Analytical study of Roman red slip ware from ancient Tripolis (Denizli, Turkey)

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1. Introduction

In recent years, interdisciplinary works on the findings (ceramic, metal, bone, marble fragments, etc.) from archaeological sites have shown that the chemical, geological and physical analysis techniques yield beneficial results [1–8]. The chemical, mineralogical and structural characteristics of ancient artifacts can help to identify the source area of the raw material used in ceramic production and to identify the technological processes associated with pottery production. In addition, knowing the mineralogical composition can shed light on the firing temperature and time of the raw material. Why is it important to 'identify technological processes' and 'firing temperature'? Because, technological processes can be used to design any series of operations aimed at transforming a raw material into a finished product. These include the geological properties of the local environment, the nature of the raw material, meteorological changes, the nature of the fuel and fluctuations in firing temperatures [9]. Firing temperature is also the most important step in the production of pottery. These can be used with caution to infer the details of ancient firing such as the regime, apparatus and fuel types used [10]. Pottery production technologies give us important information how changing social structures impacted the material culture in general and the production of pottery in particular.

There are many archaeological sites (Laodikeia, Hierapolis, and Tripolis etc.) currently under excavation in Denizli province of southwestern Turkey (Fig. 1a). The ancient city of Tripolis is located in Yenicekent town of Buldan district in Denizli Province. In the Hellenistic period, the city of Tripolis was at the crossroads of Phrygia, Caria and Lydia regions [11]. Archaeological excavations at Tripolis has intensified since 2012. In the present study, Roman red slip ware samples from the late Roman period uncovered at Tripolis were investigated by archaeometric methods.

Imported red slipped ceramics were found at Ancient City of Tripolis where is located on the banks of Maiandros during the excavation works between 2012 and 2017. Among these findings, red slipped ceramics were defined which date Early Roman Imperial Period and Late Roman Period red slipped ware. Located in the Pisidia Region, Sagalassos was home to red slip pottery production that started in the 1st century BCE and 1st century CE, and continued in different forms until the 7th century CE [12,13]. Another group identified in excavations in Tripolis during the years is the Lycos valley red ceramics [14]. About 4-7th century CE findings on regional production group were identified in Laodikeia and also in two metropols which are Tripolis and Hierapolis of the valley, the most distinctive feature of this group is that it has a reddish yellow liner. Except for the first two groups, a small group of late red ceramics with little darker red slip in the ancient cities of the Menderes Valley are generally found in 6-7th century CE layers for this reason they are named as “Sigillata from the Meander valley”.

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The main aim of this analytical study is to distinguish the ceramics of local production from wares imported from nearby regions or islands and to elucidate the manufacturing process and the firing techniques. Therefore, red slip wares were correlated to well-documented characteristics of red slip ware around Turkey [5,16,17].

2. Archeological and geological background

2.1. Historical-Archeological background

The ancient city of Tripolis is located within the territory of Yenicekent neighborhood of Buldan district in Denizli province in inner western Anatolia (Fig. 1). Remains of public and civilian architecture of the city located in the northwestern tip of the Lykos (Çürüksu) Valley spread across an area of about 3 sq.km. on the southern slope of a hill dominating the valley.

Earliest information on the location of the city is given by ancient historians and geographers (Strabo XIII.4.4, 169; Pliny, NH, V, XXIX; Hierokles, Synekdemos, 669, 4; Ptolemy V.2.18; Oracles Sibylline V, 321). The area where the city is located was considered part of Lydia as noted by Herodotus (VII.30). Pliny the Elder (NH V.29) also places the city within Lydia. Another ancient author placing the city within Lydia was Hierokles (Synek. 669.4). As a different opinion there are also some other ancient authors that placed the city within Karia, e.g. Ptol.Geogr. V.2.18. Sibylline Oracles mention the city as “Tripolis by Maiandros” (Orac. Sibyl. V.321). Tripolis has been placed within Lydia, Karia or Phrygia by different sources and this confusion is due to its location at the junction of all three regions. The most important reason for the differences in localization should be the changes in the borders through time. Nevertheless, Tripolis was part of the conventus of Sardeis for a while but then in another document it is cited within the conventus of Apameia. Considering the fact that various geographic formations such as rivers, mountains, and lakes were determinative in settling of borders will lead us to think that Tripolis on the northern bank of River Maiandros was actually part of Lydia. The phrase of “Μαιονίη Τρίπολις” in a Roman period inscription is the most important written evidence for placing Tripolis in Lydia.

