for each feature and the results averaged.

7.5 Conclusions

This method described was selected to optimize the range and depth of information that could be obtained from the glazed ceramics under study. The combination of ICP-AES and ceramic petrography made it possible to define fabric groups, establish which fabrics were produced at Corinth and which were imported, and make observations concerning ceramic technological practices. In addition, glazes were chemically characterised using EMPA, while SEM-EDS analysis of the glazes enabled more detailed investigations of their manufacture.

CHAPTER 8

RESULTS

8.1 Introduction

This chapter presents the results of the analytical investigations of the ceramic fabrics and their corresponding glazes. It is divided into three sections: 'Petrographic Analysis of the Ceramic Fabrics', 'Chemical Analysis of the Ceramic Fabrics' and 'Chemical and Microscope Analysis of the Glazes'. Where relevant, the data is presented in order of the chronological sequence of the pottery investigated.

8.2 Results of the Petrographic Analysis

The results of the petrographic analysis are given in this section. To recap, the individual samples selected for the study were assigned to fabric classes, groups, sub-groups or single sample fabrics according to similarities in properties such as micromass, mineralogical inclusions and texture (see Section 7.3.1). The petrographic analysis revealed the Byzantine glazed ceramic assemblage is diverse in nature. The 170 samples divided into 12 groups (of these 12, five groups were separated into sub-groups), and a further 17 single sample fabrics were identified. Based on geological characteristics (and in the case of one group the presence of unglazed, biscuit wasters) six were attributed to local productions, while the remaining six were considered to be imports. Summaries of the main characteristics of each fabric type are given below with initial comment on their technological and provenance interpretations. These are drawn together in Chapter 9 and discussed in relation with the other data sets, and with their historical and archaeological implications. Detailed descriptions of the fabric groups which can be used for comparative purposes are presented in Appendix IV.

8.2.1.1 Altered Feldspar Class

This is a class of related ceramic fabrics which have in common a grey to white grey micromass with inclusions of quartz and altered feldspars. The fabric class is split into groups (and sub-groups) based upon textural differences, relating to technological practices and variations in raw materials. The groups are:

8.2.1.2 Altered Feldspar Group A1

Samples: 00/139,140,141,144,146,148,149,153,154,156,159,160

(Figure 8.2.1)

Altered Feldspar Group A1 comprises exclusively examples of the eleventh century category of Constantinopolitan White Ware, and includes the decorative styles of Polychrome, Slip Painted yellow glazed, Plain Green Glazed, and Plain Brown Glazed Wares. It is characterised by its vuggy microstructure, with voids occupying between 2 and 5% of the field and which are moderately to strongly aligned with the vessel margins. The grey to white grey (xp) micromass is optically active to optically very active. Inclusions are few with a unimodal grain-size frequency distribution comprising common medium sand to silt-sized feldspars, probably potassic and showing cloudy alteration, and few, fine sand to silt-sized monocrystalline quartz containing vacuoles. In addition there are few coarse to very fine sand-sized grains of polycrystalline feldspars, again showing cloudy alteration, coarse to very fine sand-sized grains of megaquartz, and very rare silt-sized mica. A feature of this fabric is the presence of dark red to black opaque nodules, identified as iron oxide concretions. In addition, reddish brown streaks with strongly preferred orientation occur (for example 00/139, 00/140)

8.2.1.3 Altered Feldspar Group A2

Samples: 00/142,145,147

(Figure 8.2.2)

As with the Altered Feldspar Group A1, Group A2 contains examples of the eleventh century White Wares including Polychrome and Slip Painted styles. It is closely associated with Group A1, and differs only in the amount and coarseness of non-plastic inclusions. The c:f:v_{10µm} ratio here is given as 15:77:8, where it is determined as 5:93:2 to 5:90:5 for Group A1.

8.2.1.4. Altered Feldspar Group B

Sample: 00/150,151,152,155,157,158

(Figure 8.2.3)

As with the previous two groups in this fabric class Altered Feldspar Group B consists of samples from the eleventh century White Ware category and include the styles Slip Painted Yellow Glazed, Plain Green Glazed and Impressed Ware. Nevertheless, if glaze appearance and decoration are taken into consideration, these samples form a coherent group stylistically distinct from Group A presented above. This fabric is characterised petrographically by its vughy microstructure with moderately aligned voids occupying about 5% of the field. The micromass is optically very active to optically slightly active and its colour ranges from pinkish grey to pale orange grey to grey (xp). The grain-size frequency distribution is determined to be bimodal. Inclusions are common and the coarse fraction occurs in fine to medium sand-size range and comprises common rounded to sub-rounded grains of chert, and common to few sub-angular to sub-rounded grains of quartz and altered feldspars. Very few polycrystalline feldspar grains are also present and again show alteration. Their grain size ranges from coarse to very fine sand-sized. The fine fraction consists of monocrystalline quartz, feldspars and red and white micas. In addition to the dark red to black opaque iron oxide nodules observed in Groups A1 and A2 this group also contains orange red to dark red (xp x40) textural concentration features (tcfs) which range from high to low optical density and which have clear to diffuse boundaries. Furthermore, very rare reddish brown streaks with strongly preferred orientation occur (for example 00/155).

8.2.1.5 Altered Feldspar Fabric C

Sample: 00/143

(Figure 8.2.4)

This fabric is represented by a lone White Ware polychrome sample (00/143), again dating to the eleventh century. The fabric is characterised petrographically by its vughy microstructure, with voids occupying about 5% of the field and showing strongly preferred orientation. Its white grey to grey brown (xp) micromass is optically very active with a grain-size frequency distribution determined as unimodal. Inclusions are common, well sorted and consist of dominant, rounded to sub-angular grains of

monocrystalline quartz in the coarse silt to fine sand-size range. Also present are very few coarse silt to very fine sand-sized feldspars showing cloudy alteration, and very rare muscovite mica lathes. In common with the previous groups described dark grey brown to dark red brown opaque iron oxide nodules are present. However, they commonly occur as elongate nodules showing strongly preferred orientation with the vessel margin. Furthermore, the chert component present in the Altered Feldspar Groups A and B is absent.

8.2.1.6 Comment

The Altered Feldspar Class encompasses all examples of White Wares sampled for the study which are considered to be imported to Corinth from Constantinople (see Chapters 3 and 6). Petrographic analysis of this pottery group, however, demonstrates their subdivision into separate fabric groups. The fabric groups are undoubtedly related to each other, having in common their white-grey micromass and inclusions of quartz, altered feldspars and iron rich concretions indicating the use of similar clays, and so originating from the same region of production. The differences described between each group reflect, in the main, differences in technological practices, and in particular in the preparation of raw materials and firing technology. Inspection of the decorative traits of the samples belonging to each group shows they form stylistically cohesive groups. This leads to the belief that the fabric groups represent discrete workshop traditions in production technology.

The unimodal grain-size frequency distribution or normal distribution displayed in Groups A would indicate the use of clay without the addition of temper. It is unclear whether the differences in texture observed between the two sub-groups is related to natural variations within the clay deposits or represent some differences in processing of the raw materials. Nevertheless, the broad similarities in mineralogical content and decorative traits of the pottery suggest that the pottery of these two sub-groups should be considered as belonging to the same workshop. The high optical activity observed in the samples is indicative of a relatively low firing temperature. With regard to firing atmosphere, the pinkish margins and white-grey core noted in sample 00/159 indicate that when fired in an oxidizing atmosphere this clay fires to a pink colour. However, the majority of samples show a white-grey micromass indicating a neutralizing atmosphere was used, with the potters exploiting the white colour of the fabric to enhance the coloured glaze decorations.

In the case of Group B, the bimodal grain-size frequency distribution points to the addition of a quartz and chert sand temper. Moreover, the presence of tcfs would suggest the addition of a red clay component not present in Group A. Differences can also be observed in firing technologies with the fabrics either grey (the Impressed Ware samples, macroscopically dark grey (5YR 4/1)) or pinkish grey (Slip Painted and Plain Green glazed samples, macroscopically pink (5YR 8/4)) indicating firing either in a reducing or oxidizing atmosphere. These differences, the addition of sand temper, clay mixing and differences in firing technology, combined with the appearance of the pottery in this group indicate that the pottery should be considered as products of a workshop separated from Group A.

Fabric C is represented by a single sample. Nonetheless, some observations may be made. As with Group A, the unimodal grain-size frequency suggests the use of clay without the addition of temper, while the fine grained and well sorted inclusions indicate the use of a well sorted deposit or that the clay was refined by the potters. The high optical activity indicates a relatively low firing temperature and like Group A, the colour of the fabric points to firing in a neutralizing atmosphere. While the chert component observed in Groups A and B is absent, the quartz and altered feldspar components and greyish white micromass point to the same region of production. Correlative data for this fabric comes from a petrographic study of a polychrome sherd (unprovenanced) carried out by Mason and Mango (1995) which is described as containing quartz, altered potassic feldspars and red iron oxide opaques. However, from the 'petrofabric' description given (grain sizes up to 1mm) the 'petrofabric' represents a coarser body than that observed in sample 00/143.

8.2.2.1 Coarse Mudstone-Chert Class

This is a class of fabrics that is related by the presence of coarse inclusions of chert and mudstone. Differences in the presence or absence of other coarse inclusions require their separation into groups.

8.2.2.2 Coarse Mudstone-Chert Group A

Sample: 00/122, 129

(Figure 8.2.5)

The Mudstone-Chert Group A contains two samples comprising Plain Brown Glazed chafing dishes dating to the end of the tenth to eleventh centuries. It is characterised petrographically by its vughy microstructure with voids occupying about 5% of the field, with dominant macrochannels, common macrovughs and few mesovughs. The micromass is optically inactive and is coloured red (00/129) (xp), and brown black (00/122) (xp). Inclusions are common, angular to sub-rounded, with a poorly sorted and strongly bimodal grain-size frequency distribution. The coarse fraction comprises common medium sand to coarse sand-sized chert and mudstone which commonly shows polygonal cracking in pp. Also common (00/122) to few (00/129) micritic limestone is present in the same size range. The fine fraction consists of predominant monocrystalline quartz, rare red and white mica silt and very rare plagioclase and spherulitic chert. Tcfs are present and have high to neutral optical density, and sharp to clear boundaries, and are well rounded to sub-rounded with high apparent sphericity.

8.2.2.3 Coarse Mudstone-Chert Fabric B

Sample: 00/125

(Figure 8.2.6)

The Coarse Mudstone-Chert Fabric B is represented by a lone sample of Plain Brown Glazed chafing dish in eleventh century form. It is characterised by its vughy microstructure with voids occupying about 10% of the field, comprising dominant mesovughs, common macrovughs and rare megavughs. The micromass is optically inactive and dark brown (xp). Inclusions are common with a strongly bimodal grain-size frequency distribution. The coarse fraction comprises predominant angular to sub-rounded, medium sand to very coarse sand-sized mudstone which commonly displays polygonal cracks in pp, rare very fine sand to medium sand-sized chert and very rare fine sand-sized monocrystalline quartz, very coarse sand-sized serpentinite and rounded to sub-angular, medium to very coarse sand-sized micritic limestone. The fine fraction consists of predominant monocrystalline quartz and very few chert spherulites and white mica silt.

8.2.2.4 Comment

Large mudstone inclusions have been noted in Corinthian ceramics by Farnsworth (1964), Whitbread (1995) and Joyner (1997; 2007), micritic limestone by Whitbread (1995) and chert containing spherulitic structures by Whitbread (1995) and Joyner (1997). Moreover, red firing clay sampled from near the gates of the Acrocorinth naturally contain micritic limestone and chert inclusions, while mudstone exposures are noted on the southern and western flanks of Acrocorinth and Penteskouphi (Whitbread 1995, 334) (see Chapter 5). The Coarse Mudstone-Chert Group A and Fabric B are consistent with a Corinthian origin. The two fabrics are further close in composition to Joyner's Quartz-Mudstone-Chert Fabric Class (1997, 85), described as a broad group containing many different inclusion types, with no one type being dominant, and which comprise eleventh to twelfth century cooking wares from Corinth. It is considered that the Mudstone-Chert fabrics belong to this same broad tradition of Byzantine cooking ware manufacture at Corinth.

The coarseness of these fabrics and strongly bimodal grain-size distribution frequency indicate that the mudstone, chert and micrite components were added as a temper. That this class of glazed ware (Plain Brown Glazed chafing dishes) were tempered in the same manner as the Byzantine cooking wares is unsurprising given the function of the vessels as a compound dish and brazier, with the food contents in the dish heated by live coals placed in the stand. Coarse inclusions help prevent the propagation of cracks through the ceramic body caused by the stresses of differential expansion and contraction rates of the inner and outer surfaces due to the change in temperature at one surface (Tite *et al.* 2001). The thermal shock experienced by the chafing dish is likely to be less severe than that of cooking wares, nevertheless, it may be enough to cause vessel weakness over periods of use.

The optically inactive micromass indicates firing at a relatively high temperature, while the variations in colour indicate firing in an oxidizing or reducing atmosphere.

8.2.3.1 Argillaceous Rock Fabric

Sample: 00/123

(Figure 8.2.7)

The Argillaceous Rock Fabric is represented by a single sample of a tenth century chafing dish. It is characterised by its vughy microstructure with voids occupying about 10% of the field, comprising predominant mesovughs, few macrovughs, rare microvesicles and mesovesicles. The micromass is optically active and dark orange red (xp) (vessel interior) to optically inactive and grey brown (xp) (vessel exterior). Inclusions are common, poorly sorted, range from silt to very coarse sand-sized, are angular to sub-rounded and are judged to have a unimodal grain-size frequency distribution. They comprise common fine sand to coarse sand-sized argillaceous rock fragments and common medium sand to very coarse sand-sized polycrystalline quartz. These polycrystalline quartzes have sub-grains of varying sizes with straight to sutured grain boundaries and show undulose extinction. They may contain vacuoles, fractures and microlithic inclusions and rarely, recrystallization of quartz at grain boundaries occurs. Common inclusions also include medium sand-sized chert, and silt to fine sand sized monocrystalline quartz. The coarse end of the monocrystalline quartz is likely to represent terminal grades of the polycrystalline quartzes. Also present are few medium to coarse sand-sized quartz-muscovite-biotite rock fragments, very few silt-sized lathes to very fine sand-sized grains of muscovite and biotite mica, rare fine to medium sand-sized quartz-plagioclase rock fragments, polycrystalline quartz with stretched sub-grains showing undulose extinction and foliation, and very fine sand to fine sand-sized plagioclase which commonly contain microlithic inclusions and show deformation of twins. Also rare are very fine to fine sand-sized inclusions of serpentinite and volcanic glass, and medium sand-sized muscovite-phyllite is very rare.

8.2.3.2 Comment

The metamorphic character of this fabric is inconsistent with the geology of the Corinthia and demonstrates its non-local origin. The common and poorly sorted inclusions and presence of apparent terminal grades, in addition to the unimodal grain-size frequency distribution would tend to indicate that the raw materials used were poorly refined and in their natural state.

8.2.4.1 Muscovite-Schist Class

The Muscovite-Schist Class contains a group and a fabric related by the presence of coarse fragments of muscovite-containing schists.

8.2.4.2 Muscovite-Schist Group A

Sample: 00/126,130,131,132,133

(Figure 82.8)

The Muscovite-Schist Fabric Group A comprises five samples of Plain Brown Glazed Ware of chafing dish form dating to the eleventh century. It is characterised by its vughy microstructure with voids constituting 5 to 10% of the field. The micromass ranges from optically inactive and brown black (xp) to optically very active and orange red (xp). Inclusions are common, sub-rounded to angular and poorly sorted with a strongly bimodal grain-size frequency distribution. The coarse fraction comprises frequent fine to coarse sand-sized muscovite-schist and coarse to very coarse sand-sized muscovite-biotite schist, common coarse to very coarse sand-sized quartz-muscovite-biotite schist and few fine to very coarse sand-sized monocrystalline quartz. Also present are very few polycrystalline quartz of two types. These are: (a) very coarse sand-sized to granules with sub-grains of varying sizes and quartz recrystallization at the grain boundaries, and (b) medium to coarse sand-sized with equigranular sub-grains with straight grain boundaries. Fine to medium sand-sized muscovite-biotite phyllite is rare and coarse sand-sized serpentinite and medium sand-sized chert is very rare to absent. The fine fraction consists of frequent monocrystalline quartz and muscovite silt, common to few biotite silt and rare plagioclase. Orange red to dark brown black tcfs occupy between 0 and 5% of the field.

8.2.4.3 Muscovite-Schist Fabric B

Sample: 00/124

(Figure 8.2.9)

The Muscovite-Schist Fabric B is represented by a single sample of eleventh century Plain Brown Glazed Ware of chafing dish form. It is characterised by its vughy microstructure with voids occupying about 10% of the field. The black brown micromass is optically inactive. Inclusions are common, angular to sub-rounded and have a poorly sorted, strongly bimodal grain-size frequency distribution. Coarse

inclusions comprise frequent medium to very coarse sand-sized muscovite-schist, common fine to medium sand-sized monocrystalline quartz, very few very coarse sand-sized quartz-biotite-muscovite+black opaques schist and fine to coarse sand-sized micrite, and rare coarse sand sized chert. Fine inclusions consist of predominant monocrystalline quartz, common muscovite silt, few biotite silt and very rare olivine. Black tcfs with high optical density occupy about 5% of the field.

8.2.4.4 Comment

The Muscovite-Schist Class include examples of chafing dishes that were assumed to be locally manufactured (00/124 and 00/126 with dark grey fabric with the glaze appearing very dark yellow brown) and imported (00/130 to 133 with an orange red fabric and the glaze giving a reddish brown colour) based upon macroscopic examination of the sherds (Sanders 2000, pers.com). However, as demonstrated by the petrographic analysis, provenance distinctions may not be made based upon the macroscopic appearance of the fabric and glaze alone. The high content of metamorphic rock fragments present in this class is inconsistent with a Corinthian origin and all samples are now known to be imported. It is here suggested given the differences between the fabrics, in particular the presence of schist containing opaques, chert, micrite and very rare olivine in the Muscovite-Schist Fabric B that this example originates at a source different from the Muscovite-Schist Group A. This observation appears to be supported by the chemical characteristics of these samples (see Section 8.3.4.2).

Like the previous examples of chafing dishes presented above, the strongly bimodal grain-size frequency distribution indicates the coarse fraction was added as temper, similarly, the presence of both oxidized and reduced fabrics in Group A may indicate poor control of kiln atmosphere.

8.2.5.1 Fine Muscovite-Biotite Fabric

Sample: 00/127

(Figure 8.2.10)

The Fine Muscovite-Biotite Fabric is represented by a single sample of an early twelfth century Plain Brown glazed ware of chafing dish form. It is characterised by its vughy microstructure with voids occupying about 8% of the field. The dark red orange micromass (xp) is optically slightly active. Inclusions are few, angular to sub-rounded,

well sorted and unimodal in their grain-size frequency distribution. Inclusions include frequent coarse silt to very fine sand-sized monocrystalline quartz, common muscovite (lathes up to 0.25mm) and silt to very fine sand sized biotite mica, rare very fine sand to medium sand-sized biotite-muscovite phyllite and muscovite phyllite and very rare andalusite. Tcfs occupy about 15% of the field and are dark red with high optical density.

8.2.5.2 *Comment*

The Fine Muscovite-Biotite Fabric is represented by a single example with few, very fine inclusions. Nonetheless, some observations may be made. The phyllitic nature of the fabric does not seem consistent with a Corinthian origin indicating that this example of chafing dish is imported. It is possible that the inclusions could come from sediments deposited in the Corinthian area that do not reflect local geology. However, the micaceous character of the clay matrix suggests the clay itself comes from a 'schisty' area and not just the inclusions, lending strong support to the idea of it being an import. This appears to be further substantiated by its chemical characteristics (see Section 8.3.4.2).

In terms of technological characteristics, this sample shows a divergence from the coarse, tempered chafing dishes discussed above. The fine clay matrix with a unimodal grain-size frequency distribution indicates the use of either a well sorted clay deposit or a clay refined by the potter. An important component of this fabric is the common, dark red tcfs (maximum size 1.25mm, mode *c.* 0.5mm) indicating the incomplete mixing of two clays. A number of properties can be modified by clay mixing such as the workability of a clay body or the reduction of shrinkage on firing, but whether or not the resistance to thermal shock is improved is unclear. The presence of tcfs may act in the same manner as coarse non-plastic inclusions in preventing the propagation of cracks caused by thermal shock, but it is more likely that if they have a similar expansion coefficient to the clay matrix the differential thermal expansion which generates stresses during heating will be reduced, thereby providing resistance to thermal shock (see for example Tite *et al.* 2001).

8.2.6.1 Quartz-Chert-Micrite Fabric

Sample: 00/128

(Figure 8.2.11)

The Quartz-Chert-Micrite Fabric is represented by a single sample of an unglazed, biscuit-fired chafing dish waster of early twelfth century form. It is characterised by its vughy microstructure with voids occupying about 5% of the total field. The micromass is optically moderately active and orange red (xp). The inclusions are common, angular to sub-rounded, poorly sorted and have a strongly bimodal grain-size frequency distribution. The coarse inclusions are represented by common fine to medium sand-sized monocrystalline quartz, medium to very coarse sand-sized chert commonly containing radiolarian, very fine to very coarse sand-sized micrite, few fine to very coarse sand-sized polycrystalline quartz and very few very fine to medium sand-sized calcite. Fine inclusions comprise frequent monocrystalline quartz, common chert and calcite, rare biotite and muscovite silt and very rare epidote. Tcfs occupy about 5% of total field and are present as dark orange red clay pellets and striations of dark orange red clay strongly aligned with vessel margins.

