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Quarrying and construction operations in Aeolian Larisa with a reference to "building technology" and "building economy"

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Abstract
Building technology and building economy concepts are relatively new, important research subjects in archaeology. While the term "building technology" refers to technical processes and methods of construction operations such as exploitation, transportation, processing and fine dressing; "building economy" focuses on costs and consumption of resources or quantification of labor forces and costs, etc. Either way main purpose is to apprehend the background of the operations. These studies involve several researchers from various disciplines and each of them contribute according to their expertise, which ease to enrich these research areas. Quarries are initial points of construction operations and they provide useful information regarding building technology and building economy. In Larisa, observations on quarrying and as well as construction processes proceed cordially with the ongoing architectural field surveys which are being conducted since 2010. Observations have showed that every rock cluster in and around the Larisa settlement have been used as a natural resource material for the constructions. More than a hundred traces of stone extraction have been identified and have been documented through drawings and photographs. Besides, most of them have been manually recorded by a handheld GPS and were gathered in a detailed catalogue, according to their places. Thus, the applied method and the entire quarrying process can clearly have been identified through these traces. According to these marks, it is understood that levering and splitting were principal stone exploiting methods that were used in Larisa which have been applied by the entire Mediterranean & Mesopotamian civilizations throughout the centuries.

Keywords
Andesite, Building economy, Building technology, Larisa, Quarries.

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1. Introduction

In recent years, building technology and building economy have become increasingly pivotal and affluent research subjects in archaeology and history of architecture. The term "building technology" refers to technical processes and methods used in construction operations. The related topics of building technology include the exploitation or the production of raw materials, choosing the convenient building area and transportation of materials to the construction site, the tools that were used during different stages of these operations, and the construction operation itself. "Building economy" focuses on the consumption of resources, labor forces, and building costs. In other words, quantification of the expenditure on money, quantification of working hours, and energy consumption for building activities are among the topics of the building economy. Thus, the building technology and the building economy aim to explain the background of an ancient construction project thoroughly. (Martin, 1965; Martin, 1973; Glotz,1965).

Every construction project in the antiquity comprises several stages involving many different actors. Benefactors, architects, contractors, decision makers, construction/building commissions, workers, slaves, stonemasons, sculptors, carpenters, and blacksmiths, among others. The process starts with planning, and continues with providing or manufacturing raw materials, logistics, constructing, and maintenance.

Through excavations, field-surveys, studies on written and epigraphic sources, evaluations and analogies, a considerable amount of literature has been published on every stage of a building operation diachronically or on regional-local basis. Thanks to these studies, many details of ancient constructions have been revealed, and the background of these operations were apprehended clearly.

Besides being an interdisciplinary working area, studies on the building economy and building technology gather diverse experts from various disciplines, including archaeology, architecture, art history, urban planning, geology, sociology, economics, and anthropology, which enrich these studies in a broad sense. As a result, with joint efforts and collaboration of these experts, construction processes can be evaluated from different perspectives.

Quarries are initial spots of construction operations, and they provide useful information on building technology and building economy. They provide not only technical information such as extraction methods and tools used in order to get blocks, or the quantity of gained material or labor forces, but they also contribute to the understanding of the socioeconomic status of the cities, including their prosperity. Quarry areas and quarrying organizations may vary in relation to the economic situation, scale, or construction activities of the city. Some of them covered enormous areas, some were well-organized and well-established. For example, Gebel el Silsila sandstone quarries served throughout New Kingdom in Egypt or Naxian marble quarries in Greece were among the famous well organized quarrying areas of ancient the world. Some of them were smaller and they did not necessitate wide-scale organizations. In either case, these worksites had independent functions, and they were an important part of the economy which indicated potential labor forces, production force and capacity which would clarify "social business space" of a city besides giving technical knowledge on obtaining raw materials and construction. As part of the scope of recent field works at Larisa (Aeolis), quarrying operations, as well as construction processes have been explored systematically[1]. This article aims to contribute to the growing area of research on building economy and building technology by featuring the case of Larisa focusing on the site's quarrying and construction operations, and the related questions.

2. General information and research history of Larisa (Buruncuk)

In ancient times, the region along the Aegean coast and inland between Adramyttion (Edremit) and Smyrna (Izmir) was defined as Aeolis. Larisa on the river of Hermos (Gediz) was

one of the prominent cities of southern Aeolis. The hilltop over the modern Buruncuk village near Menemen, Izmir bears the ruins of ancient Larisa. The ancient settlement occupied two hilltops expanding from the Sardene (Dumanlı) volcanic mountain towards the Hermos Plain (Figure 1). Larisa surely benefited from Hermos River and the valley, which provided wealth and abundance to its inhabitants. The earliest settlers of the city were apparently indigenous people (e.g. Lelegians and Pelasgians), who were residing in the entire Aegean region before the arrival of Greek tribes (Doğer, 1998).