The first identification and scientific remarks on the ancient city came from travelers as early as the mid-seventeenth century [18–22], however, these works contain only limited information on visible remains of antiquity. Denizli Museum Directorate conducted short-term excavations and surveys in 1993, 2007–2009 [23–26] and in 2012 the authors of this article initiated excavations, which still continue [11,27,28]. The most important evidence indicating the strategical and geopolitical location of Tripolis rises from its location on trade routes.
The trade route coming from Pergamon and Germe extends via Thyatira, Sardeis and Philadelphia to Tripolis, Hierapolis and Laodikeia. Although most of scholars date the origins of Tripolis as a city back to the Hellenistic period, archaeological materials obtained in the course of surveys at Hamam Büki and Yenice Höyük located to the east and southeast of the city indicate human settlement in this area since the Late Neolithic – Early Chalcolithic period. The city was founded in the Hellenistic period under the name of Apollonia [29–35]. Then for a short period of time, she was called Antoniopolis after the visit of Marcus Antonius to Asia Minor in 41 BC; however, as the First Triumvirate was dissolved in 36 BC and Marcus Antonius left it, the city’s name should have changed in due course. Starting with the reign of Augustus, as inferred from the autonomous coins struck here, the city was then called Tripolis. The Çürüksu Valley, where Tripolis is located, housed independent cities until the Battle of Magnesia between Seleucid and the Pergamene Kingdoms in 190 BCE. Pergamene Kingdom won this battle with the support of Rome and with the Apameia Treaty signed in 188 BCE the region came under the Pergamene rule. When Attalos III, the last king of Pergamon, bequeathed his kingdom to Rome in 133 BCE the region came under the Roman rule. During the Roman Imperial period the city was part of the Conventus of Sardeis for a while; then, she became part of the Conventus of Apameia during Flavian period [22,36].

The city had high times during the Roman period. In the first century AD, the city had a main east-west street (decumanus maximus) of 9-m-width and alleys intersecting with it at right angles. The main street was flanked by houses and shops, according to evidence available at hand for the time being, from the first century BC through the mid-seventh century AD. The second main street (cardo) intersects with the east-west Colonnaded Street in the city center and it is called the Hierapolis Street. Around these two main streets are the public structures such as Arched Building, Agora, Nymphaeum and Bouleuterion as well as civilian structures (Fig. 2).

Production activities continued through ages as the city is positioned on trade routes. Hair pins and clips of bone, which have been uncovered in high quantities, indicate that animal husbandry was one of the important income items of the city. Another important item of production is pottery vessels. Mold examples uncovered indicate that the Tripolitan production did not target local consumption only but also marketed its products to the cities in the vicinity [37,38]. A significant part of the market activities should have taken place at the two agora identified to date. Numerous coins uncovered at the Agora reveal information regarding the dimension of trade and commercial activities in the city including the origins of the traders. Some of the cities trading at Tripolis attested from coin finds include Pergamon, Smyrna, Ephesus, Tralleis, Aphrodisias, Thyateira, Philadelphia, Smyrna, Ptolemais, Antioch ad Maenadrum, Kolossai, Laodikeia, Hierapolis, Pisidian Antioch, Herakleia Salbake and Stratonikeia. Other important public structures are city gates, baths, stadium, theatre and nymphaeum built according to the needs of the city, increasing in parallel to the increasing population. Not only for the pegan Roman period but also for the times of Christianity the city offers important clues. At the First Ecumenical Council held at Nikaia in AD 325, Tripolis was represented at bishopric level [21,22].

Archaeological excavations conducted in the recent years have shown that Tripolis was also affected from the earthquake in AD 60 during the reign of Nero alongside Hierapolis, Laodikeia and Kolossai, which are mentioned in the epigraphic sources. Following the concerned earthquake new construction started in the city and Tripolis also made use of the funds sent by Nero for the rebuilding of the devastated cities in the region. The second big devastation by earthquakes took place in the second half of the third century and along with the cities in West Anatolia Tripolis was also razed to ground. This earthquake led to the formation of closed contexts that facilitate dating in archaeological excavations. Another earthquake attested in the course of excavations must have taken place in the fourth century AD; skulls and bones of two adults from this catastrophe were uncovered in the debris of the Arched Building. According to the epigraphic sources Tripolis was also devastated from the earthquake of AD 494 like all the other cities in the region [32]. Another important historic clue attested at Tripolis is the evidence for the Sassanian raids of the late sixth – early seventh century AD, which are known from Aphrodisias, Sardeis and Ephesos [39].