8.2.6.2 Comment

This chafing dish sherd is an unglazed biscuit-fired waster demonstrating its Corinthian origin. It has a strongly bimodal grain-size frequency distribution indicating the coarse fraction was added as temper. In addition, the presence of dark orange red, rounded tcfs and clay striations indicate the incomplete mixing of two clays. In terms of clay preparation and paste recipe, it is distinct from that observed with the locally produced Coarse Mudstone-Chert Class discussed above suggesting these are products of separate workshops with potters utilizing unique paste-making recipes.

8.2.7.1 Quartz-Chert Fabric

Sample: 00/52

(Figure 8.2.12)

The Quartz-Chert Fabric is represented by a single sample of Slip Painted Light on Dark I dating from the end of the eleventh to the beginning of the twelfth century. It is characterised petrographically by its vughy microstructure with voids occupying about 10% of the field. Its dark red (xp) micromass is optically inactive and contains

common, angular to sub-angular, poorly sorted inclusions with a strongly bimodal grain-size frequency distribution. The coarse fraction is comprised of frequent very fine sand to medium sand-sized monocrystalline quartz, very fine sand to coarse sand-sized chert (rarely cherty fossils), and few medium to coarse sand-sized polycrystalline quartz. The fine fraction comprises predominant monocrystalline quartz and rare red and white mica silt. Dark red (xp) tcf's with high to neutral optical density are present and occupy about 2% of the field.

8.2.7.2 Comment

It must be acknowledged that there is nothing remarkable about this fabric that makes provenance determination straightforward given that quartz and chert are ubiquitous, however, there is also nothing to indicate an origin other than Corinth. Comparative data comes from Joyner's study of Byzantine and Frankish cooking wares from Corinth in which she identified a Chert and Quartz Fabric Class dating to the eleventh to twelfth century, and which is described as having a preponderance of monocrystalline quartz fragments and less dominant chert (Joyner 1997, 84). The Chert-Quartz Fabric here is comparable although maximum grain size is coarse sand-sized, whereas maximum grain size of Joyner's fabric is very coarse sand-sized. Given the closeness of these two fabrics it may be surmised that Joyner's quartz and chert tempered paste-recipe for Byzantine cooking wares was also utilized for the late eleventh to early twelfth century Slip Painted Light on Dark I ware, though in a marginally finer version more suitable to the thin-walled tablewares.

8.2.8.1 Medium Coarse Mudstone-Chert Group

Sample: 00/50,53,54

(Figure 8.2.13)

This small fabric group comprises exclusively examples of Slip Painted Light on Dark I belonging to the end of the eleventh to beginning of the twelfth century. It is heterogeneous with samples either oxidized (00/53,54) or reduced (00/50). It is characterised by its vuggy microstructure with voids occupying about 10% of the field. The micromass is optically slightly active and dark red (xp) or optically inactive and dark grey brown (xp). Inclusions are common, predominantly angular to sub-rounded and very rarely rounded, poorly sorted and show a bimodal grain-size frequency distribution. The coarse inclusions consist of common fine to coarse sand-sized chert,

common to few optically very active to optically inactive fine to very coarse sand-sized mudstone, few fine to medium sand-sized monocrystalline quartz, rare to absent fine to medium sand-sized micrite, and very rare to absent medium sand-sized volcanic rock and fine sand-sized plagioclase. Fine inclusions comprise common monocrystalline quartz and chert, few red mica silt and very rare white mica silt and plagioclase. Dark red brown to brown black (xp) tcfs occupy about 2% of the total field.

8.2.8.2 Comment

This fabric group can be attributed a Corinthian origin, with inclusions of chert, mudstone and micritic limestone consistent with the local geology. The bimodal grain-size distribution is indicative that the coarse components were added as temper. The optically slightly active to inactive micromass shows firing at a relatively high temperature, with both oxidized and reduced examples possibly indicating control of kiln atmosphere was poor. It is worth noting that while both this and the Quartz-Chert Fabric (see above) comprise exclusively examples of Slip Painted Light on Dark I, in particular compare the identical slip decoration of samples 00/52 and 00/54 (Appendix II.13), there is a clear difference in the choice of tempering materials. It is uncertain whether this indicates separate workshops exploiting different raw material resources but producing visually similar vessels, or whether these represent products of a single workshop but where different raw materials were utilized perhaps according to availability.

8.2.9.1 Clay Temper Group

The Clay Temper Group consists of three fabric sub-groups related by the presence of dark red to black tcfs and a common suit of non-plastic inclusions. They are nonetheless distinguished by clear textural differences.

8.2.9.2 Clay Temper Group A1

Sample: 00/55,62,65,116

(Figure 8.2.14)

The Clay Temper Group A1 comprises examples of Slip Painted Light on Dark I, the related Slip Painted Light on Dark Dotted style and Spatter Painted Ware each dating from the last decades of the eleventh century to the first few decades of the twelfth century. It is characterised by its vughy microstructure with voids moderately to

strongly aligned to vessel margins and occupying between 5 and 10% of the field. The micromass is optically inactive and dark green grey to dark red brown. Inclusions are common, predominantly sub-angular to sub-rounded, more rarely angular and rounded and have a poorly sorted, bimodal grain-size distribution frequency. The coarse inclusions comprise frequent very fine to medium sand-sized monocrystalline quartz, frequent to common fine to coarse sand-sized chert, few medium to coarse sand-sized polycrystalline quartz, rare to very rare fine to coarse sand-sized micrite and very rare to absent medium sand-sized mudstone. The fine inclusions consist of predominant monocrystalline quartz and very rare red and white mica silt. An important feature of this fabric is the dark red to black tcfs which make up about 2 to 6% of the field and appear as rounded clay pellets and striations of the same clay which are strongly aligned with the vessel margins.

8.2.9.3 *Clay Temper Group A2*

Sample: 00/2,4,6,7,8,9,10,72,73,74,75,76,77,78,79,80,87,88,90,91,92,93

(Figure 8.2.15)

Clay Temper Group A2 includes samples of Green and Brown Painted I, and II, Sgraffito Measles and Dark on Light Slip Painted Ware demonstrating a chronological range from the last decade of the eleventh to mid twelfth century. It is characterised by its vughy microstructure with voids occupying about 10% of the total field. The groundmass is heterogeneous ranging from dark green brown and optically inactive, red to yellow brown and optically slightly active to orange red and optically very active. Inclusions are very few to few, angular to sub-rounded and have apparent unimodal grain-size frequency distribution. They comprise frequent silt to medium sand-sized monocrystalline quartz, common to few very fine to very coarse sand sized chert and very fine to coarse sand-sized micritic limestone. The micrite in optically inactive highly fired examples commonly show decomposition to secondary calcite (e.g. 00/75). Also present is few silt to very fine sand-sized biotite, few to very rare fine to very coarse sand-sized grains of polycrystalline quartz and very rare to absent coarse sand-sized micaceous sandstone and very fine to fine sand-sized calcite. The calcite grains are present only in the optically very active low-fired samples (e.g. 00/80). Like Clay Temper Group A1 tcfs are an important component of this fabric but here occupy a significantly greater proportion of the field (between 20 and 25%) and are frequently separated from the micromass by a void.

8.2.9.4 Clay Temper Group A3

Sample: 00/89,95,96,97,100

(Figure 8.2.16)

The Clay Temper Group A3 includes examples of Sgraffito Style II and Sgraffito Measles and dates from approximately the second quarter to mid/late twelfth century. It is characterised by its vughy microstructure with voids occupying between 5 and 15% of the field. The micromass is optically slightly active and green brown to red brown (xp). Inclusions are very few, predominantly sub-rounded to sub-angular, well sorted and show unimodal grain-size frequency distribution. They comprise predominant silt and rare fine sand-sized monocrystalline quartz, few to very few fine to medium sand-sized micrite with most showing decomposition to secondary calcite, and very rare very fine to medium sand-sized chert and red and white mica silt. Tcfs occupy about 10% of the total field and are represented by predominant dark red to black rounded clay pellets and striations of the same clay which are strongly aligned with the vessel margins.

8.2.9.5 Comment

The Clay Temper Group A2 contains a number of slip decorated, unglazed biscuit-fired wasters (for example 00/72 and 00/78 to 80) providing conclusive physical evidence that this group is locally produced. The similarities between this, Groups A1 and A3 demonstrate that these are also local products and this is further supported by the comparable chemical characteristics of the three groups (see Section 8.3).

With regard to technological characteristics the Clay Temper Group is typified by the presence of dark red to black tcfs and clay striations in dark green brown to orange red micromass demonstrating the incomplete mixing of an iron rich clay in a calcareous clay base. If the local coarse tempered fabrics of the eleventh century chafing dish forms and the seemingly related Quartz-Chert and Coarse Mudstone-Chert tempered fabrics of the early twelfth Century Light on Dark glazed wares are considered, this mixed clay fabric represents a significant shift in the use of raw materials and clay preparation methods at Corinth, coinciding with introduction of glazed decorated pottery at the beginning of the twelfth century.

This fabric class shows a wide range in firing temperature demonstrated by the optical activity (from optically very active to optically inactive) and by the variation in appearance in the limestone components (from grains of calcite and micrite through to micritic clots). In addition, firing atmosphere was also variable from oxidizing to reducing revealed by the range in colour of the micromass (from orange red to yellow brown to dark green brown). This implies control of kiln temperature and atmosphere was poor.

8.2.10.1 Phyllite Group

The Phyllite Group contains two sub-groups related by their phyllite inclusions, but differentiated by distinct textures.

8.2.10.2 Phyllite Group A1

Sample: 00/01,03,05,11,12,13,14,15,16,17,18,19,20,21,22,23,24,51,56,57,58,59, 60,61,63,64, 81,82,83,84,85,86,94,98,99,101,103,113,115,117,118,119, 166, 167,168

(Figures 8.2.17-19)

The Phyllite Group A1 contains a broad range of pottery styles including Spatter Painted, Green and Brown Painted I, II, III, and Spiral, Slip Painted Light on Dark I,II and Dotted, Painted Sgraffito, Sgraffito Freestyle and Aegean Ware. The pottery styles represented date this fabric from the last decades of the eleventh to first half of the thirteenth centuries. This group is heterogeneous having phyllites and metamorphosed polycrystalline quartzes in varying proportions so that it ranges from rare fine inclusions (<0.1mm) in the clay micromass (e.g. 00/64) to frequent fine inclusions and very few poorly sorted coarse inclusions (>0.1mm) (e.g. 00/61), to common coarse inclusions (>0.1mm) in the clay micromass with very rare to few fine inclusions (<0.1mm) (e.g. 00/01). The fabric is characterised by its vughy microstructure with voids occupying between 5 and 10% of the total field. The micromass is optically very active and yellow brown (xp) to optically moderately active and red brown (xp) to optically inactive and dark brown (xp). Inclusions are rare to few, angular to sub-rounded, moderately to poorly sorted and predominantly show a unimodal grain-size frequency distribution, though some appear to have a bimodal grain-size frequency distribution with a poorly sorted coarse fraction. The inclusions comprise frequent to few very fine to coarse sand-sized phyllite (including quartz-biotite-muscovite, biotite-muscovite and

muscovite phyllite), medium to very coarse sand-sized polycrystalline quartz, either with stretched metamorphic structures, to having sub-grains of varying sizes with intergranular white mica, or cataclasites, and very fine sand to medium sand-sized monocrystalline quartz. Also present is common mica (dominant white and common red), few to rare very fine sand to medium sand-sized chert, few to very rare coarse silt to coarse sand-sized plagioclase, rare coarse silt to medium sand-sized serpentinite, rare to absent coarse sand-sized quartz-biotite-muscovite schist and coarse sand-sized rock fragments containing quartz and plagioclase in a recrystallized quartz bedding with intergranular white mica, and very rare to absent fine to very coarse sand-sized claystone.

8.2.10.3 Comment

This is a complex fabric group containing examples of pottery that have previously been attributed to a Corinthian origin (for example Green and Brown Painted I, II and III, and Slip Painted I and II) in addition to pottery that have been considered imported (such as Spatter Painted Ware, Painted Sgraffito and Aegean Ware). The metamorphic nature of the non-plastic inclusions (phyllites, fine grained schists, polycrystalline quartzes showing stretched sub-grains, intergranular white micas and cataclasites) are inconsistent with the local geology and is indicative that this group represents non-local productions from an as yet unidentified centre.

The group is texturally very varied, and while several end-members do exist there is a gradation between the end-members so that no clear breaks could be made to form separate sub-groups. This observation is supported by the absence of any correlation between the fabrics and archaeological divisions (stylistic or chronological) between the samples, and the chemical characteristics of this group strengthen the argument that they should be considered together (see Section 8.3.4.8). The meaning of the variation in texture is unclear but may relate to natural variations within the clay source, the exploitation of several similar clay deposits, or differences in the processing of raw material resources by the potters. It is considered that the coarse end of inclusions is generally too few to have been added as temper.

8.2.10.4 Phyllite Group A2

Sample: 00/104,105,108,165

(Figure 8.2.20)

This fabric group forms a distinct sub-group of the Phyllite Group, strongly related to Phyllite Group A1 based on mineralogical content, but with a discrete texture. The fabric is characterised by its vughy microstructure with voids occupying about 10% of the field. The dark red brown (xp) micromass is optically inactive to optically slightly active. Inclusions are common, sub-angular to sub-rounded, poorly sorted and have apparent bimodal grain-size frequency distribution. The coarse inclusions include common fine to very coarse sand-sized polycrystalline quartz which range from having sub-grains of varying sizes with sutured grain boundaries and intergranular red and white mica to cataclasites. Also present are common to few fine sand to medium sand-sized phyllites (including biotite-muscovite-quartz phyllite, quartz-biotite phyllite and muscovite phyllite), few to rare fine to very coarse sand-sized chert, very fine to medium sand-sized plagioclase and fine sand-sized biotite, very rare fine sand to coarse sand-sized serpentinite and very rare to absent rock fragments of plagioclase and muscovite. The fine inclusions comprise common monocrystalline quartz, and red and white mica, very few plagioclase, and rare chert and serpentinite.

8.2.10.5 Comment

The small Phyllite Group A2 is clearly related to Phyllite Group A1, containing the same range of non-plastic inclusions indicating a similar region of production. This is supported by chemical evidence (see Section 8.3). It nonetheless is considered a sub-group because of its more packed texture, and bimodal grain-size frequency distribution suggesting the coarse fraction was added as temper and distinguishing it from Group A1. Moreover, examination of the archaeological evidence suggests a stylistic grouping, with Champlevé represented, though the group does include one example of Aegean Ware, and certainly a chronological grouping, with the samples dating to the first half to mid thirteenth century.

8.2.11.1 Fine Quartz-Micrite Fabric

Sample 00/28

(Figure 8.2.21)

The Fine Quartz-Micrite Fabric is represented by a single example of Green and Brown Painted V(I) dating from the early thirteenth to the third quarter of the thirteenth century. It is characterised petrographically by its vughy microstructure with voids occupying about 5% of the total field. Its micromass is dark yellow brown (xp) and optically slightly active. Inclusions are few, well sorted, angular to sub-rounded and show a unimodal grain-size frequency distribution. They consist of common coarse silt to very fine sand-sized monocrystalline quartz, coarse silt to very fine sand-sized and rarely coarse sand-sized micrite, and equal amounts of red and white mica lathes. Also present is rare fine to medium sand-sized chert and very rare very fine sand-sized plagioclase. Amorphous concentration (depletion) features (acf) occupy about 5% of the total field and appear as halo nodules with pure cores and moderately to weakly impregnated cortexes.

8.2.11.2 Comment

Given the very fine nature of this fabric it is difficult to make a provenance determination. Nonetheless, its calcareous nature is consistent with a Corinthian origin. The fine, well sorted micromass suggests the use of a naturally fine or refined clay without any temper additions.

8.2.12.1 Micaceous Siltstone-Sandstone Class

8.2.12.2 Micaceous Siltstone-Sandstone Group A

Sample: 00/25,26,27,29

(Figure 8.2.22)

This group comprises exclusively examples of the thirteenth century Green and Brown Painted V(I) style. It is characterised by its vughy microstructure with voids occupying about 10% of the field. Its dark yellow brown (xp) micromass is optically slightly active. Inclusions are common, rounded to sub-angular, poorly sorted and show a bimodal grain-size frequency distribution. The coarse fraction includes dominant to frequent medium to very coarse sand-sized micaceous siltstone and medium sand-sized micrite, frequent very fine sand to fine sand-sized monocrystalline quartz, few medium

to very coarse sand-sized micaceous sandstone, very rare fine sand-sized plagioclase and very fine to fine sand-sized chert and very rare to absent fine sand-sized serpentinite. The fine inclusions consist of dominant monocrystalline quartz, common micrite, few red and white mica of equal proportions and very rare plagioclase.

8.2.12.3 Comment

This small fabric group is typified by its coarse inclusions of silt and sandstones. Siltstone and sandstone occur in the shale-sandstone-radiolarite formation which outcrops on Acrocorinth and Penteskouphi amongst other locations on the Corinthia (see Chapter 5). Furthermore, sandstone inclusions have previously been noted in ceramics from Corinth. In particular, Joyner's (1997) Sandstone Fabric Class should be highlighted which is described as having erratically distributed sandstone grains which contain flakes of biotite mica, and smaller grains of quartz and chert in an optically active micromass. This fabric class contains cooking wares from the Byzantine and early Frankish periods. The Micaceous Silt/Sandstone group can thus be attributed to a Corinthian origin.

The clear bimodal grain-size frequency distribution indicates that silt and sandstones were added as temper to a calcareous clay base very similar in appearance to the calcareous clay exploited for the earlier Clay Temper Group discussed above. The coarser monocrystalline quartz and mica inclusions are likely to represent terminal grades of the silt and sandstone inclusions.

8.2.12.4 Micaceous Siltstone-Sandstone Group B

Sample: 00/30,31,32,33,34,35,36,37,38,39,41,42,43,44,68,69,70,71,106,107,109,110, 111,112

(Figure 8.2.23)

This large group encompasses a range of late twelfth and late third quarter of the thirteenth century styles including Green and Brown Painted V(II), V(III) and V(IV), Slip Painted Light on Dark III, Champlevé and Frankish Incised Sgraffito. It is a homogenous group characterised by its vughy microstructure, with voids occupying about 10% of the field. The micromass is red (xp) and optically slightly active to brown red and rarely dark grey brown (xp) and optically inactive. Inclusions are common, predominantly rounded to sub-rounded and more rarely angular to sub-angular,

moderately sorted and have a bimodal grain-size distribution frequency. The coarse fraction comprises frequent medium to very coarse sand-sized micaceous silt- and sandstone, common to few medium to very coarse sand-sized micritic limestone, few to rare fine to medium sand-sized chert and very rare to absent coarse sand-sized mudstone and volcanic rock containing lathes of sanidine, and fine sand-sized serpentinite. The fine fraction includes predominant monocrystalline quartz, common white mica, few red mica and very rare to absent serpentinite. Dark red brown, rounded to distorted tcfs occupy between 2 and 5% of the field.

8.2.12.5 Comment

The inclusions of silt and sandstone, chert, micrite and serpentinite (which is present in the shale-sandstone-radiolarite formation noted above) are consistent with the local geology pointing to a Corinthian origin for this fabric group. The bimodal grain-size frequency with coarse inclusions supported in the well sorted fine fraction containing predominant monocrystalline quartz indicates the addition of a siltstone, sandstone and micrite temper to a sandy clay. While there is some variation in colour and optical activity of the groundmass (from red and optically slightly active to dark grey brown and optically inactive) suggesting poor control of kiln conditions, the consistency of the fabric in terms of composition and texture is remarkable despite its manufacture for nearly a century.

8.2.13.1 Quartz Silt Fabric

Sample: 00/40

(Figure 8.2.24)

The Quartz-Silt Fabric is represented by a single example of the early to late third quarter of the thirteenth century Green and Brown Painted V(IV) style. It is characterised by its vughy microstructure with voids occupying about 5% of the field. Its green brown micromass is optically inactive and inclusions are very few, sub-angular to rounded, well sorted and show a unimodal grains-size frequency distribution. They comprise frequent medium silt to very fine sand-sized monocrystalline quartz and red mica silt and common white mica silt. It is worth noting the presence of crystalline concentration (depletion) features which occupy about 5% of the total field. They occur as (a) lenses of microcrystalline calcite, and (b) geodic calcite on void walls accompanied by lighter halos around the pores. This second form may indicate

limestone was originally present as inclusions in the ceramic but was decomposed to secondary calcite due to its high firing.

8.2.13.2 Comment

Again, the very fine nature of this fabric makes provenance determination difficult, but like the previously described very fine fabrics, its calcareous nature is consistent with a Corinthian origin. The few well sorted, silt-sized inclusions suggest a fine or levigated clay was utilized.

8.2.14.1 Schist-Phyllite Group

This group comprises the sub-group Schist-Phyllite A1, and the single fabric Schist-Phyllite A2.

8.2.14.2 Schist-Phyllite Group A1

Sample: 00/45,46,48,49,66,67

(Figure 8.2.25)

The Schist-Phyllite Group A1 includes examples of the thirteenth century Slip Painted Light on Dark III and late thirteenth century Green and Brown Painted V(V). It is characterised petrographically by its vughy microstructure with voids occupying about 10% of the total field. The micromass is optically slightly active and orange brown to red brown. Inclusions are few, sub-angular to rounded, moderately sorted and have a unimodal grain-size frequency distribution. They comprise common silt to fine sand-sized monocrystalline quartz and muscovite mica (lathes up to 0.4mm), few silt to fine sand-sized biotite mica and very fine to very coarse sand-sized micrite, very few very fine to coarse sand-sized rock fragments of quartz-muscovite and quartz-muscovite-biotite schist, and quartz-biotite and muscovite-quartz phyllite. Silt to very fine sand-sized plagioclase, very fine sand to medium sand-sized polycrystalline quartz and coarse sand-sized rock fragments containing quartz, plagioclase, muscovite and biotite are very rare. Volcanic rock containing lathes of altered feldspar are very rare to absent. Tcfs occupy between 10 and 15% of the field and occur as two types. The dominant kind is red to brown (xp), commonly optically active and sub-rounded to sub-angular, while dark red (xp), rounded tcfs with high apparent sphericity are rare to absent.

