Proceedings of the Geologists' Association xxx (xxxx) xxx

Contents lists available at ScienceDirect

Proceedings of the Geologists' Association

journal homepage: www.elsevier.com/locate/pgeola

Petrographical and chemical properties of building stone, plaster and mortar used in Güvercinkayası Settlement (Asia Minore): An overview of material usage habits in the Middle Chalcolithic period

Davut LAÇİN

Istanbul University-Cerrahpasa, Department of Geological Engineering, G-Block, 34320, Büyükcekmece, Istanbul, Turkey

ARTICLE INFO

Article history:
Received 6 April 2021
Received in revised form 24 August 2021
Accepted 25 August 2021

Available online xxxx

Keywords:
Güvercinkayası settlement
Kızılkaya ignimbrite
Building stone
Mortar

ABSTRACT

Several ancient settlements of the Middle Chalcolithic period (*c.*5200–4750 BC) have been identified in the Asia Minore (Turkey). One of these ancient settlements, the Güvercinkayası settlement, was founded in Central Anatolia, and is the precursor of the castle city model. This study was carried out in order to reveal the basic geological features of the region where Güvercinkayası settlement was established. In addition, it was aimed to define the plaster, mortar and building stones used in settlement, to determine the source areas and to understand the selection and use of building materials in that period.

The obtained data show that the Güvercinkayası settlement was established on the Lower Pliocene (5.33–3.60 Ma) Kızılkaya ignimbrite, and mineralogical composition of the ignimbrite consists mainly of tridymite, cristobalite, orthoclase (rarely sanidine), plagioclase, quartz, biotite, and secondary calcite. The Kızılkaya ignimbrite was mainly used as building stones on the walls, and as aggregate in the mortars. Similar to the other Middle Chalcolithic period settlements in the region, it is seen that easily processed materials from nearby sources were chosen as building materials. In addition, the fact that protein and oil are not used as additives and preservatives in mortars and plasters proves that these materials are not widely used yet.

© 2021 The Geologists' Association. Published by Elsevier Ltd. All rights reserved.

1. Introduction

There are several ancient settlements belonging to the Middle Chalcolithic period in Turkey. The most important of these buildings are located around the Cappadocia region, the Güvercinkayası (Çatalsu/Aksaray), Köşkhöyük (Bahçeli/Niğde), Canhasan (Karaman) settlements are the main ones (Gülçur, 2004; Öztan, 2009; Pickard and Schoop, 2013; Steadman et al., 2019).

The Chalcolithic period is defined as the period when urban cultures first started (Gülçur, 2004; Öztan, 2009; Çaylı and Demirtaş, 2012; Binder, 2016; Steadman et al., 2019). The temple economy, which started to emerge in the Neolithic (10.000–6.000 BC) era, was institutionalized in the chalcolithic period, and economy and religion are intertwined in this system. Temples and priests control the productions. As a result, a clear stratification has emerged in the society. A new model of society has begun to take shape. During this period, copper mining gained great importance. Trade by sea and river has developed. During this period, villages turned into big cities and city-states were born from agricultural village societies, and a socio-economic differentiation has emerged between regions (Öztan, 2009).

The Cappadocia region had many natural resources (*i.e.,* fertile lands, clays, ignimbrite, obsidian, salt, and a variety of building stones) required for a settlement in ancient times. Therefore, archaelogical excavations around the Cappadocia region enhance our information about prehistoric societies.

The Güvercinkayası settlement was established on rock surface, and the natural structure of the rock, its dimensions, easy processing and distance played an important role in the selection of settlements. Due to security concerns, settlement (castle type settlement) was preferred in high elevated and rocky areas. The main building material used in Güvercikkayası and its surrounding settlements was produced from the geological formations in the region (Gülçur, 2004).

Since the Chalcolithic period (*c.*5200–4700 BC), working groups who are specialized in the certain field have been in contact through the workshops they formed together (Gülçur, 2004; Çaylı and Demirtaş, 2012; Hacar, 2020). The specialized groups in the Chalcolithic age include wall, painting, sculpture, pottery decoration, jewelry, seal, wood, dry farming, animal husbandry (sheep and goat) (Gülçur, 2012) as well as groups specialized in mineral and metal to make weapons, tools, and ornaments (Öztan, 2009) and obsidian workshops (Balkan-Atlı et al., 2008; Binder, 2016; Hacar, 2020). Mudbrick architecture with stone foundations at Güvercinkayası appears to conform to the type of village layout found at contemporary sites such as Köşk Höyük (Gülçür, 1997; Gülçur,

E-mail address: davut@iuc.edu.tr.

https://doi.org/10.1016/j.pgeola.2021.08.004
0016-7878/© 2021 The Geologists' Association. Published by Elsevier Ltd. All rights reserved.

Please cite this article as: D. LAÇİN, Petrographical and chemical properties of building stone, plaster and mortar used in Güvercinkayası ..., Proceedings of the Geologists' Association, https://doi.org/10.1016/j.pgeola.2021.08.004

ARTICLE IN PRESS

2004, 2012; Öztan et al., 2004, 2007, 2009; Öztan and Açıkgöz, 2011), Yumuktepe (Gülçur, 2004), and Late Chalcolithic (4.000–3.100 BC) Çadır Höyük (Steadman et al., 2019). An important feature of Güvercinkayası is that the horn industry is very developed. In every area of the settlement, horns of different animals are found. The density of semi-processed deer antlers is particularly striking (https://arkeoloji.nevsehir.edu.tr/tr/guvercinkayasi). The Güvercinkayası settlement started as a single building but the people who came here in different periods made additions according to the technology (wood, stone, *etc.*) of their own period and transformed it into a settlement where there are islands that cut each other perpendicularly and which have an architectural style with adjacent walls. Unlike the Neolithic period, entrances to the houses were not made from the roof of the house, but through the door opening to the street (Çaylı and Demirtaş, 2012; Gülçur, 2012).

Based on the data obtained from the excavation holes drilled on the rock surface in the Güvercinkayası settlement; It is seen that it consists of four layers reflecting a single period after a pioneer phase. First and second layers are adjacent to the bedrock and they have a rectangular plan. Third layer represents the Obeyd culture, which is foreign to the region, reflects the Late Chalcolithic period and consists of a mud-brick structure. The fourth layer ends with a tabbed perimeter wall made of mud-bricks, reflecting the Late Obeyd period (4500–3750 BC) alien to the region and indicating interaction from Mesopotamia. Güvercinkayası is synchronized with Level I of the Bahçeli - Niğde-Bor settlement in the region (Cal. C14 BC. 5210–4810). It consists of a cellar cell opposite a large room with the narrow facade entrance, the main building type directly adjoining each other, in the same dimensions, where the settlement was designed according to a certain design (Gülçur, 2004). Mud mortar and stone were used on the walls of the settlement, wood on the door jambs and wooden beams, reed bundles and soil in the roof. The existence of small silos and storage units in every house was used for the products obtained from dry farming. The building was destroyed by a heavy fire and reflected in the house of a village lord who had the surplus product. The surplus product is the grain products obtained from agriculture (wheat, *etc.*) and they are the surplus products that they accumulate to use in times of famine after meeting their needs (Çaylı, 2008; Gülçur, 2012). The building assembly was reinforced with thick walls and a tower-like structure (Gülçur, 2004). The pottery group of Güvercinkayası is generally dark coloured/black burnished ware. Pots and jars are the most common vessels and show a normalization in terms of size and shape. Normalization is an indicator of a stratified society. The decorations on the vessels in relief technique are reminiscent of animal faces. This situation emphasizes the importance of animals in terms of economic and spiritual life (Gülçur, 2004).

