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Tracing Construction Phases at the Roman Villa Horta da Torre (Fronteira, Portugal): Insights from mortars aggregates

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***Abstract* – The Roman villa Horta da Torre, built around 3th-4th century A.D., is located at Cabeço de Vide (Fronteira, Portugal). To address the construction(s) phase(s), production technology and provenance of materials, a total of 18 samples of mortar walls were collected from Horta da Torre, including renders and fillers. A multi-analytical approach to study textural, and mineralogical features of the selected mortars was developed. This work suggests the existence of three construction phases based on their aggregates; gabbroic, granitic, and mixed, used as filling and render at the excavated *pars urbana* of the villa. study also revealed that the aggregates likely come from two local sources; gabbroic river sand from 2 km north of the site and granitic quarry/outcrops 3.5 km south of the site, whereas calcitic-lime raw material was available at a distance of within a kilometer of the site.**

I. INTRODUCTION

The Roman villa of Horta da Torre is located in Cabeço de Vide (Fronteira), in the Alto Alentejo region of Portugal. Spanning an estimated area of approximately 30,000 square meters—including unexcavated sections—this villa occupied a strategic position between two major Roman cities: Augusta Emerita (modern Mérida, Spain) and Olisippo (modern Lisbon, Portugal). Due to its location, Horta da Torre likely played a significant intermediary role along the route known as the Antonine Itinerary.

Excavations and archaeological investigations, ongoing since 2003, have brought to light the villa's most distinctive architectural feature: a double apse located at the northern end of the triclinium, surrounding a *stibadium* [1]. This structure is believed to have functioned as a water reservoir, allowing for the deliberate flooding of the triclinium floor during festive occasions or the intense heat of summer. The floor itself was constructed in opus signinum (a waterproof mortar), devoid of mosaics. These together with marble panels, were used as decorative wall elements [1].

The exact chronological development of the villa remains unclear, and it is evident that it was not built in a single construction phase. Instead, it underwent various stages of modification until its eventual abandonment in the 6th century AD. This study aims to contribute to a better understanding of those developmental phases through the analysis of mortars and their raw materials. It further seeks to elucidate the construction technology, adherence to Vitruvian principles, aesthetic choices, and the provenance of materials employed by the villa's builders.

II. MATERIALS AND METHODS

Eighteen wall mortar samples were collected from the Horta da Torre Roman Villa site (Figure 1 and table 1) considering several functions and structures/spaces.

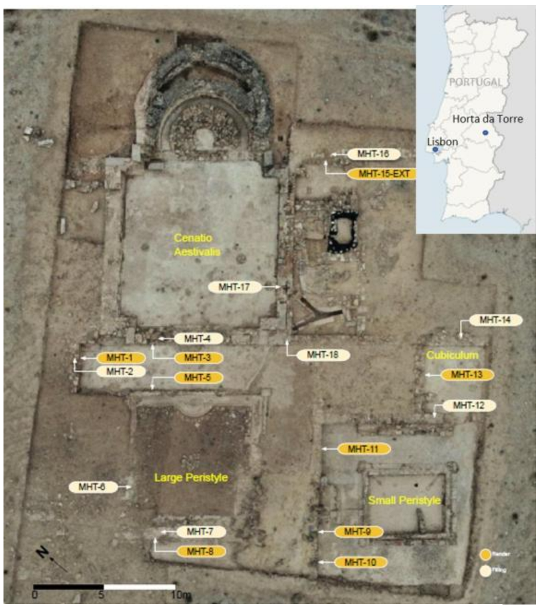

Fig. 1. Location and function of samples from the Roman villa at Horta da Torre (Fronteira, Portugal).

To address these questions, a multi-analytical and complementary approach, following the methodologies outlined in [2,3,4], was applied to both filling and render mortars. The samples, taken with hammer and chisel after cleaning and drying at 40°C were prepared for different analyses, by powdering (below100µm) and thin section production. Techniques included X-ray Diffraction (XRD) for identifying mineral phases on global faction powdered samples, with a Bruker D8 Discover X-Ray Diffractometer using a CuKα source working at 40 kV and 40 mA. The diffractograms were recorded in the range 3°-75°2θ, 0.05°/second). Thermogravimetric Analysis (TGA) for determining binder-to-aggregate ratios, was performed on a Simultaneous Thermal Analyzer STA 449 F3 Jupiter (NETZSCH), under inert atmosphere of Nitrogen with a flow rate of 70 mL/min. The heating program was set to start at 40°C and then increase it at a constant rate of 10°C/min until reaching 1000°C. Petrographic Microscopy (PM) was performed on a Leica DM2500 P Modular Polarization Microscope, and recorded with a Leica MC170 HD digital camera., and Variable Pressure Scanning Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy (SEM-EDS) for studying textural and mineralogical characteristics, as well as binder composition. A Hitachi S-3700N (Hitachi High Technologies, Berlin, Germany) Scanning Electron Microscope coupled with a Bruker XFlash 5010 (Bruker Corp, Billerica, Mass. USA) Silicon Drift Defector (SDD) Energy Dispersive X-ray Spectrometer was used to perform the micro-analysis of the samples. The analysis was performed under variable pressure, operated with an accelerating voltage of 20 kV and chamber pressure of 40 Pa. The SDD was operated on an energy scale of 0-20 keV, with a resolution of 129 eV at Mn Kα,