Figure 1. *Larisa and neighboring settlements locating upper part of western Anatolian coast (Külekçi, 2021).*

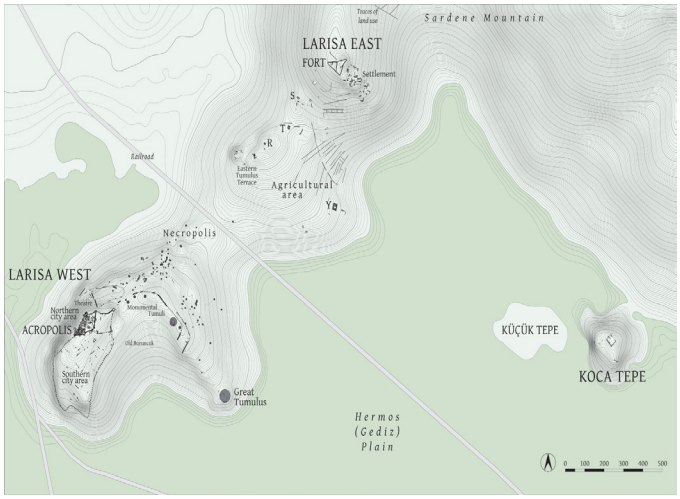

Figure 2. *General settlement plan of Larisa (Buruncuk) (Külekçi, 2021).*

Archaeological finds reveal that the settlement history of Larisa dates back to the Neolithic period. Some wall fragments and small finds from the Bronze Age are also apparent (Özdoğan, 2018, 125). However, the visible architectural remains today belong to the time between the 6th and 4th centuries BCE representing primarily the Greek and Greco-Persian layers. The inhabitants of the city abandoned Larisa abruptly by the beginning of the 3rd century BCE. Due to the lack of Roman and Byzantine settlement layers, Larisa mainly shows the characteristics of an early Greek settlement (Saner, 2018, 14).

The remains of Larisa can be seen at the top of the two hills mentioned above. The area between these two inhabited hills, shows traces of farm buildings and agricultural terraces. The lower hill 100 m. above the sea level, is defined as Larisa West while the higher one, in the East of 180 m. altitude, as Larisa East. Both are residential centers and they represent unique characteristics by means of social dynamics, and structures[2] (Figure 2).

The main settlement Larisa West consists of three districts. The acropolis is surrounded by defense walls, and it houses residential buildings of the rulers, as well as several sacred and public buildings. The urban areas consist of dwellings of the prominent families of the city and a wide necropolis has developed next to the urban center. The higher hill "Larisa East" has two major sectors. One is a triangular-shaped fort probably established during the 5th century BCE. Its construction was closely related to the construction projects of the western acropolis. The fort must have served as a shelter for the eastern dwellers and for Larisa West's

residents in case of a threat or a siege. The other sector in Larisa East is defined by the settlement area, which occupied the terraces that lead towards the Hermos Plain. In this area, there are ruins of simple dwellings meant for the eastern residents of the city, who were most probably responsible for the general logistics (Külekçi & Saner, 2021). Two hillocks rising in the level of Hermos Plain are also considered as parts of Larisa. While there are no traces of buildings on Küçük Tepe, Koca Tepe houses a monumental building, probably a farmstead with thick walls and a courtyard.

In 1902, the first excavations began as the joint effort of Germany and Sweden. Johannes Boehlau, archaeologist and museum curator from Kassel (Germany) and Lennart Kjellberg, archaeology professor from Uppsala University (Sweden) conducted the first excavations in Larisa. Kjellberg's primary motivation was to explain the bonds between Mycenaean culture and orientalizing Greek culture through studies on the history of ornament. Larisa was specifically chosen to be excavated, and to support this hypothesis. The field works terminated after three campaigns held between 1932 and 1934. A three-volume book entitled "Larisa am Hermos" was published consecutively in 1940 and 1942. After the field campaigns, the publication of the results and some further studies in the Istanbul Archaeological Museums, no other work was done in Larisa until 2010[3] [4].

Since 2010, a team from Istanbul Technical University under the directory of Turgut Saner has been conducting an architectural-archaeological field survey. The new studies focus on the documentation of settlement patterns, features of the architecture and construction techniques. Observations on the wider settlement areas have already provided a completely new comprehension of Larisa's urban character (Saner, 2016, 62). A considerable part of the documentation works at Larisa has been devoted to the activities of the ancient quarries, which have remained beyond the scope of the early 20th century field works. The location of ancient quarries and stone extraction techniques were documented with the help of the traces left on solid bedrocks and building blocks[5].