Güvercinkayası settlement is a good example of the Middle Chalcolithic period, and located in the Cappadocia region, Aksaray city in Turkey. The settlement is located on a high rock mass near the Mamasun Dam Lake, near Çatalsu Village, Aksaray (Turkey) and outcrops on the right bank of the Melendiz River. The Güvercinkayası hosts are one of the oldest settlement areas which Central Anatolia is dating back to C14 cal. 4750–5200 B.C., and is good example of castle town model, fortified with a castle (Gülçur and Endoğru, 1998; Gülçur, 1999; Gülçur and Sağır, 2003; Gülçur et al., 2011; Gülçur, 2012; Hacar, 2013) (Fig. 1). It has reached up to present from the Middle Chalcolithic Period and is the first and the oldest pioneer example of the settlement route. It is defined as fortress city in Central Anatolia. However, the findings of this settlement which can be defined as a regular village provide very important information about how the Anatolian model cities were established and later evolved. The Güvercinkayası settlement is divided by a fortification line as an upper and lower settlement (Gülçur, 2012). The village is divided into two parts; (1) the inner fortress and (2) the settlement with fortification walls, covering the top of the rock from the north. The inner castle houses demolished by a heavy fire are larger than the lower settlement houses and are richer in terms of archaeological findings. Today's houses remind us of this architecture (https://kulturportali.gov.tr/turkiye/aksaray/gezilecekyer/guvercinkayasi). The settlement plan reflects narrow, long, one-room houses of about 20–30 m^2, arranged in residential islands, aligned with the natural structure of the rock, separated from each other by streets. During the archaeological excavations, important findings were obtained regarding the settlement plan and construction period of the Güvercinkayası settlement. On the other hand, there is very limited information about the rock type of the area where the settlement was established, the stones used in the building, the binding mortar material and plaster.

The aim of the study is to investigate the basement geological characteristics of the settlement area, the mineralogic and petrographic properties of the natural building stones and mortars used in the settlement and their source areas, whether water-soluble salts, organic additives, protein and oil used as binders. Additionally, the focus is paid at determining whether additives and preservatives were used in mortar, and building stones and to understand about the mortar technology of that period. For this purpose, detailed mineralogic and petrographic analysis have been carried out with polarizing microscope, XRD and geochemical analysis. And also protein and oil tests have been done in the samples taken from natural stones and mortars.

2. Geological background

Stratigraphically basement of the region is represented by the magmatic and metamorphic rocks of the Kırşehir massif (Ayan, 1963; Erkan, 1975; Özcan et al., 1980; Tülümen, 1980; Erkan, 1980; Seymen, 1981, 1982; Akçay et al., 2008). These units are tectonically overlained by the Upper Cretaceous (100.5–66.0 Ma) ophiolitic complex consisting of gabbro, diabase, chert and serpentinite (Bailey and McCallien, 1950; Seymen and Aydın, 1980; Akçay et al., 2007, 2008; Demircioğlu, 2014) The ophiolitic rocks are unconformably overlain by the Ürgüp formation. The Ürgüp formation is composed of Cenozoic (66.0 Ma – present) continental clastics, limestones and locally volcanic intercalations. Basement of the Ürgüp formation is represented by alluvial fan deposits, sandstone, claystone and limestones. The Ürgüp formation also includes three members represented by ignimbrites (Sarımadentepe, Cemilköy and Kızılkaya). The Sarımadentepe member contains gray coloured pumice, volcanic rock fragments and obsidian blocks. The Cemilköy member contains pink, white and yellow coloured pumice, basalt, obsidian and andesitic volcanic rock fragments. The Kızılkaya ignimbrite which hosts the Güvercinkayası settlement (Fig. 2), consists of red, brown, white coloured ignimbrites and two layers as lahar and tuff. The ignimbrite has the andesitic composition, and is observed as a key layer in the region. The ignimbrites have a smooth topography, cut by Melendiz river, forming various sizes of outcrops, and distributed in the north of the Kızılkaya and Sevinçli villages (Fig. 3b). The thickness of the ignimbrite unit in the canyon, known as the Ihlara valley, is about 60 m (Sarı and Çömlekçiler, 2007). While the upper part exhibits a relatively weak structure due to discontinuities and decomposition, the lower level is more resistant. It has glassy pumice fragments in size of about 25–30 cm in glassy groundmass. The Kızılkaya ignimbrite has been dated as 6.78 $\pm$ 0.2 Ma and 6.51 $\pm$ 0.2 Ma (Upper Miocene) by K/Ar method (Schummacher and Schummacher, 1996).

The youngest volcanic unit, Acıgöl volcanics with an age range of 18.000 Ka and 1.5 $\pm$ 0.9 Ma consisting of pyroclastics, obsidian flows, rhyolitic domes, pyroclastic domes, scoria cones and basaltic lavas follow the Kızılkaya ignimbrites (Yazman et al., 1987; Bigazzi et al., 1993; Türkecan et al., 2004). Alluvium and debris flow unconformably cover all oldest units (Fig. 2).

3. Material and methods

3.1. Mineralogical and petrographical analysis

The mineralogical-petrographical studies, XRD analysis, oil, protein-salt tests, and XRF analyses have been carried out in fourteen samples belonging to the building stones, mortars, and ignimbrites exposed in the settlement area.

Please cite this article as: D. LAÇİN, Petrographical and chemical properties of building stone, plaster and mortar used in Güvercinkayası ..., Proceedings of the Geologists' Association, https://doi.org/10.1016/j.pgeola.2021.08.004

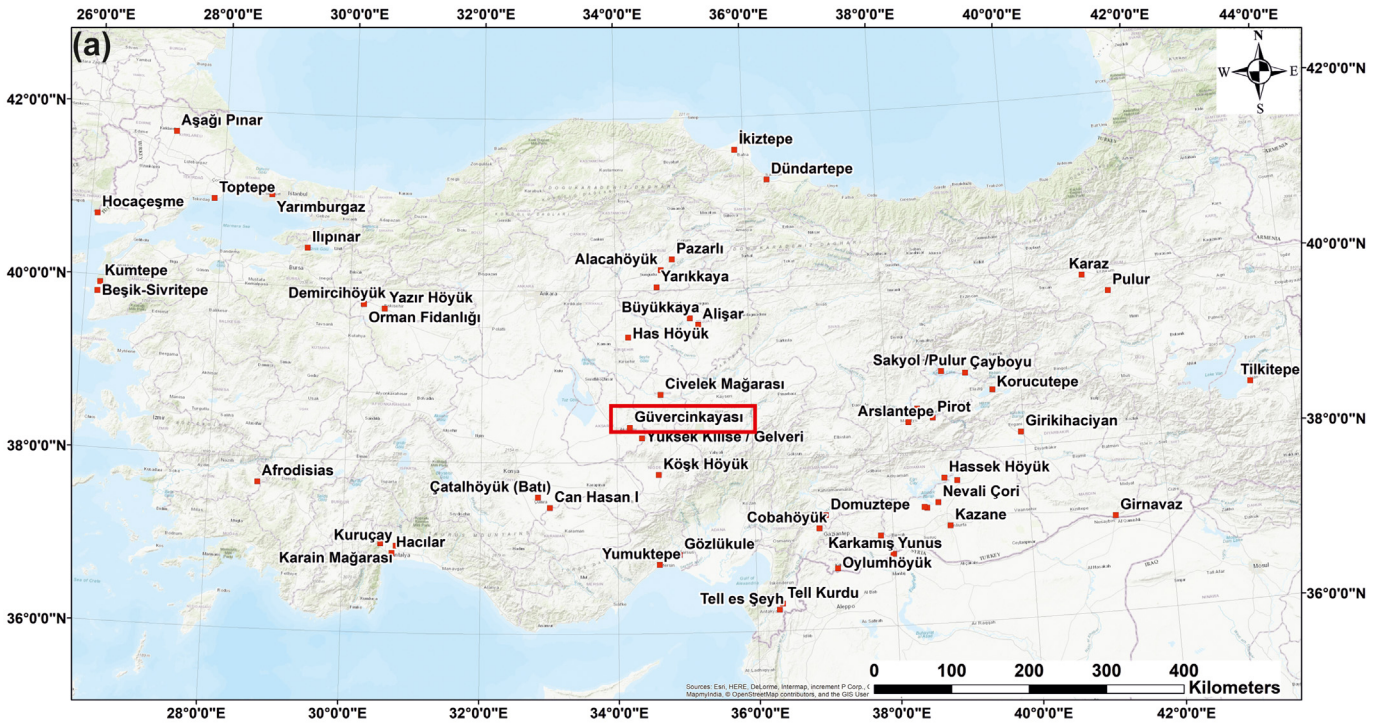




Fig. 1. (a) Chalcolithic settlements in Asia Minore (Chalcolithic settlement areas of Turkey III, 1998), (b) Güvercinkayası settlement in satellite image (downloaded from Yahoo satellite maps).