As a result of the abovementioned earthquakes and raids, the life in the city declined starting in the seventh century AD. In this process, like in the rest of Anatolia, ruralization was at high levels at Tripolis. In the eighth-nineteenth centuries AD Tripolis was perhaps only a kome with a small population. The revival of the city in the tenth century may be attested from the frescoes depicting saints on the walls of the church, daily use wares and coins of the same period uncovered in various trenches [40]. Tripolis changed hands a few times between the Turks and the Byzantines in the first half of the thirteenth century. Turkish hegemony over Tripolis/Yenice and environs started in 1304–1306 with the Germiyan Emirate [41].

2.2. Geological background

The Denizli Basin is located in WNW–ESE trending graben and very rich in archaeological sites (Attuda, Kolossai, Tripolis, Laodikeia, Hierapolis, etc.) of different periods (Fig. 3). The basement rocks of the basin are represented by Paleozoic–Mesozoic aged metamorphic rocks of the autochthonous Menderes massif and Lycian nappes [42]. The Menderes Massif covers a large area in western Turkey, and comprises of various metamorphic rocks, which are mostly composed of schist and marble, occasionally amphibolite and quartzite. Middle Eocene Lycian nappes are characterized by ophiolitic units which consist of serpentined mafic-ultramafic rocks and allochthonous carbonate rocks. Both of these units are found on the northern and southern flanks of the Denizli Graben. The basement rocks are overlain unconformably by Bayıralan formation consisting the conglomerate and gravelly sandstone. This formation is over lain conformably by the Denizli Group, which includes Kızlıburun, Sazak, and Kolonkaya sedimentary formations. [43,44]. The Neogene aged Denizli Group is unconformably overlain by the recent Quaternary units (Fig. 3).

The Kızlıburun Formation (Early-Middle Miocene) unconformably overlies the basement and passes upwards through the Sazak Formation. The formation consists of conglomerates alternating with reddish mudstones and clast-supported conglomerates. The Sazak Formation (Middle Miocene) conformably overlies the Kızlıburun formation and consists of limestone, marl, claystone, and clayey limestone. The Kolankaya Formation (Middle-Late Miocene) conformably overlies the bottom formations and consists of laminated mudstone–siltstone and marls, alternating marl–claystone, mudstone, sandstone, and clayey limestone [45–47]. Ulubey formation (Late Miocene – Late Pliocene), which is present in the northern part of Denizli basin, is composed of lacustrine limestone with claystone and marl intercalations. Asartepe Formation (Quaternary) overlies the Neogene aged units with an angular unconformity.

3. Material and methods

3.1. Material

Arched building, located on the northern end of the columnar street, extends in east-west direction and has a rectangular form. There are entrances from the porch (Columned gallery) in the west and the tabernae in the south. Arched building, built in the Late Hellenistic-Early Roman Period, has 10.6x 36.35 m area (Fig. 2). The 20 arches rising on 14 columns form two corridors. 1861 pieces of coins, 1081 pieces of bone spindles (needles, medical instruments, dice, hair pins), 289 pieces of metal works, 251 pieces of terracotta pieces, 38 pieces of marble pieces, 44 pieces of inscriptions, 15 pieces of glass pieces fabric pieces were found. The dates of the ceramic found in the structure are
from the Late Hellenistic Period to 7th century CE with no interruption. The presence of burned areas on the ground in the northern half of the structure suggests that dense amounts of iron slag, semi-worked or drafted bone artifacts, the use of baked earth molds, especially the northern corridor is used as storage space for materials produced in the southern corridor.

For this study eighteen samples were picked according to varying macroscopic properties (fabric, color, form etc.) in order to identify their structural, chemical and mineralogical properties. These samples are chosen based on dating data because the appearance of matrix and slips of the samples are close to each other. All the samples were uncovered between 187.27 m and 184.30 m levels between the northern arches of the Arched Building (Fig. 2) in 2013. Forms and photographs of all of the investigated samples are given in Table 1. Vast majority of the picked samples belong to open vessel forms such as plates and bowls and an amphora representing the closed vessels was incorporated with a single sample. The clay of the picked samples is usually pink and reddish yellow; their interior and exterior surfaces are red. Some samples distinguish themselves with their dark red slip fabric. Some samples have blackened areas caused by firing. Sample KA8 may be considered a plate based on its broken base type; however, it was not included in any form group. Samples SA1 – 10 have a clay in reddish yellow and red but their slips have a shiny surface and light or dark red color [17]. Colors and fabrics of the samples do not display any clear distinction. Their clays are hard and firm, some samples have fine pores and fine lime temper. The samples assessed here correspond to forms 1B101, 1B190, 1B221, 1C140, 1C141, 1C142, 1C160, 1C182 of Sagalassos Red Slip Wares (Table 1) [13,47–51].