Table 1. Mortars function and location (see fig. 1)

sample ref.	function	location
MHT-1	Render	Passage
MHT-2	Filling	Passage
MHT-3	Render	Cenatio Aestivalis
MHT-4	Filling	Cenatio Aestivalis
MHT-5	Render	Large Peristyle
MHT-6	Filling	Large Peristyle Thin Wall of Peristyle
MHT-7	Filling	Large Peristyle
MHT-8	Render	Large Peristyle Mixed Ceramic
MHT-9	Render	Small Peristyle
MHT-10	Render	Small Peristyle (Weathered Tank)
MHT-11	Filling	Small Peristyle
MHT-12	Filling	Cubiculum Weathered
MHT-13	Render	Cubiculum
MHT-14	Filling	Cubiculum
MHT-15-EXT	Render	Hypocaust Internal
MHT-16	Filling	Hypocaust Adjacent Interior
MHT-17	Filling	Triclinium Double Wall Part
MHT-18	Filling	Triclinium Double Wall Part

III. RESULTS

A. Petrographic Microscopy

Although not obvious from a macroscopic observation, the petrographic analysis made it possible to distinguish three petrographic groups, regardless of function, considering the composition of the aggregates: i) gabbroic, ii) granitic and iii) mixed. The gabbroic group, represented by 5 samples, is characterized by the significant presence of iron- magnesium minerals such as olivines (+/- serpentinized), pyroxenes and amphiboles, as well fragments of gabbroic rocks as previously mentioned by [2]. The aggregates tend to be rounded. The group also contains metamorphic rock fragments such as quartzite and metapelite. The granitic group (11 samples) contains minerals compatible with a granitic source such as quartz, feldspars, and biotite. The observed feldspars were alkali feldspar with perthitic texture and plagioclase (perthite). The aggregates tend to be more angular in shape.

The last group, the mixed group, contained both minerals from basic and granitic groups. Epidote was identified in this group by its bright colors in XPL. This group consists of only two samples.

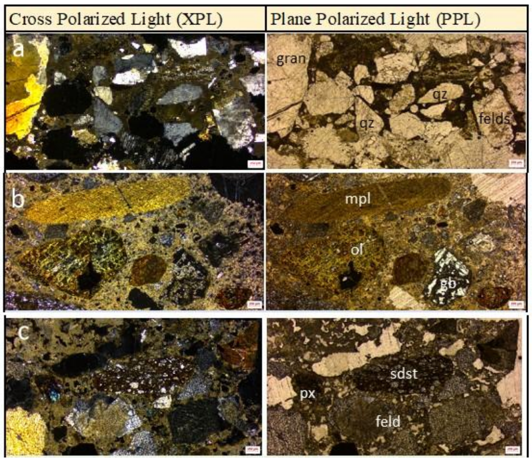

Fig. 2. : Representative micrographs of granitic, basic, and mixed groups. qz-quartz, felds-feldspar, gran-granitic, mpl-metapelite, ol-olivine, sdst-sandstone, px, pyroxene.

B. X-rays difraction

The XRD analysis (table 2) on powdered sample (global fraction), corroborated the individualization into the 3 above mentioned petrographic groups. Although there is an overlap for felsic minerals, such as quartz and feldspar, and for mafic minerals such as biotite or amphibole, there is a difference concerning the presence of olivine and pyroxene in the mortars at the gabbro group. In addition, dolomite is present only in this group. The third group (mixed) stands out for the presence of the above-mentioned previous phases, plus epidote but without dolomite.

