Akyol, Ali Akın – von Miller, Alexandra Ch. J. – Sapirstein, Philip – Verčík, Marek

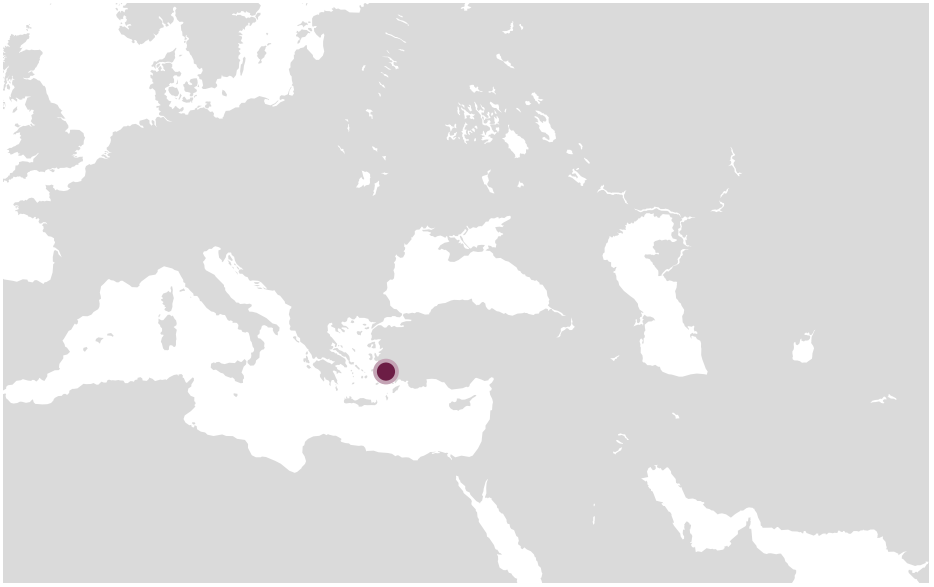
Didyma, Turkey. Archaeometric analyses of ceramics from excavations in Didyma. Season 2021

aus / from

e-Forschungsberichte des Deutschen Archäologischen Instituts, 2022-2, § 1–21

DOI: https://doi.org/10.34780/6374-4w36

Herausgebende Institution / Publisher:
Deutsches Archäologisches Institut



DIDYMA, TURKEY
Archaeometric analyses of ceramics from excavations in Didyma

Season 2021
Istanbul Department of the German Archaeological Institute
by Ali Akın Akyol, Alexandra Ch. J. von Miller, Philip Sapirstein and Marek Verčík

e-FORSCHUNGSBERICHTE DES DAI **2022** · Faszikel 2

Cooperation partner: Ankara Hacı Bayram Veli University (A. A. Akyol); Charles University Prague, project »Síderos. Technology in Pre-Classical Greece« (M. Verčík); Eurasia Department of the German Archaeological Institute, Berlin (U. Schlotzhauer); Martin-Luther-Universität Halle-Wittenberg, project »Kulte im Kult« of the Nordrhein-Westfälische Akademie der Wissenschaften und der Künste; Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf (Ü. Güder); Milet Museum, Balat; University of Toronto (P. Sapirstein).
Financial Support: Gerda Henkel Foundation; American Institute of Archaeology; Charles University Prague; National Endowment of the Humanities.
Head of Project: H. Bumke.
Team: A. A. Akyol, J. Breder, Ü. Güder, N. Günaydın, A. von Miller, G. Pantelidis, P. Sapirstein, A. Tanrıöver, M. Verčík.

Die Keramikforschung nimmt in Didyma seit Wiederaufnahme der Grabungen durch das Deutsche Archäologische Institut in den 1960er Jahren eine zentrale Rolle ein. Aus der Bearbeitung unterschiedlicher Keramikgattungen in aktuellen Projekten ist vor dem Hintergrund älterer Vorarbeiten ein Katalog lokaler bzw. regionaler gefäßkeramischer Waren und Dachziegel entstanden, der den Zeitraum von der spätgeometrischen bis in die frühbyzantinische Zeit (8. Jh. v. Chr.–7. Jh. n. Chr.) erfasst. Im Sommer 2021 wurden ausgewählte Referenzstücke einer archäometrischen Beprobung unterzogen mit dem Ziel, die archäologisch-makroskopische Klassifikation anhand komplementärer chemischer und petrographischer Untersuchungen zu überprüfen und mit naturwissenschaftlichen Daten zu hinterlegen. Die Überreste der keramischen Matrize eines bronzenen Dreifußkessels werden mittels einer Neutronen-Aktivierungs-Analyse (NAA) untersucht.

Ceramics research has played a central role at Didyma since the German Archaeological Institute resumed excavations there in the 1960s. Building

upon past preliminary work, the ongoing cataloguing and study of its various wares has created a typology of the local and regional pottery and architectural terracotta, spanning the Late Geometric to the Early Byzantine period (8th c. BC–7th c. AD). In 2021, with the aim of supplementing the current state of understanding that has been based primarily on macroscopic observation, a collection of 93 pieces representative of the current ceramic typology was sampled for archaeometric analyses, including compositional and chromatic measurements and thin-section microscopy. The residues of the ceramic casting mould of a bronze tripod leg are subjected to Neutron activation analysis (NAA).

Introduction

1 The long tradition of pottery research at Didyma ↗ has recently culminated in extensive studies of the different classes of pottery excavated by the »Kulte im Kult« project as well as architectural terracottas from the German Archaeological Institute's excavations, which have been ongoing since the 1960s. In addition to the typological, chronological, functional, and contextual evaluation of the finds, special attention has been paid to ceramology, leading to a typology of ceramic wares and fabrics based on macroscopic observation and archaeological considerations. In 2021, selected reference pieces were subjected to archaeometric analyses.

Background, research questions, and preliminary work

Pottery and lamps

2 The classification of pottery vessels and lamps from Didyma builds upon the pioneering works of Thomas Schattner and Ulrike Wintermeyer. Their typology of ceramic ›clay wares‹ (›Tonwaren‹) was derived from the macroscopic characteristics of fabric, surface treatment, and decoration as well as the repertoire of shapes, albeit without sufficiently accounting for the reoccurrence of the same paste across multiple pottery style groups (›Waren‹), and vice versa [1]. Whereas Schattner's classification of Archaic ›clay wares‹ has been published in a comprehensive manner [2], the incomplete description

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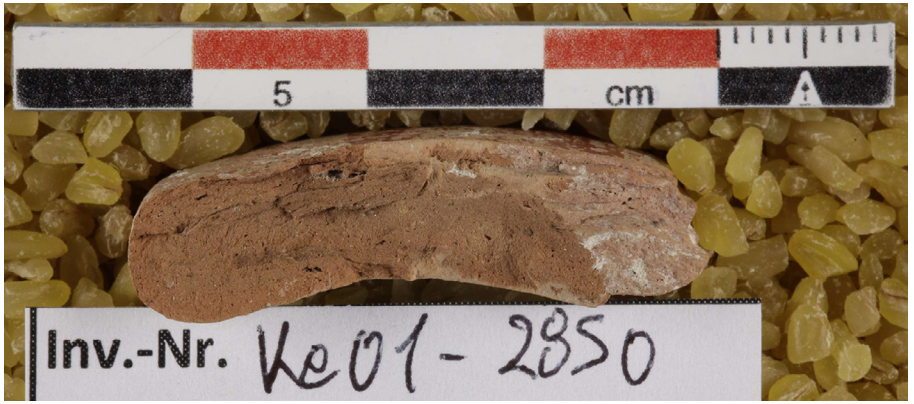


b

1 Archaic ›Braune Ware‹: reference piece Ke01-2850, sample-no. 12 (banded amphora). a. Exterior view (Photo: Alexandra Ch. J. von Miller); b. macroscopic photograph. (Photo: Ferdinand Wulfmeier)

of ›clay wares‹ from later periods [3] impairs their evaluation by researchers without first-hand experience with the pottery at Didyma. The macroscopic pottery classification was supplemented by archaeometric analyses from the 1980s and 1990s – including Neutron activation analysis (NAA) [4] and petrographic thin sections [5] – which remain preliminary in nature. The results of NAA applied on vessels from excavations at Taxiarchis Hill in 2004 have yet to be published [6].