3. Geology of the region and characteristics of the local stone

Geographical formations directly influence the development of the cities in all spheres. Thus, it is crucial to understand the geological and geomorphological essentials around Larisa (Kayan & Öner, 2016, 17) where constructions were primarily based on local andesite.

As mentioned above, the settlement hills of Larisa are natural parts of the volcanic Sardene (Dumanlı Dağ). Kayan and Öner (2016) identified that Dumanlı mountain is a complex volcanic mountain with a wide caldera, which was cut by a recent fault zone running NW-SE. An elongated andesitic ridge which extends from the southern part of this caldera dominates a part of the Hermos Delta Plain, one of the largest coastal plains in Turkey[6].

Hermos Delta Plain and its vicinity are enclosed by high mountains and natural gorges (Kayan & Öner, 2016, 9). Mountain ranges that tend towards east-west and major rivers flowing between these depressions have generated geomorphological formations of the Aegean coasts of Turkey (Kayan & Öner, 2016, 9). Essential fault zones likewise have an important contribution to the formation of the region. In Larisa's case, Dumanlı and Yamanlar mountains determined the basic formations, whereas the natural gorge of Menemen between them marks the link to the interior fertile alluvial plains of Hermos valley (Kayan & Öner, 2016, 8). Another gorge between the Dumanlı mountain and the hilly area of Foça (anc. Phokaia) also provides a natural passage to Kyme, an important harbor city, and to the northern Aegean coastal zone, including Bakırçay-Bergama inner planes (Kayan & Öner, 2016, 8). Provided by these ravines, Larisa possessed a wide and rich hinterland, extending to the inner parts of the Aegean region (Kayan & Öner, 2016, 8). Hence, Larisa's strategic location on the inner edge of the Hermos Delta Plain did not only provide an advantage of dominating and controlling the plain

but it also ensured safety against direct attacks from the sea by being distant from the coast (Kayan & Öner, 2016, 9). The position of the city dominating the fertile Hermos Plain also had control over natural trade routes between the north-south Aegean coastal zones (Ionia and Aeolis) and the roads coming/leading from/to interior regions (Lydia) (Kayan & Öner, 2016, 8).

The actual form of the Hermos Delta Plain has developed as a result of neotectonics during the third geological period, especially the Neogene (24-2.5 million years ago). Severe and long-term volcanic actions occurred as a result of these tectonic events (Kayan & Öner, 2016, 11). Landforms have developed on these volcanic formations, and as a result, the whole area now has a volcanic character. During the Neogene, the territory was covered by pyroclastic material at first, then it was covered with andesitic lava (Kayan & Öner, 2016, 11). Dumanlı mountain, where the city was founded, is a part of these formations and the resources for the Larisaean buildings were obtained from these andesitic forms.

Andesite is an extrusive igneous (magmatic) rock with porphyritic texture. Specific combination of minerals, chemical compositions and igneous textures generate different types of igneous rocks. (Erinç, 1982). Extrusive igneous rocks usually form from a volcano (in Larisa's case it is the Dumanlı Mountain), therefore they are called volcanic rocks. Andesite is hard and resistant to deterioration, and so it is considerably difficult to be processed. However, it is also suitable for architectural purposes. Just as in Larisa, in some other neighboring ancient settlements (e.g. Neonteichos, Kyme, Phokaia and Gryneion) andesite was preferred in the construction of various edifices.

Figure 3. *Multi-colored andesite block application from Larisa West.*

Andesite is composed of several minerals, predominantly hornblende and plagioclase. The minerals Fe- and Mg-rich silicates give andesite its color in accordance with their concentration (Erinç, 1982). The regional andesite presents wide range of colours of bluish grey, reddish-brown, or deep violet and sometimes even different tones of pink, plus dark basaltic versions. On-site observations have shown that this diversity of colors does not refer to a distinction between quarries; stones with all primary color groups may appear at the one and same quarry in Larisa. In Larisa East, the reddish-brown variation is predominant. Multicolored stones were randomly used together within the masonry (Figure 3). Practical usage of quarries with a minimum loss of material was apparently the main concern and considered as being more important than decorative purposes.

4. Settlement plan and quarry areas

As mentioned above, quarry areas may differ, depending on the economic situation, scale, or necessities of construction activities of the city. Quarries (including minor stone sources) may exist close to the city and sometimes they are even located inside the city. Thus, the quarrymen could easily reach out and operate them. For instance, in the ancient sites such as Athens, Piraeus, Mycenae, Delos, Syracuse and Akrai, quarry areas existed inside the cities. In Demetrios, Piraeus, Aegina, Corinth, Paros, quarry areas lie along the defense walls (Dworakowska, 1975, 94-95). However sometimes, quarries were opened far from the city, and they thus became independent operations which could occasionally be used for commercial purpose as well. The stones of Parthenon were brought from the Pentelikon quarry located 17 km away

from the construction site. Although closer quarries existed, Pentelikon was chosen for its marble's high quality (Korres & Vierneisel, 1992). Similarly, in ancient Egypt, limestone and sandstone quarries located on either side of the Nile were preferred for the buildings; however, rather than their easy access, the character of the rocks was more important (Harrell & Storemyr, 2009, 29). Either way, the main purpose was to obtain suitable raw material for constructions.