3.2. Method

Optical microscopy, powder X-Ray Diffraction analysis (XRD) and X-Ray Fluorescence (XRF) methods were used to investigate the production technology. Firstly, matrix and slip colors of ceramic samples were determined according to the Munsell Color Catalog, then thin sections for all samples were prepared from outer to inner layers and were investigated under optical microscope.

The mineralogical composition of the red slip ware was determined
by XRD using GNR APD 2000 PRO with CuKα (λ = 1.5418 Å) radiation in the Department of Geological Engineering at Pamukkale University. The XRD method is applied for the determination of all mineral phases in the samples, especially those small enough to be inspectable in the microscope. The samples were ground in an agate mortar to a particle size of less than 50 μm and undirected plaques were prepared. X-ray diffractograms were run at 40 kV and 30 mA condition in the 5–45° 2θ, (with step = 0.05, integration time = 2 s). As a result of XRD analyses, semi-quantitative percentages were estimated based on the external standard method [52]. The mineral intensity factors in XRD- bulk fraction estimations and the reflections were measured in mm.

The chemical composition was determined at the Department of Geological Engineering at Pamukkale University using Spectro XEPOS Polarized Energy Dispersive X-Ray Fluorescence spectrometer (PEDXRF) for major and some trace elements. The instrumentation was equipped with a 50 W Pd end window X-ray tube and the spectral resolution was 160 eV (1000 cps Mn Kα). During the measurement the sample chamber is flushed with Helium. United States Geological Survey (USGS) standards, which are referred as GEOL, GBW-7109 and GBW-7309 were used for XRF analysis. Red slip ware samples were crushed in a tungsten carbide crushing vessel, and 6.25 g of powdered sample was mixed with 1.4 g of wax (M-HWC). The mixture was pressed at 18 N in an automatic press to obtain a pressed disc. Dilution factor (0.8169) is calculated from the mass of the sample and total dilution mass. The total organic matter and inorganic carbon amount were determined by Loss-On-Ignition at 550 °C for 4 h and at 950 °C for 2 h [53].

4. Results and discussion

4.1. Optical microscopy analysis

Petrographic investigations of thin sections constitute a crucial tool for the study of archaeological ceramics. On the basis of the inclusion types according to optical microscopy, all red slip wares could be divided into three petrographic groups. The first is dominated by biotite, feldspar and pyroxene grains (Group 1), the second dominated by muscovite and with carbonate matrix (Group 2) and the third dominated by fine silicate crystals (Group 3).

**Group 1 (KA1, KA4, KA5, KA7)** is characterized by abundant biotite and quartz contents. In some of the samples, feldspar and pyroxene minerals were encountered in small amounts and sizes. Biotite minerals are also observed in sizes ranging from 0.5 to 1 mm (Fig. 4a). Feldspar is a rarely inclusion type present, appearing as fine clasts in the matrix. These clasts are usually angular, with an average grain size of 0.1–0.3 mm. Very fine elongated mica laths are abundant. When the matrix texture was examined it was determined that they were very well oriented during the preparation of the samples. The current orientations are interpreted as samples were red before the ceramic matrix not completely dry. In KA5 sample, very abundant biotite minerals were observed, but these minerals were found to be opaque. Furthermore, in mineralogical point of view, KA5 sample showed similar chemical properties with group 1.

**Group 2 (KA2, KA6, KA9)** is easily recognizable due to the abundance of muscovite minerals present (Fig. 4b). Muscovite minerals are up to 0.7 mm in size. Generally, in the matrix, minor amounts of small quartz grains were also observed. They are usually in the form of angular and semi-angular grains. These particles are distributed in the matrix and are in the ratio of 5%. Quartzite (1 mm) pebbles are also...
Table 1
Macroscopic descriptions of the red slip ware [13, 48–51].

