AN ARCHAEOMETRIC APPLICATION TO A GROUP OF EARLY OTTOMAN CERAMICS FROM İZNİK

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Approval of the Graduate School of Natural and Applied Sciences

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ABSTRACT

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This study investigates the physical, mineralogical and chemical characteristics of a group of pottery sherds that are mostly Miletus-ware ceramics, belonging to the Early Ottoman period and excavated during 2003 season, from the Roman theatre in İznik.

The sherds examined are mostly characterized by cobalt-blue designs which are occasionally coupled with black, green and purple paintings. After grouping the sherds according to their stylistic and color differences; petrographic, X-ray diffraction, scanning electron microscope coupled with energy dispersive X-ray and Fourier Transform Infrared analyses were carried out for investigating the mineralogical and chemical properties. Most of the ceramic samples have slip and glaze on both sides. The glaze part is mostly fresh without any devitrification products. Bodies of the ceramics have tones of reddish yellow and/or red, indicating abundant amount of iron in their raw material. Grains consist mainly of metamorphic rock fragments (quartz-mica schist), quartz, feldspar, hornblende, hematite and biotite. Pyroxene, epidote, chert, muscovite, opaque minerals, chlorite are also encountered. Micritic calcite occurs in some of the pores. Ceramic bodies investigated are usually fine-grained and well-sorted. Clay raw material used for the production of the ceramics seems to be originated from a metamorphic source. Bodies usually show a low degree of vitrification with few exceptions, indicating a rather simple technology with non-uniform and low degree of firing, probably not exceeding 900°C. Technological characteristics of the sherds examined do not seem to have changed much between 14th and 16th century.

Keywords: İznik, Early Ottoman, Roman Theatre, Miletus-ware, petrography

ÖZ

İZNİK'DE BULUNAN BİR GRUP ERKEN OSMANLI SERAMİĞİNDE ARKEOMETRİK BİR İNCELEME

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Bu çalışmada, İznik Roma Tiyatrosu'nun 2003 kazı sezonunda bulunan Erken Osmanlı dönemine ait, çoğu Milet-işi olan bir grup seramik parçasının fiziksel, mineralojik ve kimyasal özellikleri incelenmiştir.

Seramik parçaları çoğunlukla kobalt-mavisi desenlerle karakterize edilmekte, bazıları bunun yanında siyah, yeşil ve mor desenler de içermektedir. Örnekler, stillerine ve renklerine göre gruplandırıldıktan sonra mineralojik ve kimyasal özelliklerini belirlemek üzere ince kesit, X-ışını toz difraksiyon, enerji dağılımlı X-ışınları analizörü ile birlikte çalışan tarama elektron mikroskobu ve Fourier Transform Infrared spektrometre analizleri yapılmıştır.

Seramik örneklerinin çoğu her iki yüzde de astar ve sır içermektedir. Sır kısmı genellikle bozunma ürünü içermemektedir. Hamur kısımları genellikle kırmızımsı sarı ve kırmızı renkte olup, bu durum kullanılan hammaddede yoğun miktardaki demire işaret etmektedir. Hamurda bulunan taneler başlıca kuvars, feldspat, hornblend, hematit ve biotit mineralleridir. Ayrıca piroksen, epidot, çört, muskovit,

klorit minerallerine ve opak minerallere de rastlanmıştır. Kuvars ve mika-şist içeren metamorfik kayaç parçaları baskındır. Gözeneklerin bazıları mikritik kalsitle dolguludur. Seramik hamurları genellikle ince taneli ve düzenli bir görünüm sunmaktadır. Çalışılan seramiklerin yapımında kullanılan kil hammaddesi metamorfik kaynaklı görünmektedir.

Bazı istisnalar dışında düşük seviyede camlaşma gösteren örnekler, eşit dağılımlı olmayan ve muhtemelen 900ºC'nin üstüne çıkmayan, düşük derecede pişirme sıcaklığı kullanan, basit bir teknolojiyi işaret etmektedir.

İncelenen örnekler göze alındığında 14. ve 16. yüzyıllar arasındaki seramik teknolojisinin fazla değişmediği söylenebilir.

Anahtar Sözcükler: İznik, Erken Osmanlı, Roma Tiyatrosu, Milet-işi, petrografi

To the memory of my Grandfather

and

to my Parents and Grandmother…

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INTRODUCTION

1.1 İznik

1.1.1 Location

İznik is a pretty small town of Bursa in the southern Marmara region, 85 km northeast of Bursa. It is founded along the eastern shore of the lake of İznik (Figure 1.1). The lake of İznik is a freshwater lake which is an important characteristic that has urged people to settle down along its shores since the prehistoric period. It is used mainly for agricultural irrigation and fishing for its freshwaters, which is an important aspect making the area suitable for living. The plain of İznik is very fertile, covered with fruit and vegetable gardens.

İznik has also its place in the tourism of Turkey (Kılıçkaya, 1981).

Figure 1.1: Location map

1.1.2 History of İznik

The town of İznik has a long history, going back to the Neolithic period. There are several mounds dating back to ca 5000 B.C., mostly situated on the alluvial fans (Kayan, 1988). Their names are Çakırca, Üyücek, Çiçekli (Kılıçkaya, 1981) and Ilıpınar (Kayan, 1988). İznik also has some Chalcolithic settlements such as Karacakaya, Karadin and Çonga (Fındık, 2001).

However, as we learn from Strabon (ca 63 B.C. – 19 A.D.) who was the famous geographer of the prehistoric period, İznik became a forthcoming city during the time when the commanders of Alexander the Great, the king of Macedonia had shared his very grand empire as kingdoms after his death. Among these commanders, Antigonos founded the city of Antigoneia along the shores of Askania (Appendix A) Lake towards 316 B.C.. A few years later, Antigonos was killed in the war with Lysimakhos who gained the city and named it Nikaia- a dedication to his wife, Nike in 301 B.C.. This name was converted to İznik during the Turkish period (Eyice, 1991).

The city was economically wealthy, being a stop on the main trade routes reaching the east. Together with its strategic importance, its assignment was made to the kingdom of Bithynia in 293 B.C. (Kılıçkaya, 1981).

İznik had gained much importance when Bithynia became a Roman province. It was enlarged beyond its former borders and new wall-gates were built during the Roman period.

When Christianity was accepted formally as a free religion to be practiced throughout the Empire during the reign of the Emperor Constantinus I, İznik became the stage for a very important event (Eyice, 1991). More than 300 Church Fathers gathered to found the tenets of the Christian Faith in the Senate palace of İznik in 325 A.D. (Kılıçkaya, 1981; Atasoy and Raby, 1989). This meeting is known as the First Oecumenical Council which helped the union of the State and the Christians in the empire beginning to disintegrate.

In the 8th century, there came the Arabian raiders making their way to Anatolia during the spread of Islam. In 718 and 727, the Arabians besieged the city but could not succeed in entering inside. They destroyed some parts of the defensive walls.

In 1075, the Seljuk Turks captured İznik after the victory of Malazgirt in 1071. The Turks settled down in İznik although the Byzantine administration was still in charge. Soon, the Seljuk Turks took control of the whole Bithynia, and İznik was declared the capital city of the Seljuk State by the ruler Süleymanşah. The Seljuks had retained control upon İznik for 22 years which passed with continuous battles and sieges, leading to the loss of the city.

Towards the end of the 13th century, the Principality of Ottoman was fast taking control of the neighbouring province (Eyice, 1991). İznik was eventually threatened by the Ottomans, taking advantage of the authority vacuum in Bithynia with the transfer of the government to Constantinople (Atasoy and Raby, 1989). Orhan Gazi finally entered İznik through the Yenişehir Gate in 1331. So, after a 234 year-break, İznik was once again under the control of the Turks. The Byzantine Nicaea was now the Ottoman İznik and İznik was the first major capital of the Ottoman State. It also became a noteworthy center of commerce, art and culture.

During the 16th century, İznik was an important staging post and accommodation center on the military and caravan route from İstanbul to Central Anatolia. At the same time, it was a cultural center producing a great deal of poets and scholars (Eyice, 1991). Besides these important features, İznik is characterized by its fine pottery and tile art in the 16th and 17th century. It was very famous in Europe with its unique and highly qualified ceramic production marking the peak of Turkish art. The beautiful tiles adorning the interiors and exteriors of the Ottoman monuments were all manufactured here, by an advanced technique. This ceramic industry undoubtedly had its roots back in the Byzantine period (François, 1996) (for detailed information on the history of İznik ceramics, see Appendix B).

During the 17th century, İznik was told to be in a bad condition. It had lost its prosperity and population. The reasons for this collapse were probably the decline of the pottery manufacture, the development of a northern caravan route bypassing İznik and the malaria infection triggered by the damp climate of the area (Atasoy and Raby, 1989). This can also be followed through the travellers' documents that were all drawing a pitiful and wretched picture of İznik. The situation had not since changed through the 19th and 20th centuries (Eyice, 1991).

From the 1930s onwards, scholars had begun their publications about the history of İznik. Not very soon, the town had started to develop rapidly towards the end of the 1960s. Publications continued coming forward and excavations also started revealing the old ceramic kilns and ceramic pieces (Kılıçkaya, 1981; Eyice, 1991).

In conclusion, İznik is the legendary city of the Byzantine and the Ottoman periods, reflected in its historical monuments and ceramic industry, despite its small size. Although the city began to lose its grand features through the 15th century, it is still commemorated as a momentous city in the history.

İznik at the moment lives as an open-museum decorated with the green scenery of its trees and gardens. It has a great potential likely for becoming a tourism center. Unfortunately, there are not enough investments still and the town keeps its silence.

1.1.3 The Excavations in İznik

The earliest excavations in İznik were held in the mosque of Orhan İmaret during 1963 - 1969 by Oktay Aslanapa (Aslanapa, 1965a). Several findings of ceramic pieces and kiln furniture associated with four kilns were revealed during these excavations. The spoiled and burnt, pieces stuck with tripods (App. A) made sure that İznik was the main production center for the wares of Kütahya, Damascus and Rhodes (Eyice, 1991).

In 1981, excavations were once more started to reveal the tile-kilns of İznik by Oktay Aslanapa. In the season of 1984, excavations started at the Bath of Hamza Bey (Belediye Hamamı). A ceramic workshop was soon revealed on the east of the bath. This workshop had the production of red and white-bodied ware (Fındık, 2001).

The construction activities for the changing of the waterline network held by the Municipality of İznik in 1979-80 revealed several kiln debris, which initiated the rescue excavations of İznik Museum. Three kilns were found in the street of

Kılıçaslan while in the imaret of Nilüfer Hatun, one kiln debris was excavated (Ayas, 1984).

Another important excavation is the excavation of the Roman theatre, initiated by Dr. Bedri Yalman in 1980. This will be explained in more detail in the next section.

1.1.4 Roman Theatre in İznik

Roman Theatre is situated in the southwest of İznik, 400 m away from İznik Lake, in Saraybahçe spot of Selçuk quarter (Figure 1.1). Excavations have been going on since 1980 in the name of the Ministry of Culture by Assist. Prof. Dr. Bedri Yalman though it had a break during the 1996 -1997 seasons (Fındık, 2001).

The theatre is built on a flat field as a characteristic of the Roman theatres, 7 m above the lake level (Yalman, 1986). It is lying 72 m along the east-west, 67 m along the north-south directions (Yalman, 1993) (Figure 1.2).

Figure 1.2: General view of İznik Roman Theatre (2^{nd} cent.)

Figure 1.3: Partial view from the theatre

It was built during the reign of Emperor Trajan (98-117) with the supervision of the governor Plinius (111-113) in the 2^{nd} century (Ferrero, 1990) (Figure 1.3).

During the time of the Byzantine Empire in the early 8^{th} century, the stones of the theatre were dismantled and set onto the city walls that were damaged by the Arabian raiders (Yalman, 1989). 9.5 meters of earth fill was poured as the debris and after that, the theatre became out of use. The stones of the theatre had also been pulled out for the restoration of the defense walls and the construction of churches in the 13^{th} century, as well as in the 14^{th} and 15^{th} centuries.

The theatre was raised by means of 12 high barrel vault (App. A) spaces carrying the upper seats (cavea), 12 barrel vault spaces at their back and a trapezoidal vault space carrying the lower seats (cavea). There are two barrel vault galleries extending north-south, two long barrel vault galleries extending east-west and two other narrow and short barrel vault galleries in the east-west direction, for the entrance and exit of the players. In addition to those, forty-one other systems, two of them in the north-south and two of them in the east-west direction, are present for the entrance and exit of the viewers. There are also other barrel vault galleries in the secondary status (Yalman, 1996).

The horizontal corridor (diazoma) separating the seats of the theatre had been greatly destroyed. The scaena (App. A) in the north was totally put into light, as well as most of the lower seats (cavea). A great part of the orchestra (App. A) is still covered with earth (Fındık, 2001).

Figure 1.4: General view of İznik Roman Theatre from the north.

Figure 1.5: Another view from the northeast of the theatre.

In the 13^{th} century, the theatre was turned into a cemetery (Yalman, 1991). A church, ceramic workshops and kilns were constructed inside the theatre at different periods (Yalman 1983, 1988, 1990, 1992, 1993) (Figures 1.4 and 1.5).

Findings mainly include ceramic pieces, kiln furniture and skeletons. Most of the ceramics are dated to the Byzantine and Early Ottoman periods. The Ottoman ceramics including the blue and white, Damascus and Rhodian wares were also revealed. Hellenistic, Roman and Seljuk ceramics are less likely to be found (Fındık, 2001).

The other findings include architectural pieces, animal bones, coins, metal and glass objects, oil lamps and jewellery.

1.2 Ceramics

1.2.1 An Introduction to Ceramics

Ceramics are the earliest technology of the mankind, combining the four basic elements identified by the Greeks: earth, water, fire and air. Ceramics include terra-cottas, earthenwares, stonewares and porcelain as pottery and craft items, besides bricks, roof and floor tiles. Also, as a broad term ”ceramics” refers to sewer pipes, cements and plasters, refractories, abrasives (App. A), glass and vitreous materials, enameled metals, electrical insulation and conduction fragments, spark plugs and dentures. Even glass is classified under the term of ceramics.

The materials science applies the term to chemical compounds of metallic and nonmetallic elements, which has a very broad meaning (Rice, 1987). So, ceramics are so into our lives that maybe we are not aware of them. Besides the technological and industrial usage of ceramics, the making of them constitutes man’s earliest art, which is so colorful and may also have a functional aspect.

The term “ceramic” derives from the Greek “keramos” that can be translated as “burned material” or “earthenware” (Searle and Grimshaw, 1959). In the archaeological aspect, ceramics encompass cooking and serving utensils and objects of art. The term “pottery” very broadly refers to the cooking and storage vessels, tableware of terracotta, earthenware (glazed and unglazed), stoneware and porcelain, constituting the foremost industry of the ceramics-field. However, sometimes pottery may apply to low-fired, unglazed objects whereas ceramics to high-fired, usually glazed and sometimes vitrified ones (Rice, 1987). The distinction between ceramics and pottery may be unclear in some cases.

Prehistorical, historical and modern pottery and ceramics are classified as categories of bodies or wares, according to their composition, firing and surface treatment (Norton, 1970). Terra-cottas and earthenwares make up the low-fired, porous and unvitrified class of pottery while stonewares and porcelain make up the high-fired and vitrified ceramics. Terra-cottas are coarse, porous wares fired at low temperatures, usually 900°C or less and have no glazes. But, they may display various surface treatments such as roughening and slipping (Rice, 1987). The earliest fired pottery throughout the world is in the category of terra-cottas (for detailed information on the history of pottery, see Appendix C).

Earthenwares are the ones with porous, unvitrified bodies but are fired at higher temperatures from 800 / 900°C up to 1100 / 1200°C. They may be glazed or unglazed. The glaze may occur itself naturally when the body starts to fuse at the high temperatures. The low-temperature fired earthenwares are the terra-cottas. The type of clay used in the manufacture of earthenware is generally coarse, plastic clay which gets red due to firing. Earthenwares consist of a wide range of products, ranging from coarse types such as bricks and tiles, to fine types such as wall tiles and maiolica vessels with tin glazes (Herz and Garrison, 1998).

Stonewares are fired at high temperatures of 1200 - 1350°C, causing the partial fusion and vitrification of the clay body. The body is gray or light brown, has medium to coarse grains and shows opacity. Modern stonewares are manufactured from sedimentary clays like ball clays, highly plastic and low in iron content. Archaeological stonewares can either be glazed or unglazed (Rhodes, 1973; Herz and Garrison, 1998).

Porcelains exhibit the most advanced technique of fine pottery, with the firing temperatures of 1280-1400°C or even higher. The highly refractory clay of kaolin used in their making is totally vitrified, giving the product its translucency, hardness and characteristic ring (Rice, 1987). Today's porcelains are composed of 40 % and 50 % kaolin, 25 % and 30 % feldspar acting as a flux and 20 % to 25 % quartz or flint (Norton, 1970; Rhodes, 1973).

1.2.2 Importance of Ceramics in Archaeology

The main raw material for ceramics is clay, which is very abundant on earth. It is formed by the weathering of the rocks, so is fine-grained and gets plastic when wetted. This is the most important characteristic of clay minerals, making them easily mold into desired shapes. When the clay is dried, it retains its shape and furthermore, it converts into a very strong rock-like mass when subjected to fire. This mass has very high durability, making it very suitable for cooking and storage. The most common artifact that man had ever made since the ancient times is ceramics. The durability of these ceramic objects made them survive until the present day. This is why ceramics are so important in the world of archaeology. Man's history can mostly be traced through ceramics especially for the prehistoric periods, because it is the most common indestructible material left from those times. However, ceramic studies retain their importance for all historical periods, informing us about the past cultural features and socioeconomic structures.

The technical ability of the past societies can be understood by investigating their ceramic-shaping and firing methods. At the beginning, the cups were shaped in the hand and fired in bonfire. By the time, the buildup of experience resulted in the increase of knowledge, introducing new ideas and techniques. New forms were adapted and potter's wheel was born. After that, highly developed kilns were designed leading to the fabrication and serial production.

The forms of ceramics are important parameters for the comprehension about the requirements of past societies. Different types of vessels point to different applications, usage and performance. For instance, different types of pottery used in the rituals of different societies reflect distinct ritual performance. The surface treatments and decorations applied to the ceramics point to the distinction of each culture with respect to regions and time. These stylistic characteristics reveal the characteristic elements of art, resulting from different cultural features.

The interaction of different cultures is absolutely reflected in the ceramic art and technology, which is an important phenomena helping to interpret the economical and political relations of the past societies. The ways of producing pottery in a particular culture may yield data on the socioeconomic structure and specialization. Whether there was a house-based economy or pottery-making was in the hands of specialized craftsmen can be scrutinized through the characteristics of production, especially for the prehistoric periods. The fabrication of ceramic products signifies the socioeconomic organization for delivery (Ökse, 2002 and 2003).

1.2.3 Techniques of Pottery-making

Pottery making is basically carried out by the techniques of pinching and/or drawing, slab modeling, molding, casting, coiling and throwing. Sometimes, more than one technique can be used for the making of a single vessel (Rice, 1987).

The pinching method is a hand-building technique, which is suitable for small vessels. It involves the opening up the clay ball by pressing into the centre with the thumb of one hand while holding it in the palm of the other hand. The clay ball is pinched all around with the fingers of one hand while it is being revolved in the palm of the other.

The slab method is also a hand-building technique, which suits well to the making of geometric shapes. The rolled slabs of clay are joined together to form the vessel (Turoff, 1949).

In molding, the clay is pressed into a form using molds either concave or convex. It has the advantage of speeding up the production (Shepard, 1971). The molds may form the entire body or parts of the body. They are either single units or may consist of more than one piece. Molds are made from plaster or fired clay. “Ad hoc” molds are produced from large broken vessel fragments and baskets. Parting agents such as powdered clay, ash, manure, pumice or fine sand are used to make the separation from the mold easier (Rice, 1987).

Casting / Slip casting is a type of molding, including a thin suspension of fine clay in water poured into the mold. The level of the slip is kept to the top of the mold. The slip is allowed to dry for some time to form a shell of clay when the shell reaches the desired thickness, the excess slip is poured off. The cast comes off when it is leather-hard and is left to dry (Turoff, 1949).

Coiling is a common hand-building method of forming the vessel with superimposed rolls of clay (Shepard, 1971). This method includes the three types, such as ring building, segmental coiling or spiral coiling.

In ring building, individual rings of clay are laid on top of each other.

Segmental coiling involves several segments making up each circular course to build the vessel.

Spiral coiling has a spiraling rope of clay constructing the vessel. It is often used to form the entire body of a vessel whereas other types of coiling method are also used to make parts of vessels that can be completed by other techniques as well.

Coiling is a suitable method for the construction of very large vessels.

Throwing on the potter's wheel is a common method, which has been developed since the prehistoric times. There are simple devices of pottery supports and turntables besides the real potter's wheel. The tournette is a small device, consisting of two stones with a pivot and socket or a wooden board turning on a pin. It is not actually the true potter's wheel because it lacks a flywheel giving the right rotation (Rice, 1987).

The potter's wheel provides high-speed rotation by combining rotary motion and pivoting with centrifugal force. There are two major types of the potter's wheel, such as the "stick wheel" and the "kick wheel".

The stick or simple wheel contains a large head and a short axle. It works by inserting a stick into a hole at the top and turning it thirty or forty times, thus giving no constant rotation.

The kick wheel or double wheel has a wheel head and a flywheel joined by a vertical axle. The clay is shaped upon the smaller upper wheel while the lower flywheel is being kicked. The kick-wheel provides constant rotation whose speed is controlled by the rate of kicking process. Because it is a heavy and complex mechanism, it is usually involved in large-scale workshop production (Rice, 1987).

The clay which is softer and wetter than that used in hand-building, for the facilitating of the shaping process and coping with the drying caused by the air circulation during rotation is placed in the centre of the wheel. The clay has usually finer texture to prevent the additional abrasion caused by the hands. The clay is opened, by inserting the thumbs into the centre while it is being rotated. The shape is given by pressing the clay upward with one hand and drawing the exterior upward and outward with the other. When the vessel is finished, it is cut from the wheel with a wire or thread.

"Throwing from the hump" is the method for producing vessels successively from the same lump of clay (Rice, 1987).

Jiggering is another technique which includes the forming of one surface of a bat of clay by placing in a revolving mold and forming the other surface by pressing it down on the mold with a template held against the clay as it rotates (Norton, 1970).

Wheel-thrown pottery exhibits rilling marks which are rhythmic lines, spiraling around the walls of the vessels (Ökse, 1999).

The raw materials used in the making of ceramic bodies are clays, silica, and fluxes (Table 1.1). They are hydrous alumino-silicates having a fine particle size. Clay minerals are the backbone of the ceramics.

Silica, in the form of sand or flint, is very abundant on the earth. Quartz crystals are common in all types of rocks and sand. Silica is added to the ceramic bodies to reduce the drying shrinkage, thus prevent the cracking of the body, to reduce the firing shrinkage and to constitute the skeleton of the ceramic body.

Another important constituent of the ceramic bodies is feldspar. Feldspars are anhydrous alumino-silicates containing potassium, sodium and calcium. Feldspars are mainly used as fluxes in the ceramic bodies, allowing the vitrification process by decreasing the melting point. This vitrification gives strength and hardness to the ceramic body. Other fluxes such as nepheline-syenite, limestone and magnesite are also used in ceramic bodies (Norton, 1956).

The properties of pottery may be enhanced, by roughening the surfaces by beating with a cord or covering them with slips, which are solutions of fine-grained clay and water. Roughening provides the surface with the ability to absorb heat and decreases the slipping when wet. Slips are applied to the pots to smooth the surface, reduce the porosity and prevent the leaking, before the firing process. They have generally a different colour than the body. A slip consists of fine-grained clays, fluxes, fillers such as silica, hardeners like borax, opacifiers and colorants (Rhodes, 1973).

Slips are applied to the dried body of the pottery by any of four techniques which are dipping in the slip, pouring the slip, wiping the pottery with slip and applying with a brush (Rice, 1987; Ökse, 1999). A modern method is spraying with a pistol working with pressed air (Çobanlı, 1996).

A slip should adhere well to the body. The coefficients of expansion of the body and slip should be equal for the defects such as peeling or crazing (App. A) not to occur. A slip should also get hardened within the same temperature range as the body. Finally, a slip should have enough consistency to cover the entire surface of the body. The consistency of the slip is related to the type of clay mineral, particle-size range, adsorbed ions and degree of dispersion of the clay (Shepard, 1971).

A glaze is a thin coating of glassy substance, applied directly on the body and/or the slip of the vessels. It is applied for the similar reasons as the slips, for giving texture, decorating and providing the impermeability. The main constituents of a glaze are acidic oxides which are the glass forming materials, the stabilizing materials which make up the body of the glaze and fluxes which make the glaze melt (Cooper, 1992). The main glass-forming material is silica which is mainly obtained from flint (Rhodes, 1973). The stabilizing materials have the functions of increasing the viscosity of the glaze and giving strength by reducing the defects, during the firing process. The main stabilizing materials are aluminum oxide, lead oxide, zinc oxide, zirconium oxide and cadmium oxide (Rice, 1987). Clay can be used as a source of aluminum oxide, also contributing to the physical properties of the raw glaze (Rhodes, 1973). The fluxes including sodium oxide, potassium oxide, lead oxide, calcium oxide and magnesium oxide lower the very high melting point of silica which is 1710°C.

In addition to those main constituents, various metallic oxides such as the oxides of iron, copper, manganese, cobalt and chromium are added as colorants (Rice, 1987). Organic materials can also be added as binders to strengthen the raw glaze (Parmelee, 1973). According to Knapp (1954), they are classified into four groups: a) alcohols and cellulose derivatives, b) sugars, starches and flours, c) gums, d) wax emulsions.

The glaze materials are usually applied in the form of finely ground powders (Cooper, 1992). Glazes may be applied directly on the unfired body of the vessel or after the first firing, so-called “bisque firing” of the body. After the application of glaze, the vessel is subjected to a second firing. The temperature of this glost firing may be the same with the bisque firing, higher or lower (Rice, 1987).

The glazes can be classified according to their maturing temperatures. Low temperature-glazes are fired between 1000-1150°C for earthenware, medium temperature-glazes are fired between 1200-1220°C for stoneware, and finally high temperature-ones are within the range of 1250-1280°C for stoneware and porcelain (Cooper, 1992).

Glazes are either made from raw materials or from frits which are actually pre-melted glazes including raw materials such as silica and a flux melted together, cooled then ground into a powder before adding to the glaze mixture.

Glazes are applied by various techniques such as dipping, pouring, splashing, painting and spraying (Parmelee, 1973; Rice, 1987).

Various pigments can be used for underglaze painting such as iron oxide, cobalt oxide, copper oxide or chromium oxide. The combinations of these oxides are made to obtain the full range of colours. The metallic oxides are mixed with a flux to make them sinter and a refractory material such as flint to prevent running under the glaze. The very fine powder of this material mixed with water or other type of media to provide the desired consistency is applied thinly either by brushing or spraying on the raw or fired body of the vessel or on the slip of the vessel. Then, they are covered with a transparent glaze. The kind of glaze applied over the underglaze pigments, the firing temperature and the atmospheric conditions much influence the final colour (Rhodes, 1973).

Table 1.1: Raw materials used in ceramic production

BODY AND SLIP MATERIALS	GLAZE MATERIALS
Clays: 1. Phyllosilicates clays a. Kaolin group b. Halloysite group c. Smectite group d. Vermiculite group e. Illite group f. Chlorite group 2. Hydrous-magnesian clays a. Attapulgite, palygorskite b. Sepiolite	**Stabilising materials:** a. Aluminum oxide b. Lead oxide c. Zinc oxide d. Zirconium oxide e. Cadmium oxide
Fluxes: 1. Feldpars a. Potash-feldpar: Microcline, Orthoclase b. Plagioclases: Albite Anorthite c. Celsian 2. Nepheline-syenite 3. Limestone, magnesite	**Fluxes:** a. Sodium oxide b. Potassium oxide c. Calcium oxide d. Magnesium oxide e. Lead oxide
Silica: Macrocrystalline forms: Sandstone, Ganister, Quartzite Cryptocrystalline forms: Chert, Flint, Chalcedony Hydrated forms: Opal	

1.2.4 Miletus – Ware

As written before, a group of ceramics which has a coarse red clay, white slip and mostly cobalt-blue decoration and shiny transparent glaze had been largely excavated in Kütahya, Milet, Konya, Antalya, Silifke, Bursa, Ankara, İstanbul and Malatya (Paker, 1965; Yenişehirlioğlu, 1998). During his research at the site of ancient Miletus, the German scholar Frederick Sarre found numerous sherds of this type and named them as "Miletus-ware" in the 1930s (Yenişehirlioğlu, 1998). He assented that these ceramics for the very first time revealed in Miletus, had been locally produced there. According to K. Erdmann, this type of ceramics had never been made in Miletus. They might have been brought here, for Miletus was an important port during the Principalities period (1299 - 1453) (Paker, 1965).

The excavations of İznik in the 1960s revealed that the main production center was İznik, with the findings of several sherds, kiln-wasters and unfinished pieces. Several kilns have been found in the center of the city (Atasoy and Raby, 1989).

The designs were drawn in painted thick contours, or sgraffitto technique, or without contours in free brush strokes (Aslanapa, 1984). The designs are covering up the full interiors of the wares, with a continuous change. The exteriors of the wares generally do not have decoration (Öney, 1976) and have most of the time green shiny glazes.