Steep, rocky slopes of the settlement and free-standing rock clusters in and around the settled areas of Larisa were completely used for stone extraction purposes. They were apparently considered as the most convenient locations for transportation. Almost every convenient piece of rocky fields were used in constructions. Quarry areas existed inside the settlement of Larisa and they extended along the city walls. So far, a hundred and fifty traces of stone extraction activities have been identified and documented through photographs and drawings. The locations of most of these traces have been recorded by a handheld GPS in order to accomplish a detailed catalogue. The applied methods and the entire quarrying process are apt to be clearly identified through these traces.

Quarrying activities form four major groups in accordance with their areas: Larisa East, Larisa West, Koca Tepe-Küçük Tepe and the area between Larisa East and West –some areas present sub-groups. Each area has a specific code that simplifies to determine the extraction marks which form the catalogue[7]. Determination and classification of quarry areas in Larisa facilitate correlating quarry areas to buildings. In addition, it eases understanding the details of quarrying and construction operations from extracting to transporting, fine dressing and positioning/placing.

4.1. Larisa West

As previously described, acropolis, necropolis and the urban areas altogether form Larisa West, the main settlement of the wider city organization. The acropolis was surrounded by archaic and classical defense walls. Old and new palaces, buildings such as the Megaron, temple with altar, propylon, as well as the Northwest Building are to be found inside the walls, along with storages and wells. The southern and northern slopes of Larisa West were occupied by urban areas (Saner, 2018, 242). The steep northern slope was furnished with the theater and fortification walls (Külekçi & Saner, 2021). North-eastern and eastern slopes of the hill are dominated by an extensive necropolis with different types of grave units, predominantly tumuli. Quarrying activities in Larisa West have been identified in four different areas, northern quarry area, southern quarry area, acropolis and necropolis.

4.1.1. Northern quarry area

Starting from Tower F, anti-clockwise through western slopes of the acropolis, northern, north-western and western slopes of Larisa West all are considered part of the northern quarry area. On the east of tower F, which faces the abandoned village of Buruncuk and necropolis, massive rock clusters present numerous extraction marks. Above the northern quarries (with leftovers of now abandoned 20th century quarrying) on higher levels, there are traces of ancient quarrying activities on the surfaces of rock bundles. Twenty-eight extraction

Figure 4. *A column shaft which is prepared for extraction but left in situ.*

marks have been identified on the northern quarry area and, additionally, there is a column shaft lying in situ on a bedrock, prepared for extraction but left unfinished (Figure 4).

4.1.2. Southern quarry area

The second group of extraction marks defined as southern quarry area stretches along the southern and southeastern slopes of Larisa West; it marks one of the major quarrying areas of the entire settlement. Generally, small or large free standing rock clusters in and around the settlement have been used for extracting blocks. Only in the southern quarry area existed a true quarry façade overlooking the old Buruncuk village (Figure 5). Besides, there are many free-standing rock bundles which still show traces of ancient quarrying activity. Traces extend all along the city walls of the settlement, and this area must have been used to provide building material for both the outer ward and the course of the fortifications. Fifty-one different well preserved extraction marks have been identified here.

4.1.3. Acropolis and the urban area

Inside the acropolis walls and in the urban area in the south, twenty-two different exploiting marks have been documented. Some traces are found on the rock surfaces, whereas others have been identified on the blocks inside the building remains. The latter observation is important not only to understand particular extraction techniques but also to date these applications that were commonly used in Larisa. Accordingly, the earliest practice with wedge-holes has been noted at the early 5th century BCE circuit of the acropolis.

Figure 5. *A quarry detail of the long quarry wall in the southern quarry area in Larisa West which is facing through old Buruncuk village.*

4.1.4. Necropolis

Eighteen different extraction marks have been identified in the necropolis area. The quarrying activities carried out in the necropolis were rather limited to free standing rock clusters. Along the slopes below the monumental tumuli (on which the ruins of modern windmills rest), bordering the northern part of old Buruncuk, there are many rock clumps that carry traces of various extractions. The area around the Great Tumulus, which was built on a steep cliff that overlooks the Hermos valley, bears extraction traces apparently related to the construction of the tumulus. One is found next to the probable grave chamber of the grave mound. Besides, the traces along the circle of the tumulus show that the bedrock was smoothed to hold the architectural blocks of the krepis wall.