Table 2. XRD results

sample ref.	function	quartz	feldspar	calcite	micas	amphibole	chlorite	pyroxene	olivine	dolomite	epidote
Granitic aggregates											
MHT-1	Render	+++	++	+++	+	+					
MHT-2	Filling	+++	++	+++	+		+				
MHT-3	Render	+++	+++	++	+	+	+				
MHT-4	Filling	+++	+++	++	+	+					
MHT-5	Render	+++	++	++	+	+	+				
MHT-6	Filling	+++	+++	++	++	+					
MHT-8	Render	+++	+++	+++	+	+					
MHT-9	Render	+++	++	++	++	+					
MHT-10	Render	+++	+++	++	++						
MHT-13	Render	+++	+++	++	+	++	+				
MHT-17	Filling	+++	+++	++	++	+	+				
Gabbro aggregates											
MHT-7	Filling	++	+++	++	+	++	++	++	+	++	
MHT-12	Filling	++	++	++	+	+++	++	+	+	+	
MHT-14	Filling	++	++	++	+	++	++	++	+	++	
MHT-15-ext	Render	++	++	++	++	++	+	+	+	+	
MHT-16	Filling	+++	++	++	+	++	+		+	++	
Mixed aggregates											
MHT-11	Filling	+++	+++	++	+	++	+	+	+		
MHT-18	Filling	+++	+++	++	+	++	+	++	+		+

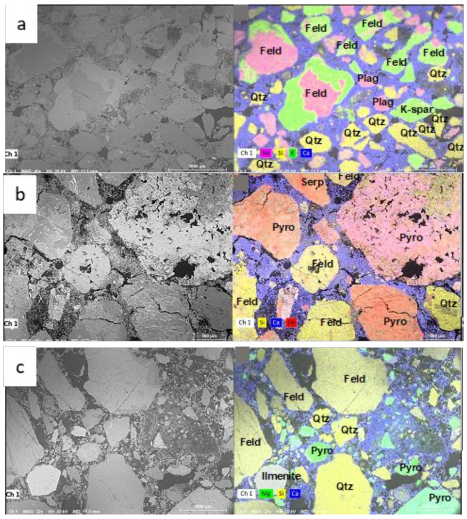

Fig. 3. SEM-EDS images. BSE images and elemetal maps distribution for the 3 groups (a-granitic, b basic ultrabasic, c- mixed)

C. Variable Pressure Scanning Electron Microscopy Coupled to Energy Dispersive X-ray Spectroscopy (VP-SEM-EDS)

In all samples analyzed using SEM-EDS (Figure 3), aggregates and binders were distinguished through silicon and calcium EDS elemental mapping. Silicon is the dominant element in the aggregates, while calcium, is prevalent binder. The elemental mapping revealed that in all samples, the binders consistently showed a higher concentration of calcium relative to magnesium. SEM-EDS maps also identified the presence of iron-rich minerals—such as pyroxenes and serpentinized olivines—in the basic group, which were absent in mortars composed solely of granitoid mineralogy aggregates (granite group). This distinction was observed in both filling and render mortars. In the third group, aggregates comprised a combination of quartz and feldspar along with iron-magnesian minerals.

D. Thermogravimetric Analysis (TGA)

Thermogravimetric analysis was carried out to quantify the binder phase as well as to assess the presence of a dolomitic binder phase, according with Földvári data base [4]. The temperature ranges considered were 60-120ºC, 120-200ºC, 200-600ºC and 600-900ºC, and calcite amount was obtained by the lost of weight at the higher temperature range. Once again, the thermograms analysed (Fig. 4) show differences between the three groups, particularly in terms of the calculated amount of calcite Although with a small overlap the granitic group show higher amount of calcite (19.1-31.7wt%, #11 samples), the gabbro group (13.1-24.0 wt%, # 5 samples), and has have been seen for others technicques, the mixed group maintains a strong similarity in the results obtained (15.1-15.2wt%, #2 samples). The weight loss observed at the temperature range 200-700ºC for the gabbro group are probably, accordingly with [5,6], associated with the decomposition of dolomite.

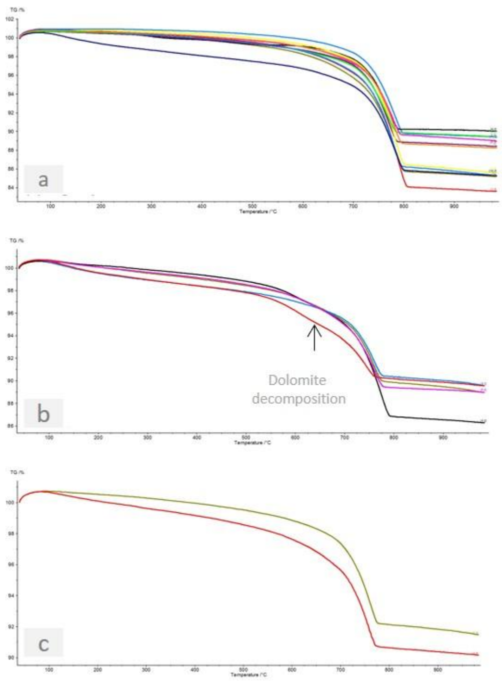

Fig. 4. Thermograms for the 3 groups of aggregates (a-granitic, b basic ultrabasic, c- mixed.)