Please cite this article as: D. LAÇİN, Petrographical and chemical properties of building stone, plaster and mortar used in Güvercinkayası ..., Proceedings of the Geologists' Association, https://doi.org/10.1016/j.pgeola.2021.08.004

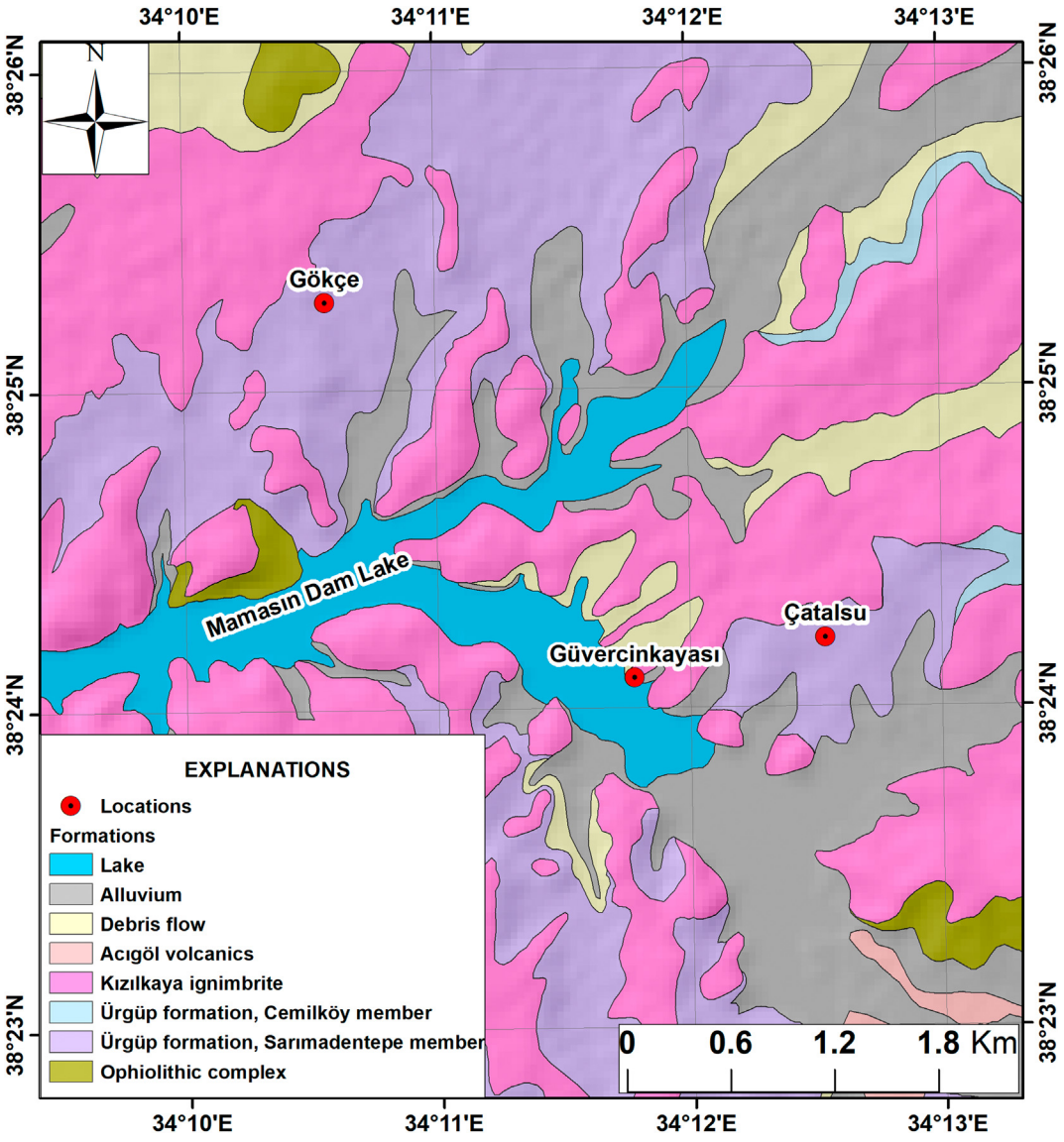


Fig. 2. Geological map of the study area and location of the Güvercinkayası settlement.

The mineralogical and petrographical analysis of collected samples have been conducted in Istanbul University-Cerrahpaşa, Department of Geological Engineering. Firstly, thin sections of the representative samples from basement geological units, buildings stones, mortars and its aggregates have been prepared. The mineral compositions and textures of these samples were described under the binocular and polarizing microscope. In addition, all samples were analysed by X-ray diffractometer (XRD) for the mineralogical composition of the mortars and adobes. For XRD analysis; about 10 g of the sample was dried and then ground into powder by grinding to a size of 100 mesh in an agate mortar. XRD analyses were carried out in XRD laboratory of the Istanbul University- Cerrahpaşa, Department of Geological Engineering. This laboratory is equipped with a GNR–APD PRO–2000 X-ray diffractometer system. Diffraction data were acquired by exposing powder samples to Cu-Kα X-ray radiation, which has a characteristic wavelength (λ) of 1.5418 Å. X-rays were generated from a Cu anode supplied with a voltage of 40 kV and a current of 30 mA. A goniometer speed of $2\theta = 1°/\text{min}$ was used during the analysis. The data were collected over a range from 5° to 55° 2θ values. Analysis of the X-ray patterns (phase identification) was carried out by using Philips High Score Plus software in conjunction with the JCPDS (Joint Committee on Powder Diffraction Standards) data base.

3.2. Simple chemical analyses

Protein, oil and salt tests are carried out in HPLC laboratory of İBB-KUDEP, İstanbul. For protein test, 0,05–0,10 g of dusted sample was placed in a capillary tube, and tip of a piece of filter paper (wedge cut), was soaked in a reagent (1 g p-dimethylamino benzaldehyde dissolved in 100 ml of HCl (% 35,5%)), was placed in the upper part of the capillary tube. The tube was heated with a flame and the pink colour formation on the tip of the filter paper indicated the presence of the protein in the sample. Gases from the sample heated in the spirit stove flame, if it creates a pink-purple colour on the paper, it is said that there is a protein in the sample. Oil tests were carried out by placing 0.1–0.2 g powder sample on the glass table and adding a few crystals of copper sulfate ($CuSO_4$) and, then, treating with a few drops of concentrated hydrogen peroxide (H_2O_2). A few drops of concentrated ammonia (NH_3) solution was then added to the mixture to check whether it contained oil (indicated by formation of stable small soap

Please cite this article as: D. LAÇİN, Petrographical and chemical properties of building stone, plaster and mortar used in Güvercinkayası ..., Proceedings of the Geologists' Association, https://doi.org/10.1016/j.pgeola.2021.08.004



Fig. 3. (a) The Güvercinkayası settlement and view of the Hasandağ volcano, (b) the columnar structure of the Kızılkaya ignimbrite around the Sevinçli Village, (c) the layered structure of the ground: Kızılkaya ignimbrite on top 1–1.5 m thick tuff layer in the middle and red-coloured lahar flow at the bottom, and (d) relationship between the red coloured lahar flow and the tuffs located over its the surface. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

bubbles) or not. Salt tests were carried out by mixing 1 g of each of them with 100 ml of distilled water, and measuring the conductivity of the suspended solution with occasional stirring a few hour and let it rest for 24 h. The solution was then filtered and tested for the presence of water-soluble salts of chloride (Cl^-), nitrate (NO_3^-), sulfate (SO_4^{2-}), carbonate (CO_3^{2-}) and phosphate (PO_4^{3-}) in the rest of the stock solution. The heat loss (calcination) analyses were carried out by weighting 0,500–1.000 g of sample in a crucible and weighting them individually by heating at 105 °C, 550 °C, and 1050 °C.