4.2. Larisa East

At the top of the eastern hill, a triangular shaped fort with cisterns inside and a housing area on the southeastern terraces define the eastern settlement. The Lesbian masonry of the fort with distinct similarities to the fort of Larisa West (early 5th century BCE) suggests that the former was built during the extensive construction project applied onto the western acropolis. The whole eastern area presents a steep topography which divides each housing terrace with big rock clusters that were used as a resource for building material both for the dwellings and the fort. Building blocks of the fort were obtained from higher levels, especially from the rock clusters in its north-northeastern parts, as exemplified by numerous quarrying traces. The dwellings' blocks have been exploited from the rock clusters nearby, on the same level as the dwellings. Twenty quarrying marks have been identified so far in Larisa

East, but it is evident that there should be many more.

4.3. The area between Larisa East and West

Today, the area between Larisa East and West is divided by a railroad (İZBAN) connecting Izmir to northern towns. The southern part of the railroad close to the level of the plain was part of the necropolis, while the northern part is occupied by the ruins of ancient agricultural establishments. Three enormous bulks of rocks with numerous extraction marks have been identified near this area. One of them is close to Building Y, while the other two are located around Building R. These rock clusters were probably used as a resource material for the construction of agricultural buildings and grave mounds here.

4.4. Koca Tepe and Küçük Tepe

The hills, called Koca Tepe (Big Hill) and Küçük Tepe (Small Hill) on the level of Hermos Plain, are considered as part of the Larisaean territory. Ruins of a monumental farmstead (5th or 4th c. BCE) are to be found on Koca Tepe, where seven groups of quarrying traces have been identified. Rock clusters here were obviously used for the construction of the farmstead and related buildings. On Küçük Tepe, no traces of buildings exist. However, there are many extraction traces identified on the rock surfaces suggesting that this area served the construction process on Koca Tepe.

5. Quarrying and construction process in Larisa

The remains of Larisaean constructions are mostly preserved up to a modest height. Foundations, retaining walls and independently rising wall sectors are all made of andesite obtained from nearby quarries or rock clusters. Upper parts of the walls were constructed of mud brick and timber and they disappeared throughout the centuries. Many different tones of local andesite are to be seen in the foundations, at the wall bases, walls and also at moulded architectural elements. In addition to andesite, a local tuff called "Phocaea stone" was also used primarily for the production of architectural elements, such as column capitals and frieze blocks. Additionally, a somewhat shiny white flat limestone can be seen inserted into the masonry as well. The majority of these stone building materials consists of andesite, and quarrying and construction processes can be traced via andesite quarries which exist in the vicinity of the settlement. Stone extraction marks are scattered all over the rock clusters, therefore it is very easy to understand the extraction methods applied for the Larisaean constructions.

Studies have shown that there were basically three types of block extraction methods in the ancient world: levering, splitting or channeling. Levering

Figure 6. *Different type of stone extraction marks on the quarry wall. Upper part of the rock, a single wedge mark was left on the surface for splitting (S); on the bottom-front of the rock, possible lever/crowbar mark was left for levering (L).*

refers to inserting levers, crowbars or stone tools into the stones to expand open fractures, splitting means creating fractures by strokes with a sledge-hammer and wedging, channeling (carving) points out opening channels on the rock by carving with hammer and chisel, pickaxe or stone tools, heating with fire, sawing or drilling[8]. Either of these methods or a combination of them were used in the ancient world for extraction purposes (For detailed information please see Quarryscapes project fact sheet nr.5, URL-1). At Larisa, the traces indicate that levering and splitting techniques were used to exploit the natural andesite (Figure 6). Numerous wedge marks and grooves have been identified on the surfaces of rock clusters (and worked stones).

Figure 7. *Wedge marks showing before the splitting process.*

Figure 8. *Wedge marks showing after the splitting process.*

Markings left by wedge holes and grooves reveal different dimensions, positions and numbers.

