XRF Analysis of Village and Urban Basalt Architecture in the Hippos Territorium During the Roman Period

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Abstract

The case study presented below deals with the archaeological question of urban-rural relationships by determining if the public and monumental structures from a village and urban site shared the same quarries and perhaps stonemason's workshops. We examine the use of X-ray fluorescence (XRF) as an effective method for defining distinct chemical compositions of local basalt stone from different sources, even when their quarries have not been identified. Ninety-eight samples from the southern Golan, mainly from the polis of Hippos and the village of Majduliyya were analyzed. The evidence shows that Hippos and Majduliyya did not use the same quarry for the architectural stones in their respective monumental structures, providing new and important information on the nature of city-village relationships in the southern Golan during the Roman period. Methodological questions and the application of this method in the archaeological research of basalt-based architecture are also addressed.

INTRODUCTION

Basalt was a common building material used in Roman and Byzantine-period architecture in the volcanic regions of the Levant. In the Hauran/Southern Syria and northern Arabia, basalt was one of the main stone materials used in private and public monumental structures both in cities and surrounding rural areas (e.g., Segal, 2008; Mazzilli, 2018). However, the production, acquisition, socioeconomic significance and

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especially the analytical analysis of basalt used in historical periods as a building material has received limited attention in comparison to marble, granite or limestone. One of the reasons for this is the difficulty in identifying basalt quarries and outcrop sources.

The case study presented below deals with the archaeological question of urban-rural relationships by determining if the public and monumental structures from a village and near-by urban site shared the same quarries and perhaps stonemason's workshops. We also examine whether private and public construction within a single site used the same sources as well diachronic differences of different quarries throughout the hundreds of years of the Roman period. It also examines whether or not X-ray fluorescence (XRF) can be an effective method for defining distinct chemical compositions of local basalt materials from different sources, even when their quarries have not been identified.

Cities of the Roman East reached their peak of monumental construction and growth, mainly during the 1st through early 3rd centuries CE, and utilized centralized quarries and skilled laborers. In contrast, public and monumental structures are much rarer in rural areas. A priori it would seem that the construction of a monumental building in a rural site would share the same quarry and skilled laborers available for the urban center. In this study we examine, for the first time, basalt architectural elements of monumental structures from the polis of Hippos of the Decapolis and the village of Majduliyya in its territorium based on analytical, geological, archaeological, and architectural parameters. Hippos Territorium in the southern Golan is the main focus of an ongoing research project with an overall goal of exploring and defining the cross-cultural and socio-economic relationships between a Roman period city and its hinterland during the Roman period (e.g., Osband & Eisenberg 2018; 2019; Pažout & Eisenberg, 2021). Hippos and Majduliyya (Figure 1) were chosen since they provide chronologically well-defined Roman period contexts and strata of the 1st–3rd centuries CE based on recent archaeological investigation. Our main goal is not to determine the site-specific quarry but rather if the urban center and village both used the same quarry even if its exact location is undetermined.

BACKGROUND

The Study Sites

Antiochia Hippos (Sussita in Aramaic), one of the poleis (cities) of the Decapolis, is located 2 km east of the shores of the Sea of Galilee (Figure 1), in modern Israel. Situated on Mt. Sussita, the city rises to a height of about 350 m above the lake. Antiochia Hippos was founded after the Battle of Paneion (ca. 199 BCE) by the Seleucids. After Pompey's conquest in 64 BCE, the city was incorporated into Provincia Syria. It flourished throughout the Roman period, being the only polis directly next to the Sea of Galilee from the east with a territorium including all of the southern Golan (Pažout and Eisenberg, 2021, 10–14). As early as the mid-4th century CE, Hippos became the seat of a bishopric, and during the Byzantine period at least seven churches were built in the city. In 749 CE, just at the end of Umayyad rule, Hippos was destroyed by an earthquake and never resettled.