For acid loss analysis, the dried beaker is tarred with a sensitivity of 0.01 g and this value is recorded (W_0). Then, about 20–30 g of sample is placed in the beaker and the weighing value is recorded (W_1) and the sample is dried in an oven at 105 °C. The dried sample was reweighted after cooling in the desiccator, and was recorded (W_2). Total 25 ml of 10% HCl acid was added to the sample continuously until the sample does not react with acid. At the end of the experiment, the sample was tried to be neutralized by washing the upper solution with pure water. After neutralization, the sample remaining in the beaker was

Please cite this article as: D. LAÇİN, Petrographical and chemical properties of building stone, plaster and mortar used in Güvercinkayası ..., Proceedings of the Geologists' Association, https://doi.org/10.1016/j.pgeola.2021.08.004

ARTICLE IN PRESS

dried at 105 °C for 4 h. The dry sample cooled in the desiccator was weighed and the W_3 value was determined; moisture % and acid loss % were calculated as follows:

$$\text{Humidity}\% = W1-W2/W2-W0 \times 100$$

W_0: The weight of dry beaker.
W_1: W_0 + Sample.
W_2: W_0 + Dry sample.

$$\text{Remainder}\% = W_3-W_0/W_2-W_0 \times 100$$

Loss % = 100 - Remainder %.
W_0: The weight of dry beaker.
W_1: W_0 + Sample.
W_3: Dry sample remaining after W_0 + Acid loss

The sample obtained from the acid loss analysis is sieved after drying at 105 °C for 4 h, and the sample is examined under a stereo microscope to determine the type and their ratios of aggregates of the rest of the sample, except the carbonate aggregates. Acid loss and calcination processes allow reaching the values of calcium carbonate aggregate and binder ratios in the samples.

4. Results

4.1. Mineralogy and petrography

Two samples (Basement rock: BR–5,6) from the ignimbrite rocks on which the settlement is located, four samples (Kızılkaya ignimbrite: KI–1,2,3,4) from the ignimbrite rocks around the settlement, two samples (Wall rock: WR–7,13) from the walls of the settlement, three sample (Mortar and plaster: M–10,11,12) was taken from the mortar-plaster material between the masonry. The mineralogical and petrographic properties of the building blocks and mortars used in Güvercinkayası settlement are explained in detail below.

4.1.1. Samples from the Kızılkaya ignimbrite

Representative ignimbrite samples (KI–1 and KI–2) were collected from the near vicinity of the Güvercinkayası settlement. Brownish gray coloured samples show elongated fiamme and glassy shards formed by breakage of gas gaps (Fig. 3). Güvercinkayası settlement is established on the Kızılkaya ignimbrites. Based on optical microscopy and XRD analysis, the Kızılkaya ignimbrite contains plagioclase, sanidine, cristobalite, tridymite, hornblende, biotite phenocrysts, and glassy shards in glassy-groundmass. Secondary mineral phase represented by illite, montmorillonite, and calcite (Figs. 4 and 5). Mafic minerals (biotite and/or amphibole), and mainly eutaxitic and rarely spherulitic texture can be easily seen in hand specimens and petrographic thin sections. Ignimbrite samples are generally pinkish, gray and light beige in colour. The Kızılkaya ignimbrites are the basic geological formation (BR–6) of Güvercinkayası settlement area. The building stones produced from this unit were used both in walls (WR–7) and in mortars as aggregates (M–11 and M–12).

4.2. Geochemistry

Geochemical analysis of the studied samples belonging to Kızılkaya ignimbrite (KI–1 and KI–2) and stones of basement (BR–6), wall (WR–7), and mortar (M–11 and M–12) of the settlement has been given in Table 1.

4.2.1. Ignimbrite samples

SiO_2 and Al_2O_3 contents of sample KI–1 are 66.25% and 3.95%, respectively (Table 1). Al_2O_3 content probably originates from clay minerals within the sample. Fe_2O_3 content (1.64%), due to alterations of minerals in ignimbrite, must be removed from the environment. The fact that the LOI value of Kızılkaya ignimbrite is slightly higher than KI-1 supports this view. In contrast, K_2O content is high and ignimbrite transforms into mica minerals (illite etc.), while K element is kept in the environment. This situation is also consistent with XRD analysis of the sample (Fig. 7). SiO_2 and Al_2O_3 contents of sample KI-2 have 73.56% and 9.52%, respectively and probably originate from clay minerals within the sample as in KI–1 (Table 1).

4.2.2. Basement stone sample

The sample BR-6 is composed of SiO_2 and Al_2O_3 as 74.01% and 8.65%, respectively. Moreover, it contains 0.71% Fe_2O_3 and 7.75% CaO (Table 1). BR-6 sample contains 6.64% K_2O, that probably originates from mica minerals (Fig. 4d). No oil and protein-like substances were found in the sample except of Cl^- (Table 2).

4.2.3. Wall stone sample

SiO_2, Al_2O_3, Fe_2O_3 and CaO contents of sample WR–7 are 68.45%, 11.74%, 1.23% and 4.39%, respectively (Table 1). One of the important features of the ignimbrite samples is the low loss of ignition (LOI) value, which indicates the low decomposition rate.

4.2.4. Mortar samples

Samples M-11 and M-12 were taken from the mortar of the settlement and compared to other samples, the content of SiO_2, Al_2O_3 and K_2O is much lower, but LOI values are higher. These examples are not ignimbrite, but these are the soil filling between them (Table 1). Protein and oil-like organic additives or substances were not detected in the samples, except for the small protein amount detected in sample M-11, which is considered to be caused by residues of insects and similar creatures. The excessive amount of Cl^- and SO_4^{2-} ions in two samples (Cl^- in M-11; Cl^- and SO_4^{2-} in M-12); can be interpreted as SO_2 pollution caused by the burning reaction of fuel and $CaCO_3$, during the forming gypsum (Table 2).

5. Results and discussion

Determining whether organic, inorganic (flax, bristle, straw) or liquid (egg, oil, *etc.*) substances were added as additives in the technology of mortar to improve the resistance to various environmental conditions, helps to estimate the mortar technology of that period. For this purpose, the tests were carried out to determine whether protein, phosphorus and/or oil based materials are used in the composition of the mortars used in the construction and to determine the quality of the binder, preservative and/or consolidant to be applied in the protection-repair work. P_2O_5 contents of M–11 and M–12 samples taken from plaster-mortar material were 0.07% and 0.21%, respectively (Table 1). Phosphorus (P) is an incomparable element in that it gives clues about human activities. In the past, it has been used frequently by archaeologists for informing the public about the existence of human occupation and giving clues about human activity (Holliday and Gartner, 2007).

Although movable and/or immovable artifacts represent human occupation in archaeological investigations, in recent years archaeologists have identified various chemical markers such as phosphorus found in the settlements both temporal (Cook and Heizer, 1965; Ahler, 1973; Skinner, 1986; Lillios, 1992; Schlezinger and Howes, 2000) also used it as a spatial (Cook and Heizer, 1965; Eidt, 1977; Conway, 1983; Woods, 1984; Sandor et al., 1986a, 1986b; Cavanagh et al., 1988; Pogue, 1988; Lippi, 1988).

Finding protein and Cl- traces in the M-11 sample is due to human-induced activities and/or insect *etc.* suggests that it may be of organic origin (Evershed, 2008; Salque et al., 2013; Debono Spiteri et al., 2016; Drieu et al., 2018). Many elements are left in the soil by humans, but their very few (such as phosphorus) are ubiquitous and persistent as an indicator of human activity

Please cite this article as: D. LAÇİN, Petrographical and chemical properties of building stone, plaster and mortar used in Güvercinkayası ..., Proceedings of the Geologists' Association, https://doi.org/10.1016/j.pgeola.2021.08.004

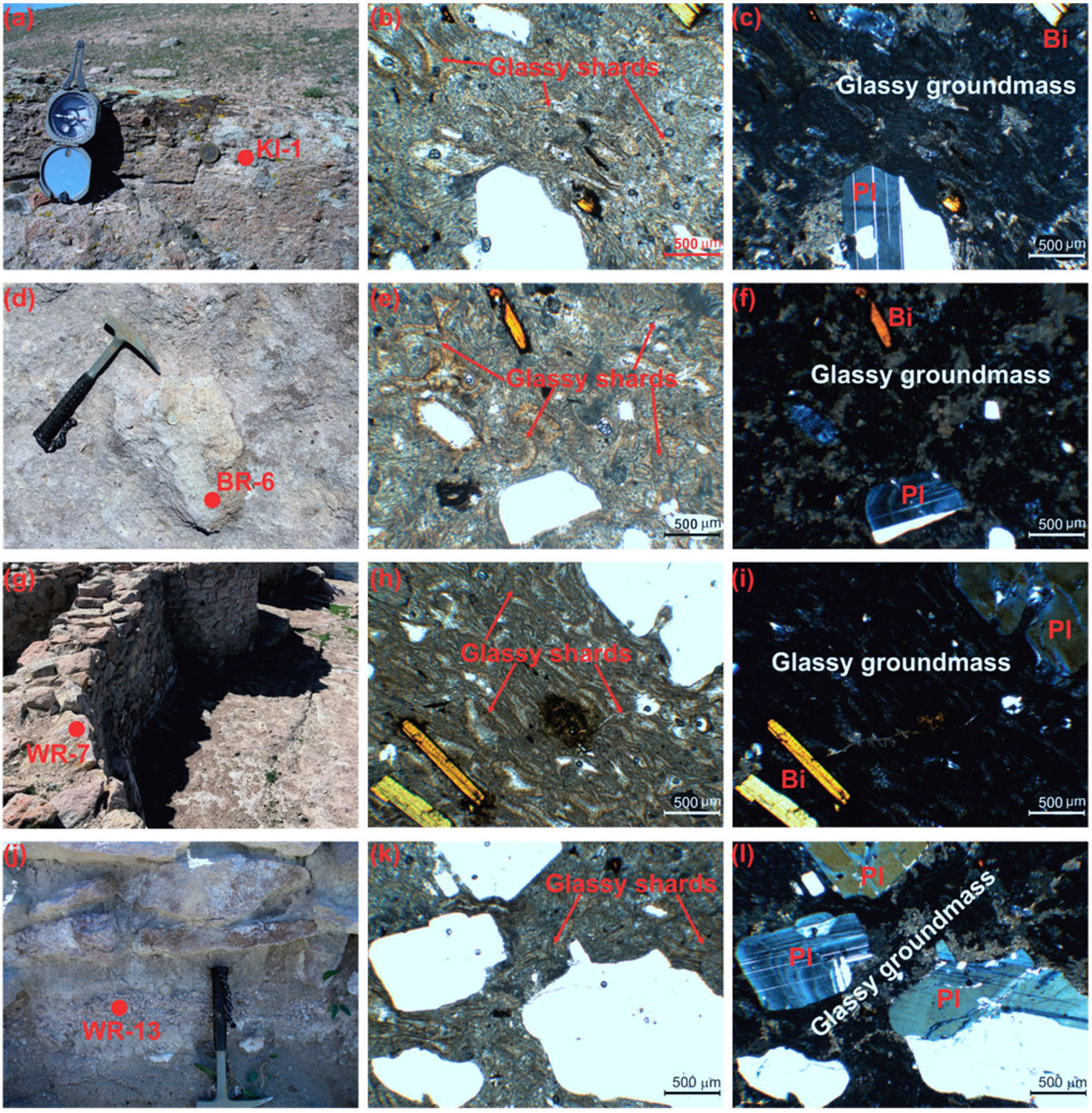


Fig. 4. Sample KI-1; (a) Outcrop photograph for the Kızılkaya ignimbrites along the Mamasın Dam Lake, (b) Glassy shards, plagioclase and biotite phenocrysts in the glassy groundmass, plane polarized transmitted light (PPL) and (c) crossed polarized transmitted light (CPL), Sample BR-6; (d) The close view of the Kızılkaya ignimbrite on which the Güvercinkaya settlement is located and the volcanic texture in the ignimbrites, (e) glassy shards, biotite and plagioclase phenocrysts in glassy-crystal tuff texture PPL and (f) CPL. Sample WR-7; (g) one of the walls of the settlement and the location of the ignimbrite sample taken from it, and biotite and plagioclase phenocrystals with glassy shards in glassy groundmass (h) PPL and (i) CPL. Sample WR-13; (j) one of the walls of the settlement and the broken corner-semi-angular ignimbrite fragments used between the walls, (k) glassy shards and plagioclase phenocrysts are seen in a glassy groundmass under thin section PPL and (l) CPL.

(Woods, 1982; Middleton and Price, 1996; Entwistle et al., 2000; Wells, 2004). Phosphorus is stable as phosphate in soils and is generally immobile element (Holliday and Gartner, 2007) and is an archaelogical significant indicator of human activity among agricultural and pre-agricultural societies (Woods, 1982; Middleton and Price, 1996; Entwistle et al., 2000; Wells, 2004).

The CaO content of the samples of M–11 and KI–1 is 12.36% and 14.55%, respectively, showing a slightly higher value than the other samples. The reason for this must have been due to the presence of calcite mineral formed due to the weathering (susoritization) (Boztuğ et al., 1994; Koçak and Şenol, 2013; Üner and Aksoy, 2018; Beyarslan et al., 2018; Karataş, 2019; Ahmed et al., 2020) of feldspar minerals in ignimbrite. This situation is clearly seen in the XRD record taken from the samples (Fig. 5). In addition, the fact that the LOI value of the M–11 sample is quite high compared to the other samples taken from the settlement (33.55) indicates that the alteration is due to the advanced stage. The high LOI, Cl^- and SO_4^{2-} values in the M–12 sample also supports this situation (Table 2).

Please cite this article as: D. LAÇİN, Petrographical and chemical properties of building stone, plaster and mortar used in Güvercinkayası ..., Proceedings of the Geologists' Association, https://doi.org/10.1016/j.pgeola.2021.08.004

ARTICLE IN PRESS

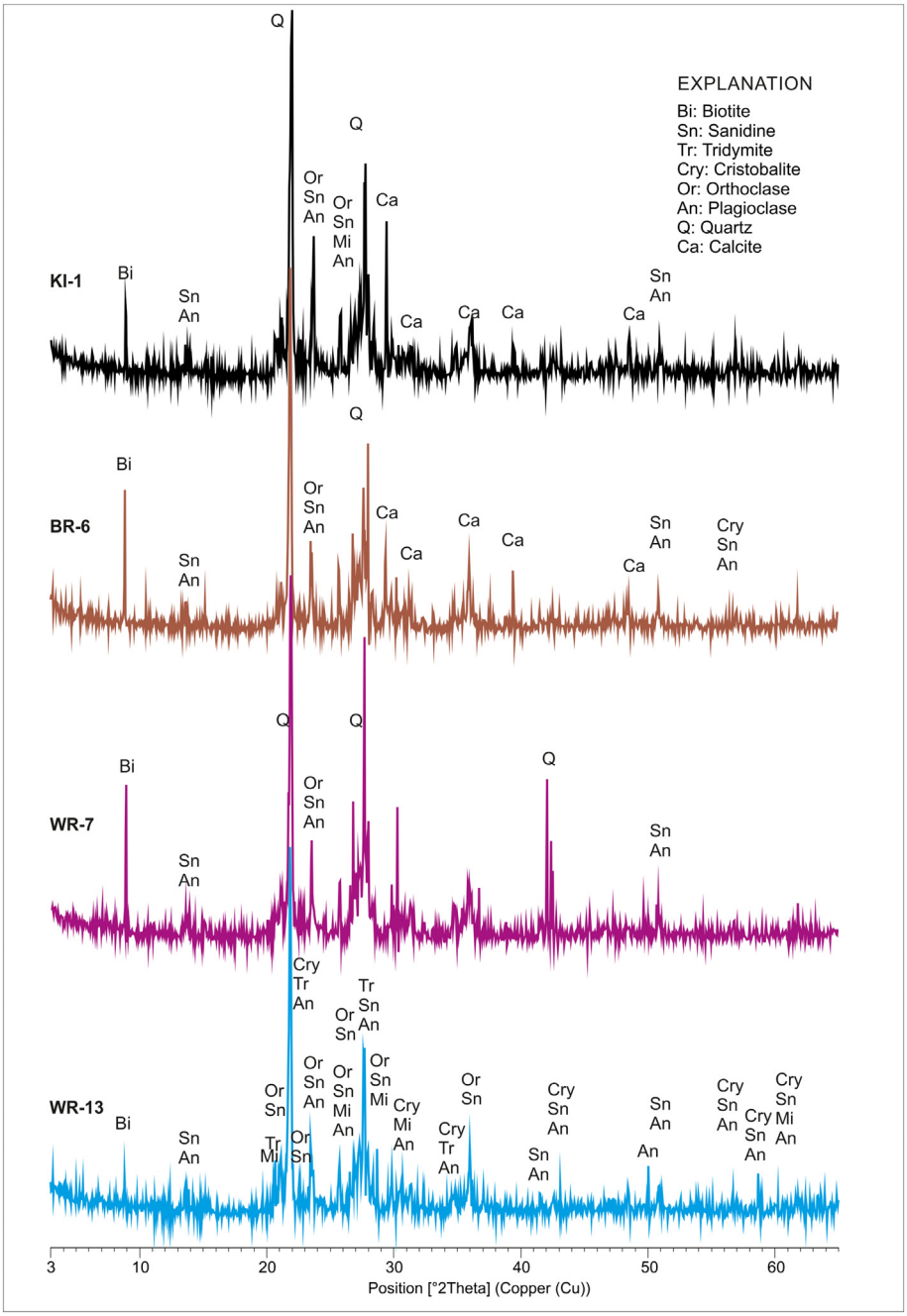


Fig. 5. Unoriented (dust sample) XRD graphics of Kızılkaya ignimbrite (KI–1), building blocks (WR–7), mortars (WR–13), and the floor (BR–6) of the Güvercinkayası settlement.