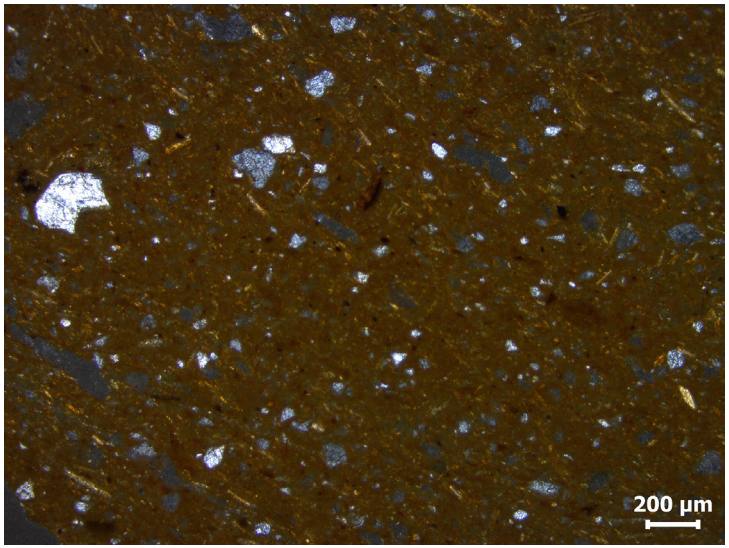
3 In order to address these deficiencies in previous research, in 2019 we initiated a new systematic recording and redefinition of the local/regional pottery from the Geometric to the Early Byzantine periods (8th c. BC–7th c. AD). It builds upon a database of wares created in 2014 and has expanded since with a growing array of reference samples. The entry for each ware covers archaeological and macroscopic observations regarding the fabric composition, surface treatment, repertoire of shapes and decoration, production techniques, and provenance. Having completed the preliminary analysis in 2021, the database comprises 152 Didyma wares, of which 47 are believed to be local or regional products, from the Geometric to the Early Byzantine periods (e.g. Archaic ›Braune Ware‹, Figs. 1a. b. c. d).

4 A total of 73 diagnostic pieces were selected for sampling, including two heavily over-fired fragments (Inv. nos. Ke01-2152, Ke03-217). Along with the vitrified remains of a ceramic kiln (Inv. nos. MM01-722c, MM09-261, MM09-264) [7] and residues of a casting mould (see below), they provide the first, even if scanty evidence confirming production activities related to ceramics in the immediate surroundings of the sanctuary at Didyma in the Archaic period (7th/6th c. BC). Our reference collections also include the sherds on which the aforementioned NAA had been conducted.

Architectural terracottas and roof tiles

5 Architectural terracotta is well represented at Didyma due to the massive quantities from the Archaic to Byzantine eras (6th c. BC–15th c. AD) and their systematic collection in recent excavations. The basic attributes of Archaic and Hellenistic roofs have been known since the foundational study by Åke Åkerström [8], but considerably more was saved since the directorship of

c



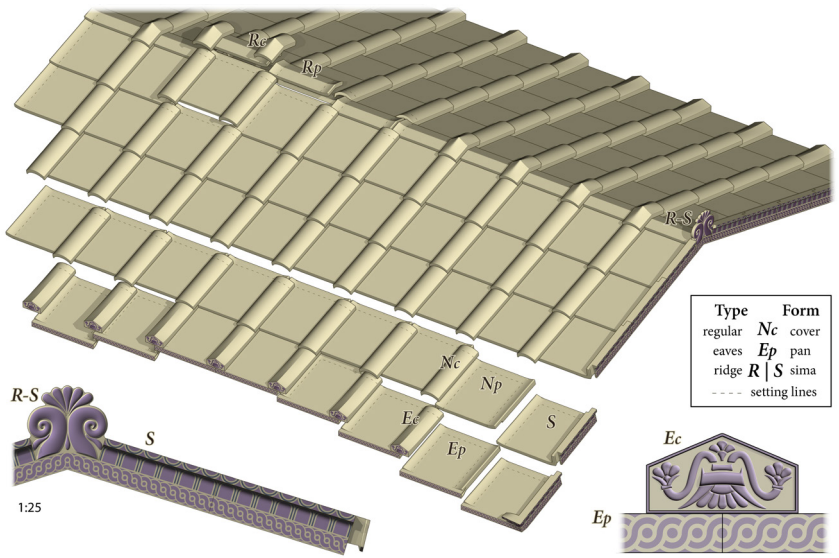
d

1 Archaic ›Braune Ware‹: reference piece Ke01-2850, sample-no. 12 (banded amphora). c. Microscopic photograph (Photo: Alexandra Ch. J. von Miller); d. thin section photograph. (Photo: Ali Akın Akyol)

