

KAMENOLOMI STAROGRADSKOG ZALJEVA: PROBLEMATIKA PODRIJETLA KAMENA KORIŠTENOG ZA IZGRADNJU BEDEMA ANTIČKOG FARA

U fokusu arheoloških istraživanja najčešće su prostori s najvećom koncentracijom ostataka materijalne kulture jedne zajednice poput naselja i nekropola, dok krajolici, pa time i oni industrijski, često ostaju na margini istraživanja. To je slučaj s kamenolomima, koji svjedoče o industrijskoj prošlosti jednog prostora, a daju uvid i u socijalnu organizaciju društva određenog vremena. U mediteranskoj regiji, pa tako i našoj obali i otocima, antički su kamenolomi izuzetