North African amphorae from Cumae

Mineralogical-petrografic analysis for the provenance of North African amphorae from Cumae (South-Italy)

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INTRODUCTION

The target of this work is a selected sample of African amphorae found in the Forum of Cumae, which were examined in order to define their precise areas of origin.

This work is a preliminary analysis that aims to define the trade that the ancient city of Cumae had with North Africa. The samples were analyzed with a mineralogical-petrographic method, as well as a previous archaeological study.

The regions involved in amphoras production are Zeugitania and Byzacena, located in the south-central Tunisia, Tripolitania, located between southern Tunisia and western Libya, and *Mauretania Caesarensis,* located between Marocco and Algeria (Fig. 1a). These regions were also known for the production of other items, including cooking and fine ware (Bonifay, 2004). With the aim of defining the precise areas of production, nineteen samples of amphorae were selected from the most common types at the Cumae site, dated from the 2nd to the 6th centuries CE.

In this period, the trade with the North African regions became more intense and frequent, because of the crisis in the local trade, which led to a change in the trading system: from the provinces to Rome. North African amphorae are known to have carried liquid goods, such as high-quality oil, *garum* and fish sauces, with the occasional association of wine, which is restricted to a few defined types: Dressel 30 and Africana III (Di Giovanni, 2010; Rizzo, 2018).

From the 3rd century CE onward, the trade from North Africa became more and more dense, to the stage of almost total control of the markets. Due in part to the fact that the North African peoples experienced no internal crises, as had been the case in western regions, and due to their enduring prosperity given by agriculture based on settler *families* living in villages (Rizzo, 2014).

The Forum of Cumae

This area, located in the lower part of the city, is the center of political and commercial activities. It has been investigated with archaeological survey and excavations since 1994, with the Kyme project, that involves the Soprintendenza Archeologica di Napoli e Caserta, the University of Naples Federico II, the University of Naples "L'Orientale" and the *Centre Jean Berard* (Capaldi, 2021).

The Forum area (Fig. 1b) in the roman period was surrounded by a double-order *portico*, with Doric order columns at the bottom and Ionic order columns at the top. It was decorated with stone theatrical masks on the eastern side and with stacks of weapons on the western side (Capaldi, 2016). Behind the arcade of the *portico*, there were places used for commerce and craft activities, known as *tabernae* (Gasparri, 2008, 2009). The forum was dominated by the main temple on a high podium, the *Capitolium*, from the Flavian era, located on the western side and dedicated to the Capitoline triad (Gasparri, 2008). Another major temple is the one incorporated in the building known as the "*Masseria del Gigante*," built in the classic *porticus triplex* pattern, it is devoted to *Divus Vespasianus* (Gasparri, 2008, 2009).

Geological setting

North Africa is an area affected by a long history of transformations, both geopolitical and geological. Geologically, Africa is divided into two zones separated by the Southern Atlassic Front: the first is the mountainous zone bearing the imprint of Alpine tectonics, consisting of Cenozoic sedimentary tectonics; the second is the Saharan region, consisting of a Precambrian basement with a Phanerozoic sedimentary cover (Capelli-Bonifay, 2014; Gallala et al., 2009).

Sedimentary rocks are dominant in North Africa (especially in the Tunisian area), but they are not the only features of the entire area: metamorphic rocks are widespread on the coast of Algeria (Baghdad et al., 2017), and in Libya volcanic rocks are present, albeit in smaller percentages. Some areas of North Africa then show similar lithology, having a similar geologic history, as well as can find even driven similarities with deposits scattered throughout the Mediterranean (an example is north-central Sicily).

THE ARCHAEOLOGICAL MATERIALS AND ANALITICHAL METHODS

The materials examined are the result of an archaeological type sampling. The nineteen amphora samples were selected as representative among the African amphorae found at the Cumae site in the excavation campaigns between 1994 and 2018. Seven types of amphoras were selected (Fig. 1c).

North African amphorae consistently turn out to be the most attested type at Cumae, in line with the trade situation.

The Macroscopic analysis of the ceramic body was performed with a precision lense (30X) to determine a visual comparison between the colours (compared with the Munsell Soil Colour Chart) and the hardness (Cuomo di Caprio, 2007).

The archaeometric investigation was performed via mineralogical-petrographic techniques.

Polarized light microscopy (PLM) in thin section was used to investigate the textural and petrographic features of ceramic pastes with an OPTIKA V-600 POL microscope and a ZEISS Axiocam 105 color camera (ZEN 2.3 Lite software) for capturing the images (Terry-Chilingar, 1995; Quinn, 2013).

X-ray Powder Diffraction (XRPD) was used to determine the bulk mineralogical composition of samples on random powders. A diffractometer PANalytical X'Pert PRO 3040/60 PW, equipped with a CuKα generator operating at 40 kV, 40 mA, was used for measuring the samples at a scanning interval from 4-70° 2θ (step interval of 0.020° 2θ, a step counting time 120 s, with RTMS X'Celerator detector). The mineral standards used are reported in Guarino et al. (2019) and Franciosi et al. (2019); precision and accuracy of EDS analyses are reported in Rispoli et al. (2019).