Klaus Tuchelt. Thousands of tiles from excavations in the 1980s at a rural sanctuary on the Sacred Way from Miletos ↗ provided the first comprehensive view of a local roofing system which had developed by ca. 530 BC. Importantly, Peter Schneider in his final publication paid as much attention to plain tiles as to the decorated elements from the perimeter of these roofs [9].

6 Just north of the Apollo temple, excavations at Taxiarchis Hill yielded more than 900 roof tiles, the study of which has defined the first typology of Archaic through Roman material at Didyma [10]. This project has since expanded to include all tiles throughout the sanctuary, which are currently in preparation for publication. The first results of the comprehensive study have been typological. Archaic, Hellenistic, Roman, and Byzantine tile types are distinguishable by changes in fabric, interlocking system, and decoration, and their chronology correlated with stratigraphic records as well as external comparisons. Gradual changes in function are apparent from the typology. Tiles were at first primarily reserved for cult buildings in the Archaic period. By the late 4th c. BC, the Apollo temple was planned with a marble roof, whereas terracottas were limited to minor sanctuary buildings and more frequently to the residential complexes which proliferated on the outskirts of the sanctuary in the Hellenistic period and later.

7 The research has focused on architectural terracottas from the 6th c. BC, which are not only well-crafted and richly decorated, but also found in massive quantity due to the Persian destruction of Didyma in 494 BC. On the basis of variations in the design, scale, and decoration, the more than 1000 inventoried Archaic fragments at Didyma are assigned to at least eight different buildings, several of which can be associated with known foundations. These roofs belong to the same system as the aforementioned roofs from the Sacred Way published by Peter Schneider as well as others from Miletos, and as a group represent a subtype of the Aegean Island system in Nancy Winter's classification [11]. At the beginning of this series is a monumentally scaled roof obviously intended for the Apollo temple under construction by ca. 560 BC; the tiles graft decorative elements from the Greek mainland onto what is otherwise an essentially Ionian roof (Fig. 2). A



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3

2 Reconstruction of the Monumental Corinthianizing Roof (MCR) from Didyma. (Illustration: Philip Sapirstein)

3 Above: comparison of the regular tile profile of the MCR and the Lydian-Anatolian Roof (LAR); below: photographs of a cover tile, a pan tile, and moulded elements from the LAR. (Illustration and photos: Philip Sapirstein)

significant new finding from the western areas of the sanctuary is a group of more than 90 elaborately painted and moulded tiles datable to the mid-6th c. BC which differ in most regards from the local Milesian system (Fig. 3). They are instead Anatolian in both decoration and manufacturing technique, a connection that should have been obvious to any visitor who viewed the building against its neighbours. In light of the patronage of Didyma by Kroisos [12], one possibility among others is that these tiles roofed a Lydian treasury.

8 The Didyma roof tiles are an integral component of the present study. Even though archaeometric techniques are equally effective for the two types, in general the compositional analysis of ceramic tile has lagged that of pottery. Published data are rare and often concern only a few samples lacking comparability to other roofing or pottery types [13]; two Didyma tiles were also sampled in the aforementioned NAA study. The primary reference collection for assessing tile at Didyma will thus be its pottery. At the macroscopic level, the paste and surface treatments of Archaic roofs resemble those of contemporary coarse wares, prompting an initial hypothesis – that all locally produced thick-walled ceramics employed similar resources and preparatory techniques – to be tested against data from compositional and petrographic analyses. The newly identified Lydian/Anatolian roof is of particular interest, since only its fabric is visibly distinct from that of the other Archaic tiles, which are fairly homogenous. Additional research questions are diachronic, including whether the substantial change in profile and fabric in post-Archaic tile correlate to changing sources of raw materials, techniques for paste preparation, or both, as well as how these fabrics compare with pottery from their respective eras.