There are two principal design schemes in the decorations between the center and the border. The first one includes the wide bands drawn inside each other, the other one has the wide pairs of motives repeated alternately (Paker, 1965; Aslanapa, 1971).

According to Mükerrem Paker (1965), three main styles of decoration are observed in "Miletus-ware": floral, radial and geometric decoration styles. They were most of the time used together. The most common decoration is floral type of decoration. The motives of plants show a simplified, naturalistic style including stems, leaves, flowers, buds of wild flowers, fan-shaped leaves, sprays of carnations, clusters of vine and various types of rosette (Aslanapa, 1971). The decorations of fan-shaped leaves drawn by brush strokes, dispersing from a central rosette are frequently seen (Öney, 1989). Another group contains free compositions of flowers and leaf-motives. This type of decoration would influence the decorations of later Italian and Spanish maiolicas (Paker, 1965). Bird figures somehow rare are also to be observed, reflecting the Seljuk style (Aslanapa, 1965b). Also, in some cobalt-blue pieces from the Roman theatre, fish figures are to be seen (Fındık, 2001).

The group of geometrical design is relatively seldom. Sometimes, a thick network of geometrical patterns covers up the whole interior of the ware. The inside of the network is filled with stylized leaves, spirals and stars (Öney, 1976). Squares and hexagons are also encountered.

The border motives are meander-like patterns, S - motives, wave and rock motives, big circles, mutual triangles, scrolls following one another (Paker, 1965) and pearl sequences (Fındık, 2001).

The most common forms are large bowls and dishes, all having a short circular foot. The rim diameters are between 27- 32 cm. The rims of the dishes are usually turning 3-4 cm backwards. The dishes have various depths and sizes.

The interiors of the cups are fully slipped while the exteriors have a partial slip, reaching the middle section of the form. The walls of the cups are all the time thick (Aslanapa, 1965b). The closed forms are very rare. Toys had also been made (Paker, 1965).

The stylistic characteristics of "Miletus-ware" resemble to those of 15th century Iranian peasant ware, coarsely produced 11th and 12th century Syrian and Egyptian ware although their production material is different (Lane, 1957; Philon, 1980). Several types of Miletus-ware are related closely to Kubachi ware (Atasoy and Raby, 1989). Several types of Miletus-ware have close stylistic and compositional affinities with Persian Kubachi ware (Fındık, 2001).There are examples which are dated to 1468, 1473, 1480 and 1494, indicating that they were being produced in the second half of the 15th century (Reitlinger, 1938). The most important influence comes from the Seljuks of Rum-style. Excluding the characteristics of the body, designs and colors are closely linked in the two different periods. The color - scheme is totally the same as the Seljuk's (Paker, 1965). The interlocked motif of geometric bands and radial band pattern are seen in Seljuk tile tradition (Yetkin, 1986). The decorative types of the floral designs have also the vestiges of Seljuk decorations. Palmettes, rumis, lotus motives are all seen in Seljuk tiles.

Miletus-ware ceramics, also known as the ceramics of the Principalities period, have totally different decorative styles, colors and technique than the Byzantine ceramics (Paker, 1965). Besides the fact that it is a local style decorated hastily, Miletus-ware is the first original Turkish ceramic type in Anatolia (Aslanapa, 1984).

A group of ceramics produced contemporaneously in Italy shows close physical affinity with Miletus-ware and is named as "proto-maiolica" (Yenişehirlioğlu, 1998).

A recent grouping of Miletus-ware was done by Nurşen Özkul Fındık in 2001. These pieces were found in the Roman theatre excavations between 1980 and 1995. The ceramics with underglaze technique are divided into three sub-groups of slip- painting (slip), painting and incision techniques. Miletus-ware has the technique of painting which can either be monochrome or bichrome. There are also ceramics with incision and painting techniques. Monochrome painted ones have the groups of cobalt-blue, green or black. Bichrome painted ones have the groups of cobalt-blue and manganese-purple, cobalt-blue and turquoise, cobalt-blue and green, cobalt-blue and red, cobalt-blue and black. Each sub-group displays its own characteristics of painting, design and composition (Fındık, 2001).

The ceramics with black painting under turquoise glaze are thought to be the earliest group, reflecting Seljuk tradition (Fındık, 2001).

The following sequence is the possible chronology of Miletus-ware from the earliest group to the latest one: Black-painted, cobalt-blue painted, cobalt-blue and black painted, cobalt-blue and manganese-purple painted, cobalt-blue and turquoise painted, cobalt-blue and green painted, cobalt-blue and red painted and green painted (Personal communication with Assist. Prof. Dr. Nurşen Özkul Fındık).

In cobalt-blue and black painted group, cobalt-blue has a darker tone than in the others. The designs are drawn in thin contours. The geometric compositions are seen more often in this group. Cobalt-blue and black-painted group with their forms, dense decorations, compositions and painting styles, together with those characteristics told above are closer to the Islamic ceramics. It is an early group, dating to the end of the 14^{th} century and 15^{th} century. The famous cypress motif of the Ottoman art is for the first time in the ceramic tradition used in cobalt-blue and black painted group.

By the time, the blue had got lighter and the compositions had become emptier with free brush strokes and large surfaces with no decoration.

The ceramics of cobalt-blue and turquoise painted type are thought to be late productions with the detailed study of their designs.

In the early examples of cobalt-blue and green-painted group, green was only used as a thin contour surrounding the motives.

In a rare group of green-painted type, sliced - edge is seen for the first time in Miletus-ware, indicating the possibility of late 16^{th} and 17^{th} century production, for this type of rims separated from the body with lines were observed in 16^{th} century white-body Ottoman ceramics.

Application of a lighter blue tone, deformation of the motives, the style of painting and new color usage in monochrome painted, cobalt-blue and manganese-purple painted, cobalt-blue and black painted groups are all considered as late characteristics.

The only example of cobalt-blue and red painted group is a dish, found in the Roman theatre excavations (Fındık, 2001). It is dated to the 16^{th} century by Yetkin (1995).

The painted and incised group of Miletus-ware has different stylistic characteristics of decoration motives and compositions than the other groups. The painted and incised group of cobalt-blue found in the Roman theatre with its motives, dark tone of cobalt-blue and fine painting style is dated to the first half of the 15^{th} century (Fındık, 2001).

1.3 Ceramic Kilns

1.3.1 Early Ottoman Ceramic Kilns

The Ottoman ceramic kilns consisted of two sections, which were the lower firebox and the upper firing chamber. The firebox was separated from the firing chamber, by a floor that may have a single central hole or several flues or a grill. To prevent the heat loss, the firebox was usually built below the ground level and reached by steps (Raby, 1989). The firebox contained a trough on one side where the raw glaze was put. The firing chamber included pass-holes at the top for the escape of gases (Tuna, 1999).

Two types of ceramic kilns were being used in the Early Ottoman period: 1) kilns with square or rectangular bases, 2) kilns with circular bases.

In the first type, the floor has an area of 100 x 100 -140 cm and the height of the kiln is about 100 cm up to the beginning of the vault. The circular-based kilns had a diameter of about 200 cm, with a height of 160 cm up to the start of the dome (Tuna, 1999). The Ottoman ceramic kilns were built of bricks and mud brick mortar.

Both types of ceramic kilns were in use in Ottoman İznik. They were built at the spots where the proper winds provided the necessary air circulation (Fındık, 2001).

The pots were stacked in each other by the use of tripods. This was done from above in the cylindrical kilns while from sideways in the rectangular ones. This hole was then built with bricks and plastered with mortar (Tuna, 1999; Fındık, 2001).

The firing process started with the ignition of woods in the firebox. The temperature was slowly raised until it reached 850 - 900°C at the maximum. Because the lower part of the kiln had a higher temperature range with a difference of 40-60°C, the pots to be fired for the first time were placed below (Tuna, 1999). Red-bodied ceramics were stacked by tripods and supported underneath by clay rings to prevent sticking (Fındık, 2001).

It was suggested that the circular kilns provided higher firing temperatures which enabled the production of white-body fritware (Atasoy, 1989).

Two kilns found in the street of Lale, at the back of Ayasofya Church in İznik had circular plans and a circular opening on the firebox (Aslanapa, 1969).

Whether the productions of red-ware and white-ware were held distinctly in different workshops of İznik or they were being carried out together is an open question (Fındık, 2001). The technology of the two types of production differed much from each other, with the white-ware so-called fritware, which had a more advanced technique, brings the idea that they should have been produced in different types of kilns.

Most of the publications about the kiln debris and findings refer to the Miletus-ware of the Early Ottoman period. There is not much knowledge about the fritware kilns of İznik (Raby, 1989). Miletus-ware kilns had been revealed in the centre of İznik, near the church of Ayasofya, also in Dereköy and the Roman theatre (Raby, 1989; Yalman, 1992, 1993).

1.3.2 The Ceramic Kilns in the Roman Theatre

The kilns of no 1, 2 and 3 found in the Roman theatre had rectangular plans, with their fireboxes covered with pressed vaults which had several holes on them (Fındık, 2001). They were used for the production of red-ware, except the kiln of no.1 which is situated in the cavea, grid no. 12 (Yalman, 1983; Fındık, 2001). A workshop had been revealed close to the kiln no. 1 in the Roman theatre. Whether red-ware or white-ware production was being made in this workshop is not clearly understood, for this workshop had a refuse pit including red-ware, next to it.

The road excavations carried out at the locations of the other ceramic kilns might have destroyed the workshops that may have been associated with these kilns. The stoves found close to these kilns and the remains of a probable water- or mud-pool situated on the west of the kiln no.3 may support the idea of distinct productions (Fındık, 2001).

The ceramic kiln no. 2 situated on the west of the theatre, close to the grid no. 55 (Yalman, 1992) revealed pieces of different techniques such as Miletus-style, sgraffitto and monochrome glaze showing that they were being fired altogether in the same kiln. Because of the fact that these techniques were the earliest ones in the

Ottoman period, this kiln is thought to be the oldest one which might have been founded as early as 14th century (Fındık, 2001).

The ceramic kiln no. 3 situated on the southwest of the theatre, in grid no. 61 had revealed monochrome glazed and Miletus-type ceramics (Yalman, 1993), showing that they were being produced together. The ceramic kiln no. 4 situated on the south of the theatre in grid no. 63 had a circular plan (Yalman, 1993; Fındık, 2001). This kiln also had revealed monochrome glazed, Miletus-type and sgraffitto ceramics, showing the similar type of production as the kilns no. 2 and 3 (Fındık, 2001).

1.4 Previous Archaeometric Studies on İznik Ceramics

A very comprehensive study on İznik ceramics "İznik - The Pottery of Ottoman Turkey" was published by N. Atasoy and J. Raby in 1989 which was announced as the year of İznik. This extensive publication has three main approaches to the subject, which are the historical development of İznik ceramics including types and forms, the stylistic phases corresponding to different historical periods and the evolution of ceramic-making in terms of materials, equipment thus the technological characteristics.

Another forthcoming study for the classification of İznik pottery was published by Nurşen Özkul Fındık in 2001. The studied ceramics were found in the Roman theatre excavations between 1980 and 1995. The grouping of these Ottoman ceramics was done according to their production technique and stylistic differences. The typological sequences were also given.

Several studies were done by Henderson (1989) and Tite (1989) as well as Kiefer (1956a and 1956b) and Kingery and Vandiver (1986) to reveal the production methods of the body, slip and glaze parts of various types of İznik ceramics corresponding to different stylistic phases (Abraham of Kütahya, Damascus and Rhodian wares etc.) and the colorants used in their glazes.

In addition to those, mineralogical and micromorphological studies that were done by Okyar (1995) and Kapur and Sakarya et al. (1998 and 2000) contributed to the knowledge about the technology of İznik ceramics as well as the raw material sources.

Henderson and Raby (1989) carried out a comparative approach in the search for the possible roots of İznik fritware tradition that flourished in the 16^{th} century with its earliest examples in the 1470s. The remarkable technology of the famous İznik fritware with a white stone body and a transparent shiny glaze exhibiting a wide range of underglaze colors was unlike any other Islamic ceramic tradition. This fine-ware of high quality which consisted of the blue-and-whites, Damascus-ware, Rhodian-ware and İznik tiles of the 16^{th} century had a high silica body including a lead frit and a small amount of clay, a white slip also containing lead (lower than that of the body) and a (lead oxide - soda – silica) glaze in which tin was dissolved (Henderson, 2000).

The use of lead in combination with an alkali lowered the melting point of silica, allowing higher degree of vitrification at relatively low temperatures which brought savings of fuel.

The comparative studies including other types of ceramics such as Miletus-ware sherds, Master of Tabriz fragments and Chinese blue-and-white porcelains with İznik fritwares led to the conclusion that no precise antecedents were to be found for the spring of İznik fritwares (Tite, 1989; Henderson, 2000).

1.5 Aim of the Work

İznik was an important pottery production center since Byzantine times and had an industry which successfully continued till 18th century. In the excavations of the ancient Roman theatre (2nd century A.D.), several sherds of different historical periods including some Ottoman ceramics were recovered. The aim of this study is to examine the material specifications and production technology of some sherds, belonging to the Early Ottoman period.

As they are mostly Miletus-ware type, these findings may contribute to the knowledge on this one of the most remarkable type of ceramic technology.

CHAPTER 2

MATERIALS AND METHODS

2.1 Sample Locations

Samples were collected from the grids no 93, 94 and 95 in the Roman theatre (see Appendix D). Grids no 93 (Figure 2.1) and 95 (Figure 2.2) are located in the east of the theatre, in front of a barrel vault. Grid no 93 is an Early Ottoman ceramic kiln which has been the sixth kiln found so far in the Roman theatre (personal communication with Assist. Prof. Dr. Bedri Yalman, 2003). Grid no 95 is a dump associated with the kiln. Grid no 94 is placed in the orchestra section of the theatre.

Figure 2.1: Close up view of Grid no 93

Figure 2.2: Close up view of Grid no 95

2.2 Sampling

27 ceramic samples were collected from grids 93, 95 and 94 in the Roman theatre. They were coded and defined according to their decoration technique (Table 2.1).

Table 2.1: Sample descriptions (Co : Cobalt, Mn : Manganese)

Sample No	Grid No	Description	Figure No
1	G93	Co-blue painted / body piece	2.3
2	G93	Black painted / body piece (close to the rim)	2.4
3	G93	Co-blue painted and incised / bowl – rim piece	2.5
4	G93	Blue glazed / plate – edge piece	2.6
5	G93	Co-blue painted and incised / body piece	2.7
6	G95	Co-blue painted / body piece	2.8
7	G93	Co-blue painted / body piece	2.9
8	G93?	Co-blue and Mn - purple painted / body piece	2.10
9	G95	Blue glazed / body piece (close to the rim)	2.11
10	G93	Co-blue painted / body piece	2.12
11	G93	Co-blue painted / body piece	2.13
12	G93	Co-blue painted / small bowl (?) – edge piece	2.14
13	G95	Co-blue and green painted / bowl – edge piece	2.15
14	G95	Co-blue and black painted / bowl – edge piece	2.16
15	G95	Co-blue and Mn – purple painted / body piece	2.17
16	G95	Co-blue and black painted / body piece	2.18
17	G95	Co-blue and green painted / plate (?) - edge piece	2.19
18	G95	Co-blue painted / body piece	2.20
19	G94	Co-blue and black painted / body piece	2.21
20	G95	Co-blue painted / body piece	2.22
21	G93	Co-blue painted / body piece (close to the edge)	2.23
22	G93	Co-blue and black painted / body piece	2.24
23	G95	Co-blue and black painted / bowl – edge piece	2.25
24	G93	Co-blue painted (?) / bowl – edge piece	2.26
25	?	Green glazed / edge piece	2.27
26	G93	Co-blue and black painted / edge piece	2.28
27	G93	Co-blue painted / edge piece	2.29

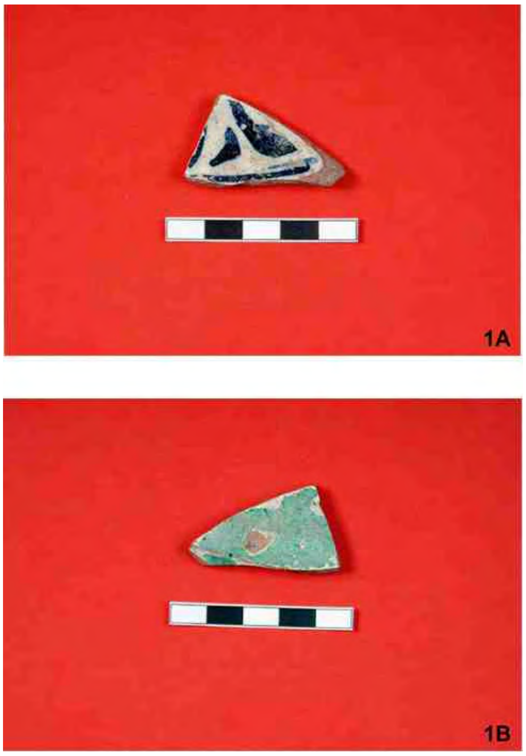


Figure 2.3: Sample no 1

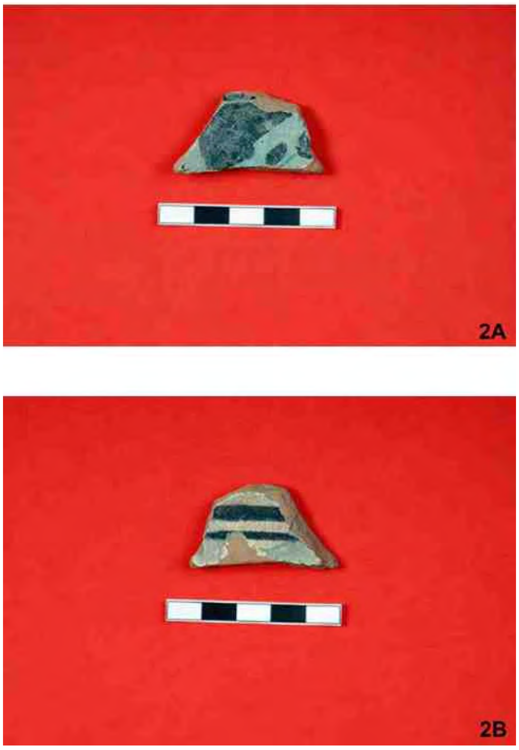


Figure 2.4: Sample no 2

Figure 2.5: Sample no 3

Figure 2.6: Sample no 4

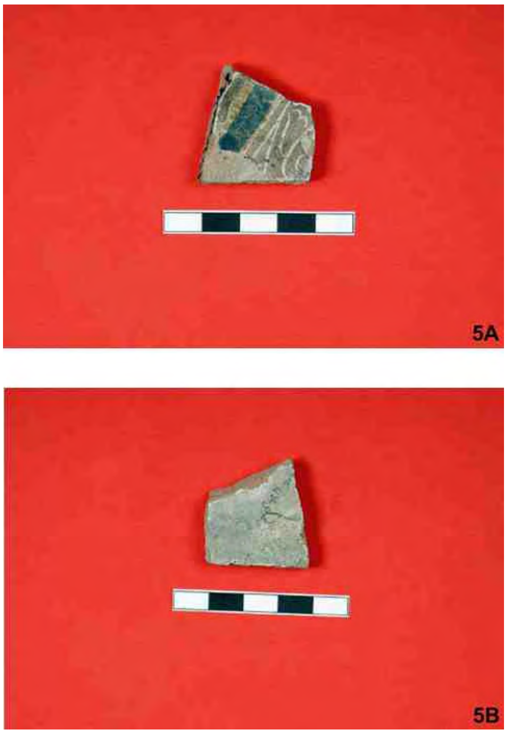


Figure 2.7: Sample no 5

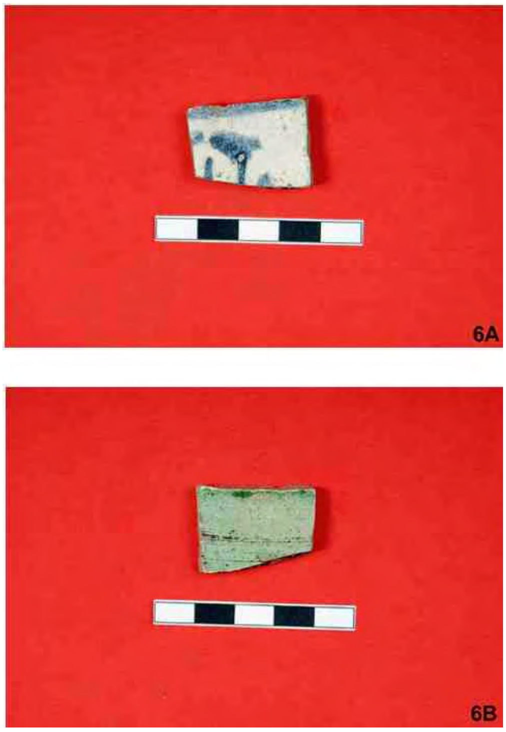


Figure 2.8: Sample no 6

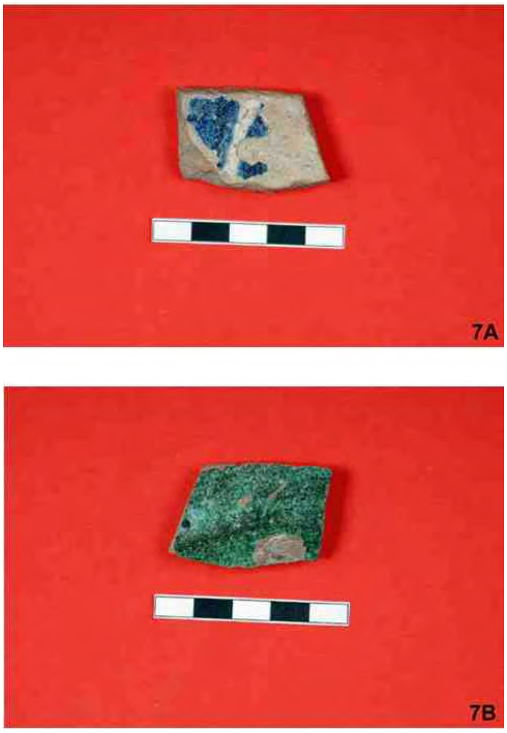


Figure 2.9: Sample no 7

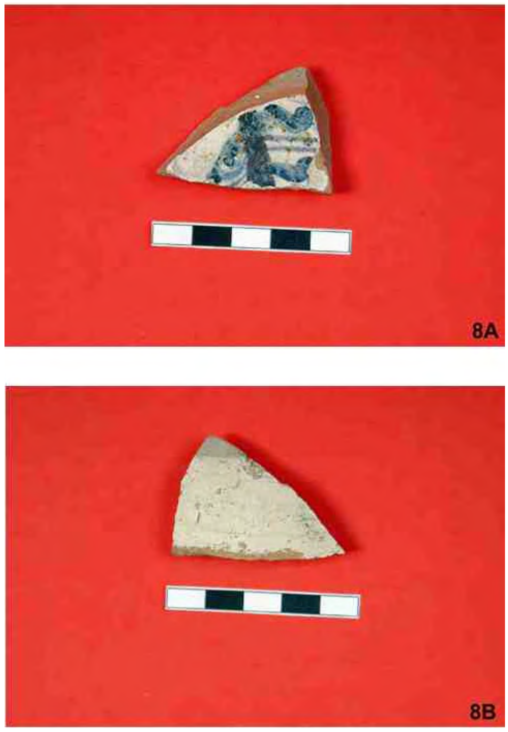


Figure 2.10: Sample no 8

Figure 2.11: Sample no 9

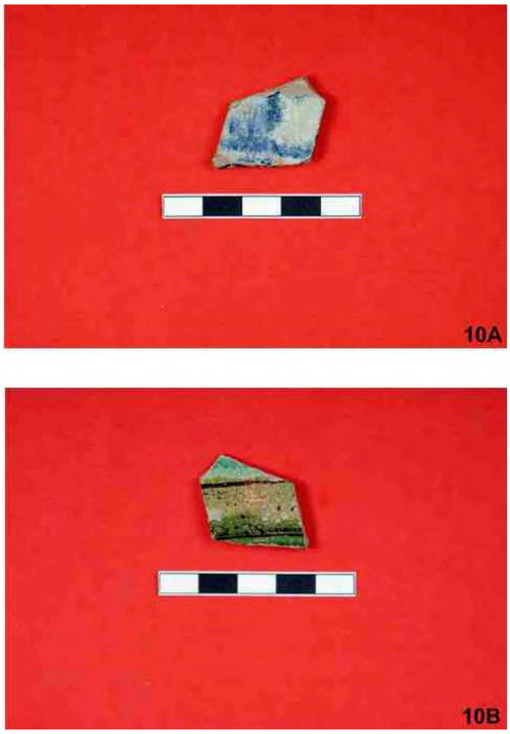
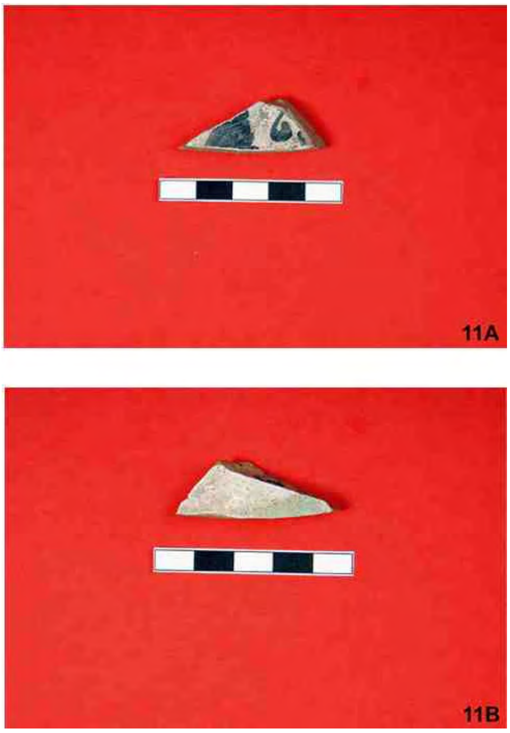


Figure 2.12: Sample no 10



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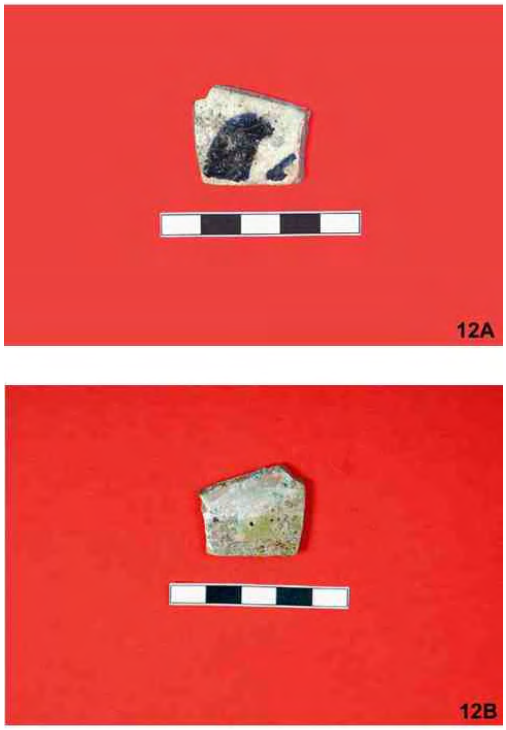


Figure 2.14: Sample no 12

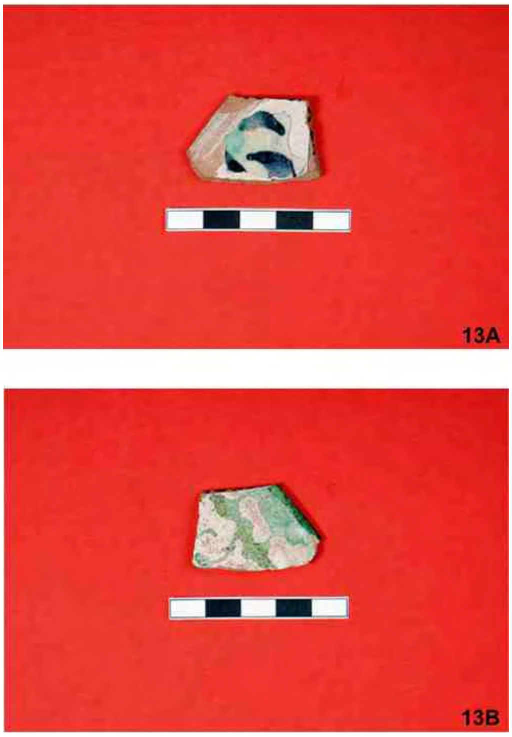


Figure 2.15: Sample no 13

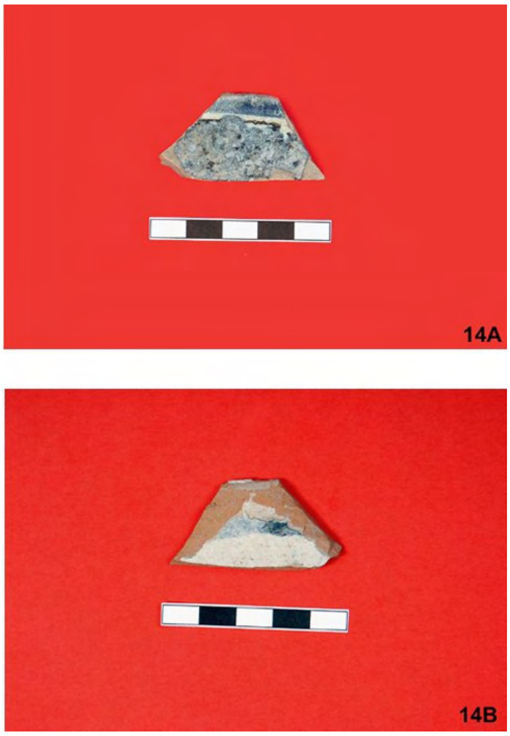
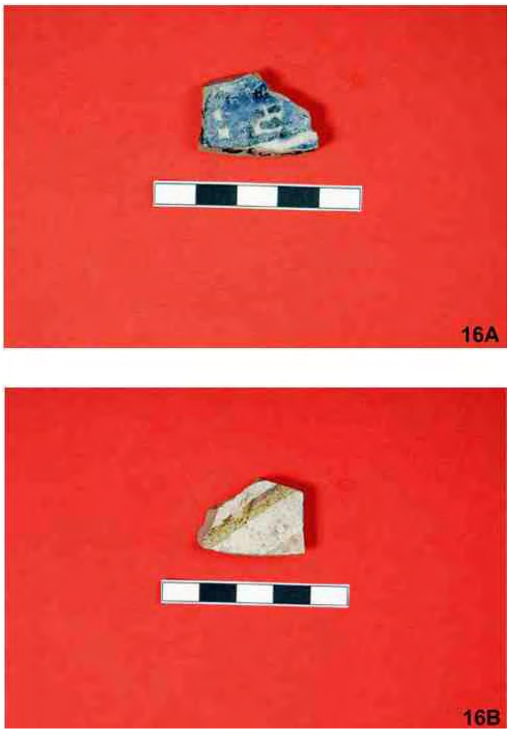