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>The red slip ware forms</th>
<th>Sample photograph</th>
<th>Form of the red slip ware</th>
<th>Clay Colour</th>
<th>Surface Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>KA1</td>
<td>tableware</td>
<td>7.5YR 7/4 very pale brown</td>
<td>10R 5/6 red</td>
<td>5YR 4/1 dark gray</td>
<td></td>
</tr>
<tr>
<td>KA2</td>
<td>tableware</td>
<td>5YR 6/6 reddish yellow</td>
<td>10R 4/6 red</td>
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<td></td>
</tr>
<tr>
<td>KA4</td>
<td>tableware</td>
<td>7.5YR 7/4 very pale brown</td>
<td>10R 5/6 red</td>
<td>7.5YR 5/2 brown</td>
<td></td>
</tr>
<tr>
<td>KA5</td>
<td>tableware</td>
<td>7.5YR 7/4 very pale brown</td>
<td>7.5YR 4/1 dark gray</td>
<td>5YR 4/3 reddish brown</td>
<td></td>
</tr>
<tr>
<td>KA6</td>
<td>amphora</td>
<td>5YR 7/4 pink</td>
<td>10R 5/6 red</td>
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<tr>
<td>KA7</td>
<td>tableware</td>
<td>7.5YR 7/6 reddish yellow</td>
<td>7.5YR 3/1 very dark gray</td>
<td>10R 5/6 red</td>
<td></td>
</tr>
<tr>
<td>KA8</td>
<td>tableware</td>
<td>2.5YR 5/6 red</td>
<td>10R 4/6 red</td>
<td>2.5YR 5/6 red</td>
<td></td>
</tr>
<tr>
<td>KA9</td>
<td>tableware</td>
<td>7.5YR 6/6 reddish yellow</td>
<td>10R 4/6 red</td>
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<tr>
<td>SA1</td>
<td>FORM 1C 160</td>
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<td>2.5YR 4/8 red</td>
<td>10R 3/3</td>
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<td>SA2</td>
<td>FORM 1B 190</td>
<td>5YR 6/6 reddish yellow</td>
<td>2.5YR 4/8 red</td>
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<td>SA3</td>
<td>FORM 1B 221</td>
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<td>2.5YR 4/8 red</td>
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<tr>
<td>SA4</td>
<td>FORM 1B 101</td>
<td>5YR 6/6 reddish yellow</td>
<td>2.5YR 4/8 red</td>
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<td></td>
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<tr>
<td>SA5</td>
<td>FORM 1C 182</td>
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<td></td>
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<tr>
<td>SA6</td>
<td>FORM 1C 160</td>
<td>5YR 6/6 reddish yellow</td>
<td>2.5YR 6/6 light red</td>
<td>10R 3/3 dusky red</td>
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<tr>
<td>SA7</td>
<td>FORM 1C 142</td>
<td>2.5YR 6/6 light red</td>
<td>2.5YR 4/8 red</td>
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<tr>
<td>SA8</td>
<td>FORM 1C 141</td>
<td>2.5YR 6/6 light red</td>
<td>2.5YR 4/8 red</td>
<td></td>
<td></td>
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</table>

(continued on next page)
observed in the sample. The pore structure was detected in small quantity and size.

Group 3 (SA1-10) is predominantly defined as very fine silicate crystal (Fig. 4c). All samples have similar mineralogical compositions and differ according to the amount of some minerals. It is characterized by its quartz, biotite and pyroxene contents. In the samples, pyroxenes and opaque minerals are observed in small and little amounts. In addition, small calcite minerals are also observed. Generally, rounded quartz grains are usually monocrystalline and partially polycrystalline grains. The dimensions of the quartz grains are up to a maximum of 0.25 mm and correspond to the fine sand size. The pyroxene mineral observed in a small amount is apparent with oblique angle of incidence. In the specimens examined, a small number of oriented voids of about 0.09 mm in diameter are observed. In most cases, elongated voids are more prominent. The long axis of these gaps is measured as about 0.5 mm. The current orientations are interpreted as firing the ceramic matrix to be completely dry. KA8 sample subdivided into subgroup 3a (Fig. 4d). This sample contains abundant quartz, muscovite, and crystallized calcite and pyroxene minerals in lesser amounts. Crystallized calcite observed as small grains in the matrix, which are probably derived from marble, was added to the clay as temper. Calcite was often preferred as a temper over quartz, especially when manufacturing tableware due to the flexibility provided to create smaller vessels of various shapes and wall thicknesses [7,54–56]. In addition, metamorphic rock fragments were identified in the sample. It was determined that the metamorphic rock fragment is a muscovite quartz schist with a size of about 2.2 mm.

4.2. Mineralogical (XRD) analysis

Results of X-ray powder diffraction are in general agreement with mineralogical–petrographic observations. Fig. 5. The semi-quantitative mineralogical results of red slip ware samples, summarized in Table 2, were calculated based on mineralogical analyses. The three petrographic groups defined according to optical microscopy findings also have different mineralogical composition.

Group 1 contains abundant illite/mica, followed by lesser amounts of feldspar and quartz and in some samples also calcite and pyroxene (Fig. 5a). Group 2 itself is characterized by the illite/muscovite and rarely feldspar and quartz (Fig. 5b). The presence of calcite indicates a parent carbonate clay. Because calcite is not detected by optical microscopy. In the XRD analyzes for Group 3, mineralogical features similar to quartz, feldspar, diopside, and hematite contents were determined predominantly. However, there are differences in the abundance of some minerals relative to each other. In most of the samples, quartz mineral is observed as dominant mineral. In the SA3 sample with carbonate content, it was found that it contained quartz and it contained more feldspar. But there is also a lack of diopside.