8.2.14.3 Schist-Phyllite Fabric A2

Sample: 00/47

(Figure 8.2.26)

Sample 00/47, an example of the late thirteenth century Green and Brown Painted V(V) ware is identified as a member of the Schist-Phyllite Group A1 described above, however, due to its very high firing temperature it is significantly different in appearance. The differences can be listed as (a) optically inactive, mottled, dark brown (xp) micromass, (b) the presence of bloated pores commonly at the vessel margin, (c) loss of the micrite and micaceous component through the majority of the sample (one end of sample which apparently received less heat during firing retains micrite and mica component). The relationship between the two subgroups is made clearer when their chemical characteristics are taken into consideration (see Section 8.3.4.5).

8.2.14.4 Comment

Morgan (1942) considered all sub-divisions of Green and Brown Painted V wares to be Corinthian products, though in the case of Green and Brown V(V) he recognized the fabric is less gritty and does not resemble other late local wares, but attributed this to the use of a finer natural clay or method of refining. The petrographic analysis shows this fabric group containing Green and Brown Painted V(V) has a metamorphic character with phyllite and schist inclusions in a micaceous groundmass, inconsistent with the local geology and indicating it is non-local in origin.

Though the grain-size frequency distribution is observed to be unimodal, the schist and phyllite inclusions dominate the coarser end of grains. However, their frequency is too few to suggest they were added as temper. The nature of the dominant tcfs suggests they are a product of raw material processing rather than intentional additions to the clay mix. The optically slightly active to optically inactive micromass is indicative of firing at a high temperature.

8.2.15.1 Quartz-Biotite Class

The Quartz-Biotite Class contains two groups (one of which is divided into a series of sub-groups) that are related by common range of non-plastic inclusions.

8.2.15.2 Quartz-Biotite Group A

Sample: 00/172,179

(Figure 8.2.27)

This small fabric group is represented by two samples of Zeuxippus Ware dating to the first third of the thirteenth century. It is characterised petrographically by its vughy microstructure with voids occupying approximately 15% of the field. The micromass is optically inactive and orange brown to orange red (xp). Inclusions are common, sub-angular to rounded, well sorted and have a unimodal grain-size frequency distribution. They include frequent silt to fine sand-sized monocrystalline quartz and coarse silt to medium sand-sized biotite mica, few silt to fine sand muscovite, very few very fine to fine sand-sized plagioclase and very fine sand-sized chert. Also present are very few to rare fine to medium sand-sized micrite and medium to coarse sand-sized polycrystalline quartz, very rare medium silt to fine sand-sized amphibole, and very rare to absent rock fragments containing quartz, plagioclase and amphibole.

8.2.15.3 Comment

Zeuxippus Ware is a class of ceramics considered to be imported to Corinth (for example MacKay 2003, 408-409). The petrographic analysis confirms this supposition given the high micaceous content of the fabric is uncharacteristic of Corinth clay deposits known to date or of confirmed Corinthian productions. The frequency and sorting of inclusions and unimodal grain-size frequency distribution suggests the use of a well-sorted sandy clay, while the optical inactive orange brown to orange red micromass indicates a high firing temperature in an oxidizing atmosphere.

8.2.15.4 Quartz-Biotite Group B

The Quartz-Biotite Group B forms a coherent stylistic group containing first third of the thirteenth century Zeuxippus Ware in addition to a single sample of thirteenth century Incised Sgraffito. Despite the group sharing a common mineralogical suite it has been divided into five sub-groups based upon textural differences.

18.2.15.5 Quartz-Biotite Group B1

Sample: 00/114,169,170,171

(Figure 8.2.28)

Sub-group B1 is characterised by a vughy microstructure with voids occupying about 10% of the field. The micromass is optically inactive and dark red brown to black (xp). Inclusions are few, well sorted, sub-angular to sub-rounded and have a unimodal grain-size frequency distribution. They consist of dominant coarse silt to fine sand-sized monocrystalline quartz, frequent silt-sized (and rarely medium sand-sized) biotite and muscovite, rare very fine sand to fine sand-sized polycrystalline quartz and none to very rare fine sand-sized quartz-biotite phyllite, plagioclase and amphibole. Kcfs occupy about 2% of the field and is present as geodic calcite on void walls accompanied by lighter halos around the pores. This may indicate limestone (micrite) was originally present as inclusions in the ceramic but was decomposed to secondary calcite due to its high firing.

8.2.15.6 Quartz-Biotite Fabric B2

Sample: 00/178

(Figure 8.2.29)

Sub-group B2 is represented by a single sample and is characterised by its vughy microstructure with voids occupying approximately 5% of the field. The micromass is dark orange brown (xp) and optically slightly active. Inclusions are few, angular to rounded, moderately sorted and have apparent slight bimodal grain-size frequency distribution. The coarse inclusions comprise frequent sand-sized monocrystalline quartz and very fine to fine sand-sized biotite, common muscovite (lathes up to 0.2mm), few fine sand-sized micrite, rare very fine to fine sand-sized plagioclase and feldspars (zoned, two cleavages, twinning absent), and very rare fine sand-sized polycrystalline quartz and very fine sand-sized amphibole. The fine fraction includes common quartz, biotite and muscovite, few plagioclase and zoned feldspars and very rare amphibole.

8.2.15.7 *Quartz-Biotite Group B3*

Sample: 00/173,174,177,180,182

(Figure 8.2.30)

Sub-group B3 is characterised by its vughy microstructure with voids occupying about 10% of the field. The micromass is optically inactive and dark red to mottled dark red and grey brown. Inclusions are few, predominantly angular to sub-angular and rarely rounded to subrounded, poorly sorted and show a bimodal grain-size frequency distribution. The coarse fraction consists of common very fine to medium sand-sized monocrystalline quartz and medium sand-sized micrite (predominantly occurring as micritic clots, few medium sand-sized polycrystalline quartz and very fine to medium sand-sized feldspars, rare to very rare coarse sand-sized quartz-biotite schist/quartz-biotite-muscovite schist and fine to medium sand-sized muscovite phyllite/quartz-biotite phyllite, and very rare to absent fine sand-sized microcline and biotite. The fine fraction includes common monocrystalline quartz, biotite and muscovite and rare zoned feldspars.

8.2.15.8 *Quartz-Biotite Fabric B4*

Sample: 00/181

(Figure 8.2.31)

Sub-group B4 is represented by a single sample and is characterised petrographically by its vughy microstructure with voids occupying about 10% of the total field. Its mottled dark red and dark grey brown (xp) micromass is optically inactive. Inclusions are few, angular to sub-rounded, well sorted and have an apparent unimodal grain-size frequency distribution. The inclusions consist of predominant silt to fine sand-sized monocrystalline quartz, few silt to fine sand biotite and muscovite, and very rare medium sand-sized amphibole and zoned feldspar.

8.2.15.9 *Quartz-Biotite Fabric B5*

Sample 00/175

(Figure 8.2.32)

This single sample is closely related to B3 but is differentiated by the absence of coarse fraction.

8.2.15.10 Comment

The sub-groups of Quartz-Biotite Group B share a common suite of mineral inclusions including quartz, biotite, muscovite, micrite, zoned feldspars and amphibole, with phyllites and schist appearing in the coarser versions. This commonality in inclusions suggests these samples originate from the same region of production. This observation is further supported by the chemical characteristics of the group (see Section 8.3). The meaning of the textural variations is unclear but may represent differing methods of clay preparation processes. For example, the very fine nature and unimodal-grain-size frequency distribution of Sub-Groups B1 and B5 indicate the use of a very fine or refined clay, while the bimodal grain-size frequency of Sub-Group B3 indicate the use of a similar clay with the coarser fraction added a temper. The micromass is commonly optically inactive and mottled dark red and grey brown, while voids often occur as vesicles demonstrating firing at high temperatures.

In terms of provenance, the range of inclusions present is indicative of a source of origin other than Corinth.

8.2.16.1 Quart-Mica Fabric

Sample: 00/176

(Figure 8.2.33)

This fabric is represented by a single sample of Zeuxippus Ware. It is characterised petrographically by its vughy microstructure with voids occupying about 7% of the field. The micromass is optically very active and light orange brown (xp). Inclusions are few, well sorted, angular to sub-rounded and in the silt to fine sand-sized range, and have a unimodal grain-size frequency distribution. They include frequent monocrystalline quartz and muscovite, common biotite, few quartz-muscovite phyllite and muscovite-biotite phyllite, rare polycrystalline quartz, plagioclase and chert, and very rare clinopyroxene.

8.2.16.2 Comment

While the fabric of this example of Zeuxippus Ware is characterised by its micaceous inclusions with muscovite, biotite and phyllites all present, it is distinct from the previous group containing Zeuxippus Ware by the additional presence of chert and clinopyroxene and absence of zoned feldspars and amphibole and is therefore

considered as deriving from a separate production centre. Again, the metamorphic nature of the fabric confirms the supposition that Zeuxippus Ware was not manufactured at Corinth.

The unimodal grain-size frequency distribution and fine, well sorted inclusions point to the use of a naturally fine, well sorted or refined or levigated clay. Unlike the previous examples of Zeuxippus Ware the fabric is optically very active suggesting firing at a lower temperature.

8.2.17 Summary and Conclusions

The petrographic analysis has shown that the Middle to Late Byzantine/Frankish glazed pottery assemblage is complex in nature with many fabric groups of local productions and imports identified. Of the locally produced pottery, a number of distinct manufacturing traditions have been recognized. These can be summarized broadly as the eleventh to early twelfth century use of various mixtures mudstone, micrite, quartz and chert temper, the late eleventh and twelfth century use of clay mixing, and the thirteenth century use of siltstone and sandstone temper. A further important finding has been the identification of a number of non-local fabrics containing pottery classes that have traditionally been thought of as locally produced. Thus a greater proportion of the assemblage than has previously been recognized has now been shown to have been imported into Corinth.

8.3 *Chemical Analysis of the Ceramic Fabrics*

8.3.1 *Introduction*

As demonstrated in Chapter 3, the majority of archaeometric investigations of Byzantine pottery have been based upon compositional analysis of ceramic fabrics for chemical characterization and provenance purposes (for example Megaw and Jones (1983), Waksman *et al.* (1996) and Armstrong and Hatcher (1997)). With this in mind compositional analysis was conducted in order to add to the existing work and provide a dataset that could be used for comparative purposes. ICP-AES was selected as the method of choice so as to provide results compatible with other research, especially the Byzantine and Allied Pottery project in which ICP-AES (carried out at the NERC ICP-AES facility at Royal Holloway, London) was the chosen analytical technique (Armstrong and Hatcher (1997)). Moreover, the use of ICP allows for some comparison with data provided by other methods (OES, PIXE, NAA) given there is some overlap of the range of elements analysed in each method. In addition to providing a dataset for comparative purposes multivariate statistical analysis was undertaken in order to further investigate the fabric groups. The petrographic analysis (Section 8.2) demonstrated the Byzantine glazed ceramic assemblage is complex in nature with a wide range of fabric groups and lone fabrics identified, and which have been attributed to local or non-local sources based upon petrographic characteristics. In this case the aim was to identify chemical groups and compare them with petrographic groups. If the two datasets were found to correspond then the fabric groups could be characterised on a more detailed level and relationships between the various fabrics and fabric groups could be investigated. Finally, since glaze composition is intimately related to ceramic body composition through mechanisms of element diffusion (Chapter 2) it is essential to have knowledge of the chemical compositions of the ceramic fabrics in order to fully explore glazing technologies. Sections 8.3.2 and 8.3.3 present the results of the statistical analysis and Section 8.3.4 discusses the chemical groups in relation to their petrographic and stylistic correlates.

8.3.2 *Basic Structure of the Dataset*

Agglomerative Hierarchical cluster analysis of all samples (for statistical methodology see Chapter 7), using the sub-composition: Al₂O₃, MgO, CaO, K₂O, Na₂O, TiO₂, MnO, Cr, Cu, Li, Sc, Sr, V, Zn, and La produced a relatively complex dendrogram, containing nine clusters (Figure 8.3.1), plus a number of individuals or “between-group units” which remain unclassified. Table 8.3.1 shows the mean element concentrations for each

group in addition to their standard deviations and standard deviations expressed as percent. It can be observed that each of the groups has a relatively low degree of internal variation with half or more elements showing less than $\pm 15\%$ standard deviation. By comparing the chemical data in Table 8.3.1 and the dendrogram it is immediately apparent that there is a clear distinction between non-calcareous materials situated to the left of the dendrogram (Groups 1 and 2) and the remainder of the groups situated to the right which must be considered as calcareous (Groups 3 to 9).

8.3.3 Principal Component Analysis

Principal Component Analysis was undertaken to further explore the relationships between the groups identified by cluster analysis (Groups 1 to 9), and to identify the elements most responsible for their separation. In order to refine the groups, end-of-cluster outliers were removed from the dataset. The initial Principal Component Analysis, where all chemical groups identified by cluster analysis were included reveal that the first three components explain 89% of the total variance observed. Table 8.2.2 shows how the components are weighted. Component 1 is characterised by positive loadings of Al_2O_3 , TiO_2 , Cu, Li and Sc, and negative loadings of MgO, CaO, Na_2O , MnO, Cr and Sr. Component 2 is characterised by high positive loadings of CaO, Cu and Sr, and negative loadings of Na_2O , while Component 3 is characterised by high positive loadings of MnO and high negative loadings of Na_2O .

Figure 8.2.2 shows a biplot of the first two components which explain 83% of the total variance. The case numbers indicate chemical group membership as defined by the previous cluster analysis. It shows three clusters. The first, situated to the right of the biplot contains only samples belonging to Chemical Group 1. It is characterised by high concentrations of Al_2O_3 , TiO_2 , Li and V, and low concentrations of CaO. The second group is isolated at the bottom centre of the plot. It is characterised by its low concentrations of CaO and contains only samples of Chemical Group 2. The remaining groups form a scatter at the left hand side of the plot, forced there by their higher CaO concentrations. The internal arrangement of the scatter reflects the chemical differences highlighted by the cluster analysis. To explore these differences further, Groups 1 and 2 were removed from the dataset and the analysis was undertaken a second time.

The second analysis reveals that the first three components extracted account for 86% of the total variance observed. Table 8.3.3 shows that the first component is characterised

by high negative loadings of CaO and Sr, the second component by high positive loadings of Na₂O and high negative loadings of MnO, while Component 3 is characterised by high negative loadings of Cr. Figure 8.3.3 shows a biplot of the first and second principal components of Chemical Groups 3 to 9 which account for 75% of the total variance. With the non-calcareous samples removed the remaining cases (which formed the scatter on the left hand side of the biplot in figure 8.3.2) are forced apart. Four scatters of cases are highlighted. The first, situated to the upper centre of the plot contains cases belonging to Chemical Group 6. This group exhibits high CaO, Sr and Cu relative concentrations. Cases belonging to Chemical Groups 8 and 9 are forced to the right hand side of the plot by their high Na₂O and K₂O concentrations, though Group 9 has a higher Cr in comparison to Group 8. Groups 7 and 3, to the bottom centre of the plot are isolated by their high MnO concentrations. The remaining cases belong to Chemical Groups 4 and 5. Their characteristics are better resolved if the Principal Components Analysis is undertaken excluding Groups 3 and 7. This analysis reveals that the first two components extracted account for 81% of the total variation. Table 8.3.4 shows that the first component is characterised by high negative loadings of CaO and Sr, while the second component is characterised by high positive loadings of Cr and high negative loadings of MnO. Figure 8.3.4 shows the biplot of the first and second components with Groups 4 and 5 highlighted. Group 5 is situated by its high Cr and MgO concentrations. Group 4, however, is fairly dispersed, being broadly split by CaO relative concentrations. The reasons for this are explained below in Section 8.3.4.4.

8.3.4 Chemical Groups and their Petrographic and Stylistic Correlates

The following sections (Section 8.3.4.1 to 8.3.4.9) explore the petrographic and stylistic characteristics of each of the chemical groups defined by Agglomerative Hierarchical Cluster Analysis and Principal Components Analysis. The general chemical characteristics of each group are also given.

8.3.4.1 Chemical Group 1

Group 1 contains 22 samples which comprise exclusively the Altered Feldspar Class (see Appendix IX) and in turn corresponds to all samples of the White Wares sampled for this study. The samples belonging to the Altered Feldspar Class were texturally varied and formed several fabric groups or sub-groups (Section 8.2.1.1). These distinctions were not reflected in the fine structuring of the dendrogram which supports

the argument that the fabrics were manufactured from similar clays and so originated from the same region of production (Section 8.2.1.6). Group 1 is characterised compositionally by a high Al_2O_3 (23.45 %), TiO_2 (1.13 %), Sc (32.86 ppm) and V (170.41 ppm), and other than Cu, which has intermediate concentrations in comparison to the other groups, all remaining elements have low concentrations. Most notable amongst these are Fe_2O_3 (2.26%), CaO (0.41 %), Cr (36.86 ppm) and Sr (38.41 ppm) (see Table 8.3.1). The overall composition of Group 1 shows a strong match to White Wares from Constantinople and Corinth analysed using optical emission spectrometry by Megaw and Jones (1983) (see Chapter 3). This observation is elaborated in Chapter 9.

8.3.4.2 *Chemical Group 2*

Chemical Group 2 contains five samples, four of which belong to the Muscovite-Schist Group A, and the fifth, which joins at a higher level on the dendrogram (Figure 8.3.1), is the single sample Fine Muscovite-Biotite Fabric. All are examples of Plain Brown Glazed chafing dishes. The Muscovite-Schist Group A contains a further sample (00/126) which is situated as an outlier at the far right of the dendrogram. It is separated from Group 2 by some chemical differences. These include higher CaO (1.69% in comparison to the mean 0.66% observed in Group 2 (see Appendix IX and Table 8.3.1), higher Cr (353 pm in comparison to the mean 144.60 ppm), lower Al_2O_3 (15.46% in comparison to the mean 19.84% in Group 2) and lower K_2O (1.96% in comparison to the mean 2.97% seen in Group 2). There are no apparent petrographic distinctions which might account for this chemical difference, though the overall coarse nature of the fabric may explain its positioning.

It was commented upon in Section 8.2.4.4 that though the Muscovite-Schist Group A and Fabric B (sample 00/124) can be related by coarse inclusions of muscovite-containing schist and so are both considered to be non-local to Corinth in origin, the differences in mineral content, especially the presence of schist containing opaques, chert, micrite and very rare olivine in sample 00/124 indicate they are imported to Corinth from different sources. This observation is supported by the overall chemical evidence and in particular by the CaO and related Sr concentrations. Where the samples belonging to Group 2 have low CaO and Sr concentrations (0.66% and 94 ppm respectively) and are so situated to the left of the dendrogram with the remaining non-calcareous material, sample 00/124 is located to the right of the dendrogram in

between Groups 8 and 9 (Figure 8.3.1) with the calcareous material (CaO and Sr concentrations are much higher at 5.72% and 130 ppm respectively) indicating manufacture from a calcareous clay. This substantiates the notion that the Muscovite-Schist Group A and Fabric B derive from different geological settings.

8.3.4.3 Chemical Group 3

Group 3 is a small group containing two samples. These correspond to Medium-Coarse Mudstone Chert Group which in turn contains only samples of Slip Painted Light on Dark I (Section 8.2.8.1). The group has low concentrations of Al₂O₃ (14.19 %), MgO (1.59 %), Na₂O (0.24%) and K₂O (1.20 %) and high concentrations of Cu (102 ppm) and Cr (463.00 ppm). The petrographic grouping contains only one other sample (00/50) which is again an example of Slip Painted Light on Dark I. Though sample 00/50 is situated immediately to the right of Group 3 on the dendrogram (Figure 8.3.1) it is joined as an end-of-cluster outlier to Group 4 demonstrating chemical differences. Most notable is its increased Sr concentration (334 ppm (Appendix IX) in comparison to the Group 3 mean 130.50 ppm (Table 3.2.1)) and decreased Cr concentration (257 ppm in contrast to the Group 3 mean 463.00 ppm). Sample 00/50 can be distinguished petrographically by it being reduced-fired; samples 00/53 and 00/54 share the same non-plastic inclusions and texture but are oxidized. It is known that firing conditions may effect element concentrations of ceramics (for example Kilikoglou *et al.* 1988 and Buxeda *et al.* 2001), and so the differences in firing may account for the observed chemical variances.