The earliest archaeological evidence for using salt comes from the Neolithic site of Çatalhöyük. In cuneiform tablets and ancient writings, Hittites have also been mentioned from the Central Anatolian salt. Moreover, the salted meat was used in a great variety of dishes in the Central Anatolia region (Erdoğu and Fazlıoğlu, 2006).

When the CaO values of KI–1 and KI–2 samples taken from surrounding ignimbrite rocks are compared, it is thought that the reason why the KI–1 sample (14.55%) is higher than KI–2 is due to susoritization (Boztuğ et al., 1994; Koçak and Şenol, 2013; Üner and Aksoy, 2018; Beyarslan et al., 2018; Karataş, 2019; Ahmed et al., 2020). This situation was also detected in the XRD analyses (Fig. 5). The P_2O_5 values of the KI–1 and KI–2 samples are 0.10% and 0.18%, respectively and close to the P_2O_5 values of the samples taken from the base (BR-6) and wall (WR–7) of the settlement (0.22% and 0.35%, respectively) (Table 1). When compared to CaO values of BR–6 and WR–7 samples; The fact that the BR-6 sample (7.75%) is slightly higher suggests that it is due to alteration. This situation can also be observed from the XRD analyses (Fig. 5). XRD analyses of Kızılkaya ignimbrite demonstrate that it is composed of mica, plagioclase, sanidine, calcite, orthoclase, tridymite, cristobalite and secondary calcite (Fig. 5). The compositions of the samples (investigated by XRF analysis) are in accordance with ignimbrites mineralogical compositions (Table 1).

The mineralogical composition of the mortars and the building blocks of the settlement are similar to mineralogical composition of the Kızılkaya ignimbrite, indicating that the Kızılkaya ignimbrite was used at Güvercinkayası settlement. In addition, mineralogical analysis of thin sections, made for petrographic purposes and the remaining aggregates of the samples after acid dissolution are consistent with the mineralogical composition of the Kızılkaya İgnimbrite (Figs. 4 and 5).

Please cite this article as: D. LAÇİN, Petrographical and chemical properties of building stone, plaster and mortar used in Güvercinkayası ..., Proceedings of the Geologists' Association, https://doi.org/10.1016/j.pgeola.2021.08.004

Table 1
Chemical analysis of the Kızılkaya ignimbrite and mortar (*) samples (%).

Major oxides (wt.%)	Kızılkaya ignimbrite		Basement rock	Wall rock	Mortar	
	KI-1	KI-2	BR-6	WR-7	M-11*	M-12*
SiO_2	66.25	73.56	74.01	68.45	41.81	53.64
TiO2	0.89	0.54	0.41	0.75	0.59	0.39
Al_2O_3	3.95	9.52	8.65	11.74	5.33	5.34
Fe_2O_3	1.64	0.89	0.71	1.23	1.33	0.85
CaO	14.55	4.71	7.75	4.39	12.36	5.99
Cr_2O_3	0.10	0.10	0.10	0.10	0.07	0.07
Mn_2O_3	0.36	0.18	0.16	0.18	0.15	0.12
MgO	0.10	0.14	0.10	0.10	0.49	0.32
Na_2O_3	0.10	0.10	0.10	3.72	0.07	1.24
K_2O	11.05	6.75	6.64	7.58	2.63	4.65
P_2O_5	0.10	0.18	0.22	0.35	0.07	0.21
SO_3	0.28	0.53	0.43	0.63	0.38	0.71
LOI	0.15	3.69	0.47	0.21	33.55	25.55
Total	99.53	100.88	99.74	99.41	98.80	99.07

6. Conclusion

In this study, it is revealed for the first time that the Güvercinkayası settlement sits on the Kızılkaya ignimbrite and was also used as filling material between wall stones and plaster-mortars of the settlement. The low amount of the water-soluble salts is observed in the sample of M–11.

The water soluble salts, organic additives, as protein and oil, were not found in the samples obtained from the settlement. As a result of the absence of efflorecence (given by data), there is no deterioration because of soluble salts. The mineralogical composition results showed that all of building blocks in the archaeological site bear the same mineralogical characteristics as the Kızılkaya ignimbrite, confirming that the Kızılkaya ignimbrite was used in the Güvercinkayası settlement.

The Kızılkaya ignimbrite (angular and semi-angular) aggregate with the andesitic composition was used in the mortars of the Güvercinkaya settlement walls (Fig. 4j). Both, thin sections and XRD analyses, were carried out in order to determine the mineralogical composition of the rocks used in the building stones and mortars of the settlement are proved this phenomena. At the same time, these methods were applied for the investigation of the Kızılkaya ignimbrite used in the building stones and the mortars of the building wall of the settlement. The investigations revealed that the mineralogical composition of all stone and mortar samples, used in the settlement, was the same as the mineralogical composition as the Kızılkaya ignimbrite (Figs. 4 and 5). When it comes to the restoration of the settlement, it is proposed that the ignimbrites in the region can be used. One of the main reasons for the existence of the structures belonging to this period in the Cappadocia region may be that the volcanic rocks, which are widely found in the region, are suitable for agriculture and these rocks can also be used as building blocks and have easy-to-shape properties. In addition, the presence of natural resources (clays, ignimbrites, obsidian, salt, and a variety of stones) is thought to be effective in choosing this region as a settlement. The protein, water-soluble salts and oil analysis show that the protein trace is found only in the sample M-11, which might be caused by insects and contamination in settlement.

The Güvercinkayası settlement is similar in terms of construction style to the Köşkhöyük (Bahçeli-Niğde) settlement, which is a Middle Chalcolithic period settlement located in Central Anatolia.

Table 2
The results of protein, oil and salt tests of samples.

Sample	Cl^-	SO_4^{2-}	CO_3^{2-}	NO_3^-	Conductivity (μS)	%Salt (Wt)	Protein	Oil
BR-6	+	−	−	−	84	0.50	−	−
WR-7	−	−	−	−	48	0.28	−	−
M-11	+	−	−	−	115	0.68	+	−
M-12	++	++	−	−	640	3.78	−	−

Declaration of competing interest

I declare that there is no conflict of interest.

Acknowledgment

The author thanks to Assist. Prof. Dr. Sinan Altuncu (Niğde University), who helped during field studies, and to Prof. Dr. Ayşe Zehra Aroğuz, Prof. Dr. Nurullah Hanilçi and Assoc. Prof. Dr. Namık Aysal (Istanbul University-Cerrahpaşa) for their contributed to the review of this study.

References

Ahler, S.A., 1973. Chemical analysis of deposits at Rogers Shelter, Missouri. Plains Anthropologist 18, 11.. https://www.jstor.org/stable/25667141.

Ahmed, D.D., Fisher, L., Pearce, M., Escolme, A., Cooke, D.R., Howard, D., Belousov, I., 2020. A microscale analysis of hydrothermal epidote: implications for the use of laser ablation-inductively coupled plasma-mass spectrometry mineral chemistry in complex alteration environments. Economic Geology 115 (4), 793–811. https://doi.org/10.5382/econgeo.4705.