X-ray fluorescence spectrometry (XRF), performed with an AXIOS PANalytical Instrument (Malvern Panalytical Ltd., Marvel, UK), on pressed powder pellets was used to analyze the bulk chemical composition of the samples, expressed by the concentration of 10 major oxides (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5 in wt%) and 10 trace elements (Rb, Sr, Y, Zr, Nb, Ba, Cr, Ni, Sc, V in ppm). The analytical uncertainty was of 1–2 % for the major elements and 5–10 % for trace elements (Cucciniello et al., 2017). The standards employed are described in Guarino et al. (2021).

RESULTS AND DISCUSSION

The colors of the pastes vary from bright red tending to dark orange (Munsell 10R3/10 and Munsell 10R4/10), to dark orange-yellowish (Munsell 2.5YR5/10 and Munsell 10YR7/8). A group of amphorae with two-tone paste, bright red and gray, stands out (Munsell 10R4/10 and Munsell 10R3/2).

The pastes are mostly coarse, with quartz inclusions visible even with only a precision lens. Samples with finer textured pastes are also present, which do not show large enough inclusions to be easily observed at the lense.

Polarized light microscopy (PLM) highlights two different groups (Fig. 1.d) of samples and some outliers according to their petrographic composition, which shows affinity with the geological features of the supposed area of production. The first group presents a coarse paste, with mostly inactive matrix, composed of not very well sorted inclusions of quartz, both rounded and angular, of large size, followed by inclusions of calcite, probably microfossils not always identifiable, and sporadic pyroxene; the second group shows a finer paste, with matrix maintaining traces of optical activity, and well sorted inclusions of smaller quartz (even 200 μm); absent almost entirely are calcite and microfossils. Four outlier samples are also identified, for their unique characteristics.

X-ray powder diffraction (XRPD) revealed, consistent with petrographic analyses, quartz as the most abundant mineralogical phase in all samples. Great homogeneity with thin section observations is also found for calcite: for samples showing abundant calcite in diffractograms, the presence of microcrystalline calcite inclusions and microfossils is equally visible in thin section. Slight diffuse presence of feldspar was also identified, found in thin section (with sporadic feldspar crystals). Pyroxene, found in thin section, was also found in mineralogical analysis, except for seven samples, which show in diffractograms this mineralogical phase, not visible in thin section. Therefore, pyroxene in these specimens is identified as a neoformed mineralogical phase.

XRPD also shows in most samples other neoformed phases represented by hematite and gehlenite. Residual clay minerals represented by illite/mica was also detected in most of the samples.

The X-ray fluorescence (XRF) chemical analysis shows high average values in SiO_2, Al_2O_3, Fe_2O_3, and lower values in MgO, K_2O, Na_2O. The majority of samples also have high concentrations of CaO (> 6 wt%); only three samples are low in CaO (with a CaO concentration of ≤5 wt%).

Thanks to the color of the ceramic body and the mineralogical-petrographic characteristics provided by archaeometric analysis, it was possible to identify the firing atmosphere and relative temperatures, based on the presence or absence of particular mineralogical phases. Therefore, the temperature is estimated to range from a minimum of 800°C to a maximum of 950°C (Maritan et al., 2006; Cultrone et al., 2001; Nodari et al., 2007.). With mostly oxidant firing atmosphere, only three samples show characteristics of a reducing atmosphere at