Hippos flourished, as did many other poleis during the peak of the Pax Romana in the mid-1st to early 3rd centuries CE. Public and funerary structures in the city and along the mountain's saddle have been uncovered in excavations that began in 2000 and continue to this day in one of the larger Classical-period archaeological enterprises in the Decapolis. A higher resolution of the chronology of these basalt ashlar-built structures in the Roman period has been gained by multiple finds including architecture, typology of decorated architectural fragments, mason's marks, coins, pottery, glass, and fresco (for the various reports see mainly: Eisenberg & Segal, 2022; Kowalewska & Eisenberg, 2019; Eisenberg, 2018; Segal et al., 2014. For the Hippos historiography see Dvorjetski 2014). The basalt quarrying sites of the many public, monumental, and decorated structures of the Roman period have not been identified. The most significant construction boom in the Roman period, for public and private construction alike, demanded centralized organization of raw-material quarrying, transport, architects, stonemasons, and builders.

The village site of Majduliyya is located 14 km north of Hippos (Figure 1). To date, seven areas have been excavated at Majduliyya, revealing a Roman-period synagogue, pottery kilns, olive presses, and residential areas (Osband & Arubas, 2020). Pottery and coins show that the site was already settled in the 1st century BCE and was abandoned at the end of the 3rd century, including the abovementioned synagogue. The first phase of the synagogue was likely built in the Early Roman period (1st century CE) with the building undergoing some changes and renovations until it was abandoned along with the village. This is the only known building in the village with public architectural remains that included column fragments, benches, well-hewn ashlars as well as remains of a mosaic floor and roof tiles. All architectural elements in the village are made of basalt.

There are a number of reasons to assume that the well-dressed ashlars, benches and column remains from the synagogue at Majduliyya would most likely have come from a basalt quarry associated with Hippos. In rural sites in this region during the Roman period only a few sites have shown evidence of public architecture, in contrast with the Byzantine period (mid-4th–mid 7th centuries CE), in which monumental structures were more common in the rural areas (Osband et al., 2020; Ben David 2007). In the case of Majduliyya, only the synagogue was found to have the architectural evidence associated with a public monumental structure. Once the structure was built, except for the occasional repair, there was no need for additional well-dressed, quarried basalt stones. In contrast, the urban center of Hippos with its multiple monumental structures would have necessitated an enormous quantity of raw material and a constant need for quarry workers for sculpting columns and decorated architectural fragments over a long period. We have attempted to determine if the same basalt source was used for the stones in Majduliyya and at least in one of the many monumental structures in Hippos. This is an important aspect in defining the nature of the city-village relationship, especially since Hippos is the closet city to Majduliyya and they are part of the same administrative region.

The Geology of the Golan Basaltic Plateau

The basaltic plateau of the Golan is the westernmost continuation of the Hauran, bordered by the Sea of Galilee and the Dead Sea Rift to the west, by the Yarmuk River in the south, and by volcanic mounds and the Ruqqad River in the east. The basalt rocks exposed on the plateau range in age mainly from the early Pliocene to late Pleistocene and the thickness increases from tens of meters in the south to hundreds of meters in the north (Mor, 1993; Heimann et al., 1996; Weinstein et al., 2006, Weinstein et al., 2020; Behar et al., 2019). The chemical composition of the Pliocene-Pleistocene Golan basalts has been studied (Weinstein et al., 2006), but we have no systematic regional study of the chemical composition of the various basalt outcrops.

In the southern Golan (roughly speaking, the Hippos Territorium), the focus of the current study, the most common basalt layer is the Pliocene "Cover Basalt" (Figure 2). There are two types of basaltic rocks exposed around Hippos, the Miocene "Lower Basalt" and "Cover Basalt," the latter covers most of the region (Sneh 2008). Majduliyya is located on the meeting point of two different basaltic rock flows, Cover Basalt to the north and the younger Pleistocene Dalwe Basalt to the west east and south (Mor, 2012).

To date there are no known quarries of architectural stones in this region. It seems possible that in many instances boulders or portions of the gorges in which hexagonal and pseudo-hexagonal natural basalt stones were exposed were used as a quarry source. Large boulders could also have been a good source of building material (Ben David, 2005). The only definitive basalt quarries identified from the Roman–Byzantine period in the Golan are of olive press remains that were not removed from their quarrying spot.