Akçay, A.E., Dönmez, M., Kara, H., Yergök, A.F., Esentürk, K., 2007. 1/100.000 Slaced Geological Map of Turkey (In Turkish).

Akçay, A.E., Dönmez, M., Kara, H., Yergök, A.F., Esentürk, K., 2008. 1/100.000 Slaced Geological Map of Turkey (In Turkish).

Ayan, M., 1963. Contribution a, l'etude petrographique et geologique de la region situee au Nord-Est de Kaman. Bulletin of the Mineral Research and Exploration 115, 332 (with English Abstract).

Bailey, E.B., McCallien, W.C., 1950. Ankara mélange and Anatolian thrust. Bulletin of the Mineral Research and Exploration 40, 12–16 (In Turkish with English Abstract).

Balkan-Atlı, N., Binder, D., Gratuze, B., 2008. Göllü Dağ (Central Anatolia): Obsidian Sources, Workshops and Trade. Anatolian Metal IV, Der Anschnitt, Beiheft 21. Deutsches Bergbau-Museum, Bochum, pp. 203–210.

Beyarslan, M., Okta, E., Ertürk, M.A., 2018. Geochemical characteristics of the Late Cretaceous Arc magmatics around the Town of Kale (Malatya). Erzincan University Journal of Science and Technology F 11 (2), 191–206. https://doi.org/10.18185/erzifbed.405603 (In Turkish with English Abstract).

Bigazzi, G., Yeğingil, Z., Ercan, T., Oddone, M., Özdoğan, M., 1993. Fission track dating obsidians in Central and Northern Anatolia. Bulletin of Volcanology 55, 588–595.

Binder, D., 2016. Stones making sense: what obsidian could tell us about the origins of the Central Anatolian Neolithic. International Developments and External Relations During The 9th - 6th Millennia Cal BC, pp. 71–90.

Boztuğ, D., Yılmaz, S., Kesgin, Y., 1994. Petrography, petrochemistry and petrogenesis of the eastern part of Kösedağ pluton from the Central-Eastern Anatolian alkaline province, Suşehri, NE Sivas. Geological Bulletin of Turkey 37 (2), 1–14 (In Turkish with English Abstract).

Cavanagh, W.G., Hirst, S., Litton, C.D., 1988. Soil phosphate, site boundaries, and change point analysis. Journal o.f Field Archaeology 15, 67–83. https://www.jstor.org/stable/530130.

Çaylı, 2008. Evaluation of Settlement and Social Structures of Güvercinkayası House Number 14 Based on Pottery Data, Istanbul University, Institute of Social Sciences Nr. 2501050741 (unpublished master thesis).

Çaylı, P., Demirtaş, I., 2012. The First Castle of Anatolia. Güvercinkayası https://www.researchgate.net/publication/325514181.

Conway, J.S., 1983. An investigation of soil phosphorus distribution within occupational deposits from a Romano-British hut group. Journal of Archaeological Science 10, 117–128.

Cook, S.F., Heizer, R.F., 1965. Studies on the Chemical Analysis of Archaeological Sites. University of California Press, Berkeley (102pp.).

Debono Spiteri, C., Gillis, R.E., Roffet-Salque, M., Castells Navarro, L., Guilaine, J., Manen, C., Muntoni, I.M., Segui, M.S., Urem-Kotsou, D., Whelton, H.L., Craig, O.E., Vigne, J.-D., Evershed, R.P., 2016. Regional asynchronicity in dairy production and processing in early farming communities of the northern Mediterranean. Proceedings of the National Academy of Sciences of the United States of America 113, 13594–13599. https://doi.org/10.1073/pnas.1607810113.

Demircioğlu, R., 2014. Geology and Structural Features of Kırşehir Massif and Cover Units around Gülşehir-Özkonak (Nevşehir). Selçuk University Institute of Science and Technology PhD. Thesis. (In Turkish with English Abstract).

Drieu, L., Peche-Quilichini, K., Lachenal, T., Regerta, M., 2018. Domestic activities and pottery use in the Iron Age Corsican settlement of Cuciurpula revealed by organic residue analysis. Journal of Archaeological Science: Reports 19, 213–223. https://doi.org/10.1016/j.jasrep.2018.02.032.

Eidt, R.C., 1977. Detection and examination of anthrosols by phosphate analysis. Science 197, 1327–1333. https://doi.org/10.1126/science.197.4311.1327.

Please cite this article as: D. LAÇİN, Petrographical and chemical properties of building stone, plaster and mortar used in Güvercinkayası ..., Proceedings of the Geologists' Association, https://doi.org/10.1016/j.pgeola.2021.08.004

ARTICLE IN PRESS

Entwistle, J.A., Abrahams, P.W., Dodgshon, R.A., 2000. The geoarchaeological significance and spatial variability of a range of physical and chemical soil properties from a former habitation site, Isle of Skye. Journal of Archaeological Science 27 (2000), 287–303. https://doi.org/10.1006/jasc.1999.0453.

Erdoğu, B., Fazlıoğlu, İ., 2006. The Central Anatolian salt project: a preliminary report on the 2004 and 2005 surveys. Anatolia Antiqua XIV 2006, 189–203.

Erkan, Y., 1975. Petrological Investigation of the Effective Regional Metamorphism in the Southwest of the Central Anatolian Massif (in the Kırşehir Region). Hacettepe University, Institute of Earth Sciences, Readership thesis, Ankara (147 p.). (Unpublished), (In Turkish with English Abstract).

Erkan, Y., 1980. Investigation of regional metamorphism affecting the northeast of the Central Anatolian Massif (Akdağmadeni, Yozgat). Geological Bulletin of Turkey 23 (2), 213–218 (In Turkish with English Abstract).

Evershed, R.P., 2008. Organic residue analysis in archaeology: the archaeological biomarker revolution. Archaeometry 50, 895–924. https://doi.org/10.1111/j.1475-4754.2008.00446.x.

Gülçür, S., 1997. Güvercinkayası: eine vorgeschichtliche Felstückensiedlung in Zentralanatolien. Anatolica 23, 85–110 (with English Abstract).

Gülçur, S., 1999. Joint Surface Survey of Aksaray, Nevşehir, Niğde Provinces in 1994 Year. Anatolian Studies XV. Istanbul University Publications, Istanbul, pp. 105–136 (In Turkish with English Abstract).

Gülçur, S., 2004. Güvercinkayası the Black/Dark Burnished Pottery: A General Overview, TÜBA-AR VII. pp. 141–164.

Gülçur, S., 2012. The Chalcolithic Period in Central Anatolia Aksaray-Niğde Region: Origini XXIV, Nuova Serie V, 2012. pp. X–XX.

Gülçur, S., Endoğru, M., 1998. Güvercinkayası Excavation in 1996 Year. 19. Excavation Results Meeting. Turkish Republic Culture and Tourism Ministry, Ankara, pp. 85–111 (In Turkish with English Abstract).

Gülçur, S., Sağır, G., 2003. Güvercinkayası Excavation in 2001. 24. Excavation Results Meeting-V. 1. Turkish Republic Culture and Tourism Ministry, Ankara, pp. 49–58 (In Turkish with English Abstract).

Gülçur, S., Çaylı, P., Demirtaş, I., 2011. Güvercinkayası Excavation in 2009 Year. 32. Excavation Results Meeting-V. 3. Turkish Republic Culture and Tourism Ministry, Ankara, pp. 294–312 (In Turkish with English Abstract).

Hacar, A., 2013. Importance of planning in the conservation of archaeological areas: Güvercinkayası area management plan and first practices, Dokuz Eylul University. Institute of Social Sciences Journal 15 (3), 395–417 (In Turkish with English Abstract).

Hacar, A., 2020. Specialization in early bronze age pottery production: interpretations on the organization of the specialized production in Southwest Cappadocia. Turkish Historical Society, Belleten 84 (300) (In Turkish with English Abstract).

Holliday, V.T., Gartner, W.G., 2007. Methods of soil P analysis in archaeology. Journal of Archaeological Science 34, 301–333. https://doi.org/10.1016/j.jas.2006.05.004.

https://arkeoloji.nevsehir.edu.tr/tr/guvercinkayasi Date of access: September 12, 2021.

https://kulturportali.gov.tr/turkiye/aksaray/gezilecekyer/guvercinkayasi Date of access: September 12, 2021.