8.3.4.4 Chemical Group 4

Chemical Group 4 contains 14 samples and in the main encompass the Quartz-Biotite Groups A and B1 to 3 and 5. As determined in Section 8.2.15.10, the Quartz-Biotite Group comprises a series of sub-groups associated by their mineralogy but differentiated by substantial variations in texture. In examining the fine structuring of the dendrogram (Figure 8.3.1) and comparing case position with the petrographic correlations (see Appendix IX), it can be seen that the petrographic sub-groups are identified in the small sub-clusters of Group 4. For instance, the sub-cluster positioned to the left containing seven members comprises the closely related Quartz-Biotite Groups B3 and B5. The central sub-cluster containing four members comprises Quartz-Biotite Group B1, and the right hand sub-cluster containing three members comprises the Quartz-Biotite Group A and Fabric B2. Though these samples cluster together in

the dendrogram, Chemical Group 4 are forced apart by Principal Component Analysis (see Figure 8.3.4). It is observed that the majority of the samples are situated to the left of the centre, positioned by their CaO relative concentrations. Examination of the data revealed these cases to belong to the petrographic groups Quartz-Biotite B3 and B5, which contain common micrite inclusions, explaining their elevated CaO contents (see Appendices IV and IX). The remainder of the samples belong to the Quartz-Biotite Group A, B1 and B2, which lack the common micrite component and so show lower CaO concentrations (see Appendix IV). A final point to note is that Cr concentrations are variable across the chemical group, with higher concentrations observed for Quartz-Biotite B3 and B5 in comparison to the Quartz-Biotite Groups A, B1 and B2 (see Appendix IX). Cr concentrations are associated with mafic minerals such as biotite and amphibole (for example Torres-Ruiz *et al.* 2003, 517; Hein *et al.* 2004, 251). Both biotite and amphibole were noted as present in varying proportions across the petrographic subgroups. For example, silt to medium sand-sized biotite was recorded as frequent in the Quartz-Biotite A and B1 fabric groups, while Quartz-Biotite B3 contains medium to coarse sand-sized biotite containing schists and phyllites in addition to common biotite in the fine fraction. The greater proportion of biotite in the Quartz-Biotite B3 sub-group may explain its elevated Cr concentrations. The common suite of mineral inclusions present in the pottery belonging to the Quartz-Biotite Class indicates they originate from a common region of production and are manufactured from similar clays. The compositional differences between the sub-groups observed on a microscopic level are also reflected in their chemistry.

8.3.4.5 Chemical Group 5

Group 5 comprises the seven samples which form the Schist-Phyllite Group. It is defined chemically by its high concentrations of MgO (5.12 %), CaO (8.93 %), Cr (493.43 ppm) and Sr (252.57 ppm). In examining the fine structuring of the dendrogram it can be seen that sample 00/47 is joined to the cluster at a higher level (Figure 8.3.1). Inspection of its chemical composition suggests this separation is mainly due to its enriched Sr concentration (404 ppm) in contrast to the remainder of the samples which contain between 179 and 278 ppm (Appendix IX). This sample equates to the Schist-Phyllite Fabric A2, which is distinguished from the main group Schist-Phyllite A1 by its firing at very high temperature (see Section 8.2.14.3). The mineral alteration (decomposition of micrite and biotite) observed in this sample may account for the chemical differences noted.

8.3.4.6 Chemical Group 6

This group contains 34 samples and incorporates all but two examples of the Clay Temper Group, all samples belonging to the Micaceous Siltstone-Sandstone Group A and the lone Quartz Silt Fabric. The most dominant chemical feature of this group is its high concentrations of CaO (17.87 %) and Sr (452.94 ppm). It includes the unglazed, biscuit-fired wasters (samples 00/72, 00/78, 00/79 and 00/80, see Appendix II.22) belonging to the Clay Temper Group, so demonstrating the manufacture of this pottery at Corinth. With regard to the Micaceous Siltstone-Sandstone Group A (Section 8.2.12.3) it was noted that silt and sandstones were added as temper to a calcareous clay base very similar in appearance to the calcareous clay exploited for the Clay Temper Group, and that based upon this a Corinthian origin was suggested for this fabric group. The chemical data here lends strength to that argument that these are local products. The same is also true of the single sample Quartz Silt Fabric. While provenance determination is difficult for this sample given its very fine character, the calcareous nature of the fabric was deemed to be consistent with a Corinthian origin (Section 8.2.13.2). Its position in the cluster and chemical characteristics supports this notion.

8.3.4.7 Chemical Group 7

Group 7 links the two samples which form the Coarse Mudstone-Chert Group A containing only examples of Plain Brown Glazed chafing dishes. Given the nature of the coarse inclusions contained in the fabric (spherulitic chert, mudstone and so on) a Corinthian origin was suggested. It can be characterised chemically by its high MnO concentrations in comparison to the other groups (0.3%, Table 8.3.1) and low Al₂O₃ and Li concentrations (13.76% and 55 ppm respectively). It does contain some CaO (6.60%), but this concentration is considerably lower than that observed in the ‘Corinthian’ Chemical Group 6. The Coarse Mudstone-Chert Fabric B is positioned as an outlier to Chemical Group 4 and is differentiated chemically from the Group A samples by increased CaO and Sr concentrations.

8.3.4.8 Chemical Group 8

Group 8 is a large group containing 48 members, which comprise exclusively the Phyllite Group (sub-groups A1 and A2). The chemical characteristics of this group can be summarised as follows: relatively high Al₂O₃ (19.84%), Fe₂O₃ (7.55%), Na₂O (1.42%) and K₂O (3.09%) and low Cu (50.88 ppm) in comparison to the other groups identified (Table 8.3.1). The group has particularly good chemical cohesion, with 11

elements having less than $\pm 10\%$ standard deviation. The low internal variation in this group is worth highlighting given that the petrographic analysis revealed this group to be heterogeneous, with a broad range in grain-size and frequency of mineral inclusions in the group (see Section 8.2.10.3). A variation in the presence and frequency of coarse mineral and rock inclusions is known to affect the underlying chemical structure of a ceramic fabric (for example Bishop 1982, 298; Kilikoglou *et al.* 1988; Buxeda *et al.* 2003, 15). It may therefore be expected that these variations be apparent in the fine structuring of the dendrogram. As can be seen in Figure 8.3.1, this is for the most part, not the case. The small cluster at the right of the main cluster is positioned there by its increased Cu concentrations (compare samples 00/12 to 00/60 with the remainder of the samples in this group (Appendix IX)). The chemical cohesion of this fabric group supports the argument that despite the variation in inclusion grain-size and frequency, the members are strongly related and derive from a unique point of origin, with differences in texture relating to either a natural variation in the raw materials used or differences in the processing of raw materials.

8.3.4.9 Chemical Group 9

This final group consists of 26 cases and includes all samples belonging to the Micaceous Siltstone-Sandstone Group B, and two examples of petrographically and stylistically unrelated pottery which are the Zeuxippus Wares belonging to the Quartz-Biotite Group (samples 00/174 and 00/181). In examining the fine-structuring of the dendrogram it can be seen that the overall cluster is split into two sub-clusters. The first contains samples 00/109 to 00/38 on the left hand side, and the second on the right hand side contains samples 00/174 to 00/112 (Figure 8.3.1). In examining the chemical data (Appendix IX) it appears that distinction is due to enriched CaO and Sr concentrations in the first, smaller sub-group. The Micaceous Siltstone-Sandstone Group B was determined to be petrographically homogenous, with each example of the fabric being remarkably similar to the next (Section 8.2.12.5). The enrichment may be explained in terms of secondary calcium contamination from the limestone-rich burial environment (for example see Cau *et al.* 2002).

8.3.5 Summary of the Chemical Analysis of the Ceramic Fabrics

A number of statements can be made based upon the multivariate statistical analysis of the chemical dataset provided by ICP-AES. They are as follows:

In general, the multivariate statistical analysis using Agglomerative Hierarchical Cluster and Principal Components Analyses was successful in that the techniques discriminated groups of pottery allowing them to be defined chemically (Table 8.1.3, Appendix IX). This information adds to the existing work and in particular refines Megaw and Jones' (1983) reference group of Byzantine glazed ceramics from Corinth. A greater range of fabric types from Corinth are now classified using a larger suite of elements.

Comparison of the chemical groups and petrographic groups showed a correspondence between the two datasets. That the two analytical techniques support each other implies the groups of pottery are “real”, representing productions deriving from different locations and different traditions of pottery manufacture. By combining the complementary datasets the groups of pottery can be described in detail. Table 8.3.5 presents a summary of the main petrographic groups and their chemical characteristics.

Chemical characterization of the main fabric groups (the Clay Temper Class and the Micaceous Siltstone-Sandstone Groups A and B), and small groups which have been determined to be locally produced based upon petrographic observations, show that chemically distinct clays were exploited for glazed pottery manufacture from the 11th and 13th centuries. These include the calcareous clays used for Clay Temper Class and the Micaceous Siltstone-Sandstone Group A where calcium content is high at approximately 18%. This is consistent with the limestone geology of the Corinthia. Low-calcareous clays were also utilized, as demonstrated by the composition of the Micaceous Siltstone-Sandstone Group B, where the calcium content was found to be <5%.

The multivariate statistical analyses were revealing with regard to the imported wares. Petrographic analysis demonstrated that the Zeuxippus Ware sampled for the study formed distinct fabric sub-groups within the Quartz-Biotite Class which could be related based upon a common mineralogy. Zeuxippus Ware and its derivatives are regarded as a mixture of diversified productions from a number of Mediterranean sites that share common techniques of production (for example Berti and Gelichi 1995). Given this knowledge, it was possible that the samples analysed in this study may have derived from more than one production location. That the Zeuxippus related fabrics grouped together chemically would support the supposition that they originated from a common, though as yet unidentified, source.

The same is true for the Phyllite Group which comprises a large heterogeneous fabric sub-group and a smaller, more homogenous sub-group that have in common a low grade metamorphic mineralogy, and which based upon the various decorative categories represented span the end of eleventh through to the thirteenth centuries. Their tight chemical grouping demonstrated both by Cluster and Principal Components Analysis would similarly suggest a single source of origin.

In addition to providing information to chemically characterise the ceramic fabrics, the data obtained through ICP-AES is used to explore glaze compositions (Section 8.4).

8.4 Chemical and Microscope Analysis of the Glazes

8.4.1 Introduction

The petrographic and chemical analysis demonstrated the Byzantine glazed ceramic assemblage from Corinth is complex in nature with a number of different fabric types identified which span the eleventh to thirteenth centuries and which can be attributed to local and non-local manufacture (see Table 8.3.4). These ceramic analyses have provided the basis for the glaze analysis. To investigate the development of glazing technologies at Corinth in the eleventh to thirteenth centuries, a selection of glazes were sampled from the main local and non-local fabric groups characteristic of each century. Where more than one decorative style was present in a fabric group, glazes were selected from each of the main styles represented, and where possible each glaze colour was analysed if more than one appeared on an individual sherd. The 51 samples chosen for analyses are presented in Tables 8.4.1 to 8.4.3. By sampling from the range of fabrics and styles present a number of specific questions are addressed. These are:

How do glaze compositions compare between pottery groups attributed to local and non-local manufacture within each century?

How do glaze compositions compare between each pottery group attributed to local manufacture between each century?

How do glaze compositions compare between the different decorative styles present within each fabric group?

Examination of the glazes in this manner allows for the identification of possible changes in glazing technologies at Corinth during the period under study and may indicate, if detected, whether or not changes in local technology can be linked to ‘non-local’ methods of manufacture. The results of the EPMA analysis are presented in the following sections in broad chronological order of the pottery.

8.4.2 Basic Glaze Compositions and their Microstructures

Analyses of the glazes show that they fall into two compositional categories. These are the Lead-Alkali Glaze Group containing only six samples from three sherds and the large High Lead Glaze Group which contain the remaining samples (Figure 8.4.1, Tables 8.4.4 and 8.4.5, and Appendix X).

8.4.2.1 Lead Alkali Glazes and their Microstructures

The lead-alkali glazes belong exclusively to the Altered Feldspar Fabric Group A (eleventh century), occur on the pottery styles of Polychrome Style II and Plain Brown Glazed, and appear here to be common to colourless, turquoise and brown glazes. The glazes contain between 28.55 to 47.28 wt% PbO, 30.61 to 49.16 wt% SiO₂ and 4.25 to 9.03 wt% Na₂O+K₂O, with the PbO content increasing where the SiO₂ and Na₂O+K₂O contents decrease as expected. In addition important quantities of CaO (between 2.49 and 5.58 wt%) and MgO (between 0.25 and 1.51 wt%) are present. As discussed in Chapter 2 body composition can effect glaze composition with body elements diffusing into the glaze during firing. However, given the low CaO content of the corresponding ceramic bodies (mean 0.41 ± 0.64 wt% CaO, see Group 1, Table 8.3.1) it must be considered as a deliberate addition to the glaze. The glazes are between 75 and 110µm in thickness and show no interaction layer between body and glaze, but may contain Ca-rich aggregates (for example Figure. 8.4.2, turquoise glaze) or Fe₂O₃ particles (Figure 8.4.3, brown glaze, (see Section 8.4.3)).

It is important to note that analysis of the yellow glaze of the polychrome sample 00/141, adjacent to the lead-alkali brown and turquoise glaze shows it falls within the High Lead Glaze Group having 61.1 wt% PbO, 29.21 wt% SiO₂ and only 0.98 wt % Na₂O+K₂O, and is close in composition to the yellow and green glazes of the plain glazed wares sampled from the same Alkali Feldspar Group (see Table 8.4.1, Appendix X). This demonstrates the use of different base glaze recipes for particular colours.

8.4.2.2 High Lead Glazes and their Microstructures

The remaining glazes belong to the High Lead Glaze Group (Table 8.4.5 and Appendix X). Element concentrations are variable with between 34.48 to 73.24 wt% PbO, 19.90 to 48.07 wt% SiO₂, 1.39 to 8.84 wt% Al₂O₃ and 0.11 to 2.67 wt % Na₂O+K₂O. As noted with the lead-alkali glazes, the PbO content increases where the SiO₂ content decreases.

Examination of the microstructures show the high lead glazes are typically between 100 to 400µm in thickness in the case of chafing dish glazes, but thinner, between 50 to 175µm in all other later fabric groups. Extensive Pb-feldspar crystal formation was noted at the glaze/body interaction zone on a number of eleventh century Plain Brown Glazed chafing dish samples (for example 00/122, 00/124, 00/127, Figure 8.4.4) and the

lead glazes belonging to the Altered Feldspar Class (for example 00/148). However, typically Pb-feldspar crystal formation was minimal, with the interaction layer measuring between 5 and 15 μm (Figure 8.4.5). It is interesting that the extensive glaze/body interaction is noted only in classes of pottery belonging to the eleventh century and not the later wares and it is an indication these were fired once only. Undissolved quartz grains were absent or very rare in the majority of samples, though occasionally they were common throughout the glaze (for example 00/38, 00/88) indicating in the case of these samples optimum firing temperature had not been achieved for glaze formation (Figure 8.4.6).

8.4.3 Lead Glaze Manufacturing Methods

It has been shown in Chapter 2 that a lead glaze may be manufactured using either PbO on its own applied directly to the surface of the vessel, or by applying a PbO·SiO₂ mixture to the vessel surface. By using the data reduction method discussed in Chapter 2 (subtracting PbO content from the glaze composition and normalising the remaining element oxides to 100%) it should be possible to determine which method was employed in antiquity. If after data reduction glaze and body composition are similar (within experimental error) it indicates the glaze was produced using the PbO method. If the SiO₂ is higher in the glaze than body and the remaining element oxides lower it indicates the PbO·SiO₂ method was employed. Colourless, yellow or green glazes (with the CuO content removed) from each of the fabric groups representing each period were selected for data reduction. The ICP-AES data were used for the corresponding body composition. Since silica is digested in the hydrofluoric-perchloric acid dissolution method of ICP-AES sample preparation (See Section 7.3.2.1), the silica contents were calculated by difference. The results are plotted in Figures 8.4.7 to 8.4.10 and are grouped according to eleventh century fabrics, which take into account the Altered Feldspar Fabric Group and the chafing dish fabrics, twelfth century fabrics, which take into account the Clay Temper Group and twelfth century styles belonging to the Phyllite Group A1, and the thirteenth century fabrics which include the thirteenth century styles belonging to the Phyllite Groups A1 and A2. The data for the plots are given in Appendix XI

A pattern emerges when plotting the normalised glaze compositions against the body compositions for the various elements (Figures 8.4.7 to 8.4.10). It can be seen that with eleventh century glazes (top) the element oxides fall on or close to the unity line,

showing compositions match between glaze and body. This implies that the only oxide used to form the glaze was PbO. The remaining oxides present in the glazes derive from the ceramic bodies, including Fe₂O₃ which is responsible for their yellow hue. If additional Fe₂O₃ had been added to the glaze mixture as an intentional colorant it would have fallen above the unity line in the plot. Conversely, the SiO₂ content for the twelfth and thirteenth century glazes is higher in the glaze than body (the cases cluster above the unity line, Figure 8.4.7, left middle and bottom) while the majority of the remaining element oxides cluster below the unity line and so is lower in the glaze than body. This is most strongly seen for the elements Al₂O₃, Fe₂O₃, MgO, CaO and MnO. There is a clear outlier to main cluster of cases noted on the MnO biplot for thirteenth century fabrics (Figure 8.4.9, bottom right plot) with one sample relating to the Schist-Phyllite fabric group falling above the unity line, so showing higher concentrations of MnO in the glaze than body. This case relates to the brownish glaze of sample 00/46 (Appendix X). An explanation for the elevated MnO levels is its addition along with Fe₂O₃ as a colorant (see Section 8.4.4). The results for K₂O are more variable. For example, a number of cases that belong to the twelfth century Clay Temper Group and thirteenth century Micaceous Siltstone-Sandstone Group B (Figure 8.4.10, middle right and bottom right respectively) fall above the unity line showing higher concentrations in the glaze than body. The overall pattern indicates that the glazes of the twelfth and thirteenth centuries were applied as a PbO·SiO₂ mixture, though glazes belonging to Clay Temper Group and Micaceous Sandstone Group showing increased K₂O may have had an additional minor alkali component added possibly in the form of potassium feldspar or potash.

8.4.4 Use of Colorants

As discussed in Chapters 3, it is the of the general opinion that Byzantine glazes were coloured using additions of CuO to the glaze mixture for green, Fe₂O₃ for yellow or brown and MnO for the dark brown glaze or paint used for decoration outlines as present on classes of ceramics such as Polychrome (for example Sanders 2001). Samples of each coloured glaze were analysed where possible to determine if this is the case in the ceramics analysed from Corinth. Typical compositions of coloured glazes from each fabric group are presented in Table 8.4.6 (lead-alkali glazes) and Table 8.4.7 (high lead glazes). Colourless glazes are included for comparison where necessary. The yellow glazes of the chafing dish class are not treated in this section as they are considered “colourless” glazes, given the close match between Fe₂O₃ content in glaze

and ceramic body following data reduction (see Figure 8.4.7, top left). This indicates the yellow hue of the glazes was produced by diffusion of Fe_2O_3 from the ceramic bodies into the glaze only and not by the deliberate addition of any colorants to the glaze mixtures.

8.4.4.1 Lead-Alkali Glazes

Contrary to previous notions that the dark brown/black glaze used to outline motifs on the Polychrome Ware is coloured using manganese, analysis has shown in these cases the colour was produced using high concentrations of Fe_2O_3 (up to 14.08 wt%).

Examination of the microstructures of these glazes shows them to be heterogeneous, with Fe-rich areas and crystals of Fe_2O_3 dispersed throughout (Figure.8.4.3). The turquoise glazes present on the same polychrome samples are coloured by addition of CuO in concentrations of around 2.5% wt%. It is interesting that both Fe_2O_3 (6.62 wt%) and CuO (2.48 wt%) were detected in the brown coloured overglaze of the Plain Brown Glazed ware belonging to the same Altered Feldspar Fabric Group as the Polychrome samples (note the absence of CuO in the dark brown/black glaze in these samples). It is possible that the CuO component is a contaminant introduced during glaze preparation, though equally it may represent a deliberate addition to the brown glaze mixture to produce the required tone. This is discussed in Chapter 9.

8.4.4.2 High Lead Glazes

Colorants of the high lead glazes were found in general to be in agreement with previous analyses (Chapter 3). For instance, the yellows were produced by the addition of Fe_2O_3 . However, some variations in concentrations were noted depending on the richness of colour. For example, the deep yellow glaze in the Polychrome sample (00/141) contained 4.22 wt% Fe_2O_3 , while the paler yellow glaze of the Slip Painted Ware belonging to the same fabric group contains lesser amounts at 1.64 wt% Fe_2O_3 . The Fe_2O_3 content in the remainder of the yellow glazes on pottery belonging to the various fabric groups from the twelfth to thirteenth centuries appear remarkably consistent with amounts appearing in the 2.15 to 2.35 wt% range.

All of the green glazes analysed were coloured with CuO. Unlike the yellow glaze, concentrations were found to be more varied between and across the fabric groups, with concentrations ranging from 0.49 to 6.33 wt%.

Some differences were detected in the use of colorants for brown glazes. For instance, the brown glaze present on the example of late eleventh to early twelfth century Green and Brown Painted I style belonging to the local Clay Temper Group was determined to be coloured by Fe_2O_3 (5.31 wt%) and CuO (1.16 wt%). The brown glaze of the slightly later style of Green and Brown Painted II belonging to the same fabric class contained 2.36 wt% Fe_2O_3 , but also a minor amounts of MnO (0.63 wt%). Given that the colourless and green glazes present on the same sherd show only trace amounts of MnO (0.01 and 0.02 wt% respectively) this is considered to be a deliberate colorant added to the glaze mixture.

The brown glaze decoration present on the late eleventh to twelfth century Green and Brown Painted I and III styles of the non-local Phyllite Group were determined to be coloured by combinations of MnO (1.02 to 2.87 wt%) and CuO (1.93 to 2.58 wt%). While 1.29 wt% Fe_2O_3 was detected in the brown glaze of sample 00/13, similar amounts were present in the green glaze present on the same sherd and so is not considered to be a deliberate addition. In the second example of Green and Brown Painted III only MnO was detected as the colorant. The brown decoration on the Green and Brown Painted Spiral and Painted Sgraffito styles belonging to the same Phyllite fabric class were found to contain Fe_2O_3 in concentrations of around 3.70 wt% for the Spiral style and 6.30 wt% for the Painted Sgraffito ware and no MnO was detected. Examination of the microstructures of these brown glazes shows them to be inhomogeneous with Fe_2O_3 crystallized out into the glaze in the manner observed brown lead-alkali glaze of the Polychrome Wares (Figure 8.4.11).