Figure 2.16: Sample no 14

Figure 2.17: Sample no 15



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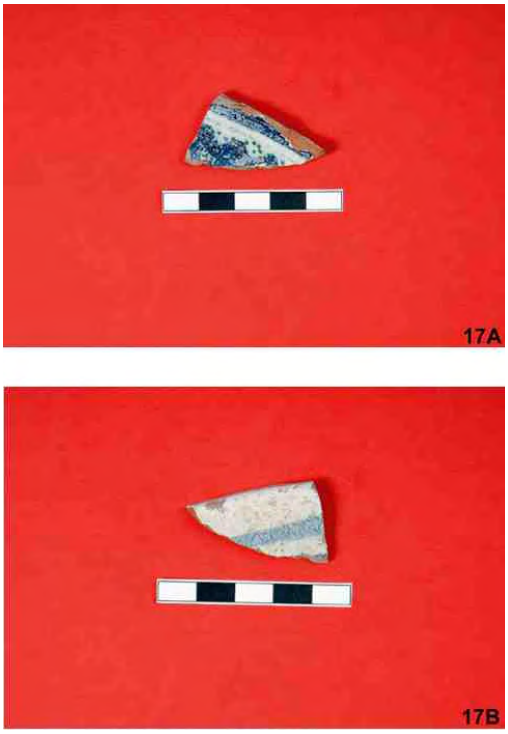


Figure 2.19: Sample no 17

Figure 2.20: Sample no 18

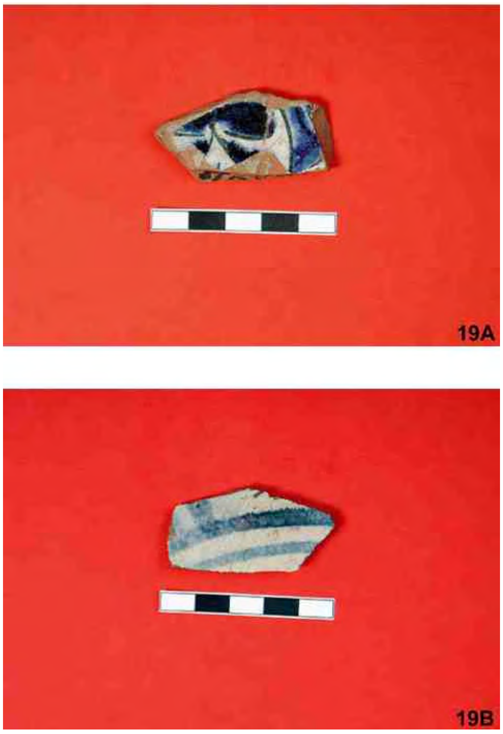
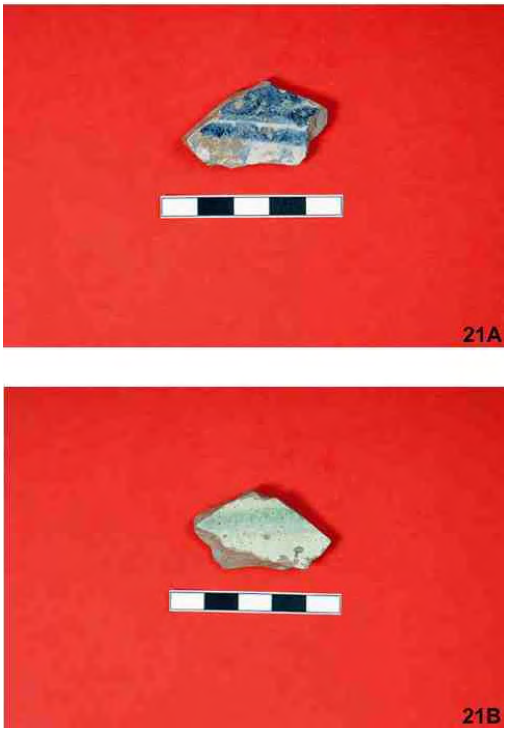


Figure 2.21: Sample no 19

Figure 2.22: Sample no 20



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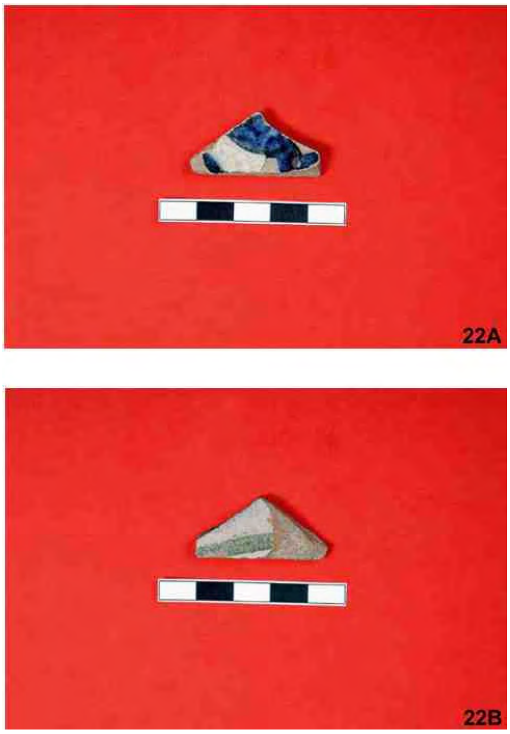


Figure 2.24: Sample no 22

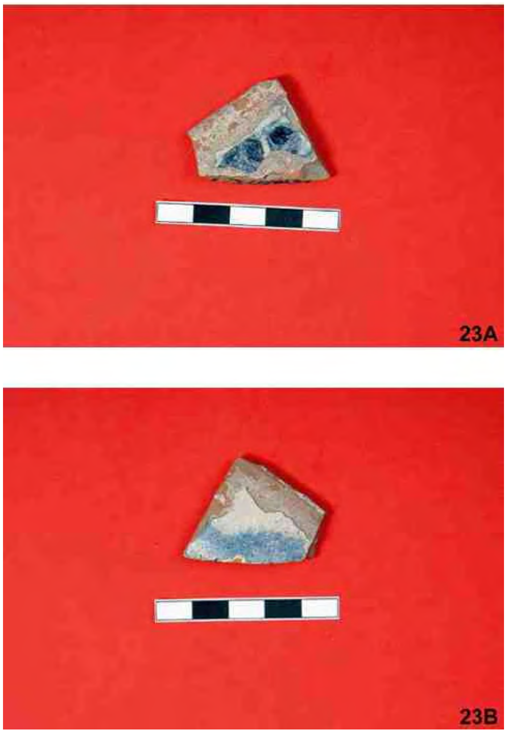


Figure 2.25: Sample no 23

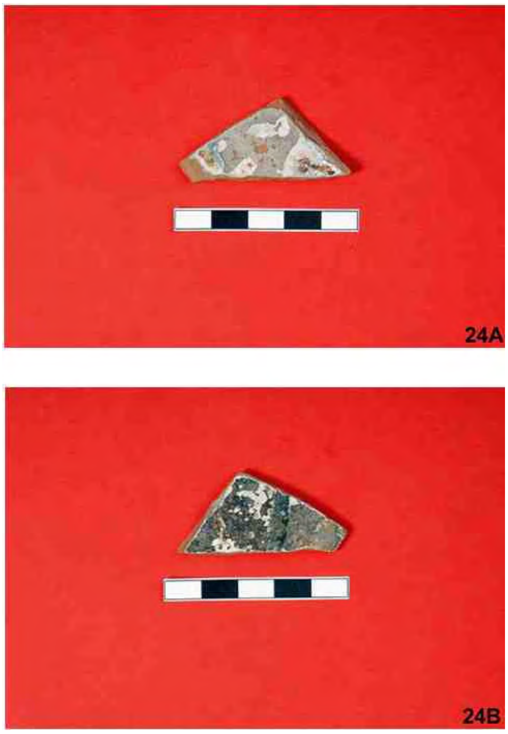


Figure 2.26: Sample no 24

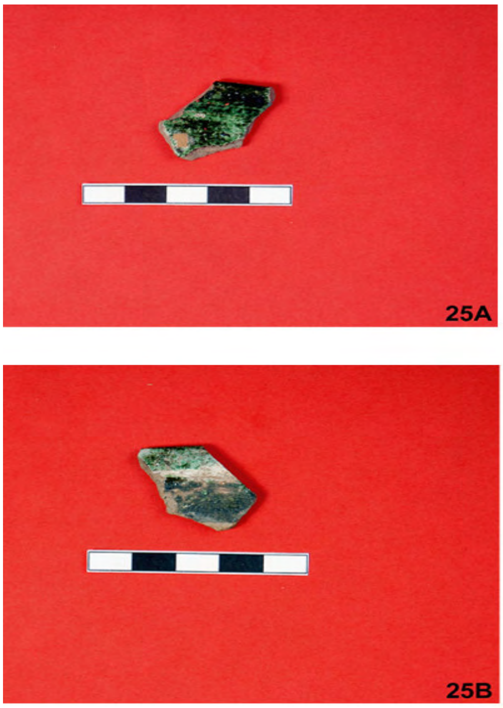


Figure 2.27: Sample no 25

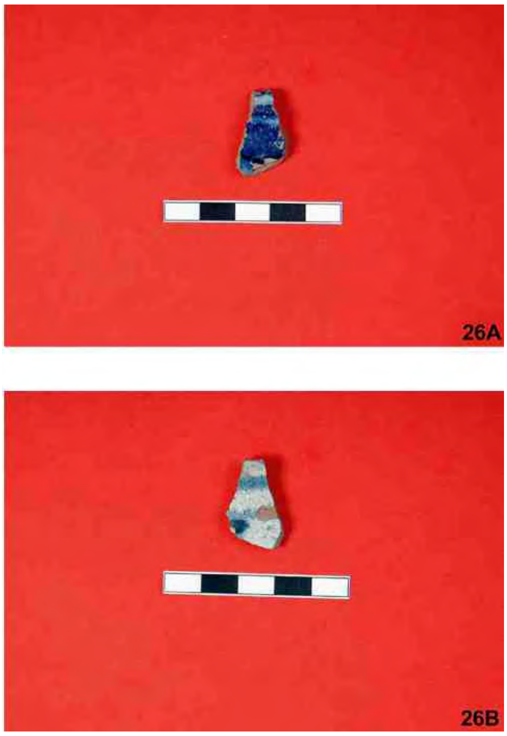


Figure 2.28: Sample no 26

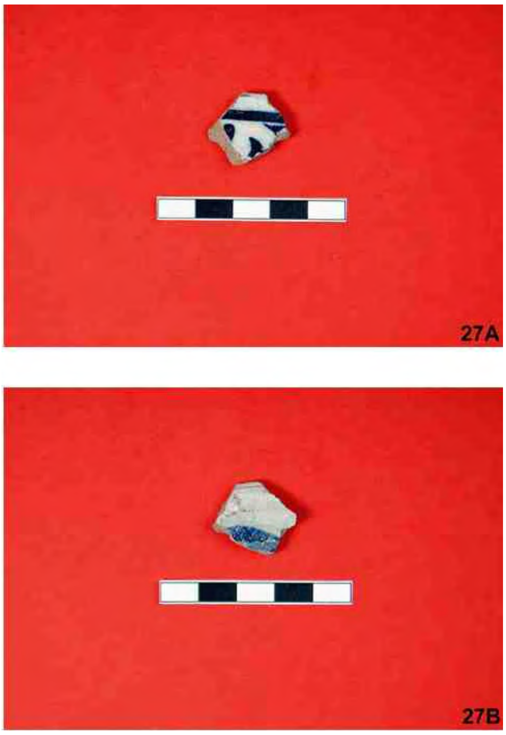


Figure 2.29: Sample no 27

The sherds are mostly Miletus-ware type except samples 4, 9 and 25. Sample 2 can be either Miletus-ware or Seljuk ceramic, as it displays black paint under turquoise glaze. Sample 24 is unidentified due to its badly preserved state. Most of the samples are body piece.

10 of the sherds are Miletus-ware with underglaze cobalt – blue paint technique. 6 of the sherds are Miletus-ware with underglaze cobalt-blue and black paint technique. 2 of them are Miletus-ware with underglaze cobalt-blue paint and sgraffitto technique. 2 of them are Miletus-ware with underglaze cobalt-blue and manganese-purple paint technique. 2 of them are Miletus-ware with underglaze cobalt-blue and green paint technique. 3 of them display monochrome glaze technique. One of them displays underglaze black paint technique.

2.3 Visual Classification and Dating

Visual classification according to the decoration technique and color and dating of the samples were done with the assistance of Assist. Prof. Dr. Nurşen Özkul Fındık based on her earlier work on İznik Ottoman ceramics from the Roman theatre (Fındık, 2001).

2.4 Color Examination

The body colors of the ceramic samples were assigned by Munsell Soil Color Charts (1998) as well as the paints and glazes using Munsell Glossy Finish Collection (1966).

Munsell Color System is the most widespread system in determining color. The degree of coloring within the ceramic bodies which is reflected through the amount of oxidized carbon and iron; gives a preliminary idea for the conditions under which the pottery was fired (Rice, 1987).

2.5 Thin Section Analysis

Thin section analyses of all the samples were carried out as follows: A slab of pottery is cut from the ceramic fragment which is then consolidated with an epoxy resin. The cut side is polished in order to obtain a smooth surface. Then, the slab is affixed on a microscope slide and ground away with abrasives to a uniform thickness of 0.03 mm. The slide is covered with a thin glass. The correct thickness is achieved at 0.03 mm when the proper interference colors of minerals are obtained in the polarizing microscope (Rice, 1987).

Thin section preparation was carried out at the Thin Section Laboratory of the Geological Engineering Department in METU. The optical examination was carried out in the laboratories of Geological Engineering Department of METU and General Directorate of Mineral Research and Exploration (MTA).

2.6 X-Ray Diffraction Analysis

Ceramics can be characterized by identifying their mineral components using X-ray diffraction analysis which is very useful in directing provenance and technology studies.

Powdered and unoriented specimens from the body sections of the ceramic samples were used for XRD analysis.

X-Ray powder diffraction analyses of all the samples were carried out at the MTA. "Phillips PW 3710" X-ray diffractometer was used with CuKα radiation with a Ni filter at a scan speed of 3°/min.

2.7 Scanning Electron Microscopy Coupled with Energy Dispersive X-Ray Analysis

Firing temperature of ceramics indicates the sophistication level of the firing process, thus it is diagnostic for production technology. The firing temperature of a ceramic object is reflected through its microstructure.

When the temperature increases, localized melting occurs, which leads to the beginning of vitrification. The level of interconnection of the grains increases with the decreasing of porosity (at about $1000^{O}C$-$1050^{O}C$). At the end, pores get isolated and rounded vesicles are created by the expansion of trapped gases (at about $1100^{O}C$-$1150^{O}C$) which also causes macroscopic bloating at higher temperatures (c.$1200^{O}C$-$1250^{O}C$) (Freestone and Middleton, 1987).

For sample preparation, a small fragment of the ceramic sherd which has not more than 1cm x 1cm area and 2 cm height is stuck onto a metal holder with glue. The detectable part is the outermost section of the ceramic piece. Because the specimen should be electrically conducting, it is plated with a very thin layer of gold (Leute, 1987).

The energy-dispersive X-ray analysis (EDX) can be used to detect the elements semi-quantitatively and is a test for chemical analysis, using no standard.

SEM coupled with EDX analysis was performed at the Metallurgical Engineering Department in METU. A JEOL JSM - 6400 SEM coupled with Energy Dispersive Noran System SIX instrument was used in the study.

2.8 Fourier Transform Infrared Spectrometry Analysis

Samples are powdered in an agate mortar with a pestle. About 0.5 mg sample and 0.2 g KBr are mixed to form a pellet of 13 mm diameter under pressure. The pellets were used to take the measurements.

FTIR analysis was performed by a Mattson 1000 FTIR Spectrometer at the Department of Chemistry in METU.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Sample Description and Dating

Visual grouping according to the decoration technique and color together with the dating of the samples were done with the assistance of Assist. Prof. Dr. Nurşen Özkul Fındık based on her earlier work on İznik Ottoman ceramics from the Roman theatre (Fındık, 2001).

Edge pieces drawn by Nadire Atıcı from METU Museum are given in Appendix E.

Samples were dated between 14th – 16th centuries. Some of the examples could not be given dates due to insufficient data. Results are given in Table 3.1.

Samples all have gritted red body and most of them wear a slip and glaze on both sides which are shown in Table 3.2. Most of the samples have transparent glaze on the inner side and greenish glaze on the outer side. Glazes of samples 3, 5 and 11 were not properly fired and appear as dark layers on the slips. Sample 24 is a damaged piece making its identification difficult.

Table 3.1: Sample description and dating (Co: Cobalt, Mn: Manganese)

Sample No	Grid	Description	Technique	Possible Dating
1	G93	Co-blue painted / body piece	Underglaze	End of 14^{th} century and 15^{th} century
2	G93	Black painted / body piece (close to the rim)	Underglaze	Seljuk (?) – Early Ottoman (mid14th – mid15th century)
3	G93	Co-blue painted and incised / bowl – rim piece	Underglaze + sgraffitto	Last quarter of the 15^{th} century
4	G93	Blue glazed / plate – edge piece	Monochrome glazed	Isochronal with Miletus-ware
5	G93	Co-blue painted and incised / body piece	Underglaze + sgraffitto	Last quarter of the 15^{th} century
6	G95	Co-blue painted / body piece	Underglaze	End of 15^{th} century (?)
7	G93	Co-blue painted / body piece	Underglaze	End of 14^{th} century and 15^{th} century
8	G93?	Co-blue and Mn-purple painted / body piece	Underglaze	15^{th} century and 16^{th} century
9	G95	Blue glazed / body piece (close to the rim)	Monochrome glazed	?
10	G93	Co-blue painted / body piece	Underglaze	15^{th} century and 16^{th} century (?)
11	G93	Co-blue painted / body piece	Underglaze	?
12	G93	Co-blue painted / small bowl (?) – edge piece	Underglaze	16^{th} century (?)
13	G95	Co-blue and green painted / bowl – edge piece	Underglaze	Mid 15^{th} century and after
14	G95	Co-blue and black painted / bowl – edge piece	Underglaze	Mid 15^{th} century and 16^{th} century
15	G95	Co-blue and Mn-purple painted / body piece	Underglaze	Early 15^{th} century (?)
16	G95	Co-blue and black painted / body piece	Underglaze	16^{th} century (?)
17	G95	Co-blue and green painted / plate (?) – edge piece	Underglaze	Mid 15^{th} century and after
18	G95	Co-blue painted / body piece	Underglaze	?
19	G94	Co-blue and black painted / body piece	Underglaze	14^{th} century
20	G95	Co-blue painted / body piece	Underglaze	16^{th} century
21	G93	Co-blue painted / body piece (close to the edge)	Underglaze	?
22	G93	Co-blue and black painted / body piece	Underglaze	14^{th} century and 15^{th} century
23	G95	Co-blue and black painted / bowl – edge piece	Underglaze	14^{th} century and 15^{th} century
24	G93	Co-blue painted (?) / bowl – edge piece	Underglaze	?
25	?	Green glazed / edge piece	Monochrome glazed	?
26	G93	Co-blue and black painted / edge piece	Underglaze	?
27	G93	Co-blue painted / edge piece	Underglaze	16^{th} century (?)

Most of the samples display floral designs, especially on their inner side while a few of them exhibit geometrical designs on both sides.

Table 3.2: Slip-glaze descriptions (+: present, -: absent)

Sample No	SLIP		GLAZE		Sample No	SLIP		GLAZE	
	Inner	Outer	Inner	Outer		Inner	Outer	Inner	Outer
1	+	+	+	+	15	+	+	+	-
2	+	+	+	+	16	+	+	+	+
3	+	+	+	+	17	+	+	+	+
4	+	+	+	+	18	+	+	+	+
5	+	+	+	+	19	+	+	+	+
6	+	+	+	+	20	+	+	+	+
7	+	-	+	+	21	+	+	+	+
8	+	+	+	-	22	+	+	+	+
9	+	+	+	+	23	+	+	+	+
10	+	+	+	+	24	+	+	+	+
11	+	+	+	+	25	+	+	+	+
12	+	+	+	+	26	+	+	+	+
13	+	+	+	+	27	+	+	+	+
14	+	+	+	+					

3.2 Color Examination

Bodies of the samples mostly have reddish yellow in the 5YR scale and/or tones of red in the 2.5 YR and 10R scales, according to the Munsell Soil Color Charts (1966) which point to oxidizing firing conditions in the kiln, as supported by the detection of abundant hematite in mineralogical analysis (Table 3.3).

Bodies of samples 11 and 15 are exceptional ones with tones of gray, pink and brown which may indicate insufficient oxidation in the kiln (Table 3.3).

Slips are mostly white which is a characteristic of Miletus-ware type.

Colors of the paints and glazes were also determined according to Munsell Book of Color (see Appendix F).

Table 3.3: Colors of the bodies and slips determined according to the Munsell Soil Color Charts

Sample No	Paste	Slip
1	5YR 7/6 (reddish yellow) – 10 R 5/4 (weak red)	white
2	2.5 YR 6/8 (light red)	white
3	5YR 7/6 (reddish yellow) – 5 YR 5/4 (reddish brown)	white
4	5YR 7/6 (reddish yellow) – 2.5 YR 5/6 (red)	white
5	5YR 7/6 - 6/6 (reddish yellow)	white
6	5YR 7/6 (reddish yellow) – 2.5 YR 5/6 (red)	white
7	5 YR 6/6 (reddish yellow) – 10 R 5/6 (red)	white
8	5YR 7/6 - 6/6 (reddish yellow)	inner: white , outer: 10 YR 8/3 (very pale brown)
9	5YR 7/6 (reddish yellow) – 2.5 YR 6/8 (light red) – 10 R 5/4 (weak red)	white
10	2.5 YR 6/6 (light red)	white
11	7.5 YR 7/4 (pink) – 7.5 YR 6/4 (light brown)	white
12	7.5 YR 8/4 – 7/4 (pink) - 5YR 7/6 (reddish yellow)	white
13	5YR 7/6 – 7/8 – 6/6 (reddish yellow)	white
14	5YR 7/6 – 7/8 (reddish yellow)	white
15	7.5 YR 7/3 – 7/4 (pink) – 6/2 (pinkish grey) – 6/4 (light brown)	2.5 Y 8/2 – 8/3 (pale yellow)
16	5YR 7/6 (reddish yellow)- 2.5 YR 7/6 - 7/8 (light red)	white
17	2.5YR 7/8 – 6/6 – 6/8 (light red)	white
18	5YR 7/6 (reddish yellow)	inner: white, outer:?
19	5YR 7/6 (reddish yellow)- 2.5 YR 7/6 - 7/8 (light red)	inner: white, outer: ?
20	2.5YR 7/6 – 7/8– 6/6 (light red)	inner:?, outer: 10 YR 8/2 (very pale brown)
21	2.5YR 7/6 – 7/8– 6/6 (light red)	white
22	5 YR 7/4 (pink) – 7/6 (reddish yellow)	inner: 10 YR 8/2 (very pale brown), outer:?
23	2.5YR 7/6 – 7/8– 6/6 (light red)	white
24	5YR 7/8 (reddish yellow)- 2.5 YR 7/6 – 6/6 (light red)	probably white (damaged piece)
25	7.5 YR 8/6 – 5YR 7/6 (reddish yellow)	white
26	5 YR 7/6 (reddish yellow) – 2.5 YR 7/6 (light red)	white
27	5YR 7/6 (reddish yellow)	white

3.3 Mineralogical Analysis

Mineralogical analysis of the samples is given considering body, slip and glaze parts separately.

3.3.1 Body

Common minerals

In the thin section analysis, common minerals detected in the bodies of the ceramic samples are quartz, feldspar, hematite, mica/biotite, opaque minerals and hornblende (Figures 3.1a - d). These observations are also confirmed by XRD analyses where quartz was present in all ceramic samples. Feldspar and hematite were also observed in most of the samples (Table 3.4, Appendix G). These minerals are quite abundant in the related thin section samples.

Among the common minerals, feldspar in the form of plagioclase was determined in samples 2, 3, 17, 22 and 25 which is easily recognized by its polysynthetic twinning under crossed polarized light in the polarizing microscope (Kerr, 1977) (Figure 3.1c).

Second common mineral, hematite found in thin sections indicates the presence of iron in the clay matrix of the samples (Figures 3.1d - e). It is in the fully oxidized form (ferric iron), giving a red-reddish brown color to the body after the firing process (Rice, 1987). This proves the presence of an oxidizing atmosphere in the kiln during firing.

Biotite (Figure 3.1c) belonging to the mica group of the phyllosilicates is often found together with the clay minerals (Worrall, 1982). Body of sample 2 appears to be much richer in micaceous minerals (Figure 3.1f), compared to the other bodies. This may be an evidence for a different clay source and/or an earlier production date, as it was predicted by previous visual examinations.

The last common mineral, hornblende, a member of amphibole group, is a very common and widespread mineral in many types of igneous and metamorphic rocks (Kerr, 1977). Sample 24 and 27 display oxidized hornblende which might have occurred during the firing process.

Less common minerals

Less common minerals observed in thin section analyses are epidote, pyroxene and mica/muscovite. Epidote was encountered in samples 1, 2 and 5 (Figure 3.1d). It is a common detrital mineral (App. A), originating from mostly various types of igneous and metamorphic rocks. Pyroxene, another less common mineral observed is among the major rock forming constituents.

Muscovite which was observed in samples 3, 23, 24, 25 and 27, is very common in metamorphic rocks like phyllites, schists and gneisses. At a temperature of about 700°C or more, muscovite decomposes (Turner, 1968), so the detection of this mineral may indicate firing temperatures not more than 700°C for the samples 3, 23, 24, 25 and 27. The SEM micrographs of samples 23 and 27 exhibit low degree of vitrification. This may also support the use of low firing temperatures for the samples indicated (Figures 3.2 a, c).

Remnant clay particles, mainly chloritic, were detected in the thin sections of samples 2, 5, 8, 9 and 13. Their presence indicates firing temperatures below 850°C (Grim, 1968). However, as they were not detected in XRD traces, they may have been left in minute amounts as a result of non-uniform firing conditions in the kiln.

Body of sample 2 shows a low degree of vitrification due to low degree of firing when viewed under SEM (Figure 3.2d). This is in accordance with the presence of clay minerals in its thin section. Individual mineral particles such as feldspar crystals in the groundmass are also easily distinguished in sample 2 (Figure 3.2e).

Rare minerals

Rare minerals present are chert and zircon. Chert is cryptocrystalline silica, usually being associated with black shales and spilites (App. A) (Gribble and Hall, 1992). It is observed in samples 14, 22, 23 and 25. A tiny fragment of zircon was found in sample 18 (Figure 3.1g). This may signify an igneous character together with the piece of glassy tuff identified in the same sample (Figure 3.1e) (Kerr, 1977).

Rock fragments

In thin section analyses, rock fragments mainly of metamorphic origin were commonly observed in the body sections. They mostly consist of polycrystalline quartz (Figure 3.1h) and/or mica/biotite and/or epidote. They are either schist fragments as in samples 2, 3, 4, 5 or phyllites as in sample 1.Thus, the clay raw material used mostly seems to be originating from a metamorphic source reflecting the metamorphic rock characteristic surrounding Lake İznik (www.mta.gov.tr/ mta _ web/500.000/500bin/ İstanbul_b.asp).

A different type of rock fragment, probably of volcanic origin was encountered in thin section of sample 6. Also in sample 18, an igneous rock fragment, a volcanic glass was also determined (Figure 3.1e). In addition to these, another igneous rock fragment which is extrusive was observed in sample 22 (Figure 3.1i).

Sedimentary rock fragments such as limestone were also encountered, as in sample 22 (Figure 3.1j). Calcium carbonate present in limestone fragment decomposes at temperatures between 650 - 900°C as follows (Rice, 1987):

$$CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$$

In its thin section, the presence of a limestone fragment for sample 22 together with the low degree of vitrification in its body SEM micrograph (Figure 3.2f) proposes a firing temperature not more than 900°C.