Production remains

9 Direct evidence for the production activities in the sanctuary of Apollo in Didyma was largely unknown or unrecognised for a long time, except perhaps for its stonemasonry [14]. Only the recent archaeological and analytical investigations have shed light on a complex spectrum of craftsmanship practised within the temenos prior to the Persian destruction in 494 BC. This includes blacksmithing, bronze working and casting, metallurgy of precious

a

b

4 Tripod leg NO F512 found southwest of the temple of Apollo; a. both views (Photo: Didyma excavation); b. detail: residues of the casting mould (?) visible on the back side of the leg. (Photo: Marek Verčík)

metals and lead, and most likely ceramic production [15]. The surprising evidence for the latter – and in particular the use of technical ceramic used for bronze casting – is also of pivotal importance for an appraisal of the productive and technological capacity present at the sanctuary in any given period. During the archaeometallurgical examination of bronze objects, residues of casting moulds and slag were observed macroscopically on a fragment of a tripod leg of the ›Matrizen‹-type (Inv. no. NO-F512; Fig. 4a. b).

10 While the finds of Geometric and Archaic tripod cauldrons from Didyma have been largely attributed to the Aegean or the Peloponnesian workshops based on typological and stylistic comparisons [16], these new findings support a hypothesis that monumental bronzes were being produced on site at Didyma, something which was recognised only at a few sites in the broader region of Ionia ↗ [17]. The project aims to test the assumptions about local/non-local production of the tripod cauldrons by analysing the provenance of the residues of technical ceramic adhering to the Didyma bronze. This approach was successfully applied on large assemblages from Olympia ↗ and Kalapodi ↗ dated from the Protogeometric to the early Archaic periods (11th–7th c. BC) [18].

The aims of the project

11 This unified archaeometric study of multiple varieties of ceramics will supplement the forthcoming studies of the pottery excavated at Didyma [19] with a refined catalogue of ceramic wares. Its dual aims are an archaeological and archaeometric typology of local or regional Southern Ionian/Milesian wares and their fabrics, especially for classes of household and other utilitarian pottery coarser than the well-known fine wares (e.g. orientalising pottery and Fikellura-style pottery). The study relies on a range of complementary compositional testing methods (see below) in order to address questions related to provenance, production, and technology. Pottery is the largest group and forms the core of the study with more than 70 sherds subjected to multiple tests, to which can be compared 20 architectural terracottas, a smaller number of lamps, and technical ceramics employed in metallurgy.

12 The archaeometric sampling pursues a number of research goals:

- To incorporate material from a broad range of ceramic objects and to represent the major eras between the Geometric and Early Byzantine periods (8th c. BC–7th c. AD);
- To test the typology of wares and fabrics indicated by macroscopic, archaeological, and stylistic analyses;
- To test assumptions about local/regional products and identify possible imports;
- To record and classify attributes indicative of pottery- and tile-production techniques;
- To identify characteristics that might differentiate individual workshops within a period, or traditions over the longer term, among the local/regional production;
- To investigate the apparent similarity at the macroscopic level between coarse pottery and tile, including whether they share the same material sources and preparatory methods;
- To identify the provenance of bronze artefacts bearing technical ceramic residues;
- To correlate the data of the 2004 NAA sampling project with data from the current petrographic and geochemical analysis, with particular attention to provenance;
- To differentiate a ceramic profile of Didyma – possibly related to the special needs of the sanctuary – against the general ›Milesian‹ production by comparing the evidence of vessel pottery, tile, and technical ceramics;
- To develop this comprehensive study at Didyma in a format compatible with previous and ongoing archaeometric studies elsewhere;
- To compare results of archaeometric analyses at Didyma to those of Western Anatolia, with a special focus on Southern Ionia, from the Geometric to the Early Byzantine periods.

13 The archaeometric programme seeks data in a form comparable to relevant archaeometric pottery studies from central and Southern Ionia [20] and Caria [21], but especially from Didyma and Miletos [22]. The analysis of a significant number of tiles with the pottery is an important dimension of this study, since the two categories of objects have seldom been analysed together. Petrographic and related analyses on tiles from Mykale [23] and Ephesos [24] also provide a reference for the sampled tile at Didyma. Due to this holistic approach, spanning the gamut of periods and genres of ancient ceramics at Didyma, the project will not only fill an important gap in pottery research at Didyma but should serve as a reference collection for other pottery studies in Southern Ionia and beyond, for the major periods of classical antiquity.