IV. DISCUSSION

This research aimed to raise considerations concerning the construction phases of the Roman Villa of Horta da Torre, the production technology, types and provenance of raw materials used for producing mortar. The integrated application of complementary techniques allows for the unequivocal identification of silicate aggregates, using PMM, XRD, and SEM-EDS, and carbonates, using XRD and TGA, in parallel with the quantitative determination (TGA) and compositional characterization (SEM-EDS) of the lime employed.

On site and as can be seen on figure 1, the double wall on the south-east of the *cenatio aestivalis* (the wall of MHT-17 and MHT-18, figure 1) suggested that there may have been different construction phases of the villa [1], as one wall visually seem to be added to another afterward. This may apply not only to the double wall, but also to the entire construction of the Villa.

The different analysis techniques applied, corroborate the division based on different mineralogy of aggregates: granitic, basic, and mixed of both, regardless of mortar function. According to the preliminary assessment of groups by the petrographic analysis, MHT-1 to MHT-6, MHT-8 to MHT-10, MHT-13, and MHT-17 belong to the granitic group, MHT-7, MHT-12, MHT-14, MHT-15-EXT, and MHT-16 belong to the basic group, and MHT-11 and MHT-18 belong to the mixed group.

Since sample MHT-7 is a filling mortar that belongs to the basic group, and MHT-8 is a granitic render mortar that covered the surface of the filling mortar MHT-7, it is possible to construct a hypothesis that the basic group is the earlier construction phase in relative to the granitic group. Even if they were in the same time construction phase, it is indicated that the basic group was created before the granitic group. Other mortar relations on different elemental constructions, such as MHT-2/MHT-1 or MHT-4/MHT-3, shows respectively, granitic filling and render.

The mixed group could represent another construction phase apart from these two phases. What seems to be clear is that MHT-11 and MHT-18 are very similar to each other in all results and have a mineralogical composition that distinguishes them from the other two groups. Therefore, the mixed group may suggest a third construction phase.

Furthermore, the wall of the hypocaust where MHT-15-EXT was taken can be another construction phase, as render mortar with basic aggregates was only found here. It is important to note that in this case the mortar sampled as render may not be a true render for a smoothed surface associated with the hypocaust.

The dominance of calcite in the samples indicates that all samples have calcareous aerial binders. This was suggested by the mineral phase of calcite identified in XRD analysis in all samples, the peak mass loss at 600–900°C in TGA, and the analyses performed by SEM-EDS. Moreover, in several samples in the petrographic analysis, fragments of calcite were observed. These fragments originate from marble fragments mixed as aggregate on some filling mortars (granitic and mixed type). Although [2] shows that the builders at villa Horta da Torre did not strictly follow Vitruvius' for mural-painting mortar (omitting the crushed-marble layer) the measured lime-to-aggregate ratios (1:3 to 1:4) in both their filling and plastering mortars nonetheless accord with his recommendations.

The TGA and XRD analyses also suggested the presence of dolomite in MHT-7, MHT-12, MHT-15-EXT, MHT-16. This was probably added as aggregate, because of the absence of Mg on the binder in these four samples or magnesite at XRD or TGA. This information reassures that all the samples have calcareous aerial binders, and the raw material used to produce the binder was likely limestone/marble and not dolostone. This lithologies occurs at a distance of around 2km to north of villa.

The lithologies to the north of the Roman villa are compatible with basic mortars. Several metamorphic rocks and an important intrusion of basic and ultrabasic rocks are mapped [7]. The watercourses in the area, which flow from north to south, explain the greater degree of roundness of these materials. On the other hand, lithologies of a granitic nature, compatible with granitic mortars, occur further south at a distance of around 5km.

V. CONCLUSIONS

Although the chronology has not been unequivocally established, it is clear that, regardless of their functions filling or render, there are 3 types of mortars (3 distinct mineralogy) that occupy relationships in the constructive elements of the Roman villa; granitic (quartz feldspar, biotite), with angular aggregates, gabbro type (olivine, pyroxene, dolomite, quartz and feldspar ±metamorphic rocks) with more rounded grains, and mixed (olivine, pyroxene, quartz, feldspar an epidote). The filling mortars with gabbro type aggregates exhibits slightly lower binder:aggregate proportion. A hypothesis was proposed suggesting that the basic group is associated with earlier structures, while the granitic group was either used as render mortar for older walls or as filling mortar in the construction of later structures. The mixed group can represent another construction phase apart from these two phases. The raw materials (aggregates and lime), are compatible with two different sources of local geology, within a maximum distance of 5 km. The data obtained highlight the relevance of studying mortars, not only as a tool for supporting the interpretation of the relative chronology of structures, but also as a source of information on the technological capabilities of Roman builders and their knowledge of local resources.

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