Chemical analysis of architectural stone remains (as opposed to smaller artifacts) from monumental structures in antiquity such as marble and limestone have been determined through various analytical methods (e.g., Pizarro et al., 2011; Holmes & Harbottle, 2003). In most of these studies the goal was to determine regional provenience or to match artifacts to site-specific quarries. XRF has been used in some geochemical studies of basalt artifacts in order to identify the regional rock formations,

outcrops or even specific quarries from which they were sourced (e.g., Latham et al., 1992; Linthout et al., 2009; Mills et al., 2022).

Geochemical archaeological studies of basalt artifacts from northern Israel and Jordan have focused primarily on relatively small and portable artifacts rather than on architectural elements (e.g. Gluhak et al., 2016). The geochemical compositions of basalt millstones from Tel Hazor were compared to an extensive set of geochemical data on basaltic rocks in Israel. Combined with petrographic features and insights from field surveys, the results show that the raw material was extracted most probably from two different locations, each several kilometers away from Tel Hazor (Gluhak et al., 2022). Around 50 geological samples and small basalt artifacts from the Southern Levant were analyzed using Wavelength Dispersive X-ray Fluorescence (WDXRF) (Philip & Williams-Thorpe 2001). A study of remains from the Byzantine basilica at Abila suggested local basalt source for building stones (Al-Bashaireh & Lazzarini, 2016). A study of the Amman Theater Statue from Jordan used XRF in order to determine potential source sites (Dillian et al., 2022). The current study is unique in that the archaeological question focuses on urban-rural socioeconomic relationships based on a relatively large number of basalt building stones from an urban and village site and is not limited to the question of quarry source.

RESEARCH GOALS

The main objectives of the present study are aimed at determining the chemical fingerprint of the architectural fragments and ashlars in order to broach fundamental archaeological questions of the urban-rural relationship and to address the hypothesis that the regional urban and village sites used the same quarry source. It is important to note that identifying the specific quarrying source was not our objective as there is no known basalt quarry of the Roman period near either of the sites, and it seems that in many cases the natural basalt bedrock provided readily available material for building material from the prismatic stones and weathered boulders that did not necessitate quarrying. A secondary goal was to see if there was a non-destructive, cost-effective

technique in which a relatively large number of stones could be sampled in order to address related questions and future regional and site-oriented research.

MATERIALS AND METHODS

Geological samples were taken from the basalt bedrock from the two main sites as well as from nearby sites for comparison as described in detail below (Figure 3 and Table 1). Basalt was removed either by breaking off a piece with hammer and chisel or by using a drill to remove a core.

Hippos of the Decapolis – Architectural Samples (N=42)

Forty-two basalt samples were taken from various building complexes and installations at Hippos and an additional nine samples were taken from several locations where the Mt.Sussita bedrock was exposed. The city's main construction materials were the two local stones: basalt and a soft calcrete/caliche (*nari*). Two geological samples from bedrock came from ca. 3.5 km east of Hippos, from the area of Afik and two by the road between these sites.

Below is a short description of the various sampling areas, from southeast to northwest.

Water Supply System Stone Pipe

The last segment of the Hippos water supply system before reaching the city was a stone pressure pipe comprised of about 1,000 basalt monolithic drums, which started south of the mount's topographic saddle and ended under the eastern part of the decumanus maximus. Recent excavations along the Saddle Necropolis revealed its original trench and several drum pieces from which samples were taken. The stone-pipe construction is dated to the first half of the 1st century CE (Eisenberg & Kowalewska, 2022: 121–123; Tsuk, 2018: 55). The pipe was dismantled during the Umayyad period (late 7th–early 8th centuries) and was apparently reused in the Umayyad al-Ṣinnabra palace on the southern side of the Sea of Galilee (Alexandre, 2017; Gluhak, 2017). It is the only case at Hippos where a basalt geochemical comparative study was conducted before the present one. The results showed that the basalt pipe drums from both sites are identical. The recent excavations of the stone water-pipe trench at Hippos strengthened this conclusion (Kowalewska & Eisenberg, 2021).