Methodology and implementation

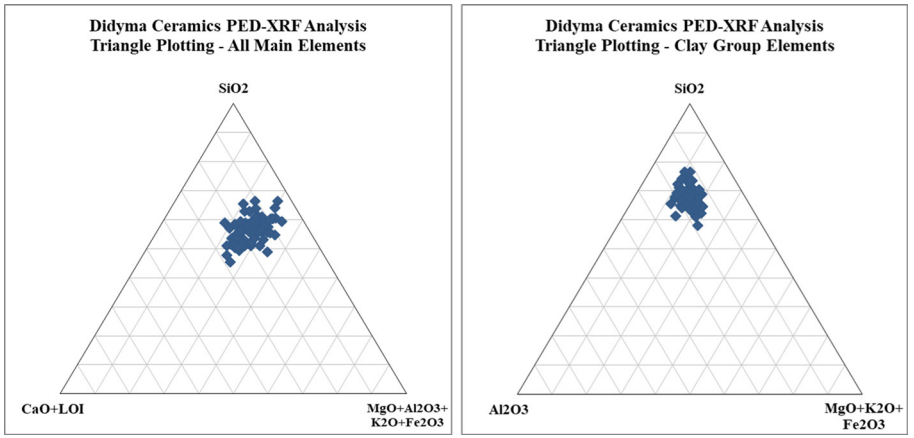
Analyses of pottery and tile

14 The samples consisting of ancient ceramic sherds were first evaluated visually, then grouped, photographed, and documented. The thickness of the sherds was measured by digital pachymeter, and the colour of the body and surface pigments with a digital chromameter for chromametric analysis. Within the scope of archaeometric studies, the petrographic properties of ceramic samples were determined by optical microscopy analysis on thin sections, and the chemical properties determined by p-XRF, PED-XRF, SEM-EDX and XRD analyses.

Petrographic thin-section optical microscopy analysis

15 Thin sections were prepared showing all layers from the exterior to the interior of each sample. Examinations with a LEICA Research Polarizing DMLP Model bottom- and top-illuminated optical microscope, connected to a Leica DFC280 digital camera for photography, were evaluated using the Leica Qwin Digital Imaging Program. Rocks and minerals making up the aggregate were defined by the Point Counting Program.

16 Microscopic thin-section analysis reveals the petrographic ›finger print‹ of the local/regional pottery production to the degree that it resembles the geology and lithology in the Milesia. The preliminary study has identified twelve rather homogeneous petrographic groups, including four subgroups, which would seem to confirm the local/regional provenance of the selected



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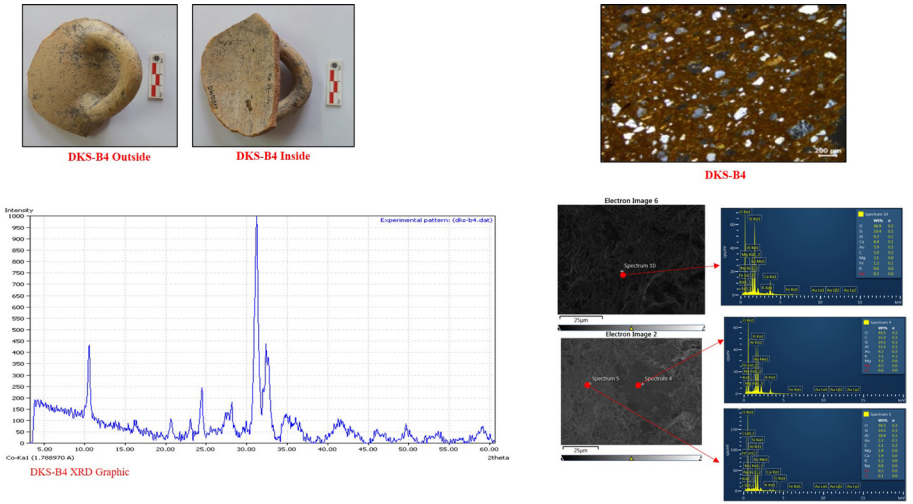

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5 PED-XRF analysis triangle plots. (Illustration: Ali Akın Akyol)

6 XRD and SEM-EDX analyses of Archaic ›Glimmerware‹: reference piece Ke01-109, sample-no. 4 (stamnos). (Illustrations and Photos: Ali Akın Akyol)

reference pieces of vessel pottery. The tile samples also belong to the same petrographic groups.