Depending on the quarrying method, two types of splitting holes can be identified: narrow-linear and wider regularly carved channels (or grooves). The narrow-linear channels are divided lengthwise into two sub-groups. These marks obviously served for the splitting of small or middle-sized blocks from the natural rock. In several cases, a single line 20-30 cm in length (occasionally even longer), 1-2 cm in width, and of 3 cm in depth can be observed on the surfaces. The other group is a series of wedge holes with each one much shorter than the previous type. These wedge-holes are about 8-12 cm long, 1 or 2 cm wide and 3-5 cm deep –the dimensions change occasionally. The distances between the wedge holes are generally 3-4 cm and each row comprises an average of 3-5 or 8-10 holes. Some of them were directly set on the surface, while the others were carved slightly deepened on the surface of the rock to form a channel. These channels can be considered as the preliminary stage of opening smaller holes on the surface. Apart from the longer or smaller/shorter wedge-holes, there are also a few cases with larger openings, which are arranged in a right angle to each other. These are 70-90 cm long, around 10 cm wide and 10 cm deep. This method seems to differ from the widespread method of splitting through other types of wedge-holes. The significant distinction is the regularity of placing of the openings/channels. The quarrying marks identified in Larisa refer either to the preparation for block extraction or to the current state after the extraction from the bedrock (Figure 7 & Figure 8).

In contrast to the considerable number of examples of block extracting marks, later processes such as transportation and lifting, can only be scarcely followed. However, there are a few examples of bosses left on the front surface of the blocks, which refer to transportation and lifting. Transportation methods depended on material or scale of the building elements or distance of the quarry site (Wright, 2000; Orlandos, 1966; Martin, 1965). Architectural

elements were transported via water or land, using ropes, sledges, wheeled systems, levers etc., including animal and manpower (Wright, 2000; Orlandos, 1966; Martin, 1965). It is unclear how the Larisaean quarrymen and workers transported building blocks from the quarry area to the building site. However, regarding the distance of the andesite quarries to the construction sites and regarding the block sizes, only a modest number of workers for each block must have been involved into the process. Cranes or pulleys must have been used for lifting as well. Architectural elements made of Phokaia stone, which was extracted quite far from the settlement, must have been transported via water (Hermos River) and land route. Finally, limestone should be brought from Yamanlar Dağ area.

There are also traces of stem-holes that were opened on the upper surfaces of the blocks, which was meant for fine placement of the blocks with the help of metal levers or crowbars. Finally, there are traces of metal clamps which were used for attaching and securing building blocks. Regarding the general knowledge on quarrying activities and construction processes in ancient times (Wright, 2000; Orlandos, 1966; Martin, 1965) and the traces of the tools remained on the surface of the blocks and rocks, it can be said that hammer, pick, pointed and flat chisels made of iron must have been used for quarrying and carving in Larisa. Other than these fine dressing tools; ropes, levers, crowbars, pulleys, cranes and measurement tools must have been used for transportation, lifting and positioning of the blocks and other architectural elements as well.

So far, technical details of the construction processes were discussed, starting from the quarrying stage to the erection of the buildings based on the surviving wall fragments, architectural elements and blocks or the traces which were left on quarries. In contrast to the technical part of the construction process (building technology), direct data for the building economy perspective are inadequate due to the lack of epigraphical and other written sources. A number of examples from well-known sites such as Erechtheion at Athens, the Temple of the Olympian Zeus at Akragas, the Temple of Apollo at Didyma give detailed information on opening quarries for a specific construction project, construction operations, labor costs and raw material costs, workshops, even the names of the benefactors, members of building commissions, architects and stonemasons. Hence, the data enable the quantification of the expenditure on money, quantification of working hours, and energy consumption for building activities (Bingöl, 2012; Wesenberg, 1985; Gruben 2001; Tuchelt, 1992). In Larisa's case, these calculations are hard to indicate. Nevertheless, the results of the architectural field surveys and excavations enable to estimate at least the dynamics of the socio-economic aspects of Larisaean building operations. An overall idea can be given about the parties involved in these projects, as well as the decision-makers and benefactors.

Technical aspects of the Larisaean constructions can be well understood based on the traces of quarrying actions. The lack of written sources prevents the calculation of labor force, labor costs and resource material costs, which actually constitute an important part of the economic aspects, from the planning to the finalization of the projects[9] [10]. It is unclear how many workers, stonemasons and craft workers were in charge of these operations. The blocks prepared for constructions at the southeastern quarry were generally "middle-sized", i.e. 70x70 cm., which two or three trained workers possibly detached, roughly processed and moved on short distances. This must have occurred so during the construction of the 4th century BCE city walls along the east slope, where a considerable part of the southeastern quarry existed. Workers who had completed the first stage must have handed over the blocks to the skilled masons for further treatment. The more or less identical, rectangular blocks must have been accurately placed into the wall immediately after the fine workmanship. The front side of these blocks are rusticated, whereas the rear sides were left uncarved. The entire course of the eastern wall is ca. 79,5m., it consisted

of an outer and an inner shell, however, the height is unknown, thus it remains hard to estimate the total number of quarry workers and skilled masons who were involved.