Two Mausolea in the Saddle Necropolis

At least two mausolea distinguished the Saddle Necropolis: the Lion's Mausoleum and the Flowers Mausoleum to its north, both fully excavated. The ground-floor vaulted chamber of the Lion's Mausoleum was preserved, measuring 7.5x7.5 m. The remains indicate that the mausoleum had three stories reaching a total estimated height of at

least 13 m. The mausoleum's construction was dated to the early 2nd century CE and its destruction to the 363 CE-earthquake (Eisenberg, 2021a). Basalt samples were taken from the construction ashlars. The Flowers Mausoleum was named after the phenomenal pieces of its decoration—basalt-sculpted reliefs of flowers that filled the metopes. Only the basalt foundations (5.5x5.5 m) up to two courses high survived. Eighty-four of the mausoleum's basalt architectural fragments have been located so far. The quality of most of the architectural elements is very high and some bear assembly marks indicating the placement of the stones within the structure (Eisenberg & Kowalewska, forthcoming). At Hippos and in the rest of the Decapolis these and other types of masons' marks are dated mainly from the 1st to the early 2nd centuries CE (Kowalewska & Eisenberg, 2019, 121, Table 3; 2020, 86–92; Uscatescu, 2022, 8–9). The height of the mausoleum can be estimated at ca. 14 m. It was constructed in the late 1st century CE /early 2nd century CE and destroyed in the 363 CE- earthquake. Basalt samples were taken from various architectural fragments (Figure 3A1–2).

The Saddle Compound Propylaeum

An extramural compound, estimated at 170x60 m, was built along the western part of the saddle. The entrance to the saddle compound was via a propylaeum of which a large part was excavated. Two square towers (ca. 6x6 m) flanked a 3.65 m-wide single passageway. All the gate's elements are made of basalt. The propylaeum and compound were built in the early 2nd century CE and destroyed in the 363 CE-earthquake (Eisenberg, 2019). Sampling was done from the western's gate tower profiles.

The Roman Basilica

The civic basilica is located in the center of the city, just north of the forum. It measures 30.5x56 m, constructed at the end of the 1st century CE and destroyed in the 363 CE-earthquake. The inner space of the basilica was divided by four colonnades that surrounded the nave and supported the roofing. All of its architectural elements were made of basalt except for a few made of marble. The basilica was built on the basalt

bedrock that covers Mt. Sussita's crest. Basalt samples were taken from the pedestals, column drums, and Corinthian capitals (Fig. 3.A3–5). Basalt samples were also taken from Ionic capitals, which were found in secondary use in the basilica and predate it by about a century (Eisenberg, 2021b).

The Decumanus Maximus and Forum

The decumanus maximus is the city's main colonnaded street, crossing its full length from east to west. The column shaft drums were set atop an Attic base and crowned by Ionic capitals, all made of basalt. The forum plaza was erected in the middle of the mount. The street and forum were all paved with basalt flagstones, about a fifth of which bear accounting mason's marks, while the shaft drums bear assembly mason's marks. The street and forum were built in one stage in the first half of the 1st century CE (Eisenberg & Segal, 2022: 348–349). Samples were taken from various mason's-marked flagstones and column parts.

The Northwest Church

The church was constructed north of the forum. Most of its architectural fragments are in secondary use, taken from Roman construction, apparently mainly from the nearby decumanus maximus. The church was built in the second half of the 5th century CE and destroyed in the 749 CE-earthquake (Młynarczyk & Burdajewicz, 2014). Samples were taken from the architectural fragments in the church atrium. Most fragments are Roman in date while others are from the Byzantine period.

The Southwest Church

An elaborate well-executed, Roman-period Ionic capital was found in secondary use in the Byzantine church and was also sampled (Staab & Eisenberg, 2020: 203).