Rock fragments are not thought to be inclusions because of their rounded edges. Probably, they were already present in the clay matrix.

An exception to the above trend, a fragment of ceramic sherd was identified in sample 9. This must have been added as filler to the paste in order to modify/ the thermal properties of the body.

Texture

In terms of their textures, bodies of the samples usually display red and/or reddish brown matrix under crossed polarized light in the polarizing microscope due to the formation of iron oxides during the firing process (Figures 3.1 a, b, f).

Bodies also have medium to fine - grain size distribution including sand, silt and clay size (Folk, 1974) (Figures 3.1 a, b, f). They exhibit porous texture (Figure 3.1a), as also revealed by SEM micrographs (Figures 3.2 d, f, 3.6 a) due to low degree of vitrification.

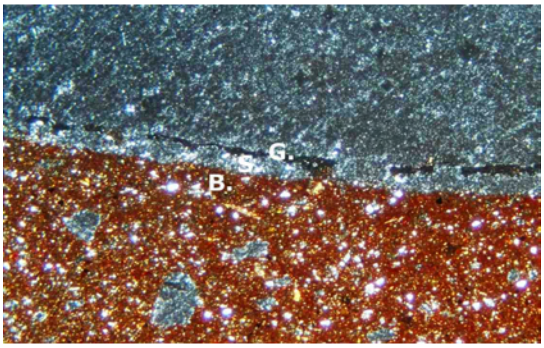
In most of the samples, micritic calcite is filling some of the pores (Figure 3.1k) probably due to depositions by the water circulation in the soil after burial. Supporting this observation, calcite was detected in XRD diffractograms of samples 14 and 25 (Table 3.4).

In samples 4 and 13, aggregates of quartz and feldspar were observed.

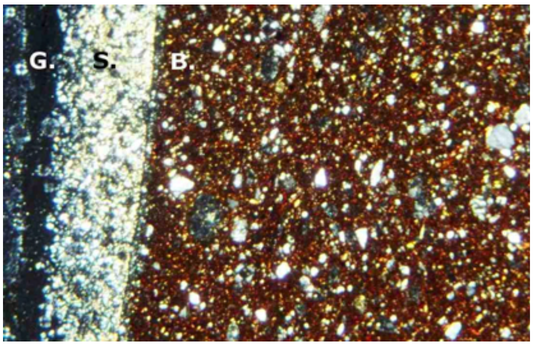
Sample 23 displays darkened regions in the body matrix under plane polarized light which may well indicate microenvironments due to improper degree of oxidation (Figures 3.1 l, m, n).

The thin section examination of the body of sample 10 indicates either a microcrystalline or vitrified structure.

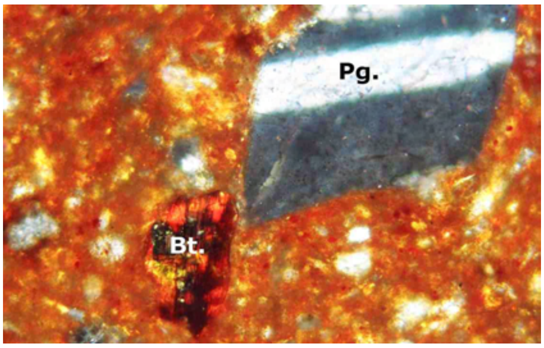
Among the bodies of samples 2, 10, 22, 23 and 27**,** samples 2 and 22 display the lowest vitrification degree of all, together with a very porous texture (Figures 3.2 d, f) while the bodies of samples 12, 23 and 27 show relatively higher degree of vitrification but porous texture (Figures 3.2 a, c, h).



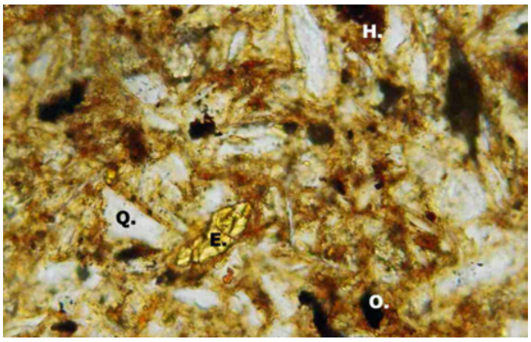
a) Cross sectional view of sample 21, XPL, x 2.5



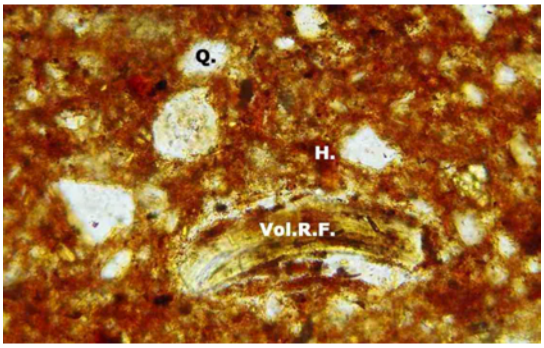
b) Cross sectional view of sample 27, XPL, x 2.5



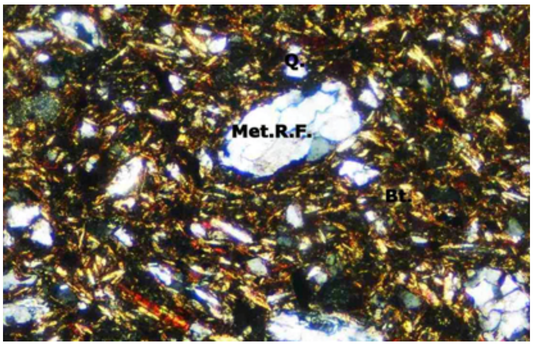
c) Close up view of body of sample 3 XPL, x 25



d) Close up view of body of sample 2 PPL, x 25

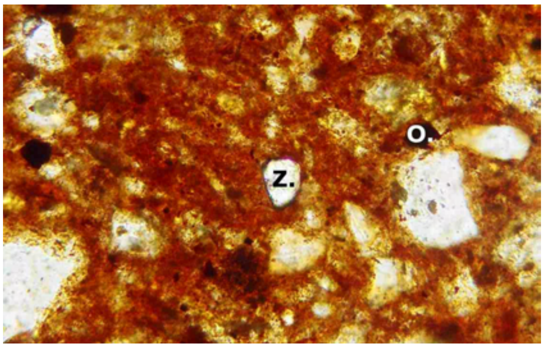


e) Close up view of body of sample 18, PPL, x 25

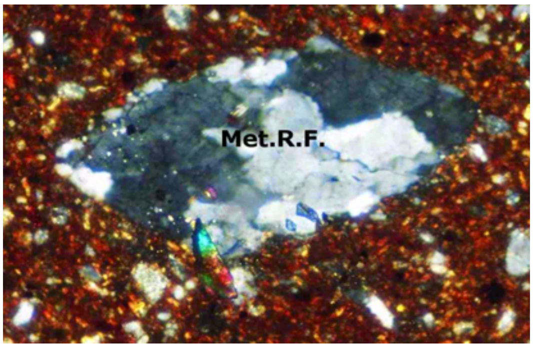


f) General view of body of sample 2 XPL, x 10

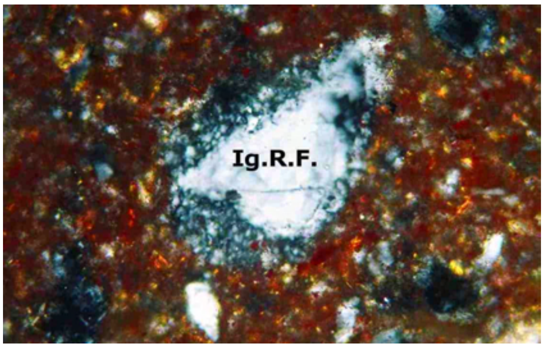
Figure 3.1: Thin section views of samples (B: Body, S: Slip, G: Glaze, Pg: Plagioclase, Bt: Biotite, Q: Quartz, H: Hematite, O: Opaque mineral, E: Epidote, Vol.R.F.: Volcanic rock fragment, Met.R.F.: Metamorphic rock fragment)



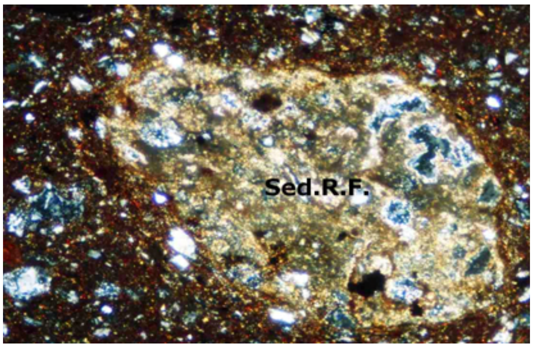
g) Close up view of body of sample 18 PPL, x 25



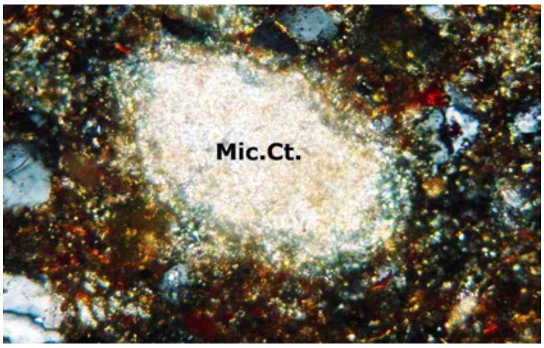
h) Close up view of body of sample 3 XPL, x 10



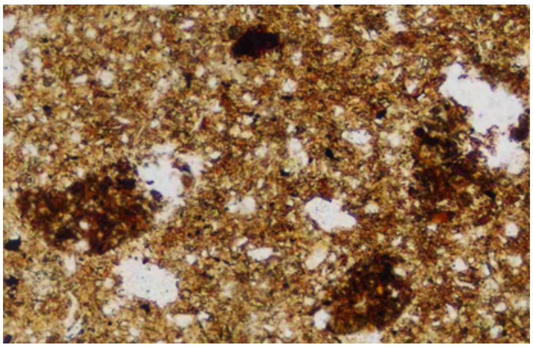
i) Close up view of body of sample 22 XPL, x 25



j) Close up view of body of sample 22 XPL, x 10

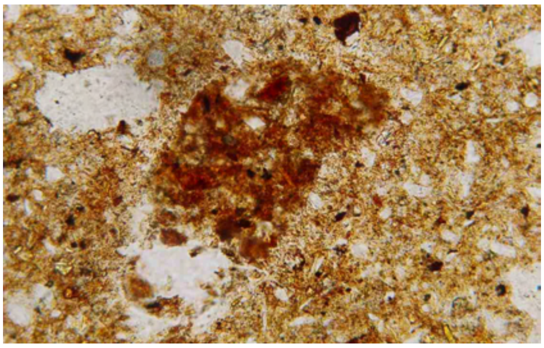


k) Close up view of body of sample 25 XPL, x 25

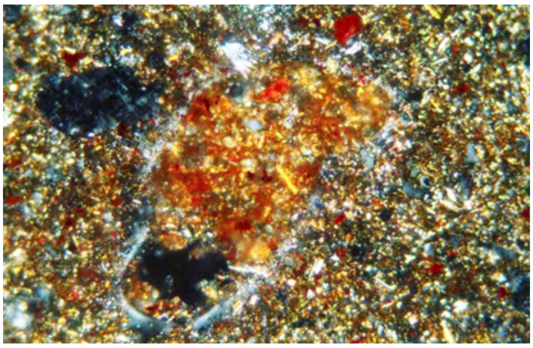


l) General view of body of sample 23 PPL, x 10

Figure 3.1 (cont'd): Thin section views of samples (Z: Zircon, O: Opaque mineral, Met.R.F.: Metamorphic rock fragment, Ig.R.F.: Igneous rock fragment, Sed. R.F.: Sedimentary rock fragment, Mic. Ct.: Micritic calcite)

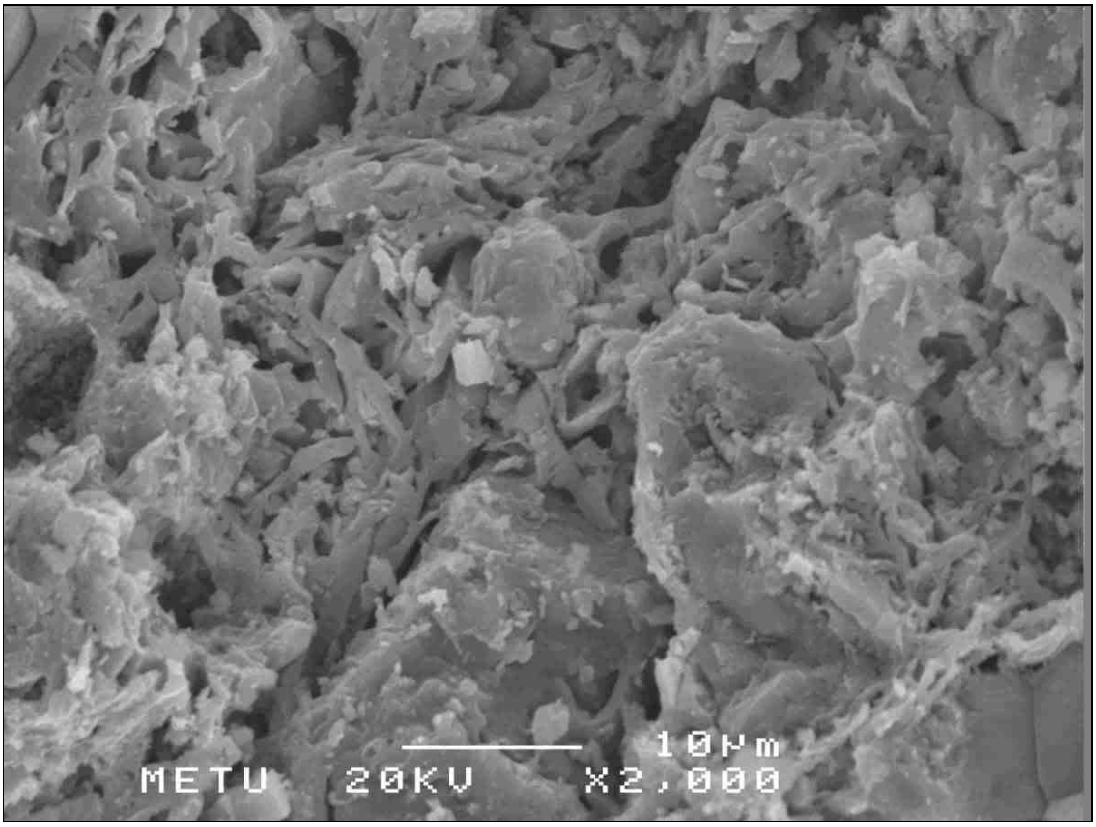


m) Close up view of body of sample 23 PPL, x 25

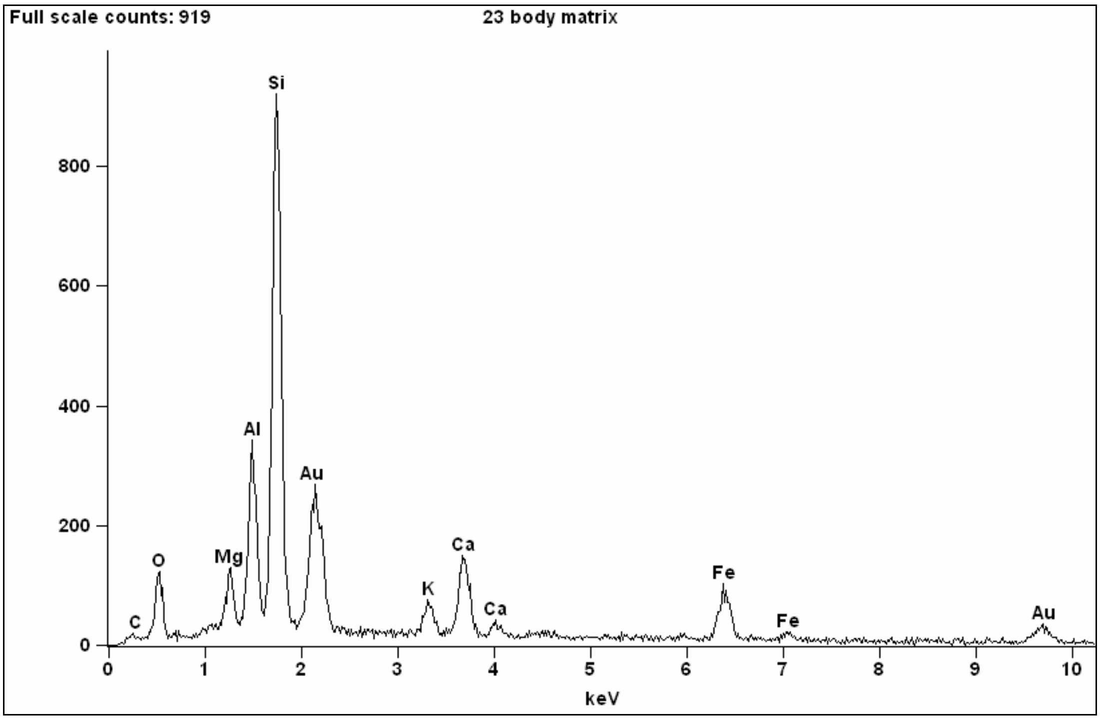


n) Close up view of body of sample 23 XPL, x 25

Figure 3.1 (cont'd): Thin section views of samples

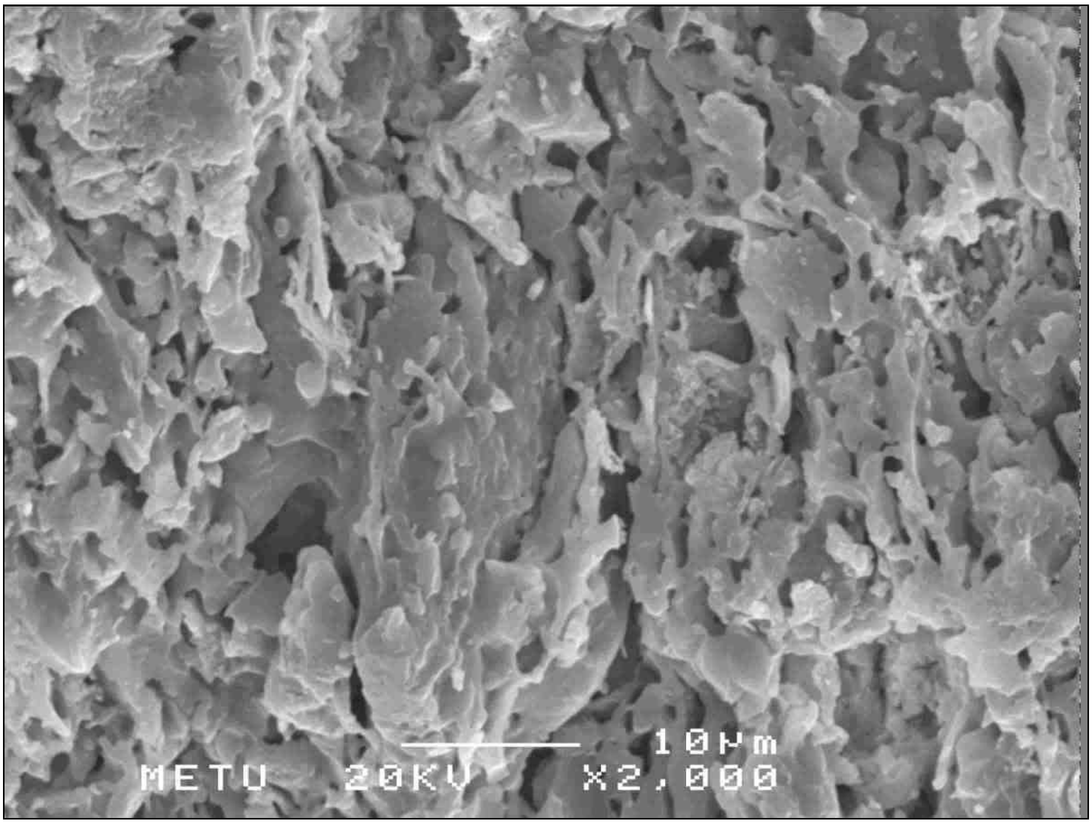


a) SEM micrograph of body of sample 23

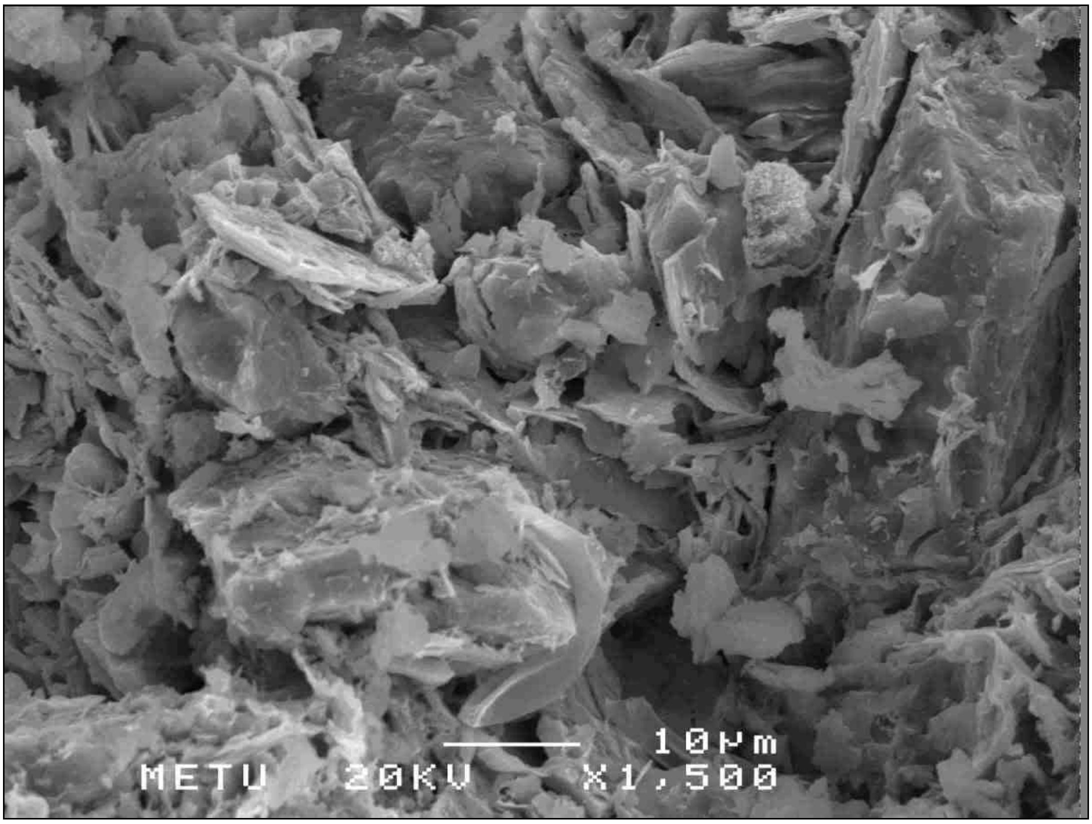


b) EDX spectrum of the point analysis of body of sample 23

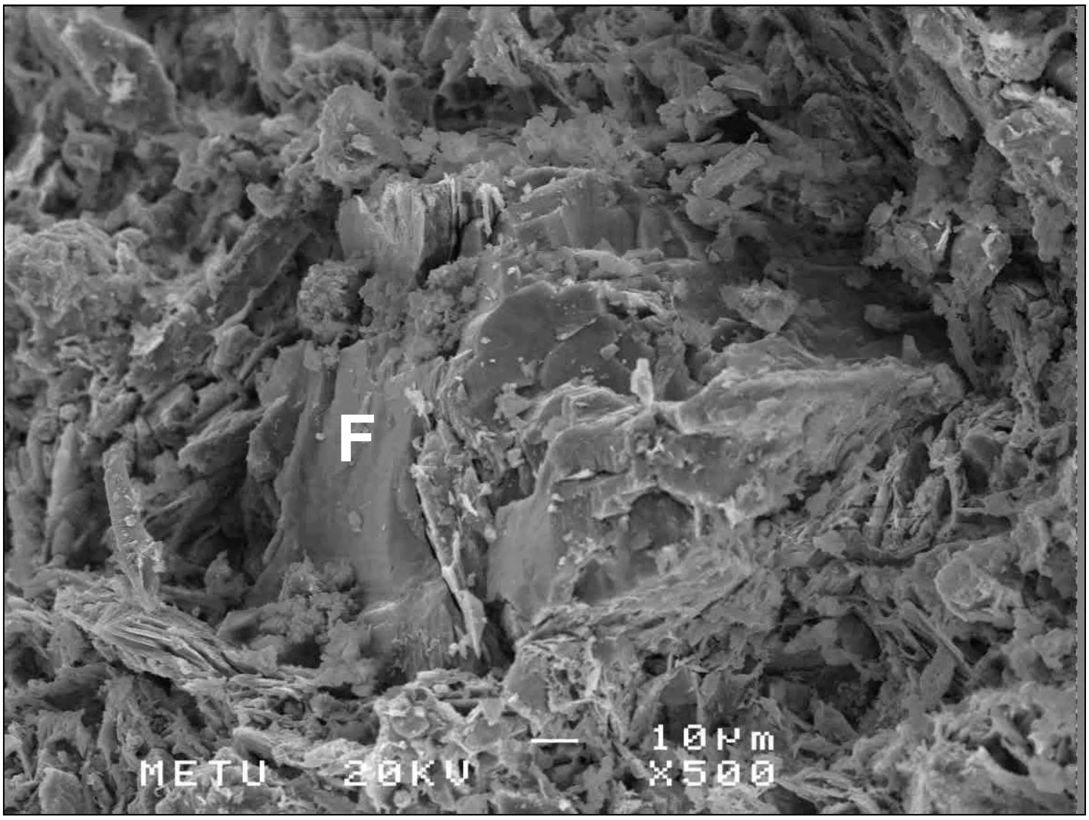
Figure 3.2: SEM-EDX analysis of bodies of samples