Geochemical analysis

17 The chemical composition of the samples was determined by using the X-ray fluorescence analysis methods (p-XRF and PED-XRF). The samples selected for analysis were powdered in agate mortar and formed into 32 mm-discs. Each disc was mixed with a chemical (wacks) used in XRF analysis and placed in the sample area of the instrument – an X-LAB 2000 model PED-XRF (Polarized Energy Dispersive-XRF) spectrometer – for analysis adhering to USGS (United States Geological Survey) standards and reference GEOL, GBW-7109, and GBW-7309.

18 Geochemical analyses complement and refine the petrographic study – especially for the finer fabrics. Triangle plotting of both main elements and clay group elements seems to confirm the general homogeneity of the sampled fabrics already indicated by the petrographic grouping (Fig. 5).

Elemental and technological analysis

19 A subset of the reference pieces was subjected to elemental analyses. The clay origins and firing properties of the ceramic samples were evaluated with X-ray diffraction (XRD) and scanning electron microscopy/energy dispersive spectrometry (SEM-EDX) analyses (Fig. 6). XRD analyses were conducted directly on clay-sized samples that had been powdered before analysis, by means of an INEL Brand Equinox 1000 Model X-ray diffractometer at 30 mA and 30 KV using cobalt (Co) and copper (Cu) anodes. SEM-EDX analyses were carried out to understand the production technology of the ceramic samples, using a Hitachi SU5000 Field Emission Scanning Electron Microscope (FE-SEM). Before the analysis, samples were coated with gold with the LEICA ACE 200 Coating Device in 16 seconds.

Analysis of the residues of the casting ceramics

20 The existence of bronze workshops producing tripod cauldrons, as well as the range of applications for technical ceramic in bronze casting at Didyma,

is investigated by means of NAA on the residues of the casting moulds. During the production process, different layers of clay were applied to the wax model of the cast parts of the tripod with a particularly fine-grained first layer [25]. This approach can provide crucial data about the characteristics of the local material. In order to clarify whether the adhered clay residues belonged to the original casting mould or resulted from post-depositional concretion on the metal, an SEM examination was conducted prior to NAA. The microstructural examination sheds light on the material's composition and thermal history [26]. For methodological reasons, two samples were taken from one object in quantities of c. 100–200 mg. The analyses are not yet completed.

Summary and outlook

21 The Didyma excavations have fostered a strong and long-lasting tradition of pottery studies. The current archaeometric programme, applied to different ceramic genres dating from the Geometric to the Early Byzantine periods (8th c. BC–7th c. AD), builds on previous scholarship with a complementary and more holistic approach. As such, it holds great potential to provide important new insights into and advance the current understanding of ceramic production and consumption at the sanctuary of Apollo – and beyond – throughout antiquity. The final results of the investigations outlined in this initial report will be discussed in detail in future papers focusing on the repertoire of local vessels and tile roofs as well as metal production at Didyma.

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Endnotes

[1] Occasionally, this resulted in contradictory interpretations, e. g. when Thomas Schattner labelled some drinking cups with everted rim as »Attic« even though a local or Ionian origin was assumed (Schattner 2007, 48f. 445).
[2] Schattner 1996, 165–168; Schattner 2007, 40–58.
[3] Wintermeyer 1980, 123–125; Wintermeyer 1984, 241–243; Wintermeyer 2004, 7–9.
[4] Gödecken 1984.
[5] Riederer 2007.
[6] The publication is currently prepared by Hans Mommsen (Helmholtz Institute, Bonn) and Udo Schlotzhauer (DAI Berlin).
[7] M. Verčík, III.C3 Eisenfunde, in: H. Bumke (ed.), Der archaische Heiligtumsbefund vom Taxiarchis-Hügel in Didyma, in drei Teilbänden, Didyma 3, 6 (im Druck).
[8] Åkerström 1966, 108–114.
[9] Schneider 1996.
[10] Ph. Sapirstein, III.F1 Architectural Terracottas and Roof Tiles, in: H. Bumke (ed.), Der archaische Heiligtumsbefund vom Taxiarchis-Hügel in Didyma, in drei Teilbänden, Didyma 3, 6 (im Druck).