![Fig. 4. Thin section photomicrographs (all in crossed Nicol) of the three main petrographic groups distinguished of the red slip ware: (a) Group 1 (sample KA1); (b) Group 2 (sample KA6); (c) Group 3 (sample SA3); (d) Subgroup 3a (sample KA8).](image-url)
content. Feldspar mineral is more in SA8 but less in SA5. The SA8 sample, which was determined to be different from all samples, had the highest feldspar and diopside content and was found to be evident by the observation of the hematite mineral (Fig. 5c). Group 3a samples contain abundant illite/mica and quartz, followed by lesser amounts of pyroxene (Fig. 5d).

The maximum firing temperature is based on the presence or absence of special minerals detected within the analyzed samples. The most important mineralogical change during firing is the disappearance of clay minerals. Increases that reach about 700–800 °C at firing temperatures gradually degrade the peak density of the clay phase. Furthermore, the thermal degradation of calcite due to increased firing conditions starts at about 600 °C and is completed at 800–850 °C. At these temperatures (above 800 °C), free CaO reacts with free silica and aluminum derived from the degradation of clay minerals and forms gehlenite at temperatures between 850 and 900 °C or 1050 °C [4,57].

Thin sections and XRD analyzes of red slip wares (groups 1 and 2) from Tripolis suggest that samples have similar compositions and the well-preserved illite mineral phase in samples indicates low firing temperature, (< 800 °C). Because Group 2 samples contain more calcite and illite/mica peak for this reason it has a lower firing temperature than Group 1. The firing temperatures (Groups 1 and 2) could be low temperature (approximately 800 °C). The firing temperature of red slip wares (Group 3) is over 800 °C, which is not found in any significant

<table>
<thead>
<tr>
<th>Groups</th>
<th>Sample Number</th>
<th>Illite/Biotite (%)</th>
<th>Feldspar (%)</th>
<th>Quartz (%)</th>
<th>Pyroxene (%)</th>
<th>Calcite (%)</th>
<th>Hematite (%)</th>
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<td>23</td>
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<td>KA4</td>
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<td>18</td>
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<td>SA5</td>
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<td>25</td>
<td>41</td>
<td>24</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>SA8</td>
<td>-</td>
<td>41</td>
<td>24</td>
<td>30</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Group 3a</td>
<td>KA8</td>
<td>51</td>
<td>-</td>
<td>40</td>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Fig. 5. X-ray powder diffraction patterns of red slip ware.
Concentration of trace (in ppm) and major (in wt%) elements normalized versus loss on ignition (LOI) are reported in Table 3. All measured elements were compared with each other by means of bivariate plots. Three main compositional groups can be distinguished on the basis of the major and trace elements. The results are accordant with the groups defined by petrographic investigations.

The lowest SiO₂ content (38.75%) and the highest CaO content (16.4%) belong to the Group 2 samples and the SiO₂ (48.2–51.4%) and CaO (6.9–12.3%) contents of the other groups are approximately similar (Fig. 6a and b). Abundant levels of SiO₂ were observed in Group 3 samples, in which these values are related to the abundant quartz and also to the feldspar contents. The changes in SiO₂ contents appear to be directly related to the silica mineral contents in the Group 3 samples. The highest SiO₂ content belongs to the SAB sample with an average of 52%. In other samples, this value is 48.5% on average. The high Loss-On-Ignition (LOI) values of Group 2 samples are attributed to the abundant calcite and CaO presence. The highest K₂O (4.07%) content was observed in Group 1 samples, reflecting their greater K-feldspar and illite/muscovite content (Fig. 6a and c). Potassium is mainly hosted in micas and K-feldspar. The highest TiO₂ (1.08%) was observed in Group 1 samples and lowest TiO₂ content in Group 2 samples (0.71%). The highest Fe₂O₃ concentrations were observed in Group 3 samples. They likely reflect the abundance of hematite/magnetite and clay minerals. Reflecting their higher clay mineral and feldspar content, Group 1 samples, contain the highest amount of Al₂O₃. Samples of Groups 1 and 2 showed similar values to one another for MgO contents. Group 3 samples contain higher MgO values. In Subgroup 3a sample, MgO contents also show significant differences. Other elements are close to each other (Fig. 6d). The major element results generally relate to the mineralogical composition of all groups.