Majduliyya Architectural Samples (N = 29)

The samples from Majduliyya come from the only public building at the site, which is the synagogue. The synagogue samples came from the column bases (4), drums (4), capitals

(13), benches (5), and an ashlar/building block (1). The synagogue was abandoned in the late 3rd century CE. It is not clear in which of the building phases (1st–early 3rd centuries) the architectural elements were sculpted. It seems that the first phase was in the 1st century CE, after which the building continued to undergo changes. Some of the samples came from a coarser-looking basalt. Some of the column fragments and benches bear mason's marks, of which six were sampled (sample IDs: BLT011, 013, 016, 017, 018, 019).

Majduliyya Olive Presses N=3

Samples were taken from olive presses found in various places on the edge of the site, from pressing installations (2) and a crushing basin (1). These were important not only in comparing them with the stones from the synagogue but also with the bedrock west of the site where evidence for the hewing of a crushing basin was found.

Natural Basalt Rock by Hippos N=11

Nine of the samples came from bedrock at the site and from two km southeast of the site. While none of these appeared to be a quarry, it was important to determine if there was similarity between the chemical composition of the basalt from the architectural samples and the natural rock on the nearby hills.

Natural Basalt Rock by Afik N=2

We also sampled bedrock near Afik which is about 3.5 km east of Hippos and was one of villages at the Hippos Roman-period Territorium (Pažout & Eisenberg, 2021: 6, 13), to see if any notable difference could be discerned in the chemical composition within the Cover Basalt.

Natural Basalt Rock at Majduliyya N=9

Geological samples from three different areas of the site were included. On the eastern side of the site, north of a pottery kiln is an area of bedrock that may have been used as a quarry (n=5).

Another sample was taken south of the synagogue (n=1) and other samples directly west of the synagogue wall (n=3), where there is exposed bedrock that may have been worked.

Natural Basalt Rock above Samekh Gorge N=2

At this spot part of an olive press was found that was hewn from the natural bedrock but never removed. It is the closest site to Majduliyya where there is clear evidence of stone hewn from the natural bedrock. It should be noted that no evidence was found here of building-stone quarrying.

XRF Method

A small piece of basalt was sawed, cored or broken off from the various architectural or geological stones and submitted for XRF analysis. The chemical composition of the stone was determined by using the Bruker Tracer 5i ED-XRF, which is a handheld portable unit. The instrument has a rhodium-based X-ray tube that operated at 50 kV and a thermoelectrically cooled silicon detector. The samples were counted for 20 seconds to measure the minor and trace elements present. The elements measured included Rb, Sr, Y, Zr, and Nb.

The available calibration for obsidian uses a new set of 37 very well-characterized obsidian sources with data from previous ICP, XRF, and NAA measurements (Glascock & Ferguson, 2012). Quantitative XRF analyses generally improve when using a matrix-specific calibration, but we have not developed a calibration specific to basalt. The different matrix, combined with different ranges of elemental concentrations, make the quantitative results of analyzing basalt with an obsidian calibration precise but not accurate. However, large, patterned differences in concentrations are still observable

even if the accuracy of the quantitative results is unreliable. In addition to the semi-quantitative measures, direct comparisons of the raw spectra were undertaken.

RESULTS

The results are presented using a series of bivariate plots. In the plot (Figure 4) of Nb and Sr there is no overlap between the samples from Majduliyya and Hippos, and they cluster into distinct groups. All of the Majduliyya architectural samples are higher in Nb than the Hippos samples and nearly all are higher in Sr. One olive-press sample from Majduliyya and one architectural sample were low in Sr and one Hippos sample from a stone pipe was higher than the other Hippos samples. This is part of the water supply system to the city and may explain why it differs from the other architectural stones. It is important to stress that the results are internally relative and not meant to accurately quantify the chemistry of the samples.

The Hippos architectural samples and surrounding geological samples are shown in Figure 5. It should be remembered that these are general samples and not from quarries, as there are no clear indications of basalt quarries at these sites. Almost none of the bedrock samples taken from inside and close to the site overlap with the architectural samples, with the exception of BLT008. The two samples from Afik are closer in composition than those from Hippos but also do not fall within the main cluster of architectural fragments.