[11] Winter 1993a, 235–249.
[12] Winter 1993b; Hdt. 1.46–1.48, 1.92.
[13] For Ionia, see Sauer 2004; Hauptmann – Al Shorman 2013.
[14] Dirschedl 2017, with further references.
[15] M. Verčík, III.C3 Eisenfunde, in: H. Bumke (ed.), Der archaische Heiligtumsbefund vom Taxiarchis-Hügel in Didyma, in drei Teilbänden, Didyma 3, 6 (im Druck).
[16] Furtwängler 2009; G. Klebinder-Gauß – N. Franken, III.C2 Bronzefunde, in: H. Bumke (ed.), Der archaische Heiligtumsbefund vom Taxiarchis-Hügel in Didyma, in drei Teilbänden, Didyma 3, 6 (im Druck).
[17] Samos: Zimmer 1990.
[18] Kiderlen 2010; Kiderlen et al. 2017.
[19] H. Bumke (ed.), Der archaische Heiligtumsbefund vom Taxiarchis-Hügel in Didyma, in drei Teilbänden, Didyma 3, 6 (im Druck); H. Bumke (ed.), Tempel, Kaiserkultmonument und Theater. Ergebnisse der zwischen 2010 und 2019 durchgeführten Grabungen in Didyma, Didyma 3, 8 (im Druck).
[20] Ephesos: Zahbelicky-Scheffenegger – Schneider 2000; Peloschek 2016; Betina 2019; Priene: Amicone et al. 2014; Fenn 2016.
[21] Iasos: Amicone 2015.
[22] Gödecken 1984; Seifert 2004; Riederer 2007; Spataro – Villing 2009.
[23] Hauptmann – Al Shorman 2013.
[24] Sauer 2004.
[25] Schneider – Zimmer 1984.
[26] Kiderlen et al. 2017.

Authors
Doç. Dr. Ali Akın Akyol
Ankara Hacı Bayram Veli University, Department of Restoration and Conservation of Cultural Properties, Faculty of Fine Arts
06830 Gölbaşı/Ankara
Turkey
ali.akyol@hbv.edu.tr
ORCID-iD: https://orcid.org/0000-0002-4174-575X
ROR: https://ror.org/05mskc574

Dr. Alexandra Ch. J. von Miller
Martin-Luther-Universität Halle-Wittenberg, IKARE – Seminar für Klassische Archäologie
Universitätsplatz 12 – Robertinum
06108 Halle (Saale)
Germany
alexandra.von-miller@altertum.uni-halle.de
ORCID-iD: https://orcid.org/0000-0001-7317-9484
ROR: https://ror.org/05gqaka33

Dr. Philip Sapirstein
University of Toronto, Department of Art History
100 St. George Street
Toronto, ON M5S 3G3
Canada
phil.sapirstein@utoronto.ca
ORCID-iD: https://orcid.org/0000-0003-4180-3320
ROR: https://ror.org/03dbr7087

Dr. Marek Verčík
Charles University, Institute of Classical Archaeology, Faculty of Arts
nám. Jana Palacha 1/2
116 38 Prague 1
Czechia
marek.vercik@ff.cuni.cz
ORCID-iD: https://orcid.org/0000-0002-8305-5183
ROR: https://ror.org/024d6js02

Metadata
Title/*title:* Didyma, Turkey. Archaeometric analyses of ceramics from excavations in Didyma. Season 2021
Band/*issue*: e-Forschungsberichte 2022-2

Bitte zitieren Sie diesen Beitrag folgenderweise/*Please cite the article as follows:* A. A. Akyol – A. Ch. J. von Miller – P. Sapirstein – M. Verčík, Didyma, Turkey. Archaeometric analyses of ceramics from excavations in Didyma. Season 2021, eDAI-F 2022-2, § 1–21, https://doi.org/10.34780/6374-4w36

Online veröffentlicht am/*Online published on*: 04.11.2022
DOI: https://doi.org/10.34780/6374-4w36

Schlagworte/*keywords*: Architectural terracottas, Archaeometry, Cast, Clay Vessels
Bibliographischer Datensatz/*Bibliographic reference:* https://zenon.dainst.org/Record/003022237