The overall operations of quarrying and construction in Larisa must have been organized under the supervision of a small commission consisting of the ruler of Larisa and "specialists" among the elite inhabitants of the city. A chief architecton must have been in charge of the projects and coordinated the quarrymen, stonemasons and craftsmen (including producers of mud brick and carpenters according to the nature of the construction). The necessary labor force for all stages must have been provided by the inhabitants of Larisa East considered as actors of logistics. As for the skilled masters and stone carvers; it is not easy to reconstruct the share of the locals and of foreign workers. The locals might have worked side by side with craftsmen invited from outside the city as it was the case with the architectural terracotta plates and other roofing elements[11].

Depending on the scale of quarries and the amount of exploited material, it seems that Larisaean quarries fulfilled the demands of the city, and the quarrying operations seem to have been small-scale but well-organized and they were not meant to be part of a wider commercial undertaking. Stones were exploited from the most convenient areas nearby, they were divided into sizes that were asked, and were practically (easily) transported to the construction site, a process, which aimed at cutting down the expenditures.

The entire area of the ancient settlement is full of extraction marks, especially wedges, and it is very likely to increase the number of these examples. However, the variety of extraction techniques would not differ that much. Levering and splitting techniques have been applied by the entire Mediterranean & Mesopotamian civilizations throughout the centuries, and these were practiced as principal stone exploiting methods in Larisa too. In Larisa, these techniques were used since the late 6th or early 5th century BCE for extracting andesite blocks from parent rock and dividing them into smaller pieces. Picks or pickaxes, wedges, hammers, chisels, levers and crowbars must have been used for these purposes.

Many unanswered questions still remain on the economic and technical aspects of the Larisaean quarrying and constructing operations. To develop a full picture of construction operations in Larisa, especially the progress of quarrying and the later stages after quarrying, such as transportation, fine dressing, etc., additional studies are needed. Quantification of the expenditure on money, working hours, and energy consumption for building activities need to be discussed and calculated at least hypothetically on the basis of the already gained data.

Endnotes

[1] For detailed results and reports of the Larisaean architectural surveys, see: Saner, T., Külekçi, I., & Öncü, Ö. E., 2018; Saner, T., Külekçi, I., & Mater, G., 2017; Saner, 2016

[2] Ilgın Külekçi studied the settlement structures of Larisa in her doctoral dissertation (Istanbul Technical University Graduate School, Architectural History Program).

[3] Excavation and research history of Larisa were examined by Gizem Mater in her Master Thesis (Istanbul Technical University Graduate School, Art History Program)

[4] The results of the 20th century excavations of Larisa were published under the name "Larisa am Hermos" in three volumes. The first volume gives general information about the geography and history of the city and gives detailed discussions on the architectural remains which were unearthed during the campaigns. A comprehensive list of the architectural stone pieces is also included. The second volume displays the architectural terracotta plates and other small terracotta finds studied by Lennart Kjellberg. The third volume provides a complete catalogue of the small finds of Larisa, including the descriptions and historical dating of each object. For more information, see: Boehlau & Schefold 1940; Åkerström & Kjellberg 1940; Boehlau & Schefold 1942.

[5] Quarrying operations in Larisa are

being examined in Mater's doctoral dissertation.

[6] For more information on paleogeography and geoarchaeology of Larisa see Kayan & Öner 2016.

[7] Stone extraction marks which were documented during field surveys were gathered altogether in a catalogue which was discussed in detail as a part of the Mater's doctoral dissertation.

[8] "The QuarryScapes Project: conservation of ancient stone quarry landscapes in the Eastern Mediterranean" gives detailed examples on quarrying activities and quarry areas through selected settlements around Eastern Mediterranean. Several factsheets, case studies and proceedings have been published by the contributors of the project. For more information, see their website: http://www.quarryscapes.no/index.php

[9] However, it is possible to undertake rough calculations about the average size of the blocks, the amount of stones invested for buildings. In addition, the distance and operations between the quarry, the construction site and buildings can also be hypothetically suggested.

[10] On the other hand, the majority of the building materials of Larisaean constructions are mudbrick. To estimate the economic aspects, such as the quantification of material and labor costs of the upper parts of the buildings, it is necessary to prepare proper restitution proposals for constructions.

[11] Emre Öncü points out the involvement of mobile/travelling terracotta workshops in the 6th century BCE in Aeolis, who had commissions in Larisa and Phokaia as proven by the archaeological finds displaying the same production techniques and forms. (Öncü, 2013, 254-255).

References

Åkerström, Å. (Ed.). (1940). *Larisa am Hermos. Die Ergebnisse der Ausgrabungen 1902–1934 II. Die architektonischen Terrakotten, by L. Kjellberg.* Stockholm: Kungl. Vitterhets Historie och Antikvitets Akademien.

Bingöl, O. (2012). *Bu Koca Taşları Nasıl İşlediler, Nasıl Kaldırdılar?* Ankara: Bilgin Kültür Sanat.

Boehlau, J. & Schefold, K. (Eds.). (1940). *Larisa am Hermos. Die Ergebnisse der Ausgrabungen 1902-1934 I. Die Bauten*. Berlin: Walter de Gruyter.

Boehlau, J. & Schefold, K. (Eds.). (1942). *Larisa am Hermos. Die Ergebnisse der Ausgrabungen 1902-1934 III. Die Kleinfunde*. Berlin: Walter de Gruyter.

Doğer, E. (1998). *İlk İskanlardan Yunan İşgaline Kadar Menemen (ya da Tarhaniyat) Tarihi*. İzmir: Sergi Yayınevi.

Dworakowska, A. (1975). *Quarries in Ancient Greece*. (K. Kozlowaka trans.). Krakow: Zakład Narodowy im. Ossolińskich Wydawnictwo Polskiej Akademii Nauk.

Erinç, S. (1982). *Jeomorfoloji 1*. İstanbul: İstanbul Üniversitesi Edebiyat Fakültesi Yayınları.

Glotz, G. (1965). *Ancient Greece at Work: An Economic History of Greece from the Homeric Period to the Roman Conquest*. (M. R. Dobie trans.). New York: Barnes & Noble.

Gruben, G. (2001). *Griechische Tempel und Heiligtümer.* Munich: Hirmer.

Harrell, J. A. & Storemyr, P. (2009). Ancient Egyptian Quarries—an Illustrated Overview. In N. Abū Jābir, E. G. Bloxam, P. Degryse, & T. Heldal. (Eds.) *QuarryScapes: Ancient Stone Quarry Landscapes in the Eastern Mediterranean*. NGU, Geological Survey of Norway.

Kayan, İ. & Öner, E. (2016). Geographical Environment of Ancient City of Larisa: Paleogeographical Evolution and Geoarchaeological Interpretations. In T. Saner (Ed.) *Larisa (Buruncuk) Architectural Survey,* (pp. 7-26). İstanbul: Ege Yayınları.

Korres, M., & Vierneisel, K. (1992). *Vom Penteli zum Parthenon: Werdegang eines Kapitells zwischen Steinbruch und Tempel.* Munich*:* Glyptothek.

Külekçi, I & Saner, T. (2021). The Early 5th-Century BCE Fort of Larisa East (Aeolis) as Part of a Multi-Centred Defence System In M. Eisenberg & R. Khamisy. (Eds.) *The art of siege warfare and military architecture from the classical world to the Middle Ages.* Oxbow Books.

Martin, R. (1965). *Manuel d'Architecture Grècque: Matériaux et téchniques*. A. et J. Paris: Picard.

Martin, R. (1973). Aspects Finan-

ciers et Sociaux des Programmes de Construction dans les Villes Grecques de Grande-Grèce et de Sicile. *Publications de l'École Française de Rome*, 99(1), 533-547.

Orlandos, A. K. (1966). *Les Matériaux de Construction et la Technique Architecturale des Anciens Grecs*. Paris : E. de Boccard.

Öncü, Ö. E. (2013). *Aiolis Bölgesi Arkaik Dönem Mimarisinde Pişmiş Toprak Çatı Elemanları* (Unpublished doctoral dissertation). İstanbul Üniversitesi, Sosyal Bilimler Enstitüsü, İstanbul.

Özdoğan, M. (2018). Larisa in Prehistory Some Considerations, Inferences and Prospects. In T. Saner, I. Külekçi, Ö. E. Öncü (Eds.) *Larisa Different Lives Different Colours*, (pp.122-143). Mimarlık Tarihi Araştırmaları 3. İstanbul: İTÜ Vakfı Yayınları.

Saner, T. (2016). Larisa (Buruncuk) *Architectural Survey*. Ege Yayınları

Saner, T., Külekçi, I., & Mater, G. (2017). Architectural Survey at the Necropolis of Larisa (Buruncuk), *Mimarlık Tarihi Araştırmaları 2*. İTÜ Vakfı Yayınları.

Saner, T., Külekçi, I. & Öncü, Ö. E. (2018). Larisa Different Lives Different Colours. *Mimarlık Tarihi Araştırmaları 3*. İTÜ Vakfı Yayınları.

Tuchelt, K. (1992). B*ranchidai - Didyma: Geschichte und Ausgrabung eines antiken Heiligtums*. Mainz: von Zabern.

URL-1: http://www.quarryscapes.no/text/Publications/QS_del11_wp9.pdf

Wesenberg, B. (1985). Kunst und Lohn am Erechtheion, in: Archäologischer Anzeiger 1985, 55–65.

Wright, G. R. H. (2000). *Ancient Building Technology, Volume 1: Historical Background*. Leiden: Brill.