Karataş, A., 2019. Ophiolite: Its Hydrography and Hydrogeology, İstanbul. 978-605-9574-17-4pp. 1–117 (In Turkish).

Koçak, K., Şenol, H., 2013. Geology and petrography of the metamagmatic and magmatic rocks around Buldan (Denizli) area. Journal of Faculty Engineering Archaeology, Selçuk University 28, 1 ISSN: 1300-5200, ISSN: 1304-8708 (Electronic).

Lillios, K.T., 1992. Phosphate Fractionation of Soils at Agroal. 57. American Antiquity, Portugal, pp. 495–506. https://doi.org/10.2307/280937.

Lippi, K.T., 1988. Paleotopography and phosphate analysis of a buried jungle site in Ecuador. Journal of Field Archaeology 15, 85–97.

Middleton, W.D., Price, T.D., 1996. Identification of activity areas by multi-element characterization of sediments from modern and archaeological house floors using inductively coupled plasma-atomic emission spectroscopy. Journal of Archaeological Science 23, 673–687. https://doi.org/10.1006/JASC.1996.0064.

Özcan, A., Erkan, A., Keskin, A., Keskin, E., Oral, A., Özer, S., Sümengen, M., Tekeli, O., 1980. The Basic Geology between the North Anatolian Fault and the Kırşehir Massif. MTA. Report Number: 6722 (Unpublished) (In Turkish with English Abstract).

Öztan, A., 2009. Republic of Turkey Ministry of Culture and Tourism, Turkey Culture Portal Project, Archeology and Art History, Ancient Anatolian Civilizations, Chalcolithic Period (Stone-Mineral Period), Ankara. pp. 1–12 (In Turkish with English Abstract).

Öztan, A., Açıkgöz, F., 2011. 2009 Köşk Höyük Excavations. Excavation Results Meeting 32 (3), 135–147 (In Turkish with English Abstract).

Öztan, A., Özkan, S., Erek, C., Faydalı, E., 2004. 2003 Köşk Höyük Excavations. Excavation Results Meeting 26 (2), 103–114 (In Turkish with English Abstract).

Öztan, A., Açıkgöz, F., Özkan, S., Erek, M., Arbuckle, B.S., 2007. 2005 Köşk Höyük Excavations. Excavation Results Meeting 28 (2), 529–548 (In Turkish with English Abstract).

Öztan, A., Açıkgöz, F., Arbuckle, B.S., 2009. 2007 Köşk Höyük Excavations. Excavation Results Meeting 30 (3), 311–328 (In Turkish with English Abstract).

Pickard, C., Schoop, U.D., 2013. Characterization of Late Chalcolithic micro-beads from Çamlıbel Tarlası, northcentral Anatolia. Archaeometry 55 (1), 14–32. https://doi.org/10.1111/j.1475-4754.2012.00672.x.

Pogue, D.J., 1988. Anthrosols and the analysis of archaeological sites in a plowed context: the King's reach site. Northeast Historical Archaeology 17, 1–15. https://doi.org/10.22191/neha/vol17/iss1/1.

Salque, M., Bogucki, P.I., Pyzel, J., Sobkowiak-Tabaka, I., Grygiel, R., Szmyt, M., Evershed, R.P., 2013. Earliest evidence for cheese making in the sixth millennium BC in northern Europe. Nature 493, 522–525. https://doi.org/10.1038/nature11698.

Sandor, J.A., Gersper, P.L., Hawley, J.W., 1986a. Soils at prehistoric agricultural terracing sites in New Mexico: 1. Site placement, soil morphology, and classification. Soil Science Society of America Journal 50, 166–173.

Sandor, J.A., Gersper, P.L., Hawley, J.W., 1986b. Soils at prehistoric agricultural terracing sites in New Mexico: 3. Phosphorus, selected micronutrients, and pH. Soil Science Society of America Journal 50, 177–180.

Sarı, M., Çömlekçiler, F., 2007. Investigation of discontinuities in Kızılkaya ignimbrites and identification of rock mass, Süleyman Demirel University. Journal of the Faculty of Engineering and Architecture 23, 1–2 (In Turkish with English).

Schlezinger, R.D., Howes, B.L., 2000. Organic phosphorus and elemental ratios as indicators of prehistoric human occupation. Journal of Archaeological Science 27, 479–492. https://doi.org/10.1006/jasc.1999.0464.

Schummacher, U.M., Schummacher, R., 1996. Problem of stratigraphic correlation and new K-Ar data for İgnimbrites Cappadocia, Central Turkey. International Geology Review 38, 737–746. https://doi.org/10.1080/00206819709465357.

Seymen, İ., 1981. Stratigraphy and metamorphism of the Kırşehir Massif around Kaman (Kırşehir - Turkey). Geological Bulletin of Turkey 24, 7–14 (In Turkish with English).

Seymen, I., 1982. Geology of Kırşehir Massif around Kaman, Readership thesis (Unpublished). 164. Istanbul Technical University, Faculty of Mining, p. 14 (In Turkish with English).

Seymen, İ., Aydın, Y., 1980. Stratigraphic evolution of Hekimhan - Hasançelebi surroundings and geotectonic evolution of Mesozoic magmatic arc. Abstracts of the 34th Scientific and Technical Congress of the Turkish Geological Institution, 74, p. 14 (In Turkish with English).

Skinner, S., 1986. Phosphorus as an anthrosol indicator. Midcontinental Journal of Archaeology 11 (1), 51–78 Retrieved September 12, 2021, from http://www.jstor.org/stable/20707959.

Steadman, S.R., McMahon, G., Arbucke, B.S., von Baeyer, M., Smith, A., Yıldırım, B., Hackley, Selover, L.D., Spagni, S., 2019. Stability and change at Çadır Höyük in central Anatolia: a case of Late Chalcolithic globalisation? Anatolian Studies 69, 21–57. https://doi.org/10.1017/S0066154619000036.

Tülümen, E., 1980. Petrographic and Metallogenic Studies in Akdağmadeni (Yozgat) Region. PhD ThesisKaradeniz Technical University Press, Trabzon, p. 157 (In Turkish with English).

Türkecan, A., Kuzucuoğlu, C., Mouralis, D., Pastre, J.-F., Atıcı, Y., Guillou, H., Fontugne, M., 2004. Upper Pleistocene Volcanism and Palaeogeography in Cappadocia, Turkey. MTA-CNRS-TUBİTAK 2001–2003 Research Programme Tubitak Report Number: 101Y109, MTA Report Number: 10652 p. 180.

Üner, T., Aksoy, İ., 2018. Textural and geochemical properties of Tectonites within the Beyşehir-Hoyran ophiolite: an example from the south of Beyşehir (Konya), Afyon Kocatepe University. Journal of Science and Engineering 18, 1067–1082. https://doi.org/10.5578/fmbd.67640 (In Turkish with English).

Wells, E.C., 2004. Investigating activity patterns in prehispanic plazas: weak acid-extraction ICPeAES analysis of anthrosols at Classic Period El Coyote, Northwestern Honduras. Archaeometry 46, 67–84. https://doi.org/10.1111/j.1475-4754.2004.00144.x.

Woods, W.I., 1982. Analysis of soils. In: Jefferies, R.W., Butler, B.M. (Eds.), The Carrier Mills Archaeological Project: Human Adaptation in the Saline Valley, Illinois, vol. II. Southern Illinois University at Carbondale, Center for Archaeological Investigations, pp. 1383–1407 (Research Paper Number: 33).

Woods, W.I., 1984. Soil chemical investigations in Illinois archaeology: two example studies. In: Lambert, J.B. (Ed.), Archaeological Chemistry.American Chemical Society, Washington D. C, pp. 67–77. https://doi.org/10.1021/ba-1984-0205.ch004.

Yazman, M., Terzioğlu, N., Unical, V., Susman, D., 1987. Geology and Geochemistry Report of Acıgöl (Nevşehir) Field, Turkey Petroleum Corporation Report Numb: 2702, (Unpublished) Ankara (In Turkish with English).

Please cite this article as: D. LAÇİN, Petrographical and chemical properties of building stone, plaster and mortar used in Güvercinkayası ..., Proceedings of the Geologists' Association, https://doi.org/10.1016/j.pgeola.2021.08.004