MnO was determined to be the colorant for the brown spotted decorations present on the Green and Brown Painted V(I) styles belonging to the two local Fine Quartz-Micrite Fabric and Micaceous Siltstone-Sandstone Group A of the thirteenth century, and is present in amounts of 1.96 and 0.57 wt% respectively. The brown glaze decorations of the third local fabric group of the thirteenth century (the Micaceous Siltstone-Sandstone Group B) contains 3.7 to 3.9 wt% Fe_2O_3 and while no MnO was detected.

The yellow-brown glaze of the Green and Brown V(V) style belonging to the Schist-Phyllite Fabric Group is coloured predominantly by Fe_2O_3 (3.37 wt%) though a minor component of MnO is present (0.21% wt%). This minor amount of MnO is considered to be a colorant here given the yellow glaze present of the Slip Painted Light on Dark III

style belonging to the same fabric group contains comparable amounts of Fe_2O_3 (3.09 wt%) while MnO was determined to be present in concentrations of only 0.01 wt%.

8.4.5 Summary and Conclusions

The glaze analysis has provided a number of important results that demonstrate the use of various methods of glaze manufacture in the Byzantine and Frankish Periods relating to local and non-local classes of pottery. These are presented in Table 8.4.8 and summarized below.

Analysis of the glazes show they fall into two compositional categories of lead-alkali glazes and high lead glazes, with the lead-alkali glazes used exclusively for specific glaze colours in the Constantinopolitan Altered Feldspar Fabric Class (colourless, turquoise and brown). No lead-alkali glazes were detected in locally manufactured glazed pottery or other classes of imported pottery.

Using the data reduction technique the high lead glazes were shown to fall into two groups: those produced using PbO on its own, and those produced using a $\text{PbO}\cdot\text{SiO}_2$ mixture. The PbO method was found to occur only on pottery manufactured in the eleventh to early twelfth centuries, specifically for green and yellow glazes belonging to the Altered Feldspar Fabric Class and the 'colourless' glazes on all chafing dishes (locally produced and imported). The $\text{PbO}\cdot\text{SiO}$ method was used for the fine decorated table wares of the twelfth and thirteenth centuries (locally produced and imported).

In general the colorants detected were typical of medieval glazes with CuO used to produce greens and Fe_2O_3 for yellows. However, a number of methods of producing brown glazes were identified within fabric groups depending on decorative class, and between fabric groups. These are the use of high concentrations of Fe_2O_3 , the use of Fe_2O_3 and smaller quantities of MnO, and MnO on its own and combinations of Fe_2O_3 and CuO, and MnO and CuO.

These results are contrary to previous published findings that little or no technological change occurred during this period (see Chapter 3). The implications of these findings in relation to understanding the development of production technologies of glazed pottery at Corinth, and concepts of technological transfer are to be discussed in Chapter 9.

CHAPTER 9

DISCUSSION AND CONCLUSIONS

9.1 Introduction

This thesis provides an in-depth investigation of Byzantine glazing techniques and their development through time at Corinth. Imported and locally produced pottery were studied so that influences in technological changes, if identified, could be explored. The pottery falls broadly into three chronological ranges in terms of petrographic/chemical and stylistic groupings. These are the eleventh century to early twelfth century, which accounts for White Wares and Plain Brown Glazed Red Wares (these wares disappear from Corinth in the early years of the twelfth century), the late eleventh and twelfth centuries, which takes into account the glaze and slip decorated wares which were introduced in the last decades of the eleventh century and are present throughout the twelfth century, and the thirteenth century which accounts for the more roughly potted Byzantine styles and fine imported wares. This chapter presents an interpretation of the results of the main groups of pottery identified according to these broad chronological ranges. A summary section considers the overall patterns of change and their implications.

9.2 Pottery of the Eleventh Century and Early Twelfth Century: White Wares and Plain Brown Glazed Red Wares.

As shown in Chapter 4, the glazed pottery assemblage at Corinth during the eleventh century forms only a small portion (0.7%) of the total ceramic assemblage for this period. These are primarily the fine glaze decorated White Wares and the coarse Plain Brown Glazed Red Wares. As well as being differentiated by fabric and glaze decoration, the two types of wares are distinguished by vessel form, with tablewares such as cups, bowls, plates and fruit stands represented in the White Ware fabrics and most commonly chafing dishes, but also jugs, pitchers and cups represented in the coarse red fabrics (Chapter 6).

9.2.1 White Wares

It is of the general consensus that the glazed White Wares were produced in Constantinople given the large quantities excavated there in comparison to other sites (Hayes 1992, Armstrong *et al.* 1997, Armstrong 2001, Papanikola-Bakirtzi 2003, see Chapter 6). Though kiln sites of the period have yet to be located in the region of

Constantinople, analytical work to date does suggest a Constantinopolitan origin for the pottery, with the chemical compositions of White Ware samples excavated from Corinth and Constantinople being consistent with compositions of kaolinitic white clay from Arnavutköy on the Bosphorus used today in modern potteries (Megaw and Jones 1983, Chapter 3). The chemical analysis of a further 22 examples of White Ware from Corinth sampled for this study are consistent with the results published by Megaw and Jones (1983) showing high Al_2O_3 , and low Fe_2O_3 and CaO , and similarly point to a Constantinopolitan origin (see Table 9.2.1).

Though forming a cohesive chemical group (see Figures 8.3.1 and 8.3.2, Chapter 8), the petrographic analysis of the White Wares demonstrates the presence of three separate fabric types, the Altered Feldspar Groups A and B, and Fabric C. While they are clearly related by a common suite of mineralogical inclusions indicating the use of similar or same raw materials they are distinguished from each other by textural differences. These are interpreted as representing different methods of raw material processing and so reflect different paste-making traditions. While it may be argued that these differences reflect temporal variances within a single workshop, inspection of the styles present in each group would indicate contemporaneous production. Therefore, an alternative explanation is that the different fabrics correspond to the output of different Constantinopolitan workshops.

Analyses of the glazes of select examples of the White Wares have provided new information which contradicts previous conclusions regarding technological developments of glazing in the Byzantine World. Based on the analysis of four samples of White Ware glazes (including samples of yellow glaze from two Polychrome Ware sherds and two samples from Impressed Ware styles) Armstrong *et al.* (1997) reported the presence of high lead glazes only, leading to the assumption that similar high lead transparent glazes were used for Byzantine White Wares and Red Wares, with no difference in glazing technology apparent (Armstrong *et al.* 1997, 228-9). In contrast, the White Ware glazes analyzed for this research show *two* types of glazes were employed in the decoration of these vessels. They are a lead-alkali glaze and a high lead glaze.

The use of lead-alkali glazes are known from other contexts in the Byzantine world, specifically, on polychrome glazed wall plaques predominately used to decorate

religious buildings in the ninth to eleventh centuries. Find spots include fourteen sites in Constantinople, various locations in Bithynia (Haydarpasa, Nicaea/Iznik, Nicomedia/Izmut and Bursa amongst others) and in and around Preslav, Bulgaria (Mason and Mango 1995; Mango 2001). ICP-MS analysis of body compositions of wall plaques from the Constantinopolitan examples show a composition similar to the white clays from Arnavutköy on the Bosphorus, again indicating their manufacture in the locality (Vogt *et al.* 1997), while those from Preslav are compositionally distinct and considered to be manufactured in the region of Preslav (Vogt and Bouquillon 1996). Examples of glaze compositions are published by Vogt and Bouquillon (1996) and Vogt *et al.* (1997) and are presented in Table 9.2.2. Since the White Ware vessels were manufactured during the same period and region as the polychrome glazed wall plaques evidence of shared glazing technologies between the two similarly decorated ceramic bodies might be expected.

It is possible the high soda content of these glazes derives from the addition of plant ash to the glaze mixture. A significant amount of CaO was also detected. Given the low CaO content of the ceramic bodies (see Table 8.3.1, Group 1), its presence cannot be attributed to diffusion from the underlying ceramic. While CaO has the advantage of increasing the hardness and reducing the solubility of low firing glazes high in PbO and Na₂O (Rhodes 1973, 92), the use of plant ash as an alkali source would account for its presence rather than it representing a deliberate addition to the glaze mixture to exploit these properties. Its use would also account for the presence of K₂O and MgO (Sayre and Smith 1974). However, the solubility of plant ash in water would require that it was fritted with the other glaze constituents (SiO₂ and PbO) in order to prepare the glaze suspension (Tite *et al.* 1998, al-Saad 2002). The vitrified frit would be ground to form a powder and the powder mixed into slurry with water and applied. Theophilus (*De diversis artibus*, II-16), writing in the twelfth century does provide some clue to this process where it is stated:

“(The Greeks) also make pottery dishes...and they paint them like this. They take all sorts of colours and crush them separately with water. With each colour they mix a fifth part of glass of the same shade which is also reduced to a powder in water. With that they paint circles, arcs, rectangles, and within these, animals, birds, foliage or some other subject. When the pots have been painted like this they put them in a glass makers’ furnace...”

(cited in de Boüard 1974, 73).

This appears to be a description of the manufacture of polychrome pottery, and that the raw glaze components were pre-prepared (fritted) before being applied as a slurried powder.

While the lead-alkali glazes shows the use of a glaze mixture containing several components, and revealing a relatively complex fritting technology, investigation of the corresponding high lead glazes present on the White Wares indicate they were produced using the simplest route (see Figure 2.3.1, Chapter 2). The closeness in composition between glaze and body following removal of the lead component from the glaze compositions and normalizing the remaining element oxides to 100% point to the use of a PbO compound on its own (plus the colorants), or with some addition of clay of the same composition of the body, rather than the use of a PbO·SiO₂ mixture (see Figures 8.4.7 to 8.4.10, Chapter 8).

The analysis of glazes from the White Ware pottery class indicates that choice of base glaze (lead-alkali or the high lead type) was influenced by the required colour of the glaze. Colourless (present on Polychrome), turquoise (on Polychrome) and brown (on Polychrome and Plain Brown glazed wares) glazes belonging to the Altered Feldspar Group A were shown to have a lead-alkali base while the green (on Plain Green glazed and Impressed Wares) and yellow glazes (on Polychrome and Plain Yellow glazed wares) belonging to the Altered Feldspar Groups A and B were high lead glazes with < 1% Na₂O + K₂O content. Choice of glaze base being colour specific is most clearly demonstrated by the compositions of glazes present on the polychrome sherd 00/141, where both glaze types were found to occur on the same sherd (see Table 9.2.3). The high lead, yellow glaze on this sherd is further comparable in composition to the two polychrome yellow glazes analyzed by Armstrong *et al.* (1997) (see Table 9.2.3). Unfortunately, no compositional information is provided for the other glazes present on Armstrong *et al.*'s two sherds (green, brown/black and colourless) thus it is not possible to say if the results noted for sherd 00/141 are repeated.

Use of colorants for the high lead glazes was shown to be typical of medieval glazes (see Chapter 3). The greens and yellows were coloured by additions of CuO and Fe₂O₃ respectively with strength of colour determined by concentrations. Thus, the pale yellow glazes of the Slip Painted Ware contained 1.64 and 2.21 wt% Fe₂O₃, while the rich yellow glaze on the Polychrome sherd contained 4.22 wt% Fe₂O₃, and the pale

green tinted glazes of the Plain Green glazed and Impressed Ware samples contained <1 wt% CuO. CuO was also used as the colorant for the turquoise lead-alkali glazes, which shifts from green in a high lead glaze to blue (copper II oxide) in the presence of alkali (Weyl 1959, Rhodes 1973).

The brown/black glaze used to outline designs on the Polychrome styles is often considered to be produced using manganese (for example Sanders 2001). Manganese has been noted as the colorant for several examples of brown glazes on polychrome wall plaques from Constantinople and Preslav (Vogt and Bouquillon 1996, Vogt *et al.* 1997) and is noted from other Medieval contexts (for example the manganese brown/black outlines of the coloured glaze decorated '*Ceurda Seca*' ceramics from tenth century Spain (Perez-Arantegui *et al.* 1999)). However, analysis of the glazes from the two Polychrome samples showed that in these instances the brown/black outlines are coloured by high concentrations of Fe₂O₃ with only minor amounts of MnO present. While iron oxide is readily soluble in glaze, Rhodes (1973, 208) notes its tendency to crystallize out upon cooling if present in considerable quantities and inspection of the microstructures of these glazes show that this has occurred (Figure 8.4.3, Chapter 8), with the Fe-rich crystals contributing to the dark, matt appearance of the glazes.

The transparent brown glaze of the Plain Brown Glazed example shows a different composition with a lower Fe₂O₃ concentration but also a significant amount of CuO, and is similar in composition to an example of a brown glaze from a Constantinopolitan polychrome wall plaque analyzed by Vogt and Bouquillon (1996) (see samples 00/160 and AC85, Table 9.2.2). In the concentrations present the CuO contents must be considered as deliberate additions to the glaze mixtures. While Fe₂O₃ on its own will produce an amber to brown colour in concentrations of 4 to 6% (Rhodes 1973), the addition of CuO to the glaze mixture could also contribute to the tone. In a reduced state CuO gives a red to brown colour in a glass or glaze with reduction being achieved through the addition of reducing agents to the glaze batch and firing in an oxidizing atmosphere, or through firing in a reducing environment (Weyl 1959, Rhodes 1973, Parmelee 1973). The white to pink colour of the ceramic fabric of the Plain Brown Glazed sherd (00/160) is indicative that it was fired in an oxidizing atmosphere, it is therefore likely the CuO was internally reduced. A precedent for the reduction of CuO using FeO in the form of magnetite (Fe₃O₄) is known from experiments in the manufacture of ruby (colloidal) glass using a potash-lead oxide-silica glass base (see

Weyl 1959, 424). Fe_3O_4 contains both Fe^{2+} and Fe^{3+} ions and can be thought of as " $\text{FeO}\cdot\text{Fe}_2\text{O}_3$ " (therefore a 1:1 molar ratio of iron (II) oxide and iron (III) oxide), so that only the FeO part is active in the reduction reaction. It is thus possible the brown tone observed on the sherd was produced by the addition of FeO and CuO to the glaze mixture, with the iron and copper oxides undergoing a redox reaction during firing to form Fe_2O_3 and Cu_2O . It should be noted that if this was indeed the reaction occurring then the copper oxide should correctly be presented as Cu_2O rather than CuO as is traditionally used in glaze composition tables.

9.2.2 Plain Brown Glazed Red Wares

The analysis of the Plain Brown Glazed Red Ware ceramic fabrics revealed the presence of five types of fabric which were distinguished by the use of different clays and tempering materials, with only two attributed to local manufacture. These are the Coarse Mudstone-Chert Class (containing Group A and Fabric B, and including chafing dishes of eleventh century form) and the Quartz-Chert-Micrite Fabric, represented by one example of an early twelfth century chafing dish.

The Coarse Mudstone-Chert Class is characterised by the use of an Fe-rich, red firing clay. Group A is tempered with common radiolarian chert and mudstone, and few micrite. Fabric B is differentiated by predominant mudstone, and very rare radiolarian chert, monocrystalline quartz, micrite and serpentinite temper. In addition it has higher CaO and Sr contents than observed for Group A and so is considered chemically distinct (see Sections 8.2.2.2 to 8.2.2.4 and Section 8.3.4.7). The differences in the chemical compositions and fine fraction components of the fabrics (see Sections 8.2.2.2 and 8.2.2.3) between Group A and Fabric B are suggestive of the use of two different clays in the manufacture of this pottery. Nonetheless, the broadly similar manufacturing technology (the use of a red-firing clay with the addition of a coarse temper including mudstone, chert and micrite in varying proportions) shows a common manufacturing tradition.

The local manufacture of the Coarse Mudstone-Chert Class is demonstrated by a number of features. Though the majority of known usable clays in the Corinthia are calcareous and pale firing, clay surveys carried out in the region have shown the existence of deposits of non-calcareous, Fe-rich clays as well as usable red-firing clays deriving from the abundant *terra rossa* soils present in the region (see Chapter 5). Of

particular interest is Whitbread's Clay 3, taken from the terraces west of the village of Anaploga, which lie between Acrocorinth and Ancient Corinth (see Figure 5.3.2). Naturally coarse, the clay contains inclusions of radiolarian mudstone, micrite and microsparite, orthopyroxene, and radiolarian chert, very rare plagioclase and serpentinite with silt-sized monocrystalline quartz, white mica and radiolaria (Whitbread 1995, 332). Thus the inclusions present in the Coarse Mudstone-Chert Fabric Class are consistent with those found in clays known in the area. In addition, the use of mudstone as a tempering material is characteristic of ceramics attributed to a Corinthian origin. Previously reported examples include Type A and A' amphorae, roof tiles (ceramic tile production at Corinth is attested by the discovery of the Tile Works operating from the mid sixth to early fourth centuries BC (Weinberg 1957)), and architectural terracottas (Farnsworth 1964, 1970, Whitbread 1995). Moreover, mudstone is readily available, with mudstone, radiolarian mudstone and mudstone breccia occurring in the shale-sandstone-radiolarite formation cropping on the southern and western edge of Acrocorinth and Penteskouphi, and with notable mudstone exposures present on the upper end of the road to Acrocorinth (Whitbread 1995, Chapter 5). As a note, Farnsworth (1970) described the inclusions in her fabrics as 'hornfels', a metamorphic rock derived from the thermal metamorphism of shale and mudstone, and sourced them to the upper end of the road from Ancient Corinth to Acrocorinth. Study of this material in thin section has since demonstrated a lack of recrystallization that would be evidence of thermal metamorphism, thus the argillaceous rock fragments common in Corinthian ceramics should be referred to as mudstone and not hornfels (see Whitbread 1995, 334-335 for full discussion).

Local manufacture of Quartz-Chert-Micrite fabric is most strongly demonstrated by the sherd (00/128) being an unglazed, biscuit fired waster (Appendix II.2), and the inclusions (mono- and polycrystalline quartz, radiolarian chert and micrite) are consistent with the local geology. The fabric reflects a manufacturing technology different than that observed with the Coarse Mudstone-Chert Class and is characterised by the use of a pale firing, calcareous clay, mixed with an iron rich clay component demonstrated by the presence of dark orange red clay striations and rounded clay pellets. Moreover, while tempered, the choice of tempering materials is differentiated by the absence of the mudstone component. Therefore, this sherd can be considered a product of a separate workshop.

Relevant to the discussion on the Byzantine glazed coarse wares manufactured at Corinth in this period are the contemporary cooking wares analysed by Joyner (1997, 2007). Using ceramic petrography she identified four major fabric classes dating from the late eleventh to twelfth centuries (Joyner 1997, 82). These are the Sandstone Fabric Class, Mudstone (well-fired) Fabric Class, the Chert and Quartz Fabric Class and the Quartz-Mudstone-Chert Fabric Class. The Quartz-Mudstone-Chert Fabric Class is the most interesting, described as a very broad and complex fabric group, not very well constrained and containing many different inclusion types with no one type being dominant. The inclusions include common quartz, chert and mudstone in addition to sandstone, polycrystalline quartz and calcimudstone (Joyner 1997, 85; 2007, 197). It is believed that the Coarse Mudstone-Chert Class identified in the chafing dish samples analysed here are related to Joyner's Quartz-Mudstone-Chert Fabric (Figure 9.2.1), and belong to this same tradition of Byzantine cooking ware manufacture at Corinth.

The remainder of the chafing dish fabrics proved to be non-local in origin demonstrated by the metamorphic character of their inclusions which are inconsistent with the sedimentary geology of the Corinthia. These include the Argillaceous Rock Fabric, the Muscovite-Schist Class comprising Fabric Group A and Fabric B and the Fine Muscovite-Biotite Fabric. Despite each fabric containing inclusions suggesting they derive from a metamorphic environment, the differences in their mineralogical and textural characteristics indicate they originated from different sources and represent different manufacturing technologies. The main variations between each fabric types are highlighted in Table 9.2.4.

Given the paucity of petrographic or chemical analysis of comparative material from other Byzantine sites there is little information available against which to test the provenance of these sherds. However, a tentative suggestion for provenance may be made for the Muscovite-Schist Fabric B. The range of inclusions observed in this fabric are similar to those noted in 'Barbarian' ware from the Menelaion, Sparta analysed by Whitbread (1992). Most of his fabrics contained metamorphic rock fragments including schist (quartz-biotite, quartz-white mica, white mica-biotite, quartz-white mica +/- black opaques and white mica-biotite +/- black opaques) and phyllite (white mica, biotite and biotite-quartz) in varying proportions (Figure 9.2.2). Limestone (micritic and crystalline), polycrystalline quartz described as having coarse sub-grains in a cherty matrix, and chert were also found to be commonly present while some fabrics contained

in addition sandstone, siltstone and mudstone, or plagioclase and epidote. The tentative link is based upon the presence of schists, in particular those containing the black opaques, and the chert and micrite components.

Sparta, situated on the River Evrotas in the southern part of the Peloponnese, is considered to be the second most important economic centre in the Peloponnese after Corinth from the tenth century and is noted as an important trade centre involved in regional and interregional trade in the eleventh and twelfth centuries (Harvey 1989, Laiou 2002b). Though scant, evidence for ceramic production at Sparta in the Byzantine period does exist in the form of tripod stilts and unglazed, biscuit-fired wasters of late twelfth century Sgraffito decoration, while glazed ceramic evidence from the eleventh century shows a similar pattern to Corinth with Constantinopolitan White Wares and Plain Brown Glazed Red Wares both recorded (Sanders 1993, Bakourou *et al.* 2003, Dimopoulos 2007). While no petrographic fabric descriptions for the Plain Brown Glazed examples from Sparta are available, the macroscopic fabric description presented by Sanders (1993, 255) suggests a 'schisty' character by the presence of sparkling inclusions which would be consistent with local manufacture. Armstrong *et al.* (1997) provide the chemical composition (major and minor elements only) for a twelfth century example of Green and Brown Painted Ware believed to be of local (Spartan) manufacture, the fabric of which is described as coarse textured and micaceous. Comparison between this sample and the Muscovite-Schist Fabric B show chemical compositions are not consistent, with the most significant difference noted in CaO concentrations (see Table 9.2.5). Nevertheless, this does not negate the hypothesis presented since the evidence from Corinth demonstrates local products pertaining to the eleventh and twelfth centuries have differing chemical compositions, dependant upon raw material selection and paste preparation methods.