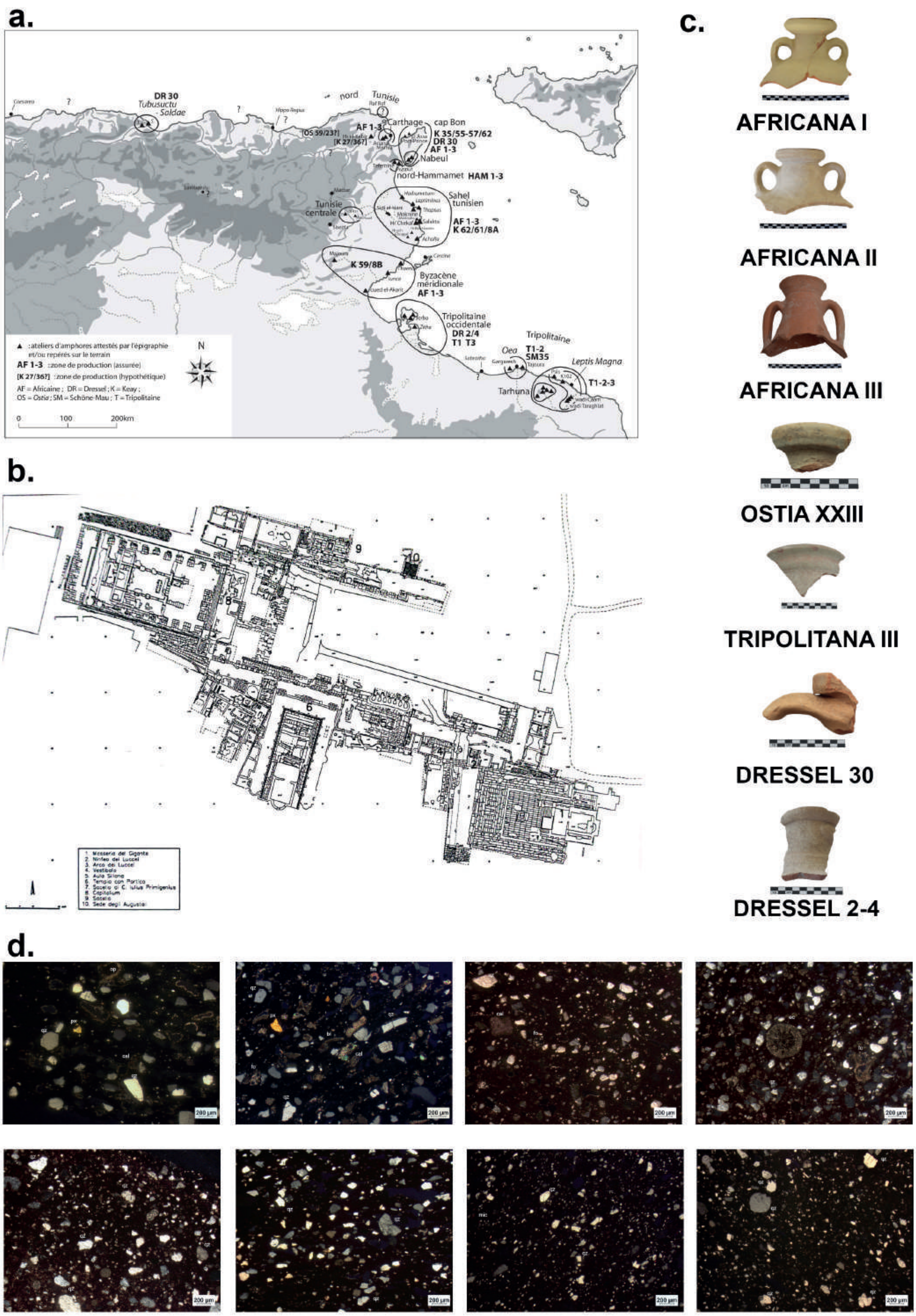

Figure 1 ***a)*** *Main production areas of African amphorae;* ***b)*** *Chart of the Forum of Cumae;* ***c)*** *Seven archaeological types of the amphorae examined;* ***d)*** *Thin-section photographs*

the beginning of the firing process and oxidizing at the end (Molera et al., 1998; Maritan et al., 2006).

CONCLUSIONS

The study of the technological characteristics showed the wide use of the oxidizing atmosphere during firing in the kiln; a fact derived from the paste color, between red and orange, of the majority of the samples. Only three samples (AA101, AA107 and AA108) deviate from this by presenting a two-tone paste: with sandwich coloring, with dark gray core and outer sections in red (black core). This highlights a particular firing atmosphere: started with reducing process and ended with oxidizing atmosphere (Molera et al., 1998; Maritan et al., 2006; De Bonis et al., 2017).

The estimation of firing temperatures was possible through the joint analysis of petrographic, mineralogical and chemical results. These analysis showed a predilection for high firing temperatures and high CaO clays. The estimated temperatures were between 850°C and 950°C (for AA102, AA107, AA108, AA111) and between 900°C and 1050°C (for AA101, AA103, AA104, AA110, AA112, AA115 and AA116). Only samples AA100, AA106, AA117 and AA118 show lower temperatures (Cultrone et al., 2001; De Bonis et al., 2014).

As for the low CaO samples, AA113 and AA114 show high firing temperatures (between 900°C and 1000°C), while AA105 shows lower temperatures (between 700°C and 750°C).

The study concerning the provenance of the samples was carried out by comparison with previous literature, either by considering the mineralogical-petrographic studies of Capelli and Bonifay (Capelli-Bonifay, 2016; Capelli-Bonifay et al., 2016), or by attempting a comparison with local clays through data found in specific publications on the study of North African sediments.

It was possible to define the provenance of the samples examined from four defined areas of North Africa: the *Mauretania Caesarensis* (present-day Algeria), Zeugitania (north-central Tunisia), Byzacena (south-central Tunisia) and Tripolitania (between southern Tunisia and Libya).

The types examined in the nineteen samples analyzed demonstrated a provenance of amphorae consistent with the archaeological literature; delineating a presence at the site of Cumae of African amphorae not only from Byzacena (thus from the producing area gravitating around the port of Hadrumentum), but also from Zeugitania (Africana I, Africana II, Africana III, and Ostia XXIII), Tripolitania (Tripolitana III and Dressel 2-4 North African), and the Algerian coast (Keay Ib).

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