It is observed that the highest zirconium (Zr) content is found in Group 3, which is also rather high (especially in Subgroup 3a [268.2 ppm]), probably linked to the igneous phases [2,58]. In other groups, these values are close to each other (Fig. 6e and f). The highest Y and Nb contents are seen in the Group 1 samples and the lowest in the Group 3 samples (Fig. 6f). These values in Group 2 samples are moderate. The concentration of Y and Nb is largely determined by the abundance of heavy resistance minerals, such as zircon, xenotime and garnet. Garnet is especially common in some metamorphic rocks like schist and amphibolite. It is a common rock-forming mineral in various temperature minerals are around 900 °C. It has been found that the SA8 had higher firing temperature than both the textural differences and the mineralogical abundance contained therein. Group 3a has a slightly higher firing temperature than those of Groups 1 and 2.

4.3. Chemical (XRF) analysis

Clay minerals. The samples indicate that the firing temperatures of the samples examined due to the presence of vitrification and high temperature minerals are around 900 °C. It has been found that the SAB had a higher firing temperature than both the textural difference and the mineralogical abundance contained therein. Group 3a has a slightly higher firing temperature than those of Groups 1 and 2.
from potassium feldspar. In addition, MgO contents show significant
differences between the sample groups (Fig. 6c). The Group 3 samples
have values close to each other in terms of their MgO content with
average value of 7.5%. In this case, it is seen that the tableware shows
similarities. The differences in MgO contents can be attributed to the
pyroxene and chlorite minerals observed in the samples [5,59]. Unlike
Group 3 samples, the subgroup 3a remains in the field of utilitarian
wares.

Some trace elements (Cr, Zr, Ti, Nb, etc.) are often used as geo-
chemical guides because they are associated with specific petrological
species [2,60,61]. Elemental profiles of trace elements show similar
properties for almost all examined samples (Fig. 6e and f). It is also
observed that the Sagalassos red slip wares have differences in terms of
their trace element contents and it is clearly understood that the utili-
tarian wares and tableware are distinctly separated [5]. In this context,
as a result of comparison of Tripolis samples, it is observed that Groups
1 and 2 specimens stay in different areas than Sagalassos samples while
Group 3 samples and Sagalassos samples are located in the field of
tableware. Subgroup 3a samples were found to be associated with Sagar-
lassos samples and with utilitarians.

NASC (North American Schist Composites), PAAS (Post-Archean
Australia Shale) and Upper Crust (UC) are widely applied in normalized
major and trace element patterns, especially in geochemical analyzes
related to magmatic, sedimentary and metamorphic petrology [62,63].
This normalization is achieved by dividing the measured values to the
normative value. In order to observe fractionization process NASC nor-
malization is used it was determined that ceramics were more closely
related to sedimentary materials. In Fig. 7, Sagalassos red slip wares
were compared by Braekmans [5]. As a result of this comparison, it was
determined that Groups 1 and 2 showed similar compositions and
Group 3 samples showed similar patterns and showed similarity with
the group called tableware (Fig. 7a). In the same way, both Sagalassos
and Tripolis red slip wares were compared with PAAS (Post-Archean
Australia Shale) [64,65] and upper crust (UC) [66] (Fig. 7b and c),
similar results were found.

4.4. A comparison of red slip wares and raw materials

Neogene clay deposits were examined from Yenicekent, Pamukkale
and Başkarcı (Denizli region) by Semiz [46,47]. These clay locations
were obtained from historical sources and interviews with local people
and modern employers in the ceramic industry [46]. It is inferred from
these studies that TR2, LE2, LE3, LE4 clays from Pamukkale, and TR3
from Başkarcı can be used in the ceramic industry, on the other hand,
TR1, TR4, TR5 from Yenicekent clays cannot be used in the ceramic
industry. In the present study, red slip wares were correlated with clay
samples from Denizli region (Fig. 6). Chemical composition of all clay
samples show differences. The MgO concentrations were lower than
that in the mafic source rocks. K2O contents were not found in high
quantity and this situation is related to lower muscovite contents. Y
contents were very low; however, in TR3 sample this content was found
to be higher. This could be interpreted that these clays originated from
metamorphic rocks. The clayey raw material from the Tripolis red slip
ware is compositionally distinctive among region clays. In our studies
on the red slip wares from Laodikeia in the Lykos Valley these were
found to be local productions related with local clays [67].