The Majduliyya architectural samples and surrounding geological samples are shown in Figure 6. In contrast with the Hippos results, there is a clear overlap between five of the Majduliyya geological samples and the cluster of the architectural samples. The only known quarry source near Majduliyya is an olive press that was left in its quarried spot above the Samekh Gorge. These two samples are outliers from the main cluster and are also distinct from the other olive press remains sampled at Majduliyya, two of which have similar compositions to the architectural samples.

The most distinctive differences between the architectural remains from the two study sites were between the elements Sr and Nb were found to be the most distinct. In

archaeological basalts analyzed from Hawaii these two elements were among those that were relatively unaffected by weathering, making them good indicators of the original chemical composition of the artifacts (Lundblad et al., 2011). These elements were also among those noted to have been found to be distinguishable between Pliocene and Pleistocene basalts in the Golan (Weinstein, 2005: 324–325) and may reflect the differences between Cover Basalt as a source for Hippos stones as opposed to the Dalwe basalt as a source for Majduliyya stones.

DISCUSSION AND FUTURE RESEARCH

Based on the results presented above, the following can be suggested:

1. Hippos and Majduliyya did not use the same quarry or outcrop for the architectural stones used in their respective monumental structures.
2. At Hippos only one of the geological samples from the site is close to the architectural chemical cluster, suggesting that the stones were quarried from farther away.
3. The area by the Samekh Gorge, from which remains of a partially quarried olive press were found, was not the source for stones or olive presses at Majduliyya. It seems that the Majduliyya stones may have come from near the site.
4. All of the Roman-period architectural fragments sampled at Hippos were quarried from basalt outcrops with a similar chemical composition that functioned throughout at least two centuries.

Most of the architectural fragments at Hippos showed similar chemical compositions. This was surprising as they are from different buildings, some of which are hundreds of meters apart. Further investigation with additional methods is needed to determine if they originated in one quarry. It seems likely that the Majduliyya stones came from a source close to the site, whereas the distance between Hippos and its basalt quarries was greater. It was not yet possible to determine where the basalt quarry was located.

The samples in the cluster from Hippos come from different buildings and suggests that they may have come from a single quarry or at least from the same general area. Determining the actual quarry and if there are multiple composition groups and therefore multiple quarries or loci within a quarry (or if quarries themselves contain multiple composition groups) would require a much larger area of sampling and the creation of a database which is not currently available. The variance in composition among stones in one basalt quarry may in fact be high even though our initial results, on the contrary, showed that the clusters are distinctively homogenous among themselves while clearly differing from each other and even from geological samples nearby. By

limiting our focus to the archaeological question of urban-village relationship, XRF was capable of directly addressing this question.

Future regional research will need to focus on determining the location of the basalt quarries themselves and the geochemical compositions and variations of lava flows from specific areas. In addition, if there are multiple sources for the stones at each site, as appears to be the case, determining provenience groups may require a higher precision than ED-XRF can provide, and it is not clear if they will be able to be matched to a possible source. The consistent promising results from various architectural basalt elements within a single site, from Hippos, should be followed by future research aimed at the determining smaller-scale groups and clusters of the various buildings at the site, while trying to correlate the results to absolute chronology, style and basalt workshops artisans.

The application of the methodology in this case study provides a new possibility for exploring urban-rural relationships as well as other inter-site and intra-site socioeconomic aspects by comparing the chemical composition of basalt building materials. The results suggest that basalt architectural stones from additional sites would give an even deeper understanding along with more traditional methods such as pottery provenience studies. The results also show that while determining the exact quarrying source would be important, since in many cases for basalt this is difficult, it should not be considered a prerequisite; important information can be gleaned by sampling a variety of structures within a site, as well as different types of architectural stones from a single structure at a site and comparing the data between sites.

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FIGURE 1 Map of Study region with sites mentioned in the article.

FIGURE 2 Geological maps of the sites in the region studied.

FIGURE 3 Architectural stones sampled from Hippos and Majduliyya (photos: M. Eisenberg and M. Osband).

FIGURE 4 Bivariate plot of all samples.

FIGURE 5 Bivariate plot of architectural and geological samples from Hippos.

FIGURE 6 Bivariate plot of architectural and geological samples from Majduliyya.

TABLE 1 Sample list and type.

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