Glazed pottery as a trading commodity is demonstrated by the presence of the White Wares at Sparta, thus, it is conceivable that as well as importing ceramic goods, Plain Brown Glazed wares manufactured at Sparta were traded to Corinth during the eleventh century.

In contrast to the White Wares where coloured glazes were used to decorate table ware, the glaze layer of the Plain Brown Glazed pottery is traditionally thought of in functional terms, employed principally to provide a waterproof surface to vessels

(Sanders 2003, see Chapter 6). If decorated, the decoration would mainly occur on the underlying vessel itself in the form of incising, or applied plastic decoration (for example Morgan 1942, 38-40; Sanders 1995, 62). The glazes from nine sherds were analysed with each of the fabric groups represented. The results demonstrate the use of the high lead glaze type only. The closeness in glaze and body composition (following data reduction) of both the locally manufactured and imported chafing dishes is indicative that the glazes were produced in a similar manner to the high lead glazes of the White Wares with the use of a PbO compound on its own or with some addition of clay of the same composition of the body, rather than the use of a PbO·SiO₂ mixture (see Figures 8.4.7 to 8.4.10, Chapter 8). This is supported by the appearance of certain examples of Plain Brown Glazed ware from Corinth, where unglazed “shadows” have been noted below overhanging features on the vessels, such as the interior ledge of chafing dishes or under handles of pitchers or jugs (Sanders 1995, 61). This would indicate that in these instances the dry, powdered flux (PbO) was dusted over the surface in the method described by Eraclius (see Chapter 2). The appearance of the glazes of these examples however, have been described as “uneven, patchy and sometimes quite rough” (Sanders 1995, 61), which is in contrast to the appearance of the samples analyzed where the surfaces of the vessels were well covered by the glaze suggesting the PbO was mixed with water and applied as a solution.

The colour of the glazes of the Plain Glazed vessels are yellow to amber and rarely tinted slightly green and some comments have been made regarding their manufacturing technology. Morgan (1942, 36), for instance, states that:

‘The transparent lead glaze seems to have been tinted with some form of iron oxide to give it a slightly yellowish tone. The frequent occurrence of tinges... of green show that a little copper oxide was added.’

While Sanders (2003, 391) states that:

‘...these vessels were dipped in a solution of yellow glaze, producing a dark thick glossy finish over the red or black-fired biscuit.’

These statements imply that the glazes were intentionally coloured with colorants deliberately added to the raw glaze mixture. However, the biplot comparing Fe₂O₃ compositions in body and glaze shows that in nearly all cases there is a close match in Fe₂O₃ content between glaze and body (Figure 8.4.8, top left, Chapter 8), suggesting the Fe₂O₃ present in the glaze derived from the underlying ceramic and not as part of the original raw glaze mixture. Three cases can be noted in which the Fe₂O₃ levels are

slightly elevated in the glaze following data reduction. They are the glazes of sherds 00/125 (Coarse Mudstone-Chert Fabric B), 00/127 (Fine Muscovite-Biotite Fabric) and 00/124 (Muscovite-Schist Fabric B). This may indicate a little Fe_2O_3 was added to the glaze mixture, perhaps introduced in the form of Fe-rich clay.

The green tinge noted in some of the glazes may also derive from Fe_2O_3 diffused from the underlying ceramic rather than representing additions of CuO to the raw glaze mixture. Where concentrations of Fe^{2+} are greater than Fe^{3+} in a glass or glaze a green colour ensues. The reduction of iron to its divalent state occurs when a glass or glaze is melted in a reducing environment and the common dark grey colour of the fabrics observed (Morgan 1942, Sanders 1995, see also Appendix I for Munsell colours of Plain Brown Glazed sherds sampled) demonstrate that kiln conditions were indeed often reducing. Therefore, based upon these observations it is suggested that the glaze colour on this class of pottery is in the main incidental, resulting from the diffusion of iron oxide into the glaze from the underlying ceramic fabric and is dependant upon kiln conditions, and does not reflect a deliberate attempt by the potters to produce coloured glazes.

9.3 Late Eleventh to Twelfth Century Decorated Wares

At the end of the eleventh century/beginning of the twelfth century the glazed ceramic assemblage at Corinth underwent a major change. White Wares ceased to be imported while the coarse Plain Brown Glazed Red Wares went out of fashion at the same time as glaze and slip decorated Red Wares were introduced into the ceramic repertoire in forms previously only seen in the Constantinopolitan fabrics (Chapters 4 and 6). The dramatic stylistic shift in glazed pottery at Corinth during this period raises the question of whether or not a change is also reflected in the production technologies of the pottery. Did the manufacturing methods used in the production of the earlier Plain Brown Glazed pottery continue with the production of the new styles of pottery or were new technologies introduced? If new technologies were introduced is it possible to identify technological influences from either the earlier White Ware imports or from contemporary Red Ware imports? An attempt is made to answer these questions by characterizing the production technologies of the locally produced glazed pottery occurring at Corinth in the twelfth century and comparing them with those identified for the eleventh century and glazed pottery imports from the twelfth century.

9.3.1 Locally Produced Glazed Pottery

Three different fabrics attributed to manufacture at Corinth during this period were identified. These are the Quartz-Chert Fabric, the Medium Coarse Mudstone-Chert Group and the Clay Temper Group. Time limitations on analytical equipment meant that compositional analysis of glazes was focused on the main fabric group only (the Clay Temper Fabric) (see Chapter 7), meaning that glaze technology cannot be discussed for the remaining fabrics. Nonetheless, it is worth including them in the discussion as some observations may be made regarding organization of glazed pottery production at Corinth during this period based upon fabric type.

The Quartz-Chert Fabric is characterised by the use of an iron-rich, red firing clay with a relatively high CaO content (see Appendix IX) tempered with coarse inclusions of mono- and polycrystalline quartz and chert, while the fine fraction comprises monocrystalline quartz, and red and white mica silt. The Medium Coarse Mudstone-Chert Group is also characterised by the use of an iron-rich, red firing clay though with a lower CaO content (see Appendix IX) while coarse tempering materials consist of chert, mudstone and monocrystalline quartz and the fine inclusions comprise silt-sized monocrystalline quartz, chert, red and white mica and plagioclase. The chemical differences and differences in fine fraction of the fabrics suggest the use of distinct clay sources in the manufacture of the pottery. The two fabrics are represented by the Slip Painted Light on Dark I style exclusively, dating their manufacture to the late eleventh/early twelfth century and can be related through similarities of inclusions to the locally produced chafing dish fabrics of the eleventh century and to coarse cooking ware fabrics identified by Joyner (1997, 2007) dating to the eleventh and twelfth centuries. For instance, the Medium Coarse Mudstone-Chert Group, though finer, shows a similar range of inclusions to the Coarse Mudstone-Chert Class containing chafing dish examples sampled for this study, and also to Joyner's Quartz Mudstone Chert Fabric discussed above (Section 9.2.2).

No counterpart was identified for the Quartz-Chert Fabric in the eleventh century wares sampled for this study, however, Joyner identified a Chert and Quartz Fabric Class described as containing a preponderance of angular monocrystalline quartz fragments with less dominant chert in cooking wares belonging to the eleventh century (Joyner 1997, 84; 2007, 194) (Figure 9.3.1). These examples indicate that in these cases similar manufacturing technologies for ceramic pastes employed for the coarser utilitarian

wares were also employed in the production of these early decorative wares, perhaps suggesting they were produced in the same workshops as the cooking wares.

Despite the differences between the Medium Coarse Mudstone-Chert Group and Quartz-Chert Fabric showing the use of different raw material resources and distinct paste-making recipes, the samples are stylistically similar. This is most clearly demonstrated by comparing the decorations of sample 00/52 (Quartz-Chert Fabric) and 00/54 (Medium Coarse Mudstone-Chert Group), where the same slip decorations appear on examples belonging to each fabric type (see Figure 9.3.2). The similarity of decoration is striking and most probably reflects close imitation between potters working in different workshops at Corinth during the same period.

A final observation is that no later styles of glazed pottery were identified in these two fabric types. While this may be a product of insufficient sampling, it may also be an indication that these fabrics went out of use early in the twelfth century for the manufacture of decorated tablewares.

The main local fabric type identified for the twelfth century is the Clay Temper Group. The samples form a cohesive chemical group (Group 6, Chapter 8), characteristically high in CaO and compositionally similar to Byzantine unglazed wasters excavated from the Corinth Agora and analyzed by Megaw and Jones (1983) (see Table 9.3.1). In addition, the high calcium content is consistent with calcareous clays from the vicinity of Corinth analyzed by Farnsworth *et al.* (1977) which were found to contain approximately 20% CaO (Chapter 3). The strongest evidence that this group was manufactured at Corinth, however, is that it contains a number of unglazed, slip decorated biscuit-fired wasters (for example, see Appendix II.22).

The characteristic petrographic features of this fabric are the presence of common red clay pellets and striations indicating the incomplete mixing of a calcareous clay with an Fe-rich clay. The fabric group is divided into three sub-groups based upon texture which range from Sub-Group A1 containing inclusions up to coarse sand-sized to Sub-Group A3 where inclusions are predominantly coarse silt-to fine sand-sized (see Appendix IV and Figures 8.2.14 to 8.2.16). The unimodal grain-size frequency distribution of inclusions in Sub-Group A1 is indicative that the inclusions are naturally occurring in the clay rather than representing temper additions and so point to the use of

clays in their natural state. The finer version, Sub-Group A2, shows some refinement of the raw materials while Sub-Group A3, the most fine, is likely to represent use of the same but levigated clays. The refinement of the same raw materials is supported if the compositional means of each sub-group are considered. Table 9.3.2 shows that while each sub-group share a very similar chemistry, Sub-Group A1 has the lowest concentrations of the majority of elements, Sub-Group A3 has the highest concentrations of the majority of elements and Sub-Group A2 fall in between, so demonstrating the “dilution effect”. The dilution effect may be summarized as the effect on paste composition by changing proportions of aplastic inclusions, especially if poor in trace element concentrations, either naturally occurring in the raw clay, removed through processes such as levigation or added as a temper. All element concentrations contained in the paste but not in aplastic components may show a uniform increase or decrease in concentrations depending on methods of clay processing (Schwedt and Mommsen 2004, 1252). Therefore, Sub-Group A1, containing common coarse inclusions of quartz and chert which are poor in trace element components show a “diluted” composition in comparison to the finer versions of the fabric where the coarse components have been removed.

The coarse A1 group contains styles attributed to the late eleventh/early twelfth century (Green and Brown Painted I, and Slip Painted Light on Dark I and Slip Painted Dotted) and the first half of the twelfth century (Spatter Painted Ware), the intermediate A2 group contain styles attributed to the early twelfth century (Green and Brown Painted I), the second quarter to mid twelfth century (Green and Brown Painted II and Sgraffito Measles) and the mid twelfth century (Slip Painted Dark on Light), while the refined A3 group contains styles attributed to the second quarter to mid twelfth century (Sgraffito Measles) and the second quarter to late twelfth century (Sgraffito Style II) (see Figure 9.3.3). This trend appears to show a preference for a finer paste as the twelfth century progressed. No later (thirteenth century) pottery styles were detected in this fabric type. It is unclear whether this suggests the pottery workshop manufacturing these glazed wares went out of production at the end of the twelfth century or whether it continued but with potters using new raw materials and paste-making recipes (see Section 9.4 below).

In comparing the Clay Temper Group with the Plain Brown Glazed Ware fabrics discussed above and with eleventh to twelfth century cooking ware fabrics from Corinth

identified by Joyner (1997, 2007) it is observed that the method of paste preparation (the mixing of calcareous and Fe-rich clays) may be related to the Quartz-Chert-Micrite Fabric which contains the single sample of chafing dish of early twelfth century form. Though the Quartz-Chert-Micrite Fabric is coarser, with the bimodal grain-size frequency distribution indicating the addition of temper, the presence of red clay pellets similarly demonstrates the incomplete mixing of calcareous and non-calcareous clays. It cannot be ascertained whether or not the Quartz-Chert-Micrite and Clay Temper fabrics represent products from the same workshop, with paste variation (the presence or absence of temper) related to vessel function, nevertheless, a shared knowledge of clay-mixing and use of common or similar resources is displayed.

It is important to highlight that the use of a mixture of calcareous and non-calcareous clay marks a divergence from raw material use and paste preparation technology identified in the chafing dish fabrics of the eleventh century, and no similar fabrics were identified in the coarse eleventh to twelfth century cooking ware fabrics identified by Joyner (1997, 2007). This supports the hypothesis presented in Chapter 4 that there was a separation of the production of coarse (cooking) and fine (glazed) wares at Corinth during the twelfth century with a move towards the specialization of production of glazed wares.

The glazes from seven of the sherds belonging to the Clay Temper Group were analyzed with examples from each of the styles Green and Brown Painted I and II, Slip Painted Light on Dark I, Slip Painted Dark on Light, Sgraffito Measles and Sgraffito Style II ensuring the chronological range was represented. The results establish the use of the high lead glaze type. Comparison of glaze and body compositions following data reduction revealed a disparity in composition between glaze and body. SiO_2 contents of the glazes were higher in the glaze, while the remaining element oxides were higher in the body (see Figures 8.4.7 to 8.4.10, Chapter 8). This pattern strongly suggests the glazes were produced using a $\text{PbO}\cdot\text{SiO}_2$ mixture (see Chapter 2), revealing the use of a new method of glaze manufacture at Corinth introduced with the Clay Temper Group, and which appears to be standard from the inception of production to the time this fabric goes out of use in the late twelfth century.

The colorants found to be present in yellow and green glazes are again typical of medieval glazes. Thus, the yellow glazes were coloured by additions of Fe_2O_3 , and

green glazes by additions of CuO. Some differences were noted in use of colorants for brown glazes between different decorative groups. The brown glaze of Green and Brown Painted I (sample 00/04) was found to contain 5.31 wt% Fe₂O₃ in addition to 1.16 wt% CuO. While it is possible that the presence of CuO may be explained by diffusion from green glazed areas on the same sherd, the composition is strikingly similar to that identified on the brown glazes identified on the White Ware examples discussed above (see Table 9.2.2, Section 9.2), supporting the hypothesis that combinations of Fe₂O₃ and CuO were deliberately used to produce browns. The brown glaze of the slightly later style Green and Brown Painted II (sample 00/07) shows a lower Fe₂O₃ content in addition to minor amounts of MnO. Since the colourless and green glazes present on the same sherd contain only trace amounts of MnO (see Table 8.4.7) its presence in the brown glaze is considered a deliberate addition. The use of iron and manganese to obtain brown in glass is well known. During melting manganese acts as an oxidizing agent changing FeO into Fe₂O₃, while the higher oxides of manganese are reduced to MnO (Weyl 1959, 116; Biek and Bayley 1979, 15). Thus, while it is demonstrated that a new base-glaze recipe was introduced with the Clay Temper Group which remained standard for the duration of production, and colorants used for the manufacture of green and yellow glazes were typical and show no change, the results demonstrate a change in the methods used to produce brown glazes within the workshop.

9.3.2 Imported Pottery of the Twelfth Century

Petrographic analysis revealed a second important fabric class (the Phyllite Class) containing 50 samples. Stylistic evidence shows its occurrence at Corinth from the late eleventh/early twelfth century and lasting throughout the century in addition to occurring in some styles belonging to the first part of the thirteenth century (for example Aegean Ware and Champlevé, see Section 9.4.3 below). It is a complex, heterogeneous fabric group showing many textural variations, but nonetheless having a common range of coarse inclusions which include phyllite, fine-grained schist, polycrystalline quartz with metamorphosed structures, chert, plagioclase and serpentinite. Despite the fact that distinct end-members do exist, a gradation in texture is present so that no clear breaks could be made to form separate sub-groups. This observation is supported by the absence of any correlation between the fabrics and archaeological divisions (stylistic or chronological) of the samples (see Chapter 8.2 and Appendix IV). The group is therefore considered to represent products of a single

region of production, though the meaning of the variation in texture is unclear. It may relate to natural variations within a clay source, the exploitation of several similar clay deposits, or differences in the processing of raw material resources by the potters.

Despite the textural variations, all samples belonging to the Phyllite Fabric Class form a cohesive chemical group with low internal variation (Chapter 8) supporting the idea that they are strongly related and derive from a single source. While it has previously been established that usable Fe-rich clay, low in CaO are present in the vicinity of Corinth, the presence of inclusions of phyllite, fine-grained schists and metamorphosed polycrystalline quartzes are inconsistent with a Corinthian origin and indicate this group originated from a metamorphic environment so suggest the pottery to be imported.

A comparison of stylistic categories occurring in this and the contemporary local Clay Temper Group shows an interesting trend. Both fabric types appear at Corinth at the end of the eleventh/beginning of the twelfth century. Initially, a common range of styles are present in each fabric. These include Spatter Ware, Green and Brown Painted I, Slip Painted Light on Dark I and Slip Painted Dotted ware (see Figure. 9.3.4).

Nonetheless, first indications suggest that the stylistic categories of the locally produced and imported wares have distinct attributes, for example, on local Slip Painted Light on Dark I decorated examples a coloured over-glaze was employed, where the imported examples are covered with a colourless glaze. Also, the dotted decorations of the Corinth examples of Light on Dark Dotted style are arranged in rows in contrast to the imported example where the dots are randomly orientated (this is represented by one or two samples only, and further sampling may elucidate whether or not this pattern can be substantiated). Towards the second quarter to mid twelfth century there appears to be a divergence of styles, with Dark on Light Slip Painted wares, Sgraffito and Sgraffito Measles occurring in the Clay Temper Group, while developed Green and Brown Painted Styles (Style III and Spiral), Slip Painted Light on Dark II, Sgraffito and Painted Sgraffito styles occur in the Phyllite Group. Thus it appears that in the early decades of the twelfth century potters from different production sites were producing pottery with common decorative themes. However, as the century progressed potters from each location seem to specialize in specific decorative repertoires.

There is at present a general paucity of petrographic or chemical analyses of relative material from other Byzantine sites against which to test the provenance of the Phyllite Group. Comparison with chemical reference groups of pottery from known Byzantine

productions sites (for example Lapithos, Lemba, Thessaloniki, Athens, Dhiorios and Kounoupi (Megaw and Jones (1983)) show no chemical match suggesting these sites may be ruled out as the source for the Phyllite Group at this time.

The similarity in decoration between pottery belonging to the Phyllite Group and pottery recovered from surface surveys in Boeotia, however, is striking and appears to link the imports at Corinth to these finds. For example, common types noted by Vroom (2003) include Slip Painted Light on Dark Dotted and Light on Dark II, Green and Brown Painted III and Spiral, Sgraffito and Painted Sgraffito (see Table 9.3.3), while the Dark on Light Slip Painted and Sgraffito Measles present at Corinth are conspicuous by their absence (Vroom 2006, pers. com.). Moreover, like the sherds recovered from Corinth, Vroom's fabrics are described as having an orange to deep orange red colour (Vroom 2003, 150-153). Though archaeological evidence for production of pottery in this region is scarce (to date only one kiln site of a slightly later thirteenth century date near the modern village of Askra is known), the abundance of the fabrics lead Vroom to suggest they were produced in the region rather than imported from elsewhere (Vroom 2003, 261).

Schwedt *et al.*'s (2006) publication on Hellenistic pottery from Boeotia provides chemical information of pottery that originated from within Vroom's study zone and so provides some chemical data for comparison with the Phyllite Group/Group 8. Samples belonging to Schwedt *et al.*'s Chemical Group L derive mainly from Aliartos and Akraiphnion. Aliartos is approximately five miles to the north of Askra. It can be seen from Table 9.3.4 that while major elements are comparable, there are some differences in the trace element concentrations, for example Cr concentrations are slightly higher in the Hellenistic pottery group. Nevertheless, prior studies demonstrate that chronologically distinct wares from a single production centre may have unique chemical characteristics (for example Waksman *et al.* 2006, see Chapter 3) and so the comparison of chemical data is inconclusive.

Examination of the geology of the area may, however, reveal a tentative geological association. Vroom's study area falls within the geological Zone of Boeotia (see Figure 9.3.5). The zone consists of boeotitic flysch, characterised by bands of fine schists, radiolarite, red clay and sandstone with intrusions of breccia and conglomerates

(Clement 1971, Katsikatsos 1992). It is therefore possible the inclusions of phyllites and fine-grained schists noted in the Phyllite fabric derive from the flysche formations.

In Chapter 4, it was established that Corinth was an important commercial and economic centre involved in regional and interregional trade during the Byzantine period, and that glazed pottery was a commodity that was manufactured for local consumption and possibly export as well as being a trade article that was imported. A regional infrastructure was certainly in place that would allow for the movement of ceramic goods from Boeotia to Corinth by road or sea. For example, the most important road in Boeotia linked Lamia to Thebes, and from south of Thebes branched to Corinth or Athens (Vroom 2003, 249) (Figure 9.3.6). The traveller Benjamin of Tudela, who made the journey from Otranto, Italy to Thessaloniki during the mid twelfth century, took three days to pass between Corinth and Thebes (Avraméa 2002). Thebes was also linked to the Gulf of Corinth with a road to the minor port of Livadostro. From there a short sea journey could be made to the Corinth harbour of Lechaion. Thus it is no surprise to find pottery from the area in Corinth.

The glazes from twelve of the sherds belonging to the Phyllite Fabric Class were analysed, with examples from the styles of Green and Brown Painted I, III and Spiral, Slip Painted Light on Dark Dotted and Light on Dark II, Sgraffito Style II and Painted Sgraffito, and Aegean Ware represented. The glazes were found to be the high lead type only, while data reduction revealed that like the locally manufactured pottery of the end of eleventh to twelfth centuries, the raw glaze was applied as a $\text{PbO}\cdot\text{SiO}_2$ mixture (see Section 8.4.3).

A limited range of colours (yellow, green and brown) were used for decorations of this group. CuO was determined to be the colorant for green glazes, with level of concentration determining strength of colour, while yellow glazes were shown to be coloured by the presence of Fe_2O_3 . However, a range of methods of producing browns were detected. The dark brown/black glaze decoration of the Green and Brown I example was found to be coloured by a mixture of CuO and MnO , a combination which is utilized to produce brown glazes today (for example Rhodes 1973, 218). The same combination was found in the slightly later Green and Brown Painted III, however, a second example of the same style was determined to be coloured using only MnO . The lighter browns of the contemporary Green and Brown Painted Spiral Ware were

coloured by Fe_2O_3 only, and the dark brown of the Painted Sgraffito coloured by increased concentrations of Fe_2O_3 . Therefore, in common with the glazing technologies identified for the Corinthian Clay Temper Group, a $\text{PbO}\cdot\text{SiO}_2$ mixture was employed as a base glaze, coloured green with CuO and yellow with Fe_2O_3 , while a range of methods were utilized to produce brown glazes.

9.4 Pottery of the Late Twelfth and Thirteenth Centuries

There was a steady increase in the amount of glazed pottery occurring in the ceramic assemblage at Corinth throughout the twelfth and thirteenth centuries (see Chapter 4). Common to other sites across Greece during the thirteenth century, Corinth saw the importation of a greater range of glazed pottery types, including Aegean and Zeuxippus Wares, Protomaiolica and towards the end of the thirteenth century, Veneto Ware. For Corinthian pottery, glaze and decorative designs are considered generally coarser in comparison to the twelfth century pottery, and are thought to represent crude imitations of the imported wares (for example Morgan 1942, 81; MacKay 2003, 404).

9.4.1 Locally Manufactured Pottery of the Late Twelfth and Thirteenth Centuries

Two fabrics that were compatible with local geology and were therefore determined to be of local origin. These are the Micaceous Siltstone-Sandstone Group A and the Micaceous Siltstone-Sandstone Group B. Provenance determination for the Fine Quartz-Micrite Fabric is more ambiguous, nevertheless certain attributes suggest it should be included within the “local” category.

The Micaceous Siltstone-Sandstone Group A is a small but interesting group. It comprises exclusively examples of Green and Brown Painted V(I) dating it from the first third of the thirteenth century (see Chapter 6). It is related chemically to the Clay Temper Group of the twelfth century clustering with Chemical Group 6 (Section 8.3.4.6 and Figure 8.3.1, Chapter 8), while petrographic examination confirms the use of the same or similar clay source to the Clay Temper Group (see Section 8.2.12.3). However, rather than displaying evidence of clay mixing as identified in the Clay Temper Group, the Micaceous Siltstone-Sandstone Group A contains coarse inclusions of micaceous siltstone and sandstone, with the clear bimodal grain-size frequency distribution demonstrating their addition as a temper, and highlighting the introduction of a new paste-making recipe for glazed wares at Corinth. Siltstone and sandstone are readily available as a raw material in the region, occurring in the shale-sandstone-

radiolarite formation which outcrops on Acrocorinth and Penteskouphi amongst other locations on the Corinthia (Whitbread 1995, see also Chapter 5). Furthermore, sandstone inclusions have previously been noted in ceramics from Corinth in the Byzantine and early Frankish periods. In particular, Joyner (1997, 2007) describes a similar fabric used for cooking wares dating from the eleventh century to c.1260 that has erratically distributed, rounded sandstone grains containing flakes of biotite mica, and smaller grains of quartz and chert in an optically active micromass (Figure 9.4.1). This may therefore indicate a known clay paste recipe utilized for Corinthian coarse wares was adapted for the production of glaze decorated table wares at this date.

The glaze of one example from this group was analyzed. Results show the use of a high lead glaze. Comparison of glaze and body composition following data reduction revealed a similar pattern to the twelfth century glazes with higher silica in the glaze in contrast to the body, while the remaining element oxides were higher in the body in contrast to the glaze, indicating the glaze was prepared and applied as a $\text{PbO} \cdot \text{SiO}_2$ mixture (Figures 8.4.7 to 8.4.10).

Green and Brown Painted V(I) pottery is decorated with pale brown glaze spots over a white slip background with a colourless overglaze (see Chapter 6 and Appendix II.33). Analysis of the brown glaze area revealed more or less equal amounts of Fe_2O_3 and MnO , with low concentrations accounting for the weak colour of the decorations (see Table 8.4.7).

This group of pottery belongs to the period of pottery production at Corinth which Morgan suggested was represented by debased manufacturing technologies. He states, for example, that while the buff-and-salmon tones of the fabrics indicate the exploitation of the same clay beds used in the twelfth century, the coarseness demonstrates the clay was less well processed. Moreover, the fact that edges of coloured designs frequently bleed into the overglaze demonstrate that decoration and glazing were carried out at the same time and that the vessels were subject to a single firing (Morgan 1942, 81). The analytical results of fabric and glaze indicate that this can no longer be held true. While petrographic and chemical evidence do indeed suggest that the similar clay beds were exploited for the manufacture of the twelfth century Clay Temper Group and this thirteenth century Micaceous Siltstone-Sandstone Group A, the coarse texture of fabric reflects a deliberate choice by the potters

manufacturing this ware, where siltstone and sandstone temper were added to manipulate paste texture, rather than it representing the use of clay in an unprocessed state. Glazes were applied as mixtures of $\text{PbO}\cdot\text{SiO}_2$ in the same manner as twelfth century glazing, and though it is acknowledged that it is problematic to determine the practice of single or double-firing procedures based upon extent of glaze/body interaction (see Chapter 2), the lack of interaction between glaze and body observed in the sample analysed may indicate that glazes were applied to biscuit-fired bodies. This, however, can only be substantiated in the future if unglazed biscuit-fired wasters in this fabric are recovered from Corinth. Thus, while the vessels are visually coarser with thicker walls and more crude decorations in comparison to the twelfth century fine wares, this does not reflect a loss of technological knowledge, but rather reflects deliberate technical choices made by the potters.

The Fine Quartz-Micrite Fabric contains a single sample of Green and Brown Painted V(I). It is characterised petrographically by its calcareous micromass with fine inclusions of quartz, micrite and chert. Chemically, this sample falls with the imported samples belonging to Chemical Group 4 (Figure 8.3.1, Chapter 8), and is separated from other Corinthian ceramics identified in this research by its lower CaO and Sr contents (see Appendix IX). However, the calcium concentration is consistent with the results of previous analyses of much earlier Corinthian ceramics, such as Farnsworth *et al.*'s (1977) reference group of seventh to third century BC Corinthian finewares, while the inclusions identified through petrographic analysis in this sample are compatible with a Corinthian origin.

Analysis of the glaze revealed it to be a high lead glaze containing. As with previous glazes identified, the composition following data reduction reveal a pattern consistent with the use of a $\text{PbO}\cdot\text{SiO}_2$ raw glaze mixture (see Figures 8.4.7 to 8.4.10, Chapter 8). The brown glaze decoration of the sherd was determined to be coloured by MnO (see Table 8.4.7. Thus, while this sherd is visually similar to examples of Green and Brown V(I) pottery in the Micaceous Siltstone-Sandstone Group A group (Figure 9.4.2), the distinct fabric and use of MnO on its own as a brown colorant indicates that more than one workshop at Corinth was producing this ware.

A large part of the late twelfth to thirteenth century pottery sampled is dominated by the Micaceous Siltstone-Sandstone Group B. It is characterised petrographically by

common inclusions with a bimodal grain-size frequency distribution. The texture of the fabric suggests the use of a sandy clay with the coarse component added as temper. This fabric group forms a distinct chemical group (Chemical Group 9 characterised by its low CaO concentration (see Section 8.3.4.9 and Table 8.3.1). Local manufacture of this group is considered likely because of the range of inclusions present, with silt and sandstone commonly occurring in the region (see Chapter 5). Serpentinite and volcanic rock are also known to occur, being present in the shale-sandstone-radiolarite formation (Whitbread 1995, 261, see Chapter 5), while serpentinite and volcanic rock inclusions have previously been noted in ceramics attributed to a Corinthian origin. Volcanic rock, for example, is present in architectural terracottas investigated by Whitbread (1995, 294-295)) and serpentinite is noted in local clays, for example, Clay 20 collected from west of Anaploga (Whitbread (1995, 332) and see Chapter 5).

This fabric group incorporates a range of styles including Green and Brown Painted V(II), V(III) and V(IV), Slip Painted Light on Dark III, Champlevé and Frankish Incised Sgraffito. This dates production from the late twelfth to late third quarter of the thirteenth century. The distinct differences between it and the Micaceous Siltstone-Sandstone Group A demonstrate the exploitation of different clay sources and use of unique paste-making recipes, leading to the preferred conclusion that separate workshops were responsible for the manufacture of pottery belonging to the two fabrics types.

The glazes of pottery from the Micaceous Siltstone-Sandstone Group B were analysed, with each decorative style represented. They were determined to be of the high lead type and applied as a $\text{PbO}\cdot\text{SiO}_2$ mixture (see Figures 8.4.7 to 8.4.10).

Yellow and green glaze colorants were shown to be consistent with previous analyses of this period, with Fe_2O_3 used to colour the yellow overglaze of the Champlevé example, and CuO used to produce the greens of the Green and Brown Painted V(II) and V(III) and Champlevé examples. The brown glazes of the Green and Brown painted styles were determined to be coloured with Fe_2O_3 on its own with only trace amounts of CuO or MnO detected (see Table 8.4.7, Chapter 8). This therefore distinguishes glazing technologies between this workshop and the workshops at Corinth producing the Green and Brown Painted V(I) styles where mixtures of MnO and Fe_2O_3 , or MnO on its own

were utilized to produce browns during the late twelfth to third quarter of the thirteenth century (see above).

In Section 8.12.2.5, the consistency of the Micaceous Siltstone-Sandstone Group B was noted as remarkable despite its manufacture for nearly a century (from the late twelfth to third quarter of the thirteenth century). This indicates that the potters manufacturing this ware made use of the same clay beds for the duration of production and prepared the paste according to a standard recipe. No differences were detected in glazing methods during the inception of this pottery to the time it went out of use. The time span during which the pottery was manufactured covers a period of political change at Corinth, with the Frankish siege of Acrocorinth occurring from 1205, until it fell in 1210, putting Corinth under Frankish control. While a decrease in the size of the city and a general decline in standard of living during the first half of the thirteenth century is recorded (for example see Williams (2002, 425-426)), the administrative change at Corinth following 1210 seemed to have had little adverse impact on trade and economy (see Chapter 4). This appears to be supported by the ceramic evidence which shows continuity of production at Corinth during these years, and especially by the seemingly uninterrupted production of pottery belonging to the Micaceous Siltstone-Sandstone Group B.

9.4.2 Late twelfth to thirteenth Century Glazed Ware Imports

Trade in glazed ceramics also continued uninterrupted as evidenced by the number of non-local fabrics identified for this period. These include the Phyllite Groups A1 and A2, the Quartz-Biotite Class and the Schist-Phyllite Group

The Phyllite Fabric A1 is a non-local fabric with the suggested source of origin given as the Boeotia region (see Section 9.3.3). Pottery styles present in the fabric date it at Corinth from the beginning of the twelfth century and continuing through to the first half of the thirteenth century, with the late twelfth to thirteenth century styles including Champlevé and Aegean Ware. The Phyllite Fabric A2 is a fabric sub-group containing only examples of Champlevé and Aegean Ware. It is related to Group A1 by its chemistry and mineralogical content, but is differentiated by its discrete texture (see Sections 8.2.10.5 and 8.3.4.8). Inclusions were added as temper so distinguishing it from sub-group A1 where coarse inclusions were too few to be considered deliberate additions to the paste. These analytical results indicate the Phyllite Fabric A2 derives

from the same region of production as Sub-Group A1 (Boeotia), but perhaps represent the products of an individual workshop.

The glazes of the late twelfth to thirteenth century pottery styles of the Phyllite Fabric Sub-Groups A1 (samples 00/166 and 00/167 (Aegean Ware)) and A2 (sample 00/105 (Champlevé)) are considered here. Compositional analysis shows that there is nothing to distinguish the glazes belonging to the two fabric sub-groups, or to the glazes belonging to the earlier styles of the A1 sub-group. Both are of the high lead type, with similar compositions (Table 8.4.7). Since glaze composition is strongly related to composition of the underlying ceramic fabric (see Chapter 2), the similarity in the glazes between the two sub-groups might be expected given the ceramic fabrics share a similar chemistry. The colorants detected for green and yellow glazes were determined to be typical of the Byzantine period, with the green glaze of the Aegean Ware example coloured by CuO additions and the yellow glazes of the Champlevé and Aegean Ware coloured by Fe₂O₃ additions.

Two important points may be drawn. In the first case, it has been suggested that the Phyllite Fabric Class originated from the Boeotia region (see Section 9.3.3). Pottery styles present in this group indicate that it was imported from the end of the eleventh/beginning of the twelfth century and this trade continued into the third quarter of the thirteenth century. Thus trade links established a century before were unbroken by the changing political situation occurring at Corinth at the beginning of the thirteenth century.

The second point regards the Aegean Ware pottery. In Chapter 6, it was established that this pottery style is widespread across the Aegean, though no source for the pottery has yet been identified. In this research the Phyllite Fabric is linked to the Boeotia region based upon the clear similarity to pottery belonging to the twelfth century found in abundance there. Therefore, while further research must be undertaken to test this hypothesis, the findings indicate that Boeotia maybe one area in which Aegean Ware originated.

Zeuxippus Ware is a class of ceramics considered to be imported to Corinth (for example MacKay 2003, 408-409, see Chapter 6) and occurs from the first third of the thirteenth century onwards. The petrographic and chemical analysis show the majority

of samples selected for analysis form the Quartz-Biotite Class/Chemical Group 4. The range of inclusions found to be present are uncharacteristic of Corinth clay deposits known to date or of confirmed Corinthian productions and so support the supposition that this ware is imported. Despite the textural variations noted, the shared mineralogy and broad chemical grouping of the Quartz-Biotite Class demonstrate a common region of origin for the majority of Zeuxippus Ware examples sampled. The meaning of the textural variations (see Sections 8.2.15.2 to 8.2.15.10) is unclear but may represent differing methods of clay preparation processes, either related to changing methods of paste preparation within a single workshop over the period this ware was manufactured, or alternatively, may indicate more than one workshop producing Zeuxippus Ware was operating in the region of production, with potters exploiting similar clay sources but utilizing distinct paste preparation techniques.

It is agreed that Zeuxippus Ware does not comprise a homogenous group of productions from a single point of origin, but rather represents a complex 'family' of related styles from a number of production centres across the Mediterranean (Sanders 1993, 157; Berti and Gelichi 1995, 85; Vroom 2003, 164; see Chapter 6). This view is supported by the single example of Zeuxippus Ware occurring in the Quartz-Mica Fabric A. It is characterised petrographically by its micaceous inclusions, nonetheless, it is distinct from the Quartz-Biotite Class by the additional presence of chert and clinopyroxene and by the absence of zoned feldspars and amphibole. It is therefore considered as deriving from a separate production centre. Again, the metamorphic nature of the fabric confirms the supposition that Zeuxippus Ware was not manufactured at Corinth.

Table 9.4.1 shows a comparison of compositions of Zeuxippus Ware examples from Saranda Kolones analysed by Megaw *et al.* (2003) (see Chapter 3) and those belonging to the Quartz-Biotite Class from Corinth. If ranges of values are taken into account it can be seen that the compositions of the two groups of Zeuxippus Ware are very similar. Given the compositional similarity between the two groups it is suggested that production centre that supplied Zeuxippus Ware to Saranda Kolones also exported the ware to Corinth.

The glazes of the four samples belonging to the Quartz-Biotite Fabric sub-groups B1 and B3 were shown to be of the high lead glaze type. Comparison of glaze and body composition following data reduction showed a similar pattern seen in glazes of the

twelfth and thirteenth centuries, revealing they were likewise applied as $\text{PbO}\cdot\text{SiO}_2$ mixtures. The yellow glaze of sample 00/170 was shown to contain 2.35 wt% Fe_2O_3 and if this is compared to the colourless glaze of sample 00/171 which contains only 0.61 wt% Fe_2O_3 , it can be seen that the iron oxide was a deliberate addition to the raw glaze mixture rather than diffusing into the glaze from the body during firing.

The final group considered to be imported is the Schist-Phyllite Group. It is characterised by its micaceous groundmass, and coarse inclusions of schists, phyllites and very rare rock fragments containing quartz, plagioclase, muscovite and biotite (see Section 8.2.14.1 and Appendix IV), and forms a cohesive chemical group (Group 5) (see Section 8.3.4.5 and Appendix IX). The group contains the thirteenth century style of Light on Dark III and the late thirteenth century style of Green and Brown Painted V(V). Morgan (1942) considered all sub-divisions of the Green and Brown Painted V style to be locally manufactured, nonetheless recognized that the small category of Green and Brown Painted V(V) could be differentiated by form (thick vessel walls in the lower part of bowls, thinning rapidly towards the upper part (compare profiles of Appendix III.79 to III.86 with profiles of III.98 and III.99)) and fabric (more refined and fired to a pinkish-buff tone). He acknowledged that the fabric did not resemble other local products in texture, but attributed this to use of different clay beds or clay refining methods. The inclusions present in the fabric (schists and phyllites) and the micaceous character of the groundmass are inconsistent with clay deposits from the Corinthia known to date or with products of confirmed Corinthian origin so indicate they derive from a source other than Corinth. The group shares a similar chemistry to the Zeuxippus fabrics (Chemical Group 4) but is differentiated by its higher Cr levels (see Table 8.3.1, Chapter 8). Despite the chemical similarity, the differences in inclusions would suggest they were imported to Corinth from different production centres.

The glazes of an example each of Slip Painted Light on Dark III and Green and Brown Painted V(V) were analysed and were shown to be of the high lead type and data reduction indicates the raw glazes were applied as $\text{PbO}\cdot\text{SiO}_2$ mixtures (see Figures 8.4.7 to 8.4.10, Chapter 8). The light brown glaze of the Green and Brown Painted V(V) and yellow glaze of the Slip Painted Light on Dark III example contain similar Fe_2O_3 concentrations, nevertheless, the brown glaze contains additional concentrations of MnO (Table 8.4.7). This indicates the yellow and brown glazes were prepared in a very similar manner, with the brown colour being achieved through the addition of MnO.

The mixture of Fe₂O₃ and MnO to produce brown coloured glazes has been identified in this study within other groups of productions. These include twelfth century pottery belonging to the locally manufactured Clay Temper Group and non-local Phyllite Fabric A1, and late twelfth to thirteenth pottery belonging to the locally manufacture Micaceous Siltstone-Sandstone Group.

9.5 Summary of the Findings

9.5.1. Technological Developments in Byzantine Glazing Methods

9.5.1.1 Base glazes

The aim of this research was to investigate in detail Byzantine methods of glazing, and the development of glazing technologies at Corinth. The results reveal rather than there being no obvious changes in glazing technologies during the Byzantine period as previously asserted (Armstrong *et al.* 1997, François and Spieser 2002), there is a period of technological transition at Corinth. Prior to the twelfth century the potters at Corinth made use of a simple glazing technology where lead oxide was applied to the surface of the pottery without any other ingredients (silica, colorants) to produced plain glazed impervious surfaces to vessels whose principal function was to contain liquids (chafing dishes, jugs, cups, pitchers, pilgrim flasks). At the beginning of the twelfth century, a new method of glazing was introduced at Corinth in conjunction with the introduction of a new fabric (Clay Temper Fabric) and new pottery styles. While still a high lead glaze, it was now applied to the pottery as a lead-silica mixture, either with or without the addition of colorants (copper, iron and manganese oxides) to produce glaze-decorated surfaces, and colourless or coloured overglazes covering slip-decorated surfaces. Once known by the potters at Corinth, this method of manufacturing lead glazes was used consistently throughout the twelfth and thirteenth centuries at the site.

There are a number of mechanisms through which the introduction of the lead-silica method of glazing could have occurred at Corinth. For instance, it may have been a local innovation, with the Corinthian potters experimenting in new ways of doing things. Alternatively, potters already knowledgeable in the technology might have moved to Corinth, bringing with them their ways of doing things (for example Day 2004), or technological knowledge could spread through contact of peoples, for example, through trade in pottery goods (such as Shepard 1956, 345). From the evidence available it is not possible to determine which mechanism is responsible for the introduction of the lead-silica glazing method at Corinth. At the very least, a

Constantinopolitan influence can be ruled out since the results show that where the Constantinopolitan potters manufacturing White Wares made use of high lead glazes, they used the simple lead oxide method with the addition of colorants. These potters also made use of lead-alkali glazes which were not detected in any of the Corinthian products. Twelfth century imported pottery thought to originate from the Boeotia region (the Phyllite Fabric Class) shows the use of the same lead-silica glaze mixture which was identified on the locally manufactured twelfth century pottery. Examination of the pottery styles present in the local and non-local pottery glazed using this method reveal the same styles (Light on Dark Dotted, Spatter Painted, Light on Dark I and Green and Brown Painted I) are present in each fabric, showing that they are contemporaneous productions. Without identifying earlier (eleventh century) pottery manufactured in the same region as pottery belonging to the Phyllite Fabric Class and examining their glazes, it is not possible to say if the lead-silica method of glazing was known prior to the twelfth century there, and so if this knowledge was received by the Corinthian potters through contact established by trade in these wares, or conversely, if the use of a lead-silica glazing recipe was a local innovation which spread out to other areas from Corinth.

It appears to be the case that the eleventh/twelfth century transition from the use of simple lead oxide glazes to lead-silica glazes identified at Corinth did not occur in isolation. All imported examples of eleventh century Plain Brown Glazed Ware analysed were glazed in the simple lead oxide method, while all imported wares of the twelfth century were glazed using the lead-silica method, suggesting that the changes in manufacturing technologies identified at Corinth also occurred at other production sites in the Mediterranean. François and Spieser (2002) reported that three broad trends emerged in the twelfth century in the Byzantine world. These are the increase in the circulation of people in the eastern and western Mediterranean basins, a general increase in pottery production, and with this, an overall increase in the commercialization and distribution of pottery in the Mediterranean. This environment would allow for the spread of technological knowledge in the region, either into or out of Corinth.

9.5.1.2 Colorants

An interesting finding that relates to glazing technologies is the use of colorants, and specifically in the variety of methods that were identified to produce brown glazes. It is frequently reported that the brown glaze/paint decoration on Byzantine red wares was

coloured by the addition of iron oxide to the base glaze (for example Dark 2001, Vroom 2003). This study has shown that in fact, numerous methods were known by the Byzantine potters. For instance, the brown glaze decoration of the Green and Brown Painted I sample belonging to locally manufactured Clay Temper Group was produced using a mixture of iron oxide and copper oxide. This same method was also noted on an eleventh century plain brown glazed White Ware example sampled for this study, and previously by Vogt and Bouquillon (1996) on an example of Constantinopolitan polychrome wall plaque. In the brown glaze of the slightly later style of Green and Brown Painted II belonging to the Clay Temper Group manganese oxide was substituted for the copper oxide component. The brown glaze of the imported example of the Green and Brown Painted I ware (Phyllite Group) was coloured using a mixture of copper and manganese oxides, while the brown of the later Green and Brown Painted III style in the same fabric was shown to be manufactured using iron and manganese oxides. This version differs from the iron oxide/manganese oxide brown glaze noted on the locally manufactured Green and Brown Painted II example by the increased manganese oxide levels and reduced iron oxide levels showing the use of different proportions of the same oxides. The brown of the Green and Brown Spiral and Painted Sgraffito styles was produced by the use of iron oxide on its own. Because of the limited number of glaze samples analysed it is not possible to say if the use of different colouring agents within each fabric group reflect broad chronological developments within the respective workshops or are strictly related to stylistic groups, with potters selecting particular recipes to execute the different designs. Further sampling might resolve this. While it might be expected that potters working at different production centres would develop disparate technologies, the same phenomenon regarding the use of a variety of methods to produce brown glazes was identified on a local level at Corinth in the late twelfth to thirteenth centuries.

By the late twelfth century the Clay Temper Group went out of use at Corinth, and three new fabric types were identified. Examination of the decorative styles occurring in each fabric indicates they are contemporaneous, with Green and Brown Painted V(I) manufactured in the Micaceous Siltstone-Sandstone A and Fine Quartz-Micrite Fabrics, and Green and Brown Painted V(II) manufactured in the Micaceous Siltstone-Sandstone B Group. The similarity in decoration between the two examples of Green and Brown Painted V(I) shows close imitation between potters working in the different workshops at Corinth producing this ware, nevertheless, the imitation relates only to the visual

aspects of pottery. The brown glaze decoration on the example belonging to the Micaceous Siltstone-Sandstone Group A was produced using a mixture of iron and manganese oxides while that on the example belonging to the Fine Quartz-Micrite Fabric was produced using manganese on its own. The brown glaze of the Green and Brown Painted V(II) decorated pottery belonging to the Micaceous Siltstone-Sandstone Group B was produced using iron oxide alone. This would imply that the potters manufacturing wares in the different workshops at Corinth during this period had unique ways of doing things, and details of technology were not shared.

9.5.2 Trends in pottery production and trade at Corinth

Chemical and petrographic analysis of the locally produced and imported glazed wares dating from the eleventh to thirteenth centuries reveal some general trends in pottery production and trade at Corinth during this period.

Local production of glazed wares during the eleventh century at Corinth was limited to the manufacture of the Plain Brown Glazed Wares. The potters exploited iron-rich clays and tempered the fabrics with coarse inclusions of mudstone, chert and micrite. Archaeological evidence indicates that during this period Plain Brown Glazed Wares were manufactured in the same workshops that produced unglazed coarse wares. This is demonstrated by the occurrence (though rare) of chafing dish wasters alongside amphora, cooking vessel and other coarse ware wasters at the Acrocorinth kiln site, and by the presence of glaze patches on unglazed cooking vessels (see Section 4.3.1.2). The petrographic evidence supports this theory, with the fabrics identified in this study having similarities to the eleventh century cooking ware fabrics analysed by Joyner (1997, 2007), indicating the coarse and glazed ware productions were related. Plain Brown Glazed Wares were also imported to Corinth during this period as attested by the presence of four fabric types containing metamorphic rock inclusions. The variability demonstrated in the fabrics indicates they originated from different locations (with one suggested place of origin being Sparta). The rare occurrence of chafing dish wasters in proportion to the unglazed coarse ware forms represented at the Acrocorinth kiln site may indicate that the output at Corinth of the Plain Brown Glazed ware type was relatively limited, and insufficient to meet the local market demands, hence the need for it to be supplemented by non-local products. White Wares were also imported to Corinth in the eleventh century. The chemical results are consistent with previous work which suggests they were produced in or around Constantinople. However, the

presence of three fabric sub-groups in the Altered Feldspar Class show that more than one workshop in the region were producing and exporting these wares.

With the introduction of the new glaze and slip decorated pottery styles at Corinth at the beginning of the twelfth century three new fabrics are identified which can be linked to local production. Two of them, the Quartz-Chert Fabric and the Medium Coarse Mudstone-Chert Fabric Group, which contain the only examples of Slip Painted Light on Dark I styles, can be related to paste preparation technologies of the local eleventh century Plain Brown Glazed wares and eleventh to twelfth century unglazed coarse wares with the use of iron-rich clays and coarse temper inclusions (quartz, chert, mudstone). This might indicate that the pottery was also produced in conjunction with the cooking wares. However, these preliminary results suggest that the production of glaze decorated tablewares in these fabrics was short-lived as later pottery styles were not identified in the fabrics.

The Clay Temper Group was also introduced at this time and was used until the late twelfth century. It represents a move away from the paste preparation technologies identified in the eleventh century Plain Brown Glazed wares. Rather than the dark red to grey firing iron-rich clays exploited in the preceding century, potters were now exploiting the abundant pale firing calcareous clays and mixing them with an iron-rich clay component. It is likely this addition of the red clay component was required to enhance workability and firing properties of the highly calcareous clays, while the lighter colour of the fired fabric enabled the potters to better make use of glaze colour. Several of the unglazed biscuit-fired wasters of this fabric group derive from Lot 418, Agora SW excavations of 1960, and are noted as coming from a “sherd dump” (Corinth Excavation Notebook 217, 52,61, 65,70). The chemical composition of this group is remarkably similar to the Corinth wasters analysed by Megaw and Jones (1983) (see Table 9.3.1) which were, likewise, excavated in the Agora in the area of the Agora S.C. 1936, South Stoa 1936 and Agora S.C. 1938 complexes (Megaw and Jones 1983, 238). It is probable given the similar compositions and location of recovery that the two groups of wasters represent the same fabric type, and this fabric is associated with one of the kiln complexes in the Agora area (see Section 4.3).

The wasters in the Agora area are predominantly of the glaze and slip decorated type. They relate to a new clay-paste recipe introduced at this time and utilize the new glaze

preparation method (the use of a $\text{PbO}\cdot\text{SiO}_2$ mixture as opposed to the use of PbO on its own as observed with the eleventh century Plain Brown Glazed Wares), leading to the conclusion that at the end of the eleventh century/beginning of the twelfth century there was a move towards specialization of the glazed pottery industry at Corinth, with glazed wares no longer manufactured at workshops in conjunction with coarse wares.

Peacock (1982, 6-11) provided a general model for the production and distribution of Roman ceramics in the Mediterranean. Six principal modes of production were identified, which increase in level of complexity and scale: 1) household production for the family; 2) household industry; 3) individual workshops; 4) nucleated workshops; 5) the manufactory; and 6) the factory. Vroom identified the Boeotian Byzantine kiln site near the village of Askra (see Section 9.3.3) as operating on an individual workshop mode, where pottery making is the main source of subsistence, but which may be practised for only part of the year and is most likely to be in a rural rather than an urban setting (Vroom 2003, 275). The situation at Corinth in the twelfth century was different. The development of the pottery workshops in the urban setting, focussed in the Agora area suggests a more complex mode of production, and possibly equates to Peacock's nucleated workshop mode. This is characterised by individual workshops grouped together to form a more or less tightly clustered industrial complex, because of the availability of labour, raw materials, market or a combination of these. The industry would use all available technologies and the products would be of high standard (Peacock 1982, 9 and 38-43).

A second important fabric group (the Phyllite Group) belonging to the late eleventh and twelfth centuries was identified as imported, and based on close similarities with pottery recovered from the Boeotian region, and by a tentative geological link, it is suggested that it originated from Boeotia. It is interesting that the earliest styles in this fabric (Spatter Painted ware, Green and Brown Painted I, Slip Painted Dotted and Light on Dark I) are also the same group of styles that are first produced in the local Clay Temper Group, showing they are contemporaneous. It is unclear at this point if the imported wares were introduced to Corinth to supplement the locally produced decorated wares or if local production in these wares was initiated to compete with the importation of the new wares. A pattern highlighted in Section 9.3.3 is that while initially the pottery styles are repeated in both fabrics, as the twelfth century progressed the Corinthian potters specialized in Sgraffito decorated wares, Dark on Light Slip

Painted Wares and combined the two styles in Measles Wares, while the imported wares appear in developed Green and Brown Painted styles, Sgraffito and Painted Sgraffito. This indicates that as production and consumption of glaze-decorated tablewares increased regions of production developed their own themes and styles of decoration.

By the late twelfth century, the Clay Temper Fabric type went out of use and was replaced by new local fabric types. The chemical characteristics of the pottery and petrographic features of the fabric groundmass show that potters manufacturing the Micaceous Siltstone-Sandstone Group A type exploited the same or similar calcareous clays as utilized for the Clay Temper Group. However, fundamental differences are noted in paste preparation technologies with the base calcareous clay now tempered with coarse fragments of siltstone and sandstone rather than the iron-rich clay component as previously seen. The second main local fabric group of this period identified was the Micaceous Siltstone-Sandstone Group B. It was, again, tempered with sandstone, though, the sandy nature of the groundmass and differences in chemistry reveal that the potters producing this ware exploited different clay sources.

The absence of these end of twelfth and thirteenth century styles (and fabric types) amongst the wasters recovered from the Agora area indicate these workshops went out of operation at the end of the twelfth century, and pottery production was relocated away from the centre of Corinth at this time. The lack of known pottery production sites dating to the thirteenth century in or around Corinth, however, means that little comment can be made on organisation of production at this time.

The view that the changing political conditions at the beginning of the thirteenth century appeared to have little adverse impact on trade and economy in Corinth (Chapter 4) is supported by the ceramic evidence from this study. The presence of pottery styles which date from the late twelfth century ((Champlevé) to the third quarter of the thirteenth century (Green and Brown Painted V(IV)) in the Micaceous Siltstone-Sandstone Group B demonstrate continuous production during this period of transition at Corinth. Pottery types which date from the late twelfth century to the first half of the thirteenth century and later (Champlevé and Aegean Ware) also occur in the Phyllite Group showing that trade networks established in the twelfth century were unbroken by the Frankish subjugation of Greece.

The increased production and commercialisation of glazed pottery first witnessed in the twelfth century continued in the thirteenth century. This is shown at Corinth by the introduction of new ware types such as Zeuxippus Ware, and Italian imports such as Protomaiolica and the late thirteenth century Veneto Ware (these last two are outside the scope of this study). The increase in Italian imports is thought to be the effect of the late thirteenth century control of Charles II of Anjou over the Peloponnese in which already existing commercial ties with Italy were likely to have been strengthened (Chapter 4). An interesting finding regarding the Zeuxippus Ware is that examples excavated at Corinth belonging to the Quartz-Biotite Fabric Class and examples recovered from Saranda Kolones, Cyprus share a similar chemistry, leading to the theory that the same production centre responsible for their production was supplying both locations in the thirteenth century. This provides some evidence for the extent of trade in this ware.

While only the main fabric groups identified using petrographic and chemical analysis were discussed in this chapter, the recognition of a number of other fabric types (local and non-local) represented by single samples (Chapter 8.1) suggest that other workshops in Corinth were producing glaze decorated pottery and pottery was imported from a variety of other sources during the time period under study. Additional sampling is required to investigate these fabrics further and build them into the overall picture of trade and production in glazed wares at Corinth.

9.6 Conclusions

9.6.1 Introduction

The Byzantine glazed ceramic assemblage from Corinth had been well studied previously from typological and chronological perspectives. The stylistic types were therefore well defined and fit into a tight chronological sequence making it an ideal assemblage for this research. With the aim to investigate development of production technologies at a local level during the eleventh to thirteenth centuries and in particular methods of glazing, it was important to establish which products derived from Corinthian workshops. Provenance assumptions had been made previously based on the macroscopic appearance of the ceramic fabrics only. For this reason, the fabrics were examined using ceramic petrography and chemical analysis. These analyses proved successful in forming fabric groups which could, in the main, be attributed to

local and non-local production. Once the fabrics were classified and ordered into the chronological sequence, the glazes of typical examples of each decorative style from the main groups were analysed and glaze compositions were investigated in relation to their corresponding body compositions to elucidate raw glaze materials and methods. This integrated analytical approach where both fabrics and glazes were treated with equal importance has proved successful. It has allowed for a number of findings which challenge the current thinking of glazed pottery production in the Byzantine World, as well as revealing some important trends which further the understanding of production and trade of the pottery at Corinth in the eleventh to thirteenth centuries. The conclusions of this research are discussed below under the headings 'Glaze Technology' and 'Pottery Production and Trade at Corinth'

9.6.2 Glazing Technology

1. The use of lead-alkali glazes is reported here for the first time on White Ware vessels from Constantinople. They had previously been known only on White Ware decorative wall tiles manufactured in the same region. These findings indicate shared knowledge amongst the various pottery industries. In the context of Byzantine glazing technologies, this knowledge appears not to extend outside the Constantinopolitan region since no lead-alkali glazes were detected on the Byzantine Red Wares analysed.

2. Also identified for the first time is the clear transition at Corinth from the use of a PbO glaze on Plain Brown Glazed vessels during the eleventh century to the use of a PbO·SiO₂ mixture, which was introduced with the new glaze decorated vessels at the end of the eleventh century. It appears that once in use, this PbO·SiO₂ glazing method was the standard method of lead glazing throughout the twelfth and thirteenth centuries at Corinth. It is noteworthy that this same pattern was identified for the imported wares, where all non-local Plain Brown Glazed Wares and the high lead glaze type of the Constantinopolitan White Wares were glazed using the PbO method, and all imported glaze decorated tablewares of the late eleventh to thirteenth centuries were glazed using the PbO·SiO₂ method. This indicates the changes in manufacturing technologies identified at Corinth also occurred at other production sites in the Mediterranean at a similar time.

3. The colorants also show distinctive technological features. The yellow glaze covering the red to grey fabrics of the Plain Brown Glazed Ware is the result of

diffusion of Fe_2O_3 from the underlying ceramic body rather than being added as an intentional colorant to the raw glaze mixture. It is only where glazes were applied over white bodies, as in the Constantinopolitan White Wares of the eleventh century, or over slipped red bodies, as in the case of glaze and slip decorated Red Wares of the late eleventh to thirteenth centuries that glaze colour is truly exploited. In these glazes the greens were produced by varying amounts of CuO and the yellows by varying amounts of Fe_2O_3 . These findings are consistent with previous analyses of medieval glazes. In contrast, the brown glazes were found to be produced using a number of methods. These include high concentrations of Fe_2O_3 , a combination of Fe_2O_3 and CuO , a combination of Fe_2O_3 and MnO , a combination of MnO and CuO , and finally MnO on its own, indicating more sophisticated technological practices for certain glazing methods than has previously been acknowledged.

9.6.3 Pottery Production and Trade at Corinth

1. The local fabrics associated with the Plain Brown Glazed Wares of the eleventh century can be related to the manufacture of unglazed cooking wares at Corinth during the same period suggesting shared raw materials or workshops. Plain Brown Glazed Ware occurs in two distinct fabric types reflecting that more than one workshop at Corinth, operating during this period, was involved in the manufacture of these wares.
2. A number of Plain Brown Glazed Wares fabrics, thought to be locally produced, showed fabrics consistent with non-local clay sources. The range of fabrics detected reveal they were imported from more than one source; one potential source is tentatively identified as Sparta.
3. New styles of glaze and slip decorated tablewares were introduced in the last decade of the eleventh century, and some of these were on locally produced ceramics. These include the Quartz-Chert Fabric, and the Medium Coarse Mudstone-Chert Fabric which contained only examples of the late eleventh to early twelfth century style of Slip Painted Light on Dark I. These two fabrics can be related to the locally manufactured Plain Brown Glazed Ware fabrics of the eleventh century and the coarse cooking ware fabrics of the eleventh and twelfth centuries identified by Joyner (1997, 2007). The similarity of these fabrics indicates a continuation of paste manufacturing technologies in the eleventh century, and shows that the manufacture of these early styles occurred in

conjunction with cooking wares. The absence of later glaze decorated styles in these fabrics may indicate the production of these fabrics was short-lived.

4. The largest local fabric group identified for the late eleventh and twelfth centuries is the Clay Temper Group. It represents a divergence from manufacturing technologies for glazed wares in the eleventh century, with the exploitation of different raw material resources and the introduction of a new paste-making recipe. The absence of comparable fabrics in the twelfth century cooking wares identified by Joyner (1997, 2007) supports the hypothesis that there was some division in the pottery production industry at Corinth, with a new workshop set up specializing in the manufacture of glazed wares.

5. A second important fabric group (the Phyllite Group), spanning the twelfth century and into the first part of the thirteenth, was thought to be manufactured locally in Corinth. The range of metamorphic inclusions identified in the fabric in this study clearly shows this ware was imported. The supporting local geology and stylistic similarities with pottery from Boeotia suggests it may have originated there.

6. The lack of late twelfth to thirteenth century pottery styles occurring in the locally produced Clay Temper fabric type indicate it went out of use towards the end of the twelfth century. At this time new fabrics occur which can be attributed to a Corinthian origin. Instead of clay mixing, the pastes were prepared by tempering with coarse fragments of siltstone and sandstone reflecting the introduction of new paste-making-recipes.

7. The analytical results confirmed that Zeuxippus Ware is an import to Corinth. Moreover, its presence in two distinct fabric types support the view that the ware was not a homogenous production deriving from a single source, but a “family” of related styles from a number of production centres across the Mediterranean. The chemical similarity between the Zeuxippus Ware belonging to the Quartz-Biotite Fabric Class and examples excavated at Saranda Kolones, Cyprus would imply that the same (unidentified) production centre was supplying both locations in the thirteenth century.

In summary, this research has shown that rather than being stagnant in the Byzantine period, glazing technologies underwent a transition, and this transition is associated

with the introduction of new pottery styles at the end of the eleventh century. These changes did not occur at Corinth in isolation but also at other pottery production centres in the Medieval Mediterranean. Furthermore, it has previously been recognised that Corinth was an important producer of glazed pottery in the Byzantine period and that ceramics were produced for local consumption *and* for trade. This research has shown that imported pottery also forms an important part of the glazed ceramic assemblage at Corinth and the movement of pottery as a trading commodity facilitated the spread of technological knowledge in the region.

9.7 Considerations for Future Research

The results and conclusions reported in this thesis have highlighted areas that would benefit from further investigations.

1. Further analysis should be carried out on material dating to the end of the eleventh/early twelfth century period of transition. Specifically, whether the different fabrics identified in the Slip Painted Light on Dark I style are indeed short lived or a feature of insufficient sampling. Further analysis of the Byzantine glazed assemblage at Corinth may clarify this point.
2. Petrographic analyses of Slip Painted Light on Dark I fabrics suggest that the paste-making technologies were related to those of the eleventh century Plain Brown Glazed Wares and unglazed coarse wares. Glaze technologies were not investigated, and so it is not known if these early decorated tablewares underwent the same technological change from PbO glazes to PbO·SiO₂ glazes observed in the Plain Brown wares. Further investigation is needed to elucidate this period of transition in glazing technologies and reveal how these wares fit into the overall pattern of pottery manufacture at Corinth.
3. Byzantine Red Wares formed a greater proportion of the imported assemblage than was previously realised. Analysis of comparative pottery from other sites in the region may help to resolve the provenance of this group of ceramics. Potential origins include Sparta in the case of the Plain Brown Glazed Wares, and Boeotia in the case of the twelfth century wares. Conversely examples of pottery from contemporary sites could be studied with a view to establishing a potential Corinthian origin of some of the pottery found (for example, the stylistically 'Corinthian' Measles Ware exports to

Otranto, southern Italy). In this way, the networks of pottery trade in the Byzantine world could be more thoroughly investigated.

4. The most important aspect of any future work should be to make available the Corinthian glazed pottery dataset in a format readily accessible to other researchers, since it expands and updates the only available chemical information on the Corinthian glazed pottery assemblage published by Megaw and Jones in 1983.

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