When the three groups of samples identified according to miner-
alogical and chemical studies were assessed for their source areas, these
were understood to be different. In this context, Group 1 (Lykos Valley
Red Slip Ware, n = 4) is characterized by very high levels of K2O, TiO2,
Y and Nb. the clay color is pink (7.5YR 7/4) and reddish yellow (7.5YR
7/6) and the interior and exterior surfaces are red. However, some
samples have blackened areas caused by firing. Samples with similar
form and slip fabric are also found at Hierapolis and dated to the late
fourth century AD. [68,69]. Both chemical and petrographic results
suggest that Lykos valley red slip ware was also produced from local
clay material (Pamukkale area) in Denizli region. Group 2 (Menderes
Valley Red Slip Ware, n = 3) is characterized by very high levels of CaO
(up to 15 wt%) and relatively low amounts of trace elements. This
group distinguishes itself from the pottery of the Lykos Valley with
regards to clay, slip and form. The slips of these wares with dark red slip
have flaked off due to its fine texture [70]. This flaking should be re-
lated with the muscovite mineral content. The presence of abundant
muscovite and metamorphic rock fragments brings forward the source
of its raw material beyond the Menderes Massif. Group 3 (Sagalassos
Red Slip Ware, n = 11) can be considered as very distinct from the
other chemical groups. Braekmans [5] mentioned that there are many
clay deposits developed especially in different valley systems in the


Y concentrations (in ppm) in the red slip wares from Tripolis (TR2, LE2, LE3, LE4 clays from Pamukkale, TR3 from Başkarcı, and TR1, TR4, TR5 from Yenicekent clays
does not hallucinate.

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from Semiz [46,47] and Sagalassos references samples from Braekmans [5]).
excavations in many ancient cities outside Sagalassos during the Ancient Ages. These ceramics were produced in the interior of Anatolia unlike other red slipped ceramic groups and exported to the different regions and geographies. In this study, it is seen that Sagalassos Sigillatas were also used intensively in Tripolis that is located in the western Anatolia borders. These ceramics found in Tripolis have a thick walled structure except a few samples. This findings are already supported by several publications that Sagalassos potters produce their products that are made for export at far distances and suitable for the land transportation.

Among Sagalassos Red Slip Ware in Tripolis, there are limited number of samples with ornamentation, especially the examples of samples dated to the 4th century CE indicate a commercial relation with Sagalassos in this period. These commercial relations are supported by the discovery of a lot of coins found on such dates in Tripolis Arched Building.

5. Conclusions

This study is about the characterization of red slip ware from ancient Tripolis in Denizli province. The red slip ware samples show differences in their mineralogical and chemical composition, reflecting variation in the manufacture technology and the type of clays used. Differences in matrix, and the distribution and size of grains were also analyzed. The red slip wares were classified into three distinct groups: (i) Group 1 (Lykos Valley) – dominated by biotite, feldspar and pyroxene grains (ii) Group 2 (Menderes Valley) - dominated muscovite and with carbonate matrix (iii) Group 3 (Sagalassos) – dominated by fine silicate crystals. The major element compositions of the three groups generally related to mineral composition of the samples. It is observed that the samples of Groups 1 and 2 were fired < 800 °C and samples of Group 3 were fired at temperatures up to 900 °C.

All the data were evaluated and it was determined that the red slip ware ceramics recovered in Tripolis had different origins in terms of archaematic properties. Group 1 was probably produced from local clays in Denizli region. Group 2 shows clear similarity with the local clay but it has a different origin (probably Menderes Massif clays). Whereas Group 3 is not a local production of Tripolis. Furthermore, it was understood that the samples were imported from another geography, namely Sagalassos in Burdur province. In order to clarify the Denizli region clays, investigation of clay raw materials in the surrounding area of the archaeological site needs to be carried out in the future.

References


Fig. 7. Spider diagrams for Tripolis red slip ware samples and Sagalassos references samples [5] normalized to NASC [59,63], PAAS [64,65] and UC [66].

4.5. Archaeological implications

The Sagalassos Sigillatas where production started from the Late Hellenistic Period to the 7th century A.D were found in archaeological region. In this context, detrital clays of the Çağaklı valley, that is associated with the alternation of shale, is used for the production of the Sagalassos red slip wares [5,16,71]. This clay consists mainly of chlorite and smectite type clays. As a result, the Çağaklı clays mainly consists of illite and chlorite, besides kaolinite and less smectite, plagioclase and feldspar, quartz, pyroxene and biotite. It is believed that these clays are probably moved during the deposition processes due to their granular content. It can also be said that clays contain very high MgO. As a result of the evaluation of all data, a group of red slip wares in Tripolis were found to be product of Sagalassos and the results also indicated that clay materials was obtained from the Çağaklı plain. Subgroup3a is more compatible with the detrital clays from the western part of the Ağlasun valley [71]. Although closer dates are foreseen for various find sites the Tripolitan materials can be attributed to the fourth century AD based on supporting materials and comparisons.