c) SEM micrograph of body of sample 27

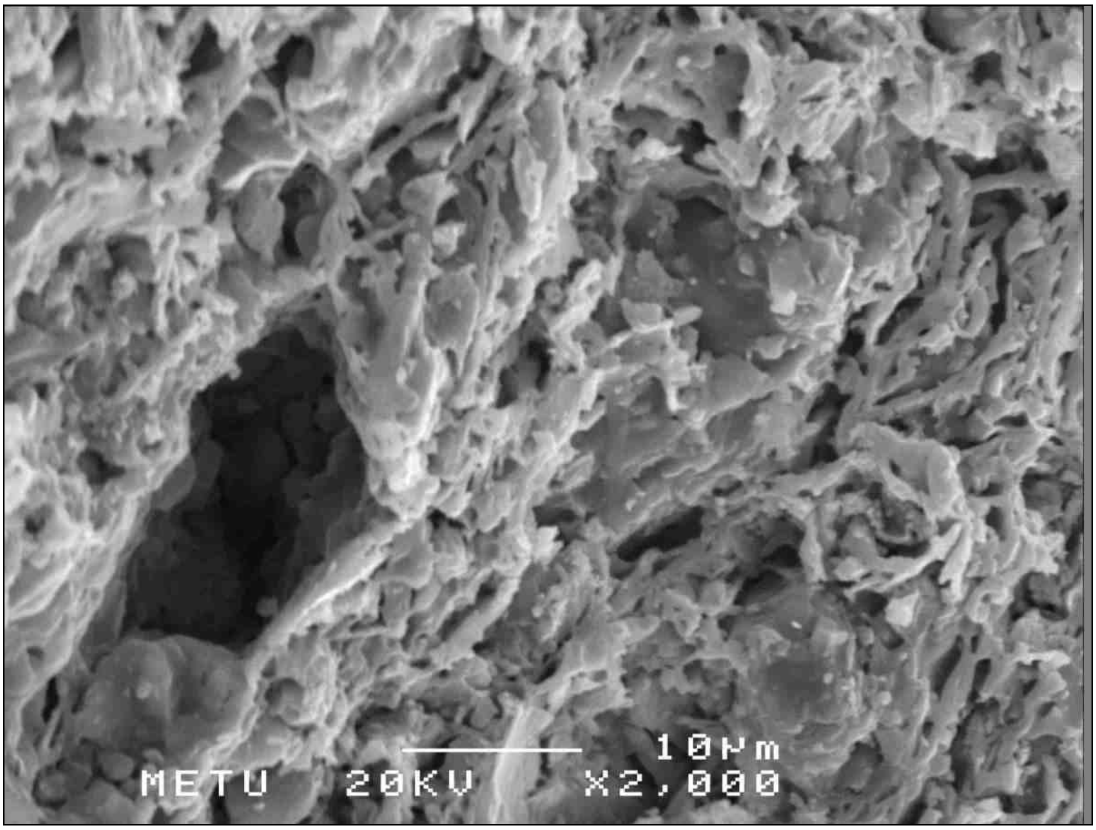


d) SEM micrograph of body of sample 2

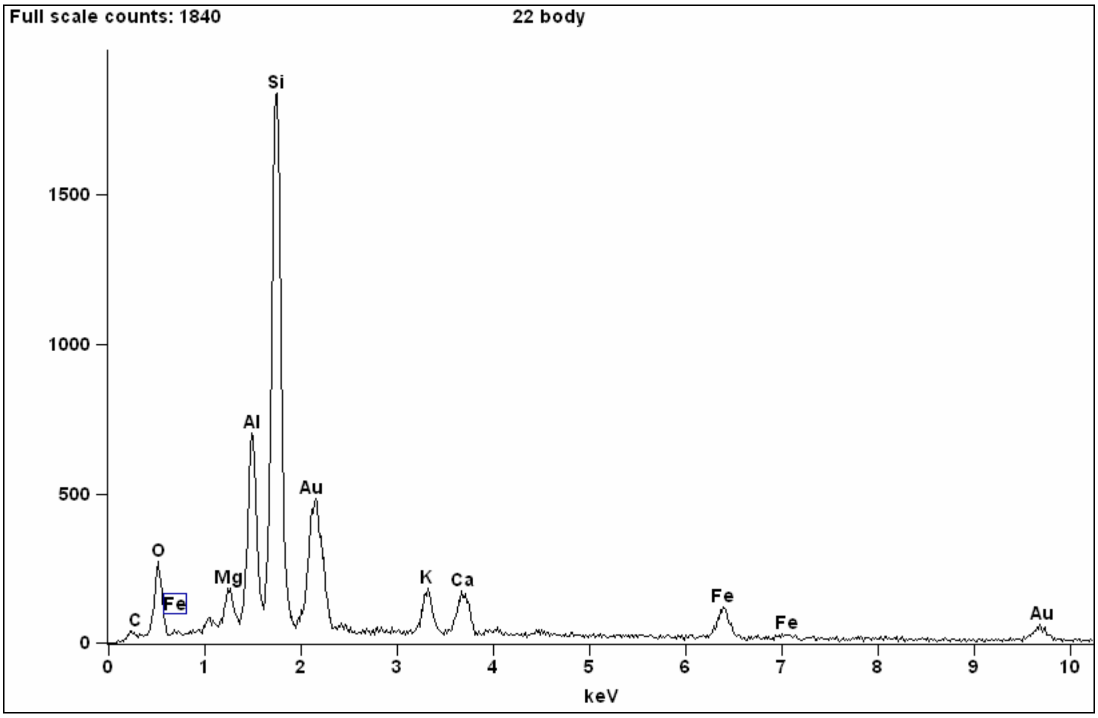


e) Close up SEM micrograph of feldspar (F) in the body of sample 2

Figure 3.2 (cont'd): SEM micrographs of bodies of samples

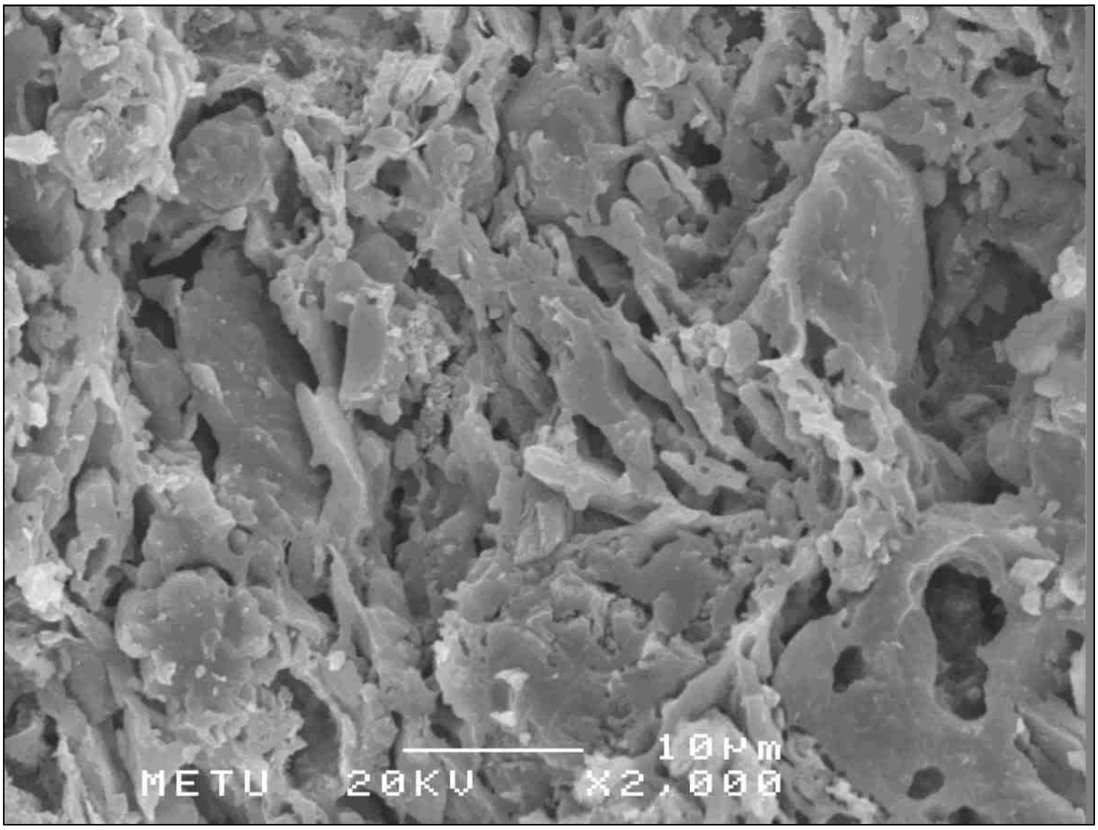


f) SEM micrograph of body of sample 22

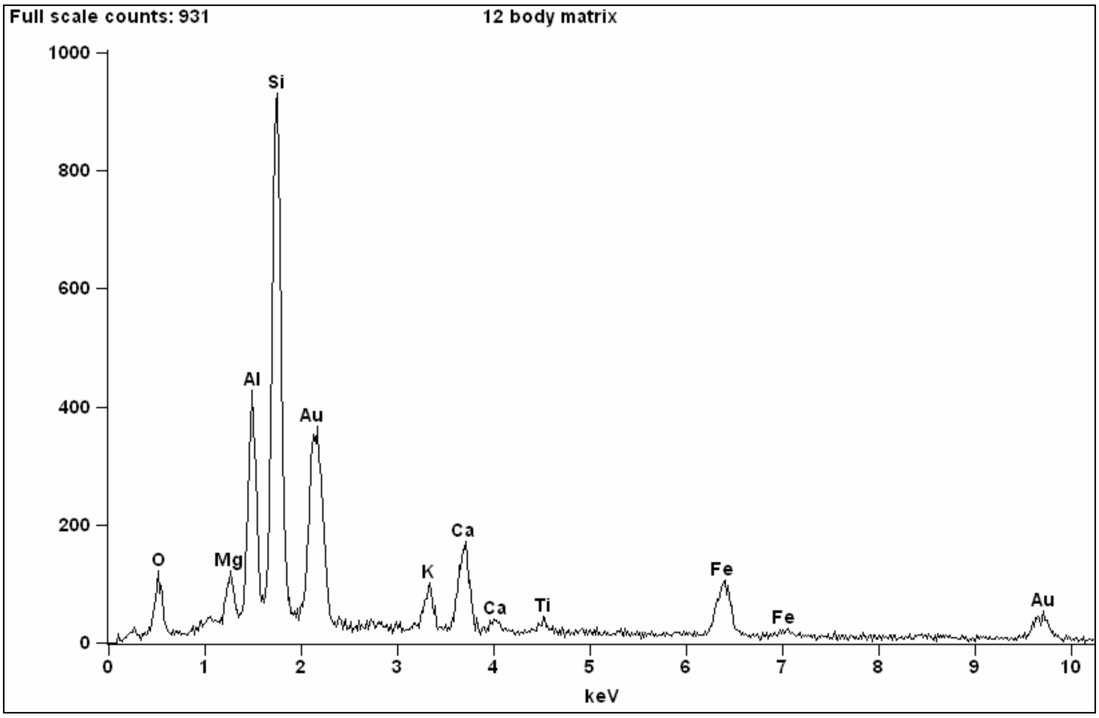


g) EDX spectrum of the point analysis of body of sample 22

Figure 3.2 (cont'd): SEM-EDX analysis of bodies of samples



h) SEM micrograph of body of sample 12



i) EDX spectrum of the point analysis of body of sample 12

Figure 3.2 (cont'd): SEM-EDX analysis of bodies of samples

Table 3.4: XRD Results of the powdered ceramic samples

Sample No	d-spacings of major reflections (A^o)				
	Quartz	**Feldspar**	**Hematite**	**Calcite**	**Epidote**
1	3.32				2.91
2	3.33				
3	3.33	3.25	2.68		
4	3.35	3.20	2.69		
5	3.35	3.19	2.69		
6	3.34	3.22	2.68		
7	3.34	3.19			
8	3.34	3.23	2.69		
9	3.34	3.19	2.69		
10	3.35	3.20	2.69		
11	3.34	3.28	2.70		
12	3.34	3.21			
13	3.34	3.22	2.69		
14	3.34			3.02	
15	3.34	3.19			
16	3.34	3.28	2.70		
17	3.35	3.20			
18	3.35	3.22	2.70		
19	3.34	3.20	2.69		
20	3.34	3.28	2.69		
21	3.34	3.28			
22	3.34	3.21			
23	3.35	3.19	2.70		
24	3.35	3.19	2.70		
25	3.34	3.19	2.69	3.01	
26	3.34	3.19			
27	3.33	3.21	2.68		

3.3.2 Slip

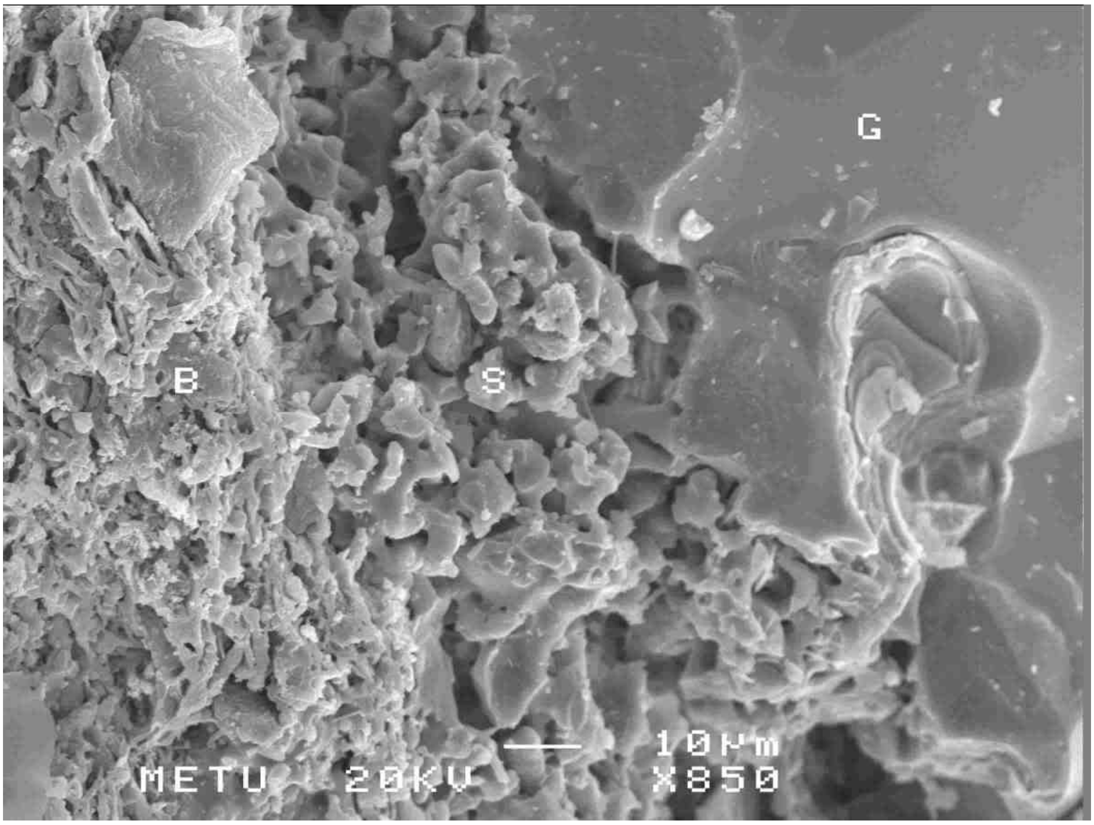
Most of the samples have slips on both sides (Table 3.2). Common minerals observed in thin section analysis are quartz and feldspar (Figures 3.1 a, b).

The texture is generally fine-grained including silt and clay size (Figures 3.1 a, b) and/or partially vitrified (Figure 3.3a), compared to the body sections of the samples. Higher degree of vitrification is due to the fine-grain size of the raw material used. This makes the melting process easier, eventually leading to vitrification.

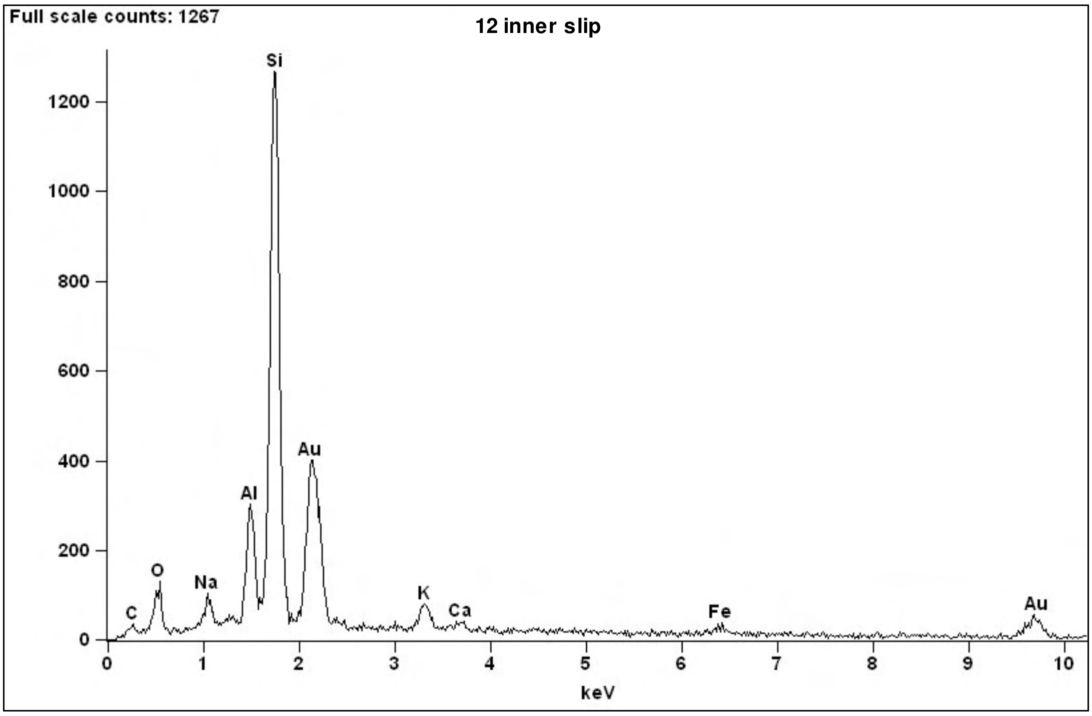
The slips of samples 10, 22, 23 and 27 show higher degree of vitrification, compared to their body sections (Figures 3.3 c, e, g, i).

Sample 12 shows a semi-vitrified slip on both sides. This is also proved by the SEM micrograph showing a high degree of vitrification (Figure 3.3a).

Micritic calcite is also present within the micropores of samples 1, 23 and 27 (Figure 3.1b).

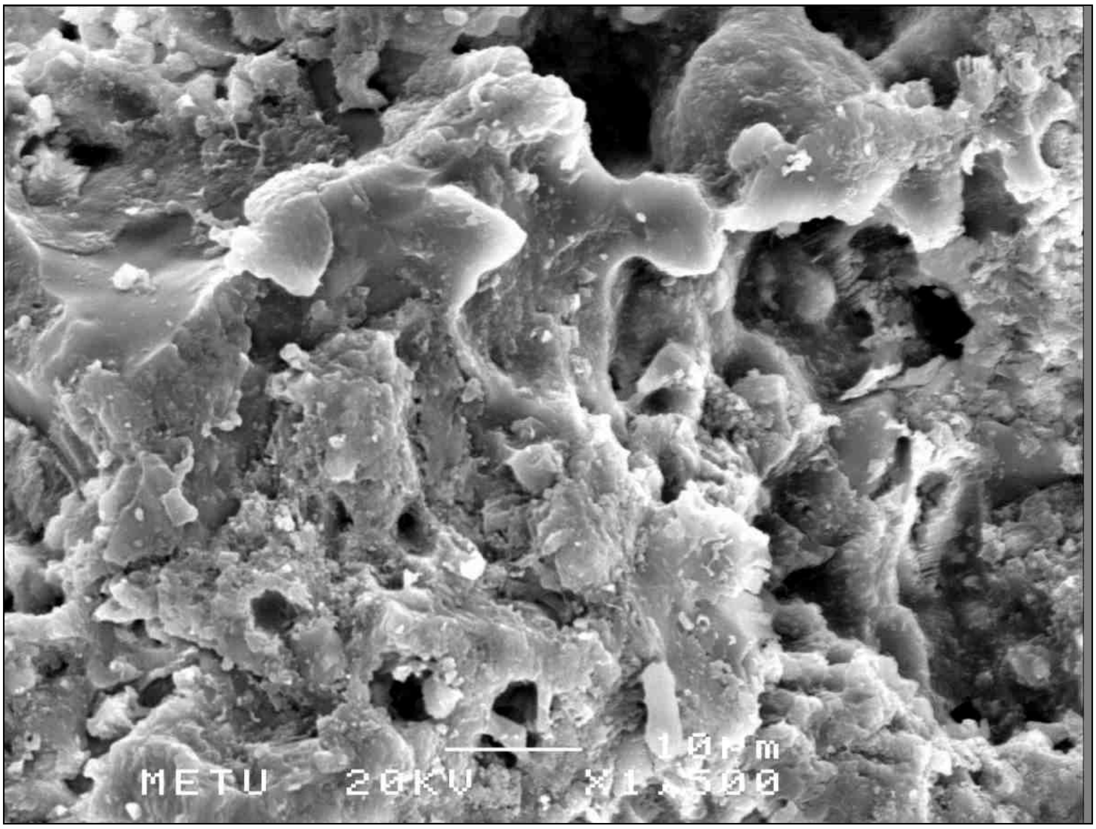


a) SEM micrograph of a cross section of sample 12 showing inner side

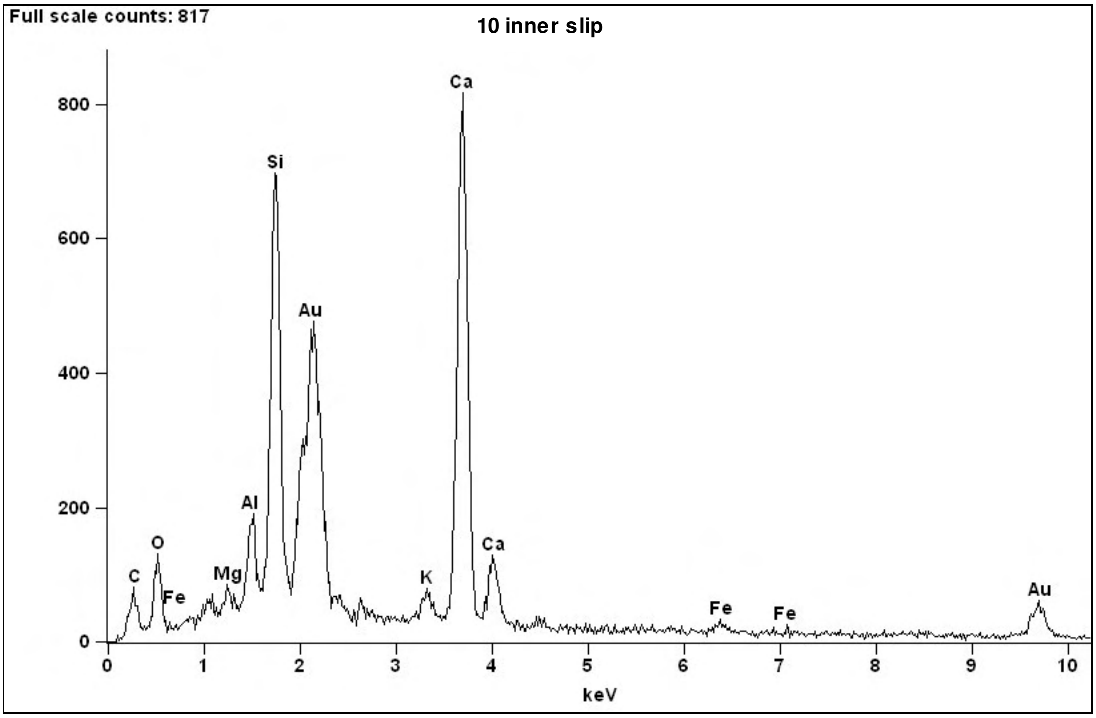


b) EDX spectrum of the point analysis of inner slip of sample 12

Figure 3.3: SEM-EDX analysis of slips of samples (B: Body, S: Slip, G: Glaze)

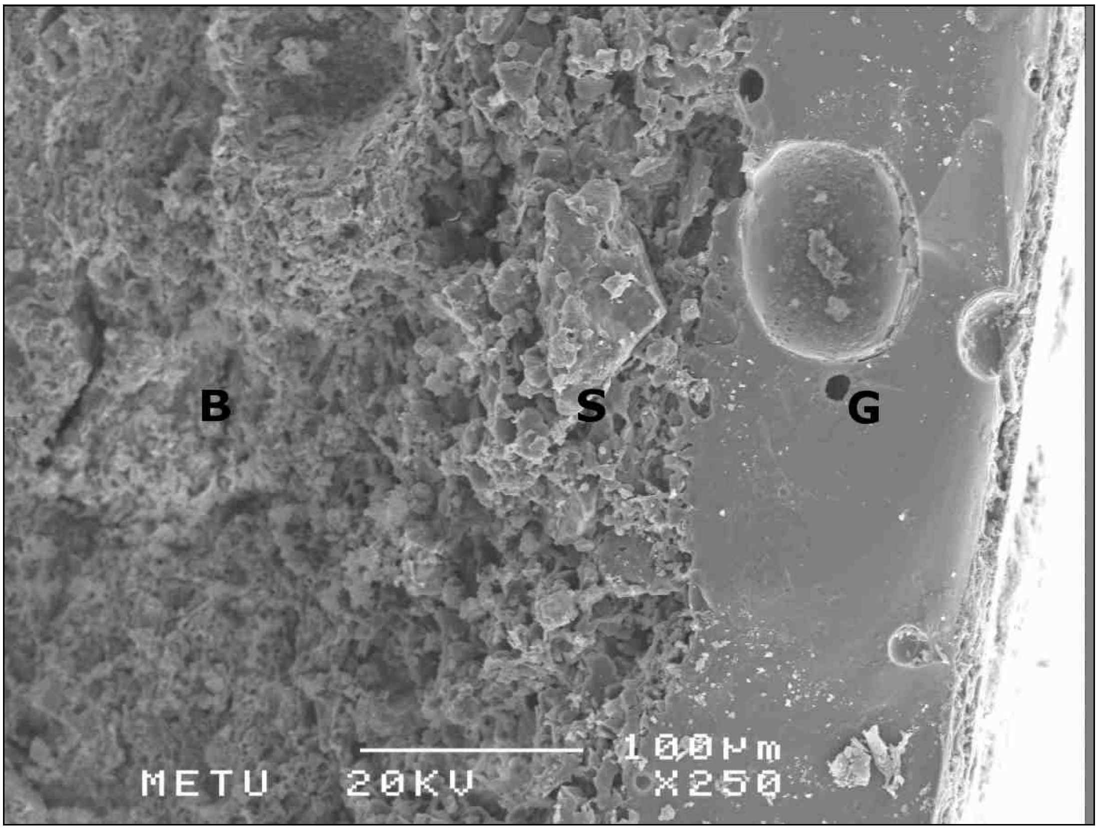


c) SEM micrograph of inner slip of sample 10

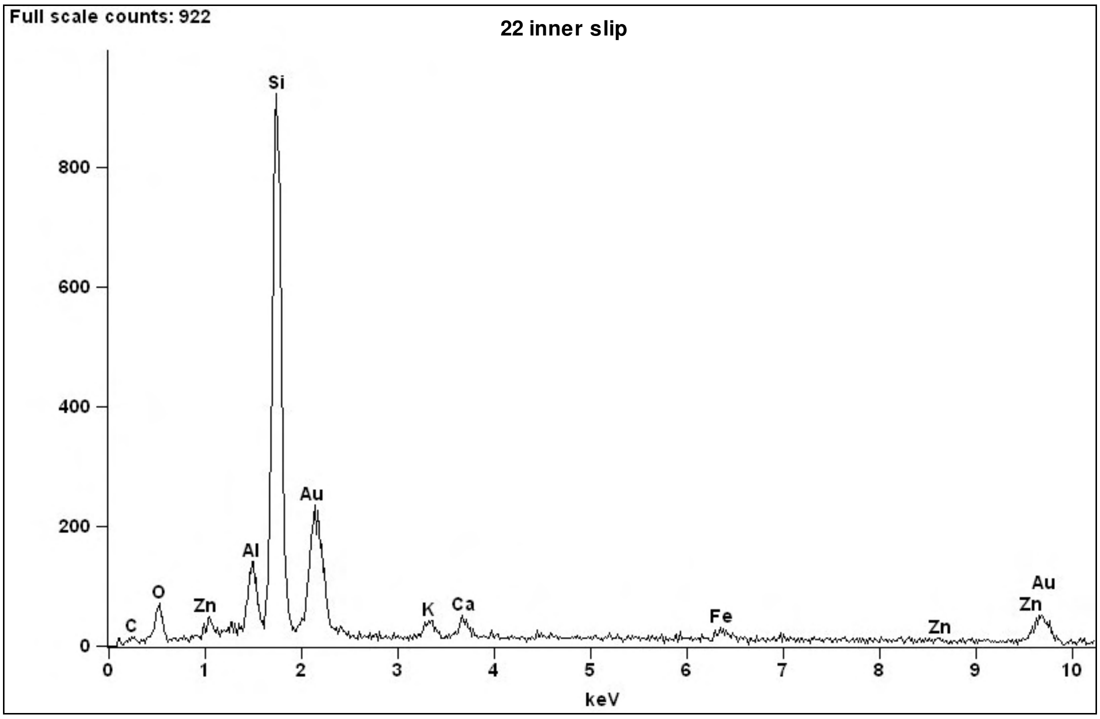


d) EDX spectrum of the point analysis of inner slip of sample 10

Figure 3.3 (cont'd): SEM-EDX analysis of slips of samples

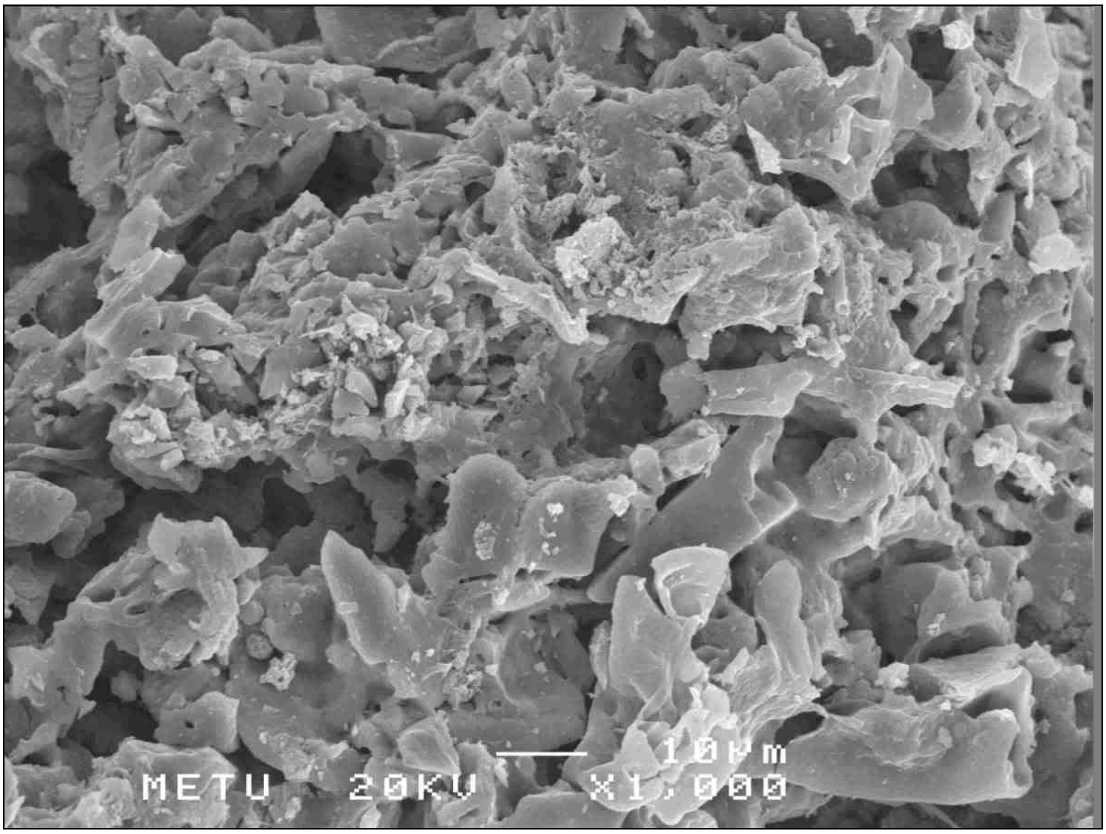


e) SEM micrograph of a cross section of sample 22 showing inner side

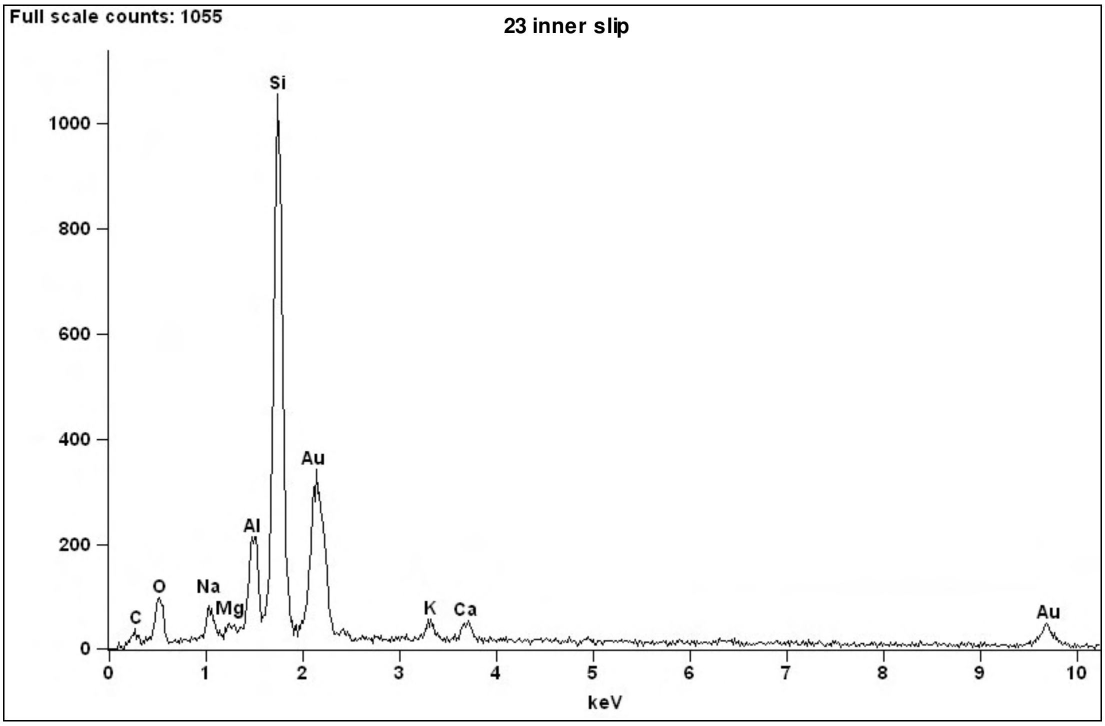


f) EDX spectrum of the point analysis of inner slip of sample 22

Figure 3.3 (cont'd): SEM-EDX analysis of slips of samples (B: Body, S: Slip, G: Glaze)

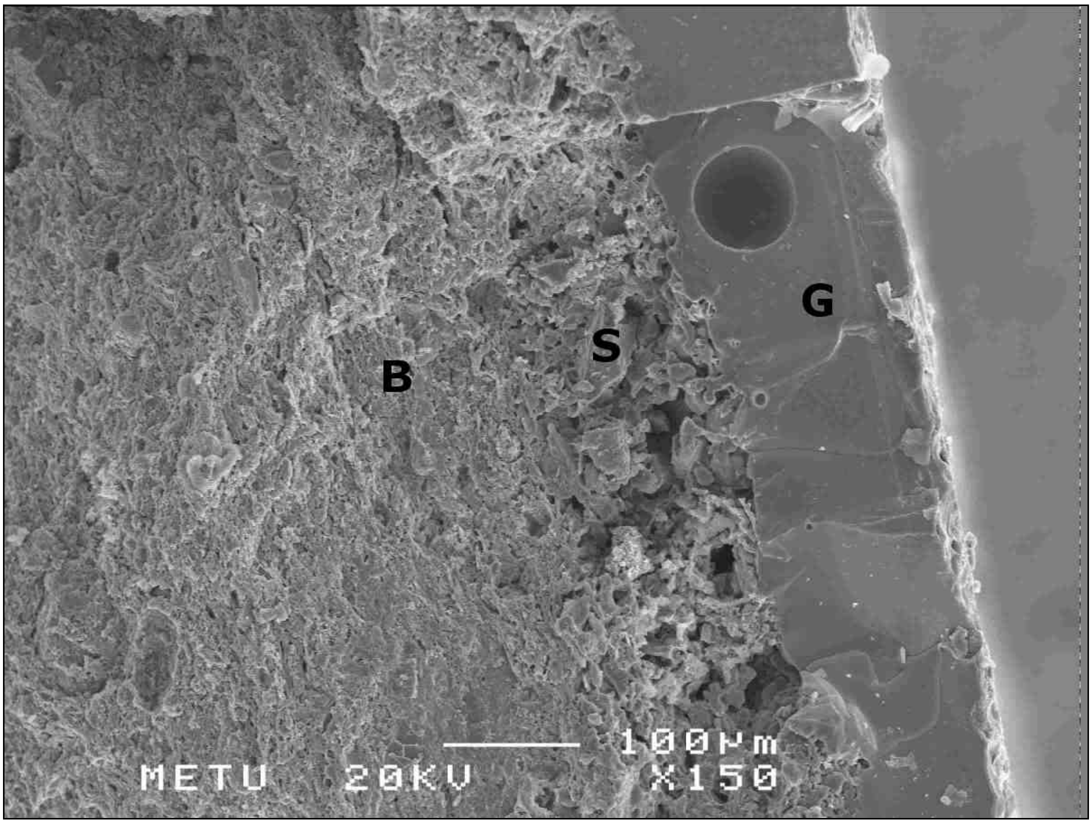


g) SEM micrograph of inner slip of sample 23

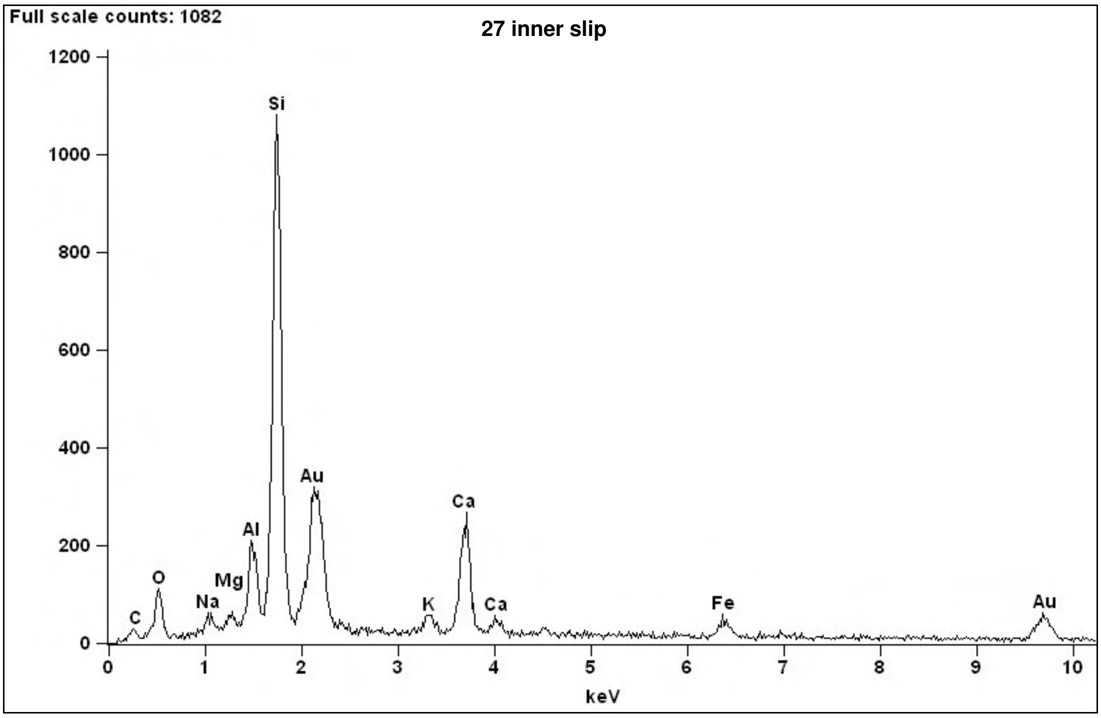


h) EDX spectrum of the point analysis of inner slip of sample 23

Figure 3.3 (cont'd): SEM-EDX analysis of slips of samples



i) SEM micrograph of a cross section of sample 27 showing inner side



j) EDX spectrum of the point analysis of the inner slip of sample 27

Figure 3.3 (cont'd): SEM-EDX analysis of slips of samples (B: Body, S: Slip, G: Glaze)

3.3.3 Glaze

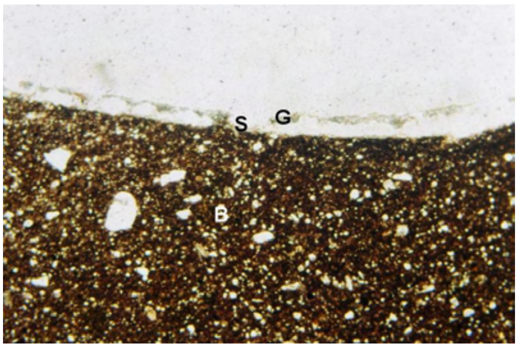
Most of the samples wear glazes on both sides (Table 3.2). However most of the time, they could not be observed under the optical microscope. In the ones detected, the glaze is a thin layer which appears either colorless or greenish under plane polarized light as a glassy layer on the inner and/or outer parts of the samples (Figure 3.4a). In sample 10, the inner glaze penetrates through the slip (Figure 3.5a).

Glazes observed in thin sections are generally fresh without any devitrification products. An exception to this is sample 12 which contains microcrystalline quartz and feldspar minerals on both sides (Figure 3.3a). Inner section of sample 26 also contains quartz crystals. Cooling rate of the glaze may be a possible source for these observations.

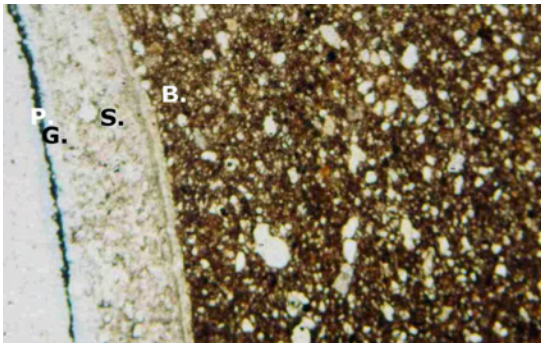
Detailed SEM examinations show that the inner glazes of samples 2, 10, 22, 23 and 27 (Figures 3.3 e, i - 3.5 a, c) and outer glaze of sample 2 reveal porosity which are also confirmed by thin section analyses in some cases. The porosity is possibly caused by partial evaporization of the glaze when the firing temperature increases rapidly (Cooper, 1992).

As revealed by thin section analysis, sample 12 wears a cracked glaze on the outer while samples 10 and 27 also have cracked inner glazes as shown by SEM micrographs (Figures 3.3i, 3.5a). It is known that to achieve a well fitting glaze, the expansion of the glaze and body should be more or less equal. This can be provided by the use of proper fluxes with the suitable proportions of high expansion and low expansion ones (Cooper, 1992). When these conditions are not met properly, the cracks may form due to the unbalanced expansions of the body and glaze during firing.

Paint layers were examined underneath the inner glazes of samples 1, 5 and 27 (Figure 3.4b) by thin section analysis. These are associated with the underglaze paint and decoration of the cobalt-blue painted group. Sample 27 displays a bluish glaze around the paint layer under plane polarized light (Figure 3.4b).

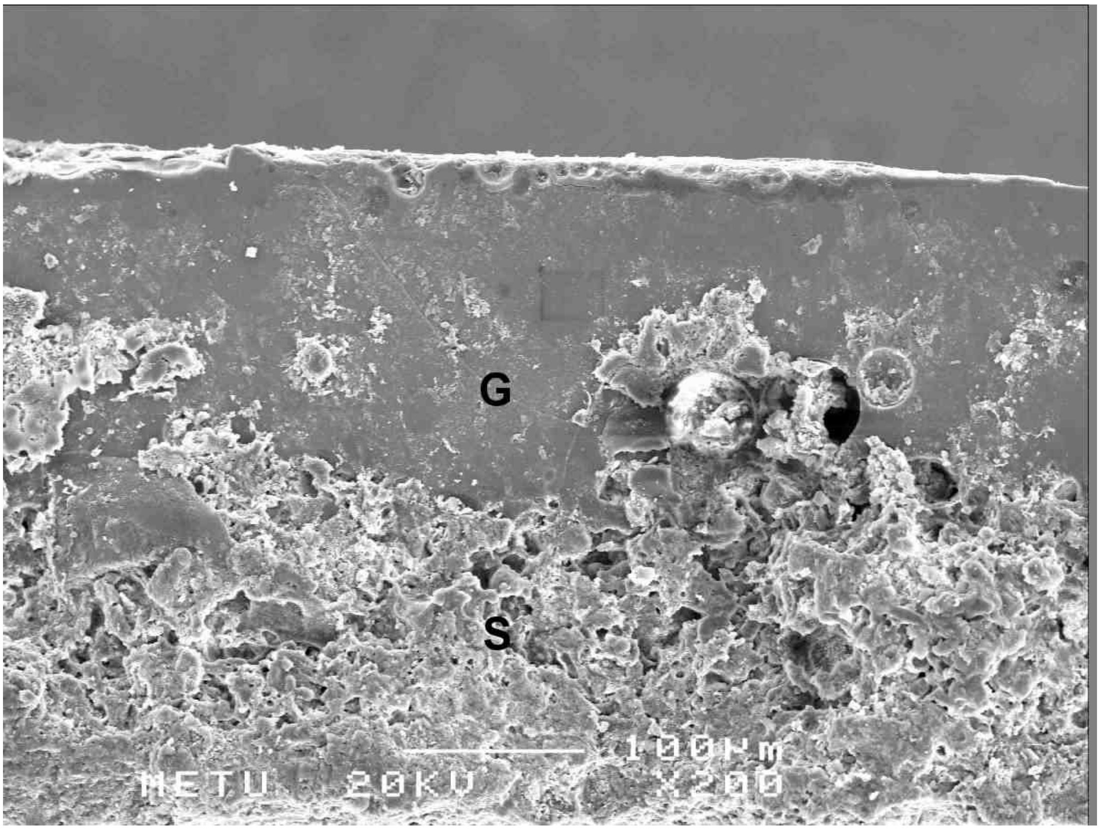


a) Cross sectional view of sample 21 PPL, x 2.5

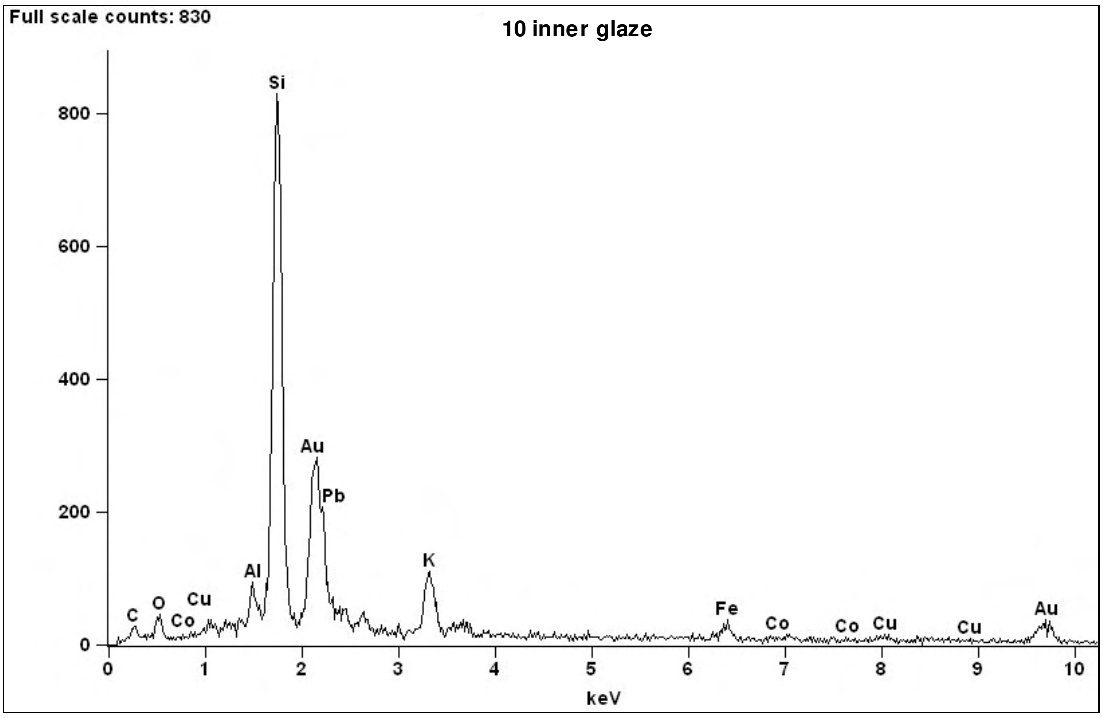


b) Cross sectional view of sample 27 PPL, x 2.5

Figure 3.4: Thin section views of samples (B: Body, S: Slip, G: Glaze, P: Paint)

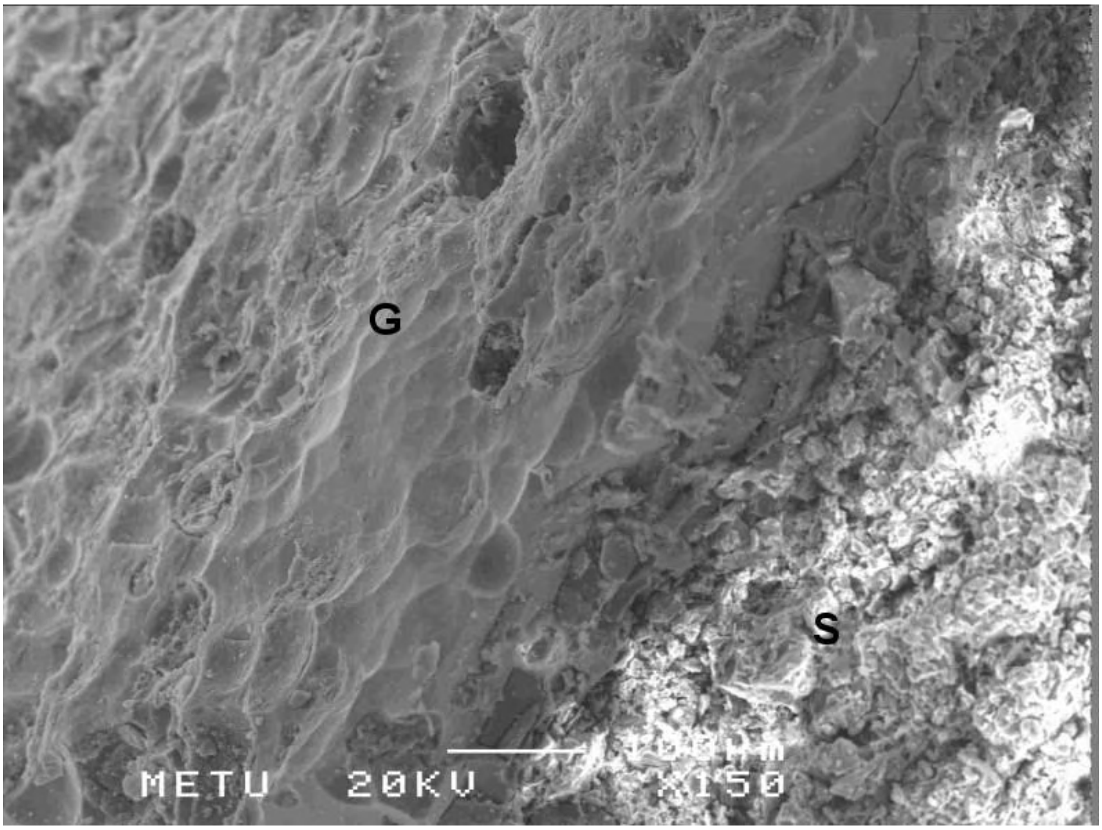


a) SEM micrograph of a cross section of sample 10 showing inner side

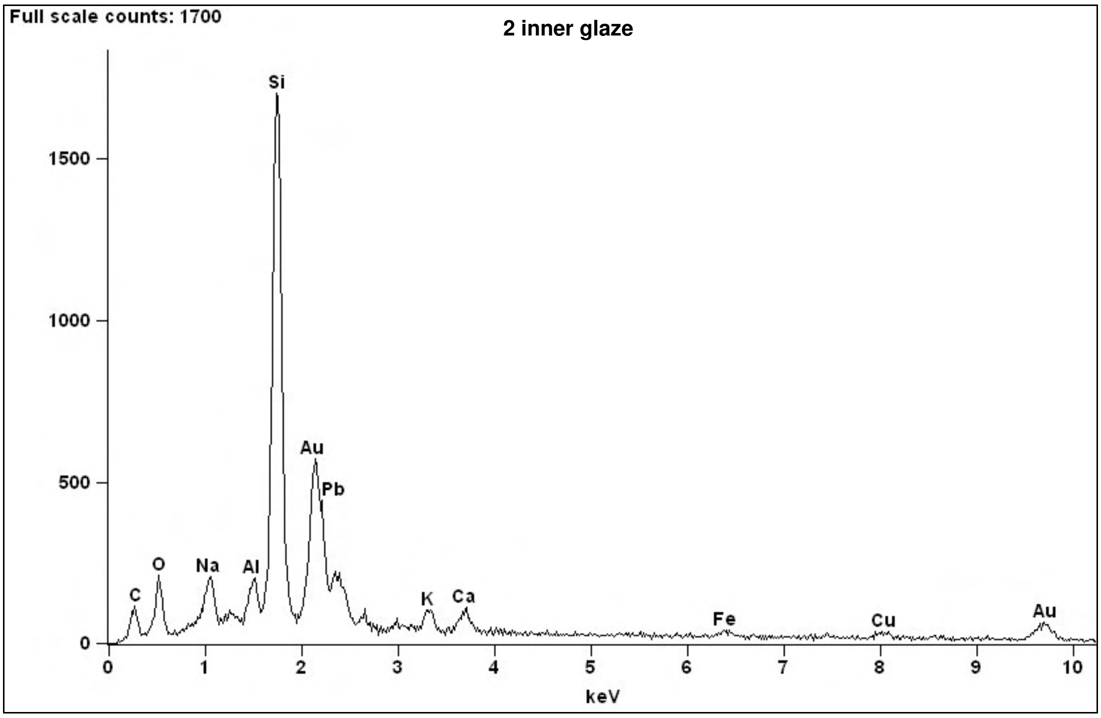


b) EDX spectrum of the point analysis of inner glaze of sample 10

Figure 3.5: SEM-EDX analysis of glazes of samples (S: Slip, G: Glaze)



c) SEM micrograph of a cross-section of sample 2 showing inner side



d) EDX spectrum of the point analysis of inner glaze of sample 2

Figure 3.5 (cont'd): SEM-EDX analysis of glazes of samples (S: Slip, G: Glaze)

3.4 Chemical Analysis

Samples 2, 10, 12, 22, 23 and 27 were selected for further analysis (SEM-EDX and FTIR) based on the results of their visual and petrographic analyses.

3.4.1 SEM-EDX Analysis

3.4.1.1 Body

Bodies of samples 10, 12, 22 and 23 reveal high amounts of silicon (50 to 60 % SiO_2) and aluminum (15 to 20 % Al_2O_3) due to abundant quartz and feldspar contents in the body. Table 3.5 shows the chemical compositions in terms of their oxide percentages. These are also confirmed by thin section and XRD analyses (Table 3.4, Figure 3.2 b, g, i). They also include about 3 to 4 % magnesium oxide, 2.5 to 4 % potassium oxide and 5 to 10 % calcium oxide. Rather high amounts of aluminum oxide in the body may have resulted from the raw clay material such as kaolin, although it was not detected due to its collapse when heated above 500^{O}C (Richardson, 1972).

Impurities of calcium in the clays used may have contributed to the calcium content of the body although some of it is in the form of micritic calcite which is deposited by the water circulation in the soil.

High aluminum and calcium contents of the bodies were already mentioned in a previous study on Miletus-ware sherds (Henderson, 1989).

Relatively high amounts of iron oxides (8 to 18 % as Fe_2O_3) are well reflected in the reddish bodies of these ceramics.

Titanium which is a widespread contaminant of clays is also detected in EDX analysis (Worrall, 1968).

Table 3.5: EDX chemical composition results of body parts

Sample No	MgO	Al_2O_3	SiO_2	K_2O	CaO	Ti_2O	Fe_2O_3
10	3.27	18.54	57.47	3.02	5.50	1.53	10.67
12	2.90	16.11	48.68	3.09	9.43	1.65	18.13
22	3.33	17.94	61.36	4.01	4.98	-	8.38
23	3.96	14.85	51.64	2.50	10.03	-	17.02

3.4.1.2 Slip

The inner slips of samples 10, 12, 22, 23 and 27 have higher silicon content (as 35 to 80 % as SiO_2) compared to those in bodies (Table 3.6, Figures 3.3 b, d, f, h, j). This is an outcome of the abundant quartz and feldspar minerals found in the slip due to the use of high proportions of feldspars (fluxing agent) which provides melting at relatively low temperatures.

Rather low amounts of aluminum and magnesium corresponding to 8 to 13 % Al_2O_3 and 0.8 to 2.4 % MgO may indicate lower clay content in the slip.

The slips also contain potassium and sodium (2 to 3 % K_2O and Na_2O).

A striking feature is the highly varying calcium content in the slips (1 to 50 % CaO). The high calcium content of the inner slip of sample 10 (50% CaO) (Figure 3.3d) may indicate a different type of clay source as micritic calcite was not observed in the slip of sample 10 during thin section analysis.

On the contrary to the contents of the bodies, lower amounts of iron oxides about 1.5 to 8 % were determined in the slip structures due to the lower clay content of the slips (Table 3.6).

Table 3.6: EDX chemical composition results of slip parts (Oxide percentages, I: Inner).

Sample No	MgO	Na_2O	Al_2O_3	SiO_2	K_2O	CaO	Fe_2O_3	ZnO
10-I	2.41	-	7.60	36.73	2.15	49.51	1.61	-
12-I	-	3.18	12.67	75.82	3.23	1.46	3.64	-
22-I	-	-	7.96	81.56	2.45	3.04	3.43	1.57
23-I	0.80	3.24	13.31	76.87	2.20	3.57	-	-
27-I	1.56	2.49	9.56	60.01	1.92	16.32	8.14	-

3.4.1.3 Glaze

Chemical composition

Glazes of samples 2, 10, 12, 22, 23 and 27 display very high SiO_2 content, between 40 to 80 % since the main glass-forming material is silica (Table 3.7, Figures 3.5b, d - 3.6b).

Al_2O_3 shows variations within the range of 1 to 10 percent. The glazes also contain potassium and sodium corresponding to approximately 1-8 % K_2O and 4-7 % Na_2O. Calcium content corresponds to 1-5 % CaO. The origin to these is the potassium, sodium and calcium compounds which are used as fluxes to lower the high melting point of silica (~1710^{O}C) to provide vitrification (Rice, 1987).

Lead oxide, commonly being used in the Early Ottoman glazes, provides elasticity and helps the fit of the glaze (Henderson, 2000). The lead oxide contents of the glazes in the studied samples vary from 3 to 38 %. Among those, samples 10 and 22 indicate the application of high lead glazes (Table 3.7, Figure 3.6b).

Colorants

The turquoise color of the inner glaze at sample 2 may be associated with copper (~ 6% CuO) in the glaze. When copper is present in high alkali medium (9% K_2O + Na_2O in this case) together with some PbO (Table 3.7, Figure 3.5d) it produces turquoise color (Tite, 1989; Henderson, 2000).

In addition, the high amount of copper (8.78% CuO) in the outer glaze of sample 2 produces green color in the presence of iron oxides (3.27%) (Henderson, 2000).

High copper content as about 5% CuO in the outer glaze of sample 10 produces a green color with a high lead (~35% PbO) and low alkali (~%3 K_2O) contents (Tite, 1989). The EDX measurements done at points A and B which have different tones of green (10 OA and 10 OB) reveal that they have similar compositions (Table 3.7). These different tones may be due to the lack of slip at different points**.** The varying thickness of the glaze applied may also contribute to this diversity.

Amounts of copper and cobalt in the inner glaze of sample 10 that are 2% CuO and about 1% CoO respectively result in the formation of a blue color, with a high alkali content of ~8% K_2O and PbO content of about 25% (Table 3.7, Figure 3.5b). According to Weyl (1951), copper in a lead-alkali glaze produces a blue color. CoO is a much powerful colorant giving blue whereas it is distributed less evenly within the glaze (Cooper, 1992).

The outer glaze of sample 27 produced blue color with a high amount of CuO

(8.30%) in the presence of lead oxide and low alkali (2.25% K_2O) (Table 3.7).

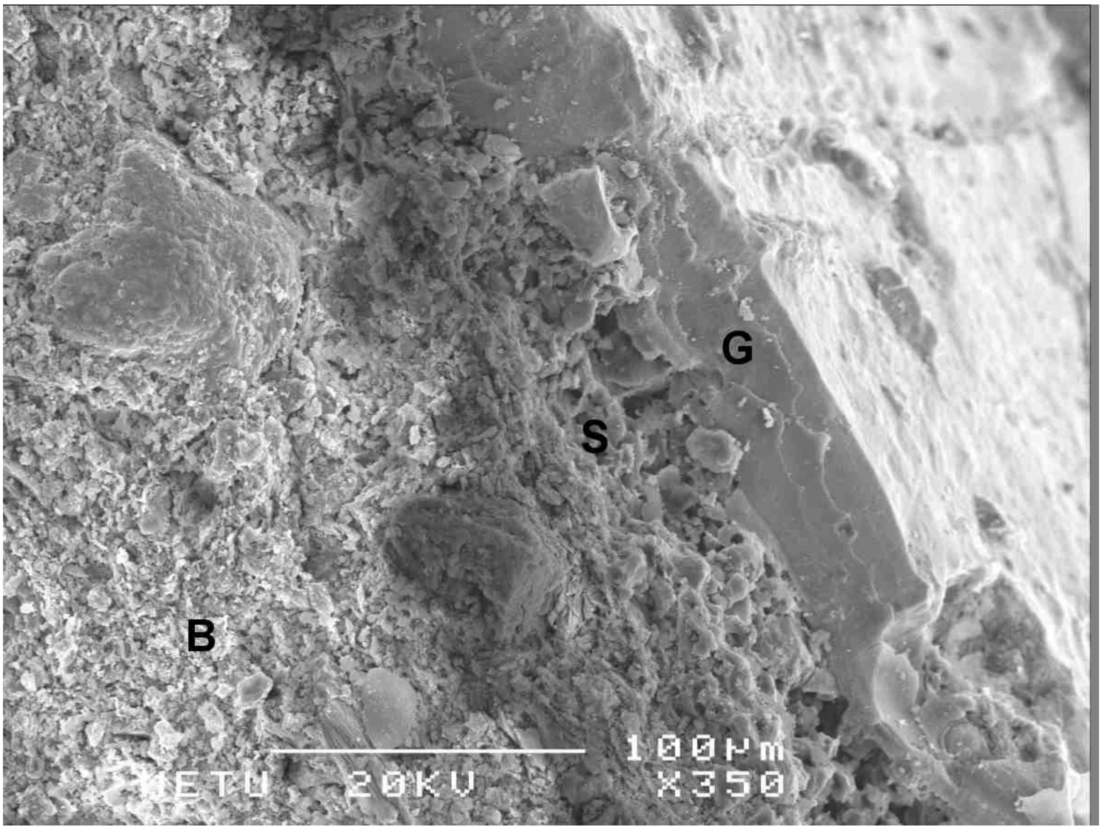
The inner glaze of sample 22 includes a high quantity of CoO (~3%) which gives black color with the presence of high PbO (~30%) and alkali (1.36% K_2O). This result is in correlation with the results of a previous study on a 15th century tile from Mahmut Paşa Türbesi in İstanbul, wearing a nearly black glaze, colored by 1.5% cobalt in a lead oxide-silica glaze with about 3% alkali (Henderson and Raby, 1989).

According to Henderson (2000), in the late 15th and early 16th century, the impurities detected with the cobalt were iron, nickel and copper, which suggested the use of a manganiferous cobalt source. The presence of nickel, iron, copper together with cobalt may point to a similar cobalt source in case of samples 10 and 22 which were dated to the 15th and 16th centuries (Table 3.1, 3.7).

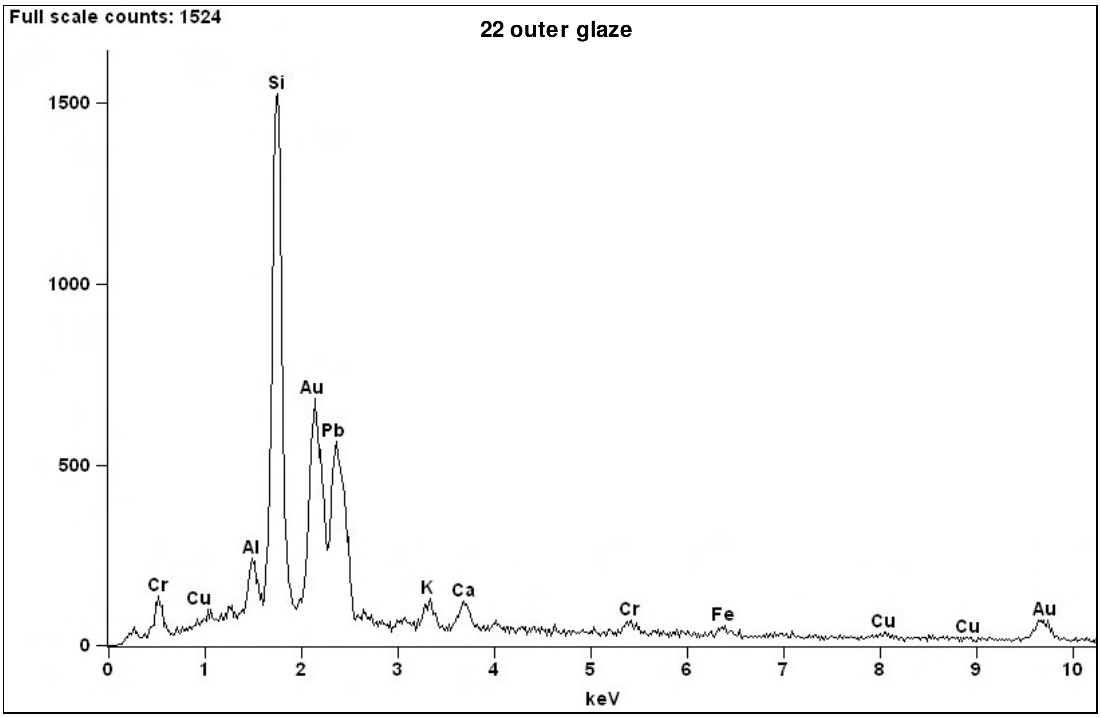
The dark green band on the outer side of sample 22 may come from chromite which includes iron - chromium oxide, in the presence of copper (Figure 3.6b). Relatively low contents of iron and chromium as 1.65% Fe_2O_3 and 2.22% Cr_2O_3 respectively may prove the presence of chromite.

Table 3.7: EDX chemical composition results of glaze parts (Oxide percentages, I: Inner, O: Outer, S: Surface).

Sample No	Al_2O_3	SiO_2	CaO	Cr_2O_3	ZnO	NiO	Fe_2O_3	Na_2O	K_2O	CoO	CuO	PbO	Observed color
2-I1	4.14	69.29	3.54	-	-	-	3.47	7.25	1.92	-	6.41	3.99	Turquoise
2-I2	-	79.08	5.16	-	-	-	-	7.08	1.57	-	-	7.11	Turquoise
2-O	9.14	66.73	2.73	-	-	-	3.27	5.75	3.60	-	8.78	-	Green
10-I	1.05	59.91	2.35	-	-	1.77	4.12	-	1.88	1.84	1.92	25.16	Blue
10I-S	4.21	76.17	-	-	-	-	4.79	-	8.35	0.47	2.11	3.90	Blue
10OA	4.47	48.19	2.47	-	-	-	0.99	-	1.28	-	5.18	37.42	Green
10OB	8.24	49.11	1.43	-	-	-	-	-	1.81	-	5.45	33.96	Green
12-I	4.80	68.03	3.35	-	-	-	5.34	4.14	2.42	-	-	11.92	Dark blue
22-I2	1.88	47.77	2.25	-	-	0.96	7.95	-	1.36	2.90	4.11	30.82	Black
22-O2	4.86	50.19	3.14	2.22	-	-	1.65	-	2.49	-	1.17	34.28	Dark green
23-I	2.36	77.09	1.67	-	-	-	8.39	5.50	1.85	-	-	3.14	Blue
27-I	2.73	78.37	3.43	-	-	-	2.54	-	1.88	-	-	11.04	Dark blue
27-O	10.02	57.25	2.77	-	-	-	-	-	2.25	-	8.30	19.42	Blue



a) Cross sectional SEM micrograph of sample 22 showing outer side



b) EDX spectrum of the point analysis of outer glaze of sample 22

Figure 3.6: SEM-EDX analysis of glaze of sample 22 (B: Body, S: Slip, G: Glaze)

3.4.2 FTIR Analysis

FTIR spectra of samples 2, 10, 12, 22, 23 and 27 showed that silicates are the common minerals as also determined by thin section and XRD analyses (Table 3.8).

Observed narrow bands around 1090 cm^{-1}, 780 cm^{-1}, 462 cm^{-1} indicate the presence of quartz in the samples studied.

The quartet bands between 695 and 800 cm^{-1} observed in the samples may signify quartz and plagioclase constituents.

Strong bands around 1428 cm^{-1} and 878 cm^{-1} found in samples 2, 12, 22, 23 and 27 are diagnostic for carbonyl group. Presence of carbonyl band which is associated with calcite in sample 2 may result from firing temperatures less than $900^{O}C$ since calcite collapses at about $900^{O}C$ maximum (Rice, 1987). This is also confirmed by the SEM micrograph showing low degree of vitrification (Figure 3.2d).

Presence of calcite in samples 12 and 22 is probably due to micritic calcite as also revealed by thin section analysis (Figure 3.7).

Lack of carbonyl bands in sample 10 is the most remarkable observation of FTIR analysis (Figure 3.7), for it may indicate a firing temperature higher than $900^{O}C$. This observation is supported with the evidence from thin section analysis pointing to either a microcrystalline or vitrified body.

Sample 23 displays a carbonyl peak at around 1460 cm^{-1} which may come from the clay content. This interpretation is due to the rather higher degree of vitrification being observed in the SEM micrograph (Figure 3.2a) and no detection of micritic calcite in thin section analysis. However, body of this sample contains a high amount of calcium as about 10% CaO which may increase the degree of vitrification at temperatures less than 850^{O} - $900^{O}C$ (Table 3.5) (Tite and Maniatis ,1975).

Table 3.8: FTIR Results

Sample No	Quartz	Plagioclase	Calcite
2	+	+	+
10	+	+	-
12	+	+	+
22	+	+	+
23	+	+	+
27	+	+	+

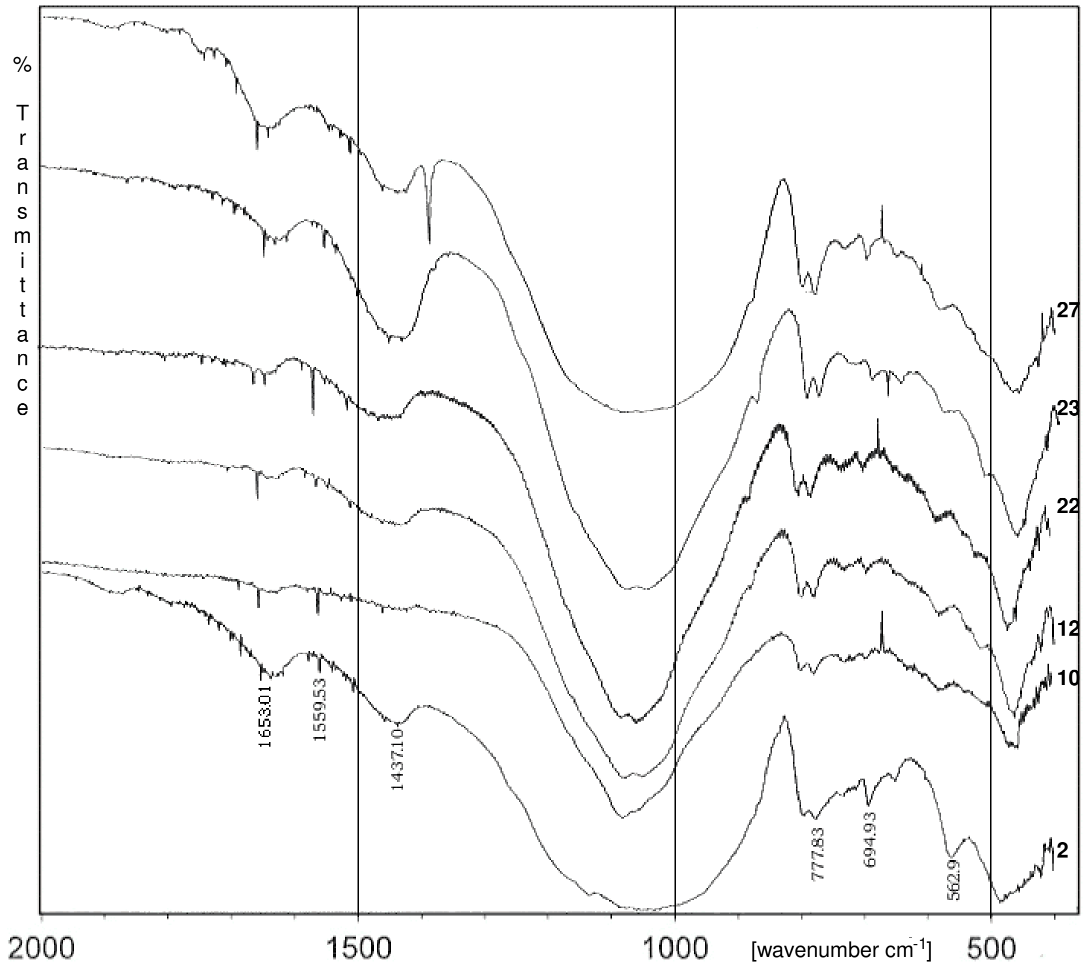


Figure 3.7: FTIR spectra of bodies of samples

CHAPTER 4

CONCLUSION

The visual, petrographical and chemical analyses of the ceramic samples lead to the following remarks:

- Ceramic sherds studied in this work, belonging to the Early Ottoman period and found at the Roman theatre in İznik are mainly dated to the 14th century to the 15th century according to their decoration techniques, color and design schemes.
- They are mostly characterized by cobalt-blue designs.
- Bodies of the samples mostly have reddish yellow in the 5YR scale and/or tones of red in the 2.5 YR and 10R scales, according to Munsell Soil Color Charts which point to oxidizing firing conditions in the kiln, as supported by the detection of abundant hematite in mineralogical analysis.
- These ceramic sherds of the Early Ottoman period have similar mineral content and rock fragment types as shown by thin section and XRD results.
- The clay raw material usually seems to be originating from a metamorphic source.
- Rock fragments mainly of metamorphic origin were observed and

usually seem as if they were not added later as inclusions.

- Remnant clay particles found in some samples may point to non-uniform firing conditions in the kiln, since no clay minerals were identified by XRD analysis.
- Slips show higher degree of vitrification compared to the body parts due to the finer grain size, as revealed by thin section and SEM analyses.
- The glazes are most of the time fresh without any devitrification products.
- The production technology of these ceramics indicates a rather simple technology with non-uniform and low degree of firing probably not exceeding $900^{O}C$.
- In general, we may conclude that the technological characteristics of these Ottoman sherds do not seem to have changed between 14th and 16th century.

Significance of the Study:

Earlier investigations on İznik ceramics mainly concentrated on fritware technology rather than the pottery tradition of the Early Ottoman period (Henderson and Raby, 1989; Tite, 1989). In addition, these studies are rather general and do not include discussions on specific characteristics.

This present study, on the other hand puts forward more detailed results for the material characteristics and technology of Early Ottoman İznik ceramics by means of detailed archaeometric investigations. In fact, it is the first archaeometric study applied on the ceramics that were found in the Roman theatre at İznik.

The results obtained in this study can be a basis for a comparative study of İznik ceramic technology with those present in Europe, such as in Italy, during the same time period.

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APPENDIX A

GLOSSARY

Abrasive: A substance used for smoothing or polishing a surface by grinding and scraping.

Askania: The prehistoric name for İznik Lake.

Barrel vault: An arched building element that supports the structure of a ceiling or roof.

Crazing: A glaze defect which shows cracks extending from the outer surface of the glaze to the glaze-body interface.

Detrital: Formed from mineral material formed by mechanical means and removed from its place of origin.

Orchestra: Space between the audience and the stage in the ancient theatres.

Peeling: A glaze defect when the glaze flakes off the ceramic piece at the rims and/or on the edge of the handles.

Scaena: The stage section of the ancient theatres.

Shale: A type of fine-grained sedimentary rock, formed by the compacted layers of clay, silt or mud.

Spilites: Altered subsilicic igneous rocks.

Tripod: A 3-footed type of kiln furniture (made of clay) placed among the ceramic pieces to prevent their sticking.

APPENDIX B

CERAMIC TRADITION IN İZNİK

Both red and white-bodied ceramics were produced during the Byzantine period, proven by the burnt, spoiled ceramic sherds, semi-products and kiln furniture found in the excavations. White-bodied monochrome-glazed, underglaze polychrome painted ceramics and ceramics that are undecorated or decorated with impressed patterns were found in the Roman theatre excavations, dating to the 9^{th} – 10^{th} centuries. In addition, red-bodied monochrome glazed, slip decorated, underglaze painted, engraved and incised ceramics were found, dating to the 12^{th} – 13^{th} centuries. These are products of high quality (Fındık, 2001).

İznik keeps its importance in the ceramic production of white and red body during the Byzantine times, between 10^{th} – 13^{th} centuries (François, 1996). These ceramics are of very well refined clay and are slipped. The glaze contains lead, giving the shiny effect and has the tones of mustard yellow, green and light green (Fındık, 2001). It has been concluded from the findings that in the 13^{th} century, mainly ceramics of sgraffitto technique were being produced.

Besides the excavation in the Roman theatre, the excavations of the tile kilns and the excavations conducted at other spots in İznik point to a rich, colorful and qualified ceramic tradition during the Byzantine period.

İznik had stayed under the control of the Seljuks for a short time period. It has been understood from excavation finds in Konya, Kayseri, Alanya and Kubadabad that the Seljuks of Rum were very advanced in pottery and tile production. The techniques of sgraffitto and underglaze painting were generally used, following mainly the techniques utilized in Iran and Syria (Atıl, 1973).

The Great Seljuks had developed the “technique of luster” which had its roots in Samarra. However, the usage of overglaze enamels that is known as the “minai technique” was the actual innovation introduced by the Great Seljuks. This technique was born in the ceramic centers of Rayy and Kashan and was sometimes being applied together with the luster technique. The wares of gilt lustre-minai were the most attractive ones among this type of ceramics. Lusterware is closely related to miniature art.

The ceramic sherds found in Kalehisar and others have the typical features of the Seljuk style, with colored lead glaze and slip. Also, ceramics with black decoration under turquoise glaze were much widespread in Seljuk tradition (Aslanapa, 1971).

The Seljuk style had given freshness to Islamic art. The heavy formal designs had turned into livelier and more natural ones (Lane, 1959). Most of the time, ceramics with human and bird figures were seen (Öney, 1976).

If we consider the advanced ceramic technique of the Seljuks, we can conclude that they had a ceramic industry also in İznik, in spite of the fact that they had stayed for a short period of time, there. However, the matter keeps its secret still because there are not enough findings and written documents (Fındık, 2001).

According to Oktay Aslanapa (1971), Ottoman ceramics are divided into five main groups. The first group are those with a coarse red body, corresponding to the earliest period of the Ottoman Empire. They were produced by the slip-painting, monochrome glaze and incision techniques (Fındık, 2001). Yet, the most common technique used was slip-painting. The body of the ceramic was being covered with a slightly raised white slip or a painted slip, then was fired for a second time, after being dipped into the colorless or polychrome glaze (Öney, 1976).

The manufacturing process of this first group of Ottoman ceramics from the middle of the 14th century onwards, was closely related to that of the Seljuk wares known from Kalehisar and other sites. These Ottoman ceramics were manufactured in blue, green, light brown or dark brown monochrome glaze. The designs included scrolls, arabesques and stylized flowers (Aslanapa, 1971). Pieces with blue, green, light and dark brown slips have also been recovered in İznik (Öney, 1976).

The second group of the Ottoman ceramics is known as “Miletus-ware”, named by F. Sarre in 1930 because they had been largely found in Miletus, an Aegean port-town in western Anatolia. However, this type of ceramics which is usually dated to the second half of the 14th century and the 15th century by general scholarship, was accepted to be produced in İznik by K. Otto Dorn. İznik excavations led by Oktay Aslanapa have proven that İznik was the main production center for Miletus ware (Öney, 1976).

Miletus-ware was made of coarse red clay and white slipped (Lane, 1957). Over this white slip, decorations were applied by painting, sgraffitto or dipping technique, then were covered with a transparent lead glaze. The essential technique was underglaze decoration. The predominant color was dark cobalt-blue, besides light blue, turquoise, purple and green. In addition, examples with Seljuk tradition of black decoration under turquoise glaze had been recovered (Aslanapa, 1971). The glaze applied can either be colorless or colored with turquoise, green or blue (Öney, 1976).

According to Mükerrem Paker (1965), three main styles of decoration come forward in Miletus-ware: Floral, radial and geometric styles of decoration.

These 14th - 15th century ceramics indicating the public taste and art had laid the foundation of the fore coming Ottoman ceramics that have a more advanced technique and quality of design. They had brought a fresh breath to the ceramic art with previously unknown patterns of various leaves, flowers, rosette, fans, spirals and interlaced geometric designs (Öney, 1976).

The most beautiful examples are exhibited in the museums of İznik, Kütahya and İstanbul - Çinili Köşk. These ceramics were widely used by inserting them on mihrabs made of stucco which became a characteristic feature of the Principalities period. These examples can be seen in the mescids in Ankara such as Örtmeli and Molla Büyük.

The serial production of these ceramics for daily-use include the common forms of deep bowls, dishes with broad rims. The forms of jugs and vases are seldom (Öney, 1989).

It can be concluded from the many kiln-wasters, kiln furniture and unglazed semi-product pieces revealed in İznik and various fragments excavated in places such as Kütahya, Antalya, Çanakkale, Balıkesir, Eskişehir, Saraçhane (Fındık, 2001), Konya, Silifke, Malatya, Bursa (Öney, 1989) that this kind of ceramics was being very largely produced in İznik as well as being imported to other countries (Aslanapa, 1971).

White-body ceramic production emerged towards the end of the 15th century. This new type of ceramics with hard white body makes up the third group of İznik Ottoman ceramics (Aslanapa, 1971). These blue-and-white ceramics are dated approximately between 1490-1525. They looked like the Chinese blue-and-white porcelains (Lane, 1957). They are of high quality with their hard, smooth body, clean and solid surface, fine pure transparent glaze. Dark blue was still being used. However, by the time a lighter and warmer blue began to be used. Besides, a light turquoise was applied together with blue in some examples dating to 1530-1540 (Aslanapa, 1971).

During the end of the 15th century and the early 16th century (until 1520), "Baba Nakkash style" was on the scene. This style, developed by Baba Nakkash at the Nakkaşhane, was displaying the rumi and hatayi designs together, fully covering the surfaces of the pieces (Kınık, 1989). The most common motives for this group are peonies of Chinese influence, chrysanthemums, arabesques, clouds, fish-scales, stylized dragons and three ball, also known as "chintamani" (Öney, 1976). The chintamani motive would turn out to be one of the leading motives of the classical Ottoman decoration. These three circles are often used together with cloud and lightening motives.

The hatayi design of China-based stylized flowers is synthesized with large leaves with scrolling and refracting pointed tips, introducing a new style called "saz yolu". The well-known master of this style is the famous Şah Kulu, coming from Baghdad. He was the head of nakkaş during the time of Süleyman the Magnificent. Another important feature of sazyolu style was its strong calligraphic outlines (Çağman, 1983).

In this third group of ceramics; also tulips, hyacinths, carnations and spring flowers of naturalistic style, vine clusters, dogs, foxes, birds, deers, hares and fish, animal combat scenes, texts written in naskhi and kufi calligraphy are observed (Öney, 1976). These inscriptions were drawn either white on a blue ground or blue on a white ground (Aslanapa, 1971). The obvious influence of the Far East to the designs of these ceramics may be considered to come from the 14th century Yuan and 15th century Ming porcelain (Atıl, 1973; Öney, 1976). The sultans of the Ottoman Empire were very fond of Chinese porcelain which was either introduced to the palace as a gift or imported by the Court (Öney, 1976). Besides the predominant effect of the Far East, motives of Seljuk tradition were being developed and used (Aslanapa, 1971).

In the early scholarship, this type of ceramics was known as "Abraham of Kütahya-ware" and thought to be produced in Kütahya. The reason for this misunderstanding had risen from a dragon-shaped ewer underneath of which was written in Armenian "1510 - Abraham of Kütahya" found in the Godman Collection in England. This ewer was taken as a standard, causing the incorrect naming of the blue-and-whites as "Kütahya of Abraham - ware". Finally it was revealed after the 1963 excavations of İznik by Oktay Aslanapa that the main production center was İznik. According to Carswell and Dowsett (1972), Kütahya was holding the secondary status for the blue-and-white production as a support to İznik. Yet, the situation stays in darkness because no excavations can be carried out in Kütahya (Öney, 1976).

In 1514, the last sultan of the Empire of Timur - Bediüz-zaman Mirza and his artist companions from Herat were taken refuge by Selim I who conquered Tabriz. These people together with the Tabrizian artists were sent to İstanbul. They had influenced the Ottoman court art a great deal, but for a short-time period (Çağman, 1983). Among these artists were the potters from Khorasan whom Şah İsmail sent from Herat to Tabriz in 1510. The ones, who couldn't stay in İstanbul, were settled in İznik. Thus, a link had been established between ceramic art of Timur period in Herat and that of İznik (Diez, 1946). These masters had revived the "cuerda seca technique" (Kınık, 1989).

The blue-and-white ceramics include a less common group of ceramics with an ivy motif decorated with tiny leaves springing and forming fine spirals (Öney, 1976). These fine spiral scrolls also look like calligraphic lines. The products, wrongly named as the "Golden-Horn ware (Haliç-işi)", mark an original stage of the blue-and-whites. At first, long delicate leaves and dark-colored arabesque medallions were performed among the spiral scrolls. Later, at the beginning of the 16th century, just spiral scrolls and lighter, simple designs composed of tiny leaves and flowers started to be seen. These patterns were drawn together with the patterns of the blue-and-whites (Aslanapa, 1971).

İznik excavations had also made sure that the principal production center of this type of ceramics was İznik (Öney, 1976). The earliest examples of this type of decoration are found in the tiles of the Keykubadiye Palace in Kayseri. So, the roots of this style likely go back to the Seljuk period (Aslanapa, 1971). It is known that the "Golden-Horn ware" was being imitated in Italy in the 16th century. This type of ware was so-called "maiolica", being produced in Venice.

The inscriptions in Armenian mentioned above are the proof that Armenian masters were working together with the Turkish ones.

New types of form were introduced by this group of ceramics. The most common ones are dishes with and without rims, hollow and flat dishes with and without foot, deep bowls, vases, ewers, dippers, jugs, mosque lamps and balls, kalemdans and mataras (Öney, 1976).

The fourth group of İznik Ottoman ceramics are the so-called "Damascus-ware" (Aslanapa, 1971). They exhibit a rich variety in decoration and use of color. Starting in 1525, they are mainly dated to the middle of the 16th century (1555) (Lane, 1957; Öney, 1976). Some examples of this group are observed in various monuments of Damascus. Consequently, they were named as Damascus-ware with the supposition that they had been imported from there. But, the excavation finds in İznik proved us that they had been actually produced in İznik. The tiles in Damascus must have been manufactured with the effect of the ceramics imported from İznik (Öney, 1976).

As a continuation of the blue-and-white group, Damascus-ware displays turquoise and three shades of blue under the glaze, applied on the white body, as well as olive green and violet. The contours had the color of greenish black. The vivid colors of the previous ceramic groups had now turned into matt and misty colors. A bluish ground with slightly corrugated nuances had replaced the white ground in some instances (Aslanapa, 1971). The glaze was again transparent (Süslü, 1996).

At the very beginning, the color used was blue together with turquoise and the designs were reflecting the style of the blue-and-white group. Most of the examples were the imitations of the 15th century China blue-and-white porcelains. The next color was sage green which derived from iron. From about 1540, purple started to be used, deriving from manganese (Lane, 1957).

In this group of ceramics, both naturalistic and stylized flower motives were leading the way (Kühnel, 1970) together with the motives of Chinese peony, fish scales, chrysanthemum, cloud, three-ball found in the blue-and-white group (Öney, 1976). The works being made towards the middle of the 16th century included soft greenish black spirals, blue and turquoise arabesque medallions. Damascus-ware had a free style when compared with the introverted and densely decorated style of the blue-and-whites.

Besides Chinese porcelains, Italian maiolicas had also been realized, making their own contributions to this new style, in design and form. During this period; the tulips, bluebells and carnations of later İznik ceramics appeared for the first time.

The ceramics between 1540 -1555 were the best, made so far in İznik. The realistic flower decorations coming in the first place of these ceramics were reflecting the Turks' well-known love for flowers (Lane, 1957).

During the reign of Süleyman the Magnificent (1520 -1566), a new style called "national Turkish style" emerged with the realistic floral motives of Kara Memi - the head of Nakkaş of the Court. "Kara Memi style", dependent on his observations had opened a new era in Turkish decorative arts (Çağman, 1983). The most common floral depictions of Damascus-ware are tulips, carnations, hyacinths, roses and rose-buds, artichokes and lilies. In addition, various types of rosette, leaf and spring branch depictions, grapes and cypresses were also painted. Besides these naturalistic motives, the Persian palmettes, lanceolate leaves and rosettes, arabesques and cloud bands represent the stylized floral decorations (Kühnel, 1970; Öney, 1976). In conclusion, this group of ceramics exhibits an original and unique Turkish style of decoration, despite the fact that they had been influenced by Chinese porcelains and Italian maiolicas, in their design and form.

Common forms of Damascus-ware are jugs, vases, dippers and decanters, together with various types of dishes and bowls (Öney, 1976). Architecturally, this kind of tiles is only found in Yeni Kaplıca, supervised by Rüstem Pasha in Bursa (Süslü, 1996).

Because of the expansion of tile production in İznik and Kütahya from the second half of the 16^{th} century on, there happened to be an abrupt decline in pottery industry.

The matt and smoky colors of Damascus-ware, being not very suitable for architectural decoration resulted in the search for more vivid and livelier tones, giving the start for the last and most successful phase of İznik ceramics (Aslanapa, 1971).

The last group of İznik Ottoman ceramics is roughly dated to 1555-1700 (Lane, 1957). They are called as "Rhodian or Lindos-ware", referring to the island of Rhodes where a great number of these ceramics had been bought by Cluny Museum at Paris. The later data from İznik excavations and the inscription fragments confirmed that the principal production center was İznik. Kütahya was probably supporting the industry as a secondary center.

The technique included slip and underglaze on the white body. The quality was the highest so far. The colors were cobalt-blue, soft green, turquoise, white and black (Öney, 1976). A rare group displayed salmon-pink, deep chocolate brown and pale blue (Lane, 1957). These were sometimes applied with relief on colored ground (Aslanapa, 1971).

The most important color was the famous underglaze red, seen for 50 years, since 1557. It was a low-relief red, called either raised tomato-red or coral red. This brand new color disappeared strangely with the death of its master. The tomato-red over the white ground was first experienced between 1550 - 57 in İznik pottery. But, the real development was shown in tiles (Süslü, 1996). This red is in fact a kind of slip made of clay, containing a high amount of iron. It was known as “Armenian bole” in medieval and Renaissance Europe. The best bole was known to come from the Turkish territory. It was a very hard process for the potters to achieve a good red that can be fired underglaze, for the ferruginous clay tended to repel the glaze and a dull, rough surface came out. İznik potters probably owed their success to the viscous and stable glaze which adhered perfectly as a glass film over the raised areas (Lane ,1957).

The contours were drawn black for the paints not to run (Aslanapa, 1971). Under the shiny hard glaze, the colors were set onto the white, green, turquoise, red, blue and navy blue ground (Öney, 1976). The sage-green and manganese purple of Damascus-ware were not used in this group of ceramics (Lane, 1957; Kühnel, 1970). These colors tended to discolor if the firing conditions were insufficient. Thus, it would have been uneconomical to use them in the mass production of tiles. Also, as written before, it is possible that these soft colors had been abandoned for they did not have the desired effect on the architectural decoration (Lane, 1957).

The pieces from the middle of the 16^{th} century until the end of the same century were the most beautiful and qualified ones. Naturalistic decorations of tulips, carnations, roses, buds, hyacinths, violets, lilies, pomegranate and plum blossoms, daisies, spring branches, large and curved leaves, vines and cypresses were decorated. Besides, Chinese cloud, Chinese rock, fish scales, three-ball, chrysanthemums, peonies, flowered medallions are the other important motives (Aslanapa, 1971; Öney, 1976). Various types of arabesque were also painted (Lane, 1957).

In addition to those motives also used in tiles, other motives of sailboats and animals were also painted. The animal depictions exhibit a stylized fashion, resembling Seljuk figurative style, in opposition to the plant depictions (Öney, 1976).

In some pieces, human figures and European-based motives such as buildings are to be observed (Kühnel, 1970). Also, knitting patterns, meanders and naskhi inscriptions are seen (Çorum, 1976).

The most common forms of this last group consist of dishes with and without rims, bowls, ewers with and without handles, mugs, goblets, pressed down vases with thin necks, sugar bowls with covers, decanters, mosque lamps, dippers and candlesticks (Öney, 1976).

İznik ceramics were famous in Europe and north Africa. They were sold to the merchants of Venice and Genova in İstanbul. So, they were reaching Germany and northern Europe by the help of these merchants. The cross signs found underneath some of the vases confirm that these ceramics were produced upon the special orders from the European countries. The maiolica imitations of İznik-ware in Padua also verify the importation of İznik-ware during the 17th century. It was probably the merchants of Europe that were supporting the pottery industry which had declined, because of the advance in tile production (Lane, 1957; Öney, 1976).

During the first half of the 16th century, the ateliers of the Court were manufacturing a great deal of pottery and tiles. However, it turned out to be İznik who got hold of tile production from the Court in the middle of the 16th century (Necipoğlu, 1990). The pottery and tile production of İznik had the same advanced quality as the Court's. The shift to İznik can be due to the insufficiency of the Court's kaşihane to produce enough tiles for the increased demands of architectural decoration (Fındık, 2001).

Now, İznik was the main ceramic production center of the Ottoman Empire, controlled by the Court in İstanbul. The designs were drawn in the nakkaşhane according to the Court's taste, then sent to İznik. When the orders came from the Court, İznik was not able to make the production for the public (Yenişehirlioğlu, 1983). This particularly went on from the mid-16th century till the end of the 17th century. Actually, there had been production for the public since the pre-Ottoman times, until the 18th century (Fındık, 2001).

Between 1620-1700, with the withdrawal of the Court's support, the ceramics began to lose their quality. The glaze had gone bad, the ground had turned out to be dirty white and stained. The drawings had been spoiled. The lively and dynamic compositions were replaced by simplified and haphazard ones. The colors had run over the contours and lost their spirit. The red color had been replaced by a brownish tone. The blue and green had been damaged. Forms also had regressed. Finally, in the 18th century, the ceramic and tile production came to an end (Lane, 1957; Öney, 1976; Fındık, 2001). A shift to Kütahya had occurred (Aslanapa, 1971).

In 1724, Vizier Davud İbrahim Pasha founded a workshop in Tekfur Palace in İstanbul, with the remaining masters of İznik, aiming to revive the tile-making. However, the tiles of this workshop could not reach the stylistic and technical ability of the İznik ones (Fındık, 2001).

The question of why İznik was chosen for ceramic production while the Court was in İstanbul with the Persian tile masters, comes to our minds. The primary reason can be the settled pottery tradition, coming from the Byzantine times (François, 1996). The clay beds around İznik, being exploited during the Byzantine period must also have been a rich source for the ceramic production in the Ottoman period. The factors such as the masters being ready from the strong ceramic tradition, the raw materials and fuels easily provided from the region and the closeness to İstanbul can also be put forward. In addition to those factors, the Court workshops not being able to serve the needs can be another reason why the settled system in İznik was used (Raby,1989; Fındık, 2001).

APPENDIX C

HISTORY OF POTTERY

The investigation of ceramic history should begin with the acknowledgment of clay as a useful raw material. Earliest archaeological evidence for its use points to the Upper Paleolithic period of the central and western Europe where the walls and floors of Paleolithic caves had designs onto clay, and animal paintings. Two modeled bison made from unfired clay had been recovered at the Tuc d'Audoubert cave in France (Rice, 1987). Earliest fired clay objects were found at Dolni Vestonice in Czechoslovakia, dating to 30000 B.C.. The firing temperatures reached 500 - 800°C and crushed mammoth bone was added to clay (Rice, 1987; Herz and Garrison, 1998). Also, other Upper Paleolithic sites such as in France, Russia and Japan had revealed fired clay objects (Herz and Garrison, 1998).

Fired clay pieces of basketwork traces, dating from 15000 to 10000 B.C. have been recovered in Gambles Cave in Kenya, constituting the idea that pottery making might have been discovered when a basketwork, smeared with clay to strengthen it was accidentally burnt (Rado, 1969).

The Neolithic period includes the increased amount of pottery making, with the nomadic societies transforming into the sedentary communities (Arnold, 1985). Vessels of fired clay have also been found in England, Belgium, Germany, North and South America, Egypt, Mesopotamia etc. and elsewhere, dating to about 5000 B.C.. (Searle and Grimshaw, 1959).

The invent of pottery making is so important for it has established the basis of other technologies such as metallurgy, brick architecture and engineering.

Certainly the Near East appears as a foremost region for pottery making in the world history. After about 10000 B.C., clay was being used for a great deal of purposes such as architecture, pottery and modeled objects.

Pottery was probably in use as early as 8500-8000 B.C. at Beldibi in southern Turkey (Bostancı, 1959; Schmandt-Besserat, 1977).

The earliest pottery of the Near East was being made by coil technique. They included some kind of finish, related to roughening or scraping the surface. They were fired in bonfires, using wood or dung cakes as fuel. The forms were bowls, cups and trays, later including painted and incised decorations of plant and animal motives and scenes of human activity (Rice, 1987).

By 1500 B.C., major innovations had occurred, with the development of kilns, the potter's wheel and glazing (Rice, 1987). The potter's wheel and glazes appeared in Egypt, as early as 3000 B.C. (Zakin, 1990). The earliest kilns probably had open tops. The later kilns had been developed to have enclosed chambers, providing higher temperatures and firing control. Fuel was more efficiently exploited in these advanced kilns, giving way to the manufacture of high-fired ceramics (Rice, 1987). A kiln near Susa in Iran has been dated to the 7th millennium B.C. (Majidzadeh, 1975).

The potter's wheel on which the vessels are thrown by turning during the forming is the most important discovery, leading to the mass production of standardized forms.

The Egyptians had succeeded in manufacturing glassy coatings of very high temperature on the pottery. Glazes are formed of materials melting at enough temperatures to become vitreous substances. They were both decorating the surfaces and making them waterproof. The Near East is characterized with alkali glazes of tin which are thick white coatings made of tin oxide and lead. These were first applied to the bricks by the Assyrians after 900 B.C. (Rice, 1987). A lead glaze was also found in Babylon during 1750 - 1170 B.C. and it spread into Persia (Cooper, 1988). The Persians are known to make colored glazes by adding various metal oxides to an alkaline base (Searle and Grimshaw, 1959).

The ceramic art had flourished with the advent of Islam, displaying highly decorated, glazed pieces. The ceramic tradition of Islam is traced back to the traditions of Egypt and Mesopotamia (Çobanlı, 1996). The alkali-tin glaze continued to be used by the Islamic potters during the 9th century (Cooper, 1988). The copper-based alkaline turquoise glazes were also being used in the 12th century (Çobanlı, 1996).

Kashan, Rayy, Rakka and Gurgan through the 12th and 14th centuries became to be the most important production centers (Cooper, 1988). Vessels and tiles were being produced by press-molding. They were painted by a slip after which was covered with an alkaline or lead glaze. Other techniques associated with fritted white clay bodies, polychrome slip-painted ware and lusterware were also being applied (Zakin, 1990). Frit is a mixture of two or more materials fused with heat, then ground into a powder after cooling (Rice, 1987). This is added to the clay bodies to lower the melting point and make the vitrification process easier. The fritted white clay bodies were the imitations of white porcelain.

Chinese history carries momentous technical achievements in ceramic production. These particularly include the high-fired ceramics and glazes. Stonewares were being manufactured in the kilns of very high temperatures, reaching 1200°C between the 15th and 13th centuries B.C. (Li Jiazhi, 1985). The glazes were produced using a combination of lime and wood ash as fluxes (Zhang Fukang, 1985). Also, lead glazes including lead as a flux by lowering the melting point of the glaze mixture were developed during the Han Dynasty (206 B.C. to 200 A.D.) (Shangraw, 1978).

During and after the Yuan Dynasty (1280 – 1367 A.D.), the relations with the Near East to import the blue cobalt pigment led to the production of the famous Chinese blue-and-white porcelains which in turn influenced the decoration of the Islamic pottery (Zhang Fukang, 1985; Zakin, 1990).

The ceramic technology of Europe was closely linked to the technology in the Near East (Rice, 1987). The forerunner of the European culture was the “Minoan” of the 3rd and 2nd millennium B.C., in the island of Crete. Minoan ware was developed by the potters emigrating from Egypt and Mesopotamia and it is characterized by rich decorations and slips (Çobanlı, 1996).

The Renaissance became the period of revival in pottery with the influence of Islamic ceramics (Zakin, 1990). The Islamic potters introduced the technique of tin-glazing to the European world. It passed from north Africa to southern Italy, then to Spain, France, Germany and the Netherlands, finally arriving at England in the 17th century (Rice, 1987; Cooper, 1988). It was widely being used in the maiolica-wares of Italy, during the 15th and 16th century. Maiolica is fine earthenware actually originating from the island of Majorca.

In the early 18th century, the Germans achieved making of white porcelain which spread from Dresden to all over Europe. European porcelain appeared to be different than the Chinese porcelain. It was less plastic though with fewer inclusions. However, the work was fine and aristocratic (Zakin, 1990).

In the late 18th century, a new porcelain-like fine stoneware type came forward in England, referred to as “bone china” which was manufactured with the addition of calcined ox bones to the body. The result was a white translucent and very hard stoneware (Rice, 1987).

APPENDIX D

PLAN

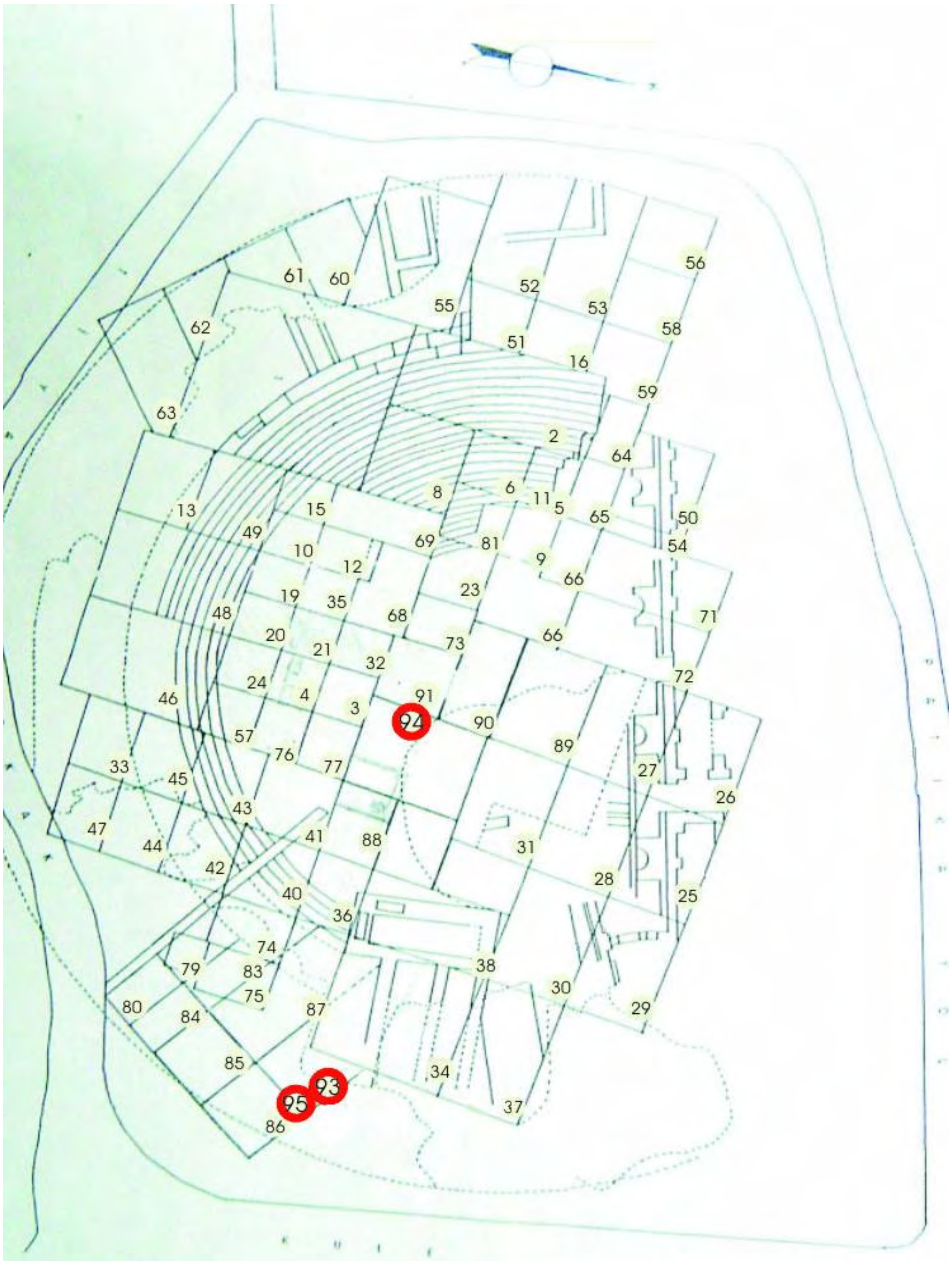


Figure D: Plan of the Roman Theatre (2nd century A.D.), showing grids

APPENDIX E

CERAMIC DRAWINGS

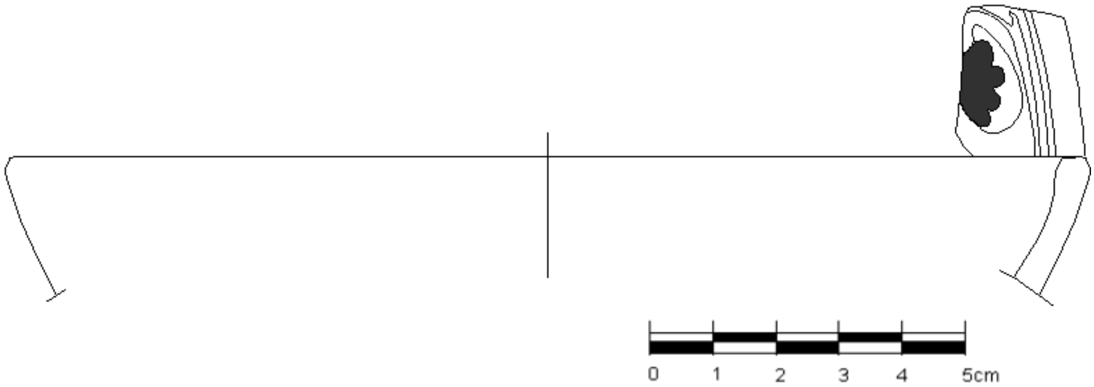


Figure E.1: AutoCAD drawing of sample 3 (Atıcı, Bakırer and Kırmızı, 2004)

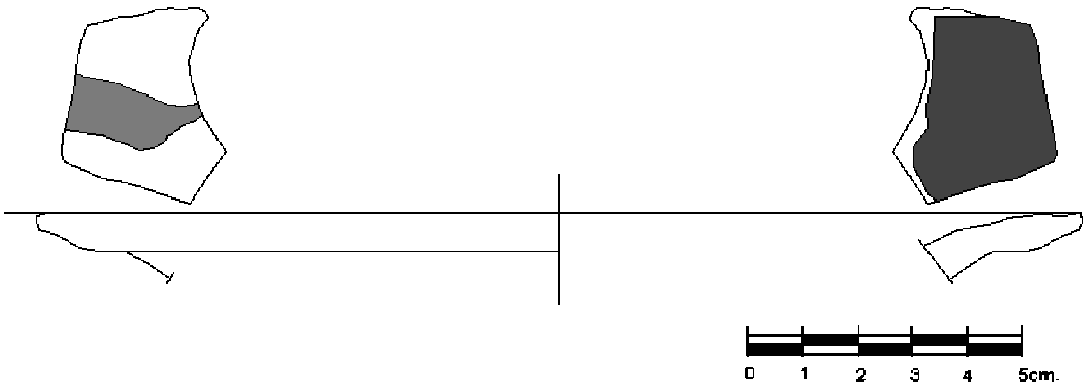


Figure E.2: AutoCAD drawing of sample 4 (Atıcı, Bakırer and Kırmızı, 2004)

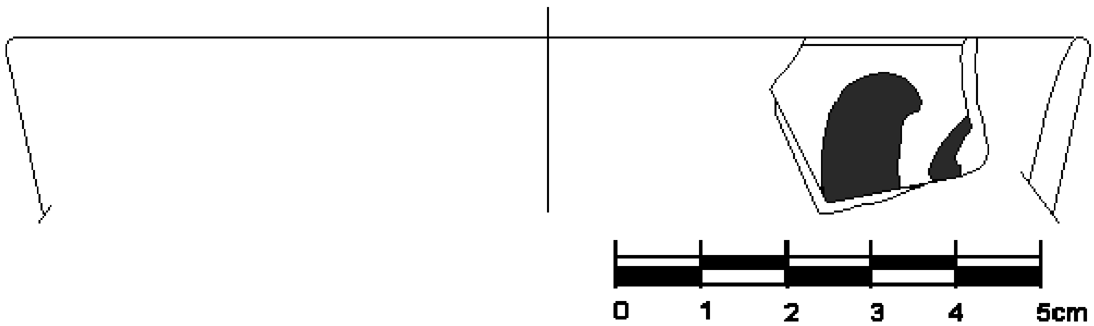


Figure E.3: AutoCAD drawing of sample 12 (Atıcı and Bakırer, 2004)

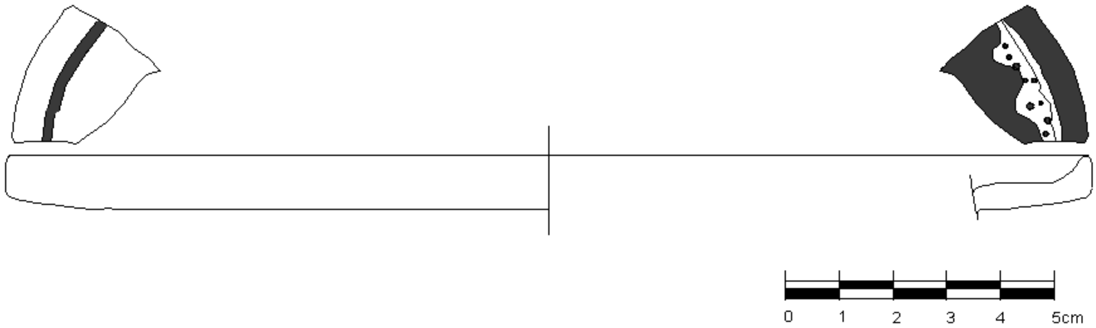


Figure E.4: AutoCAD drawing of sample 17 (Atıcı and Bakırer, 2004).

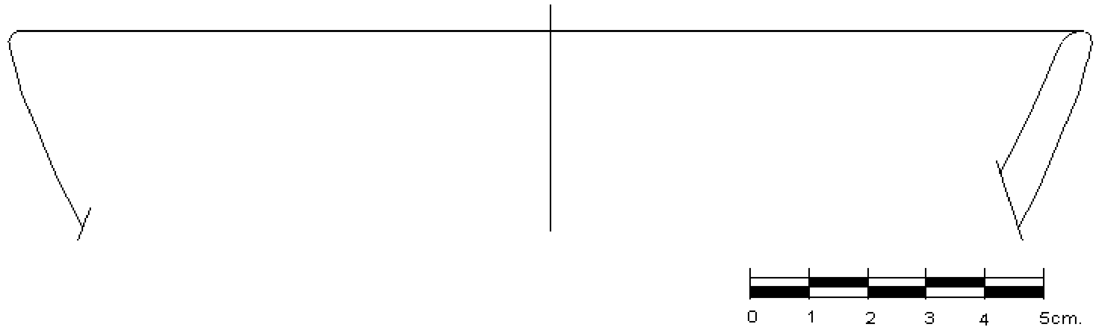


Figure E.5: AutoCAD drawing of sample 23 (Atıcı and Bakırer, 2004)

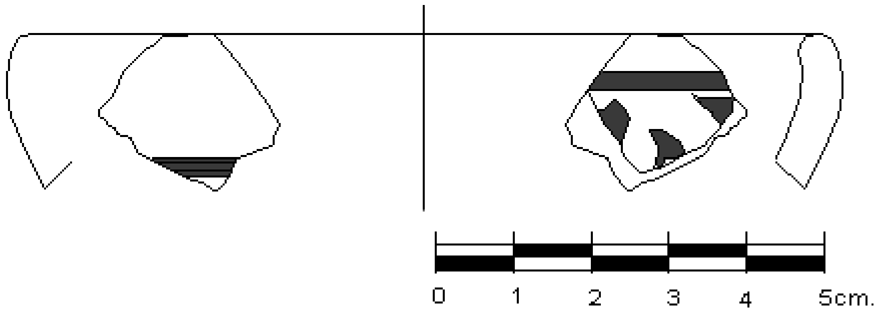


Figure E.6: AutoCAD drawing of sample 27 (Atıcı and Bakırer, 2004)

APPENDIX F

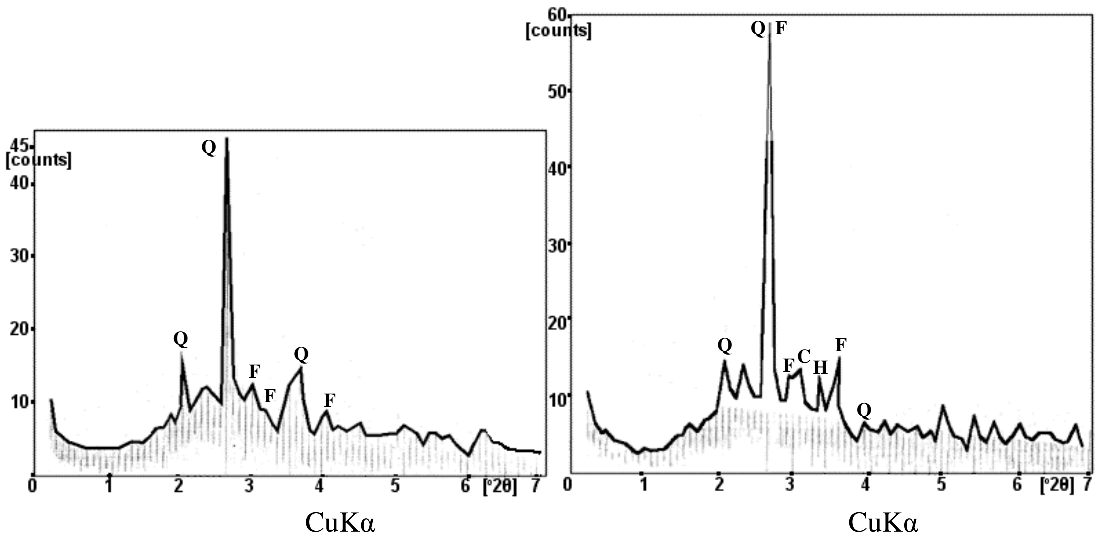
COLOR EXAMINATION

Table F: Colors of the paints and glazes according to the Munsell Book of Color

Sample No	Inner	Outer
1	design: 5 PB 2/1- 2/6	glaze: 2.5 BG 4/8
2	glaze: 2.5 B 5/6	glaze: 2.5 BG 5/8
3	design: 2.5 PB 2/2	
4	glaze: 5 PB 2/2 – 2/6	glaze: 7.5 GY 8/2 , design: 10 GY 4/4
5	design: 2.5 PB 2/4	
6	design: 2.5 PB 2/2-3/4	glaze: 10 GY 6/6
7	design: 5PB 2/2 -2/4- 2/8	glaze: 10 GY 2/4 – 2.5 BG 4/8
8	designs: 2.5 PB 2/2 – 2/6, 10 P 2/2	
9	glaze: 5 PB 2/4	lines: 7.5 Y 2/2, glaze: 7.5 Y 8/4, rim glaze: 10 GY 2/4,
10	design: 5 PB 4/6	glaze of the pointed edge: 7.5 G 5/8, middle glaze: 7.5 Y 5/4, bottom glaze: 2.5 GY 4/4
11	unidentified	glaze: 7.5 GY 7/4
12	design: 5 PB 2/1 – 2/6	glaze: 10 Y 5/6
13	designs: 5 PB 2/1 – 3/4, 2.5 BG 4/6 – 5/8	glaze: 10 GY 4/6 –5/6
14	design: 5 PB 2/6 –3/8	design: 5 PB 2/2 – 4/4
15	designs: 5 PB 2/1- 2/4, 10 P 2/1	
16	design: 5 PB 3/6	design: 5 Y 6/6, 10 YR 3/4
17	designs: 5 PB 2/2 – 2/6, 5 GY 3/4	design: 5 PB 3/6
18	design: 5 PB 2/1 - 2/4, lines: 5PB 3/6	glaze: 7.5 Y 6/4, 10 YR 6/4, line: 5 GY 2/2 – 3/4
19	design: 5 PB 2/1 – 2/4	design: 5 PB 2/2 – 3/4
20	design: 5 PB 2/2 – 2/4	
21	design: 5 PB 2/6 – 2/8	glaze: 10 GY 5/6 – 7/4, 5 GY 9/2
22	design: 5 PB 2/4 – 2/8	design: 5 GY 4/2
23	design: 5 PB 2/6 – 2/8	design: 5 PB 3/6 – 4 /6
24	unidentified	unidentified
25	glaze: 10 GY 2/1 – 3/6 – 6/6	glaze: 10 GY 2/1 – 3/6 – 6/6
26	design: 7.5 PB 2/8 , 5 PB 2/8	design: 5 PB 2/1- 4/4
27	design: 5 PB 2/2	design: 5 PB 2/6 – 2/8

APPENDIX G

XRD GRAPHICS



a) Sample 22 b) Sample 25

Figure G: XRD graphics of the bodies of samples (Q: Quartz, F: Feldspar, C: Calcite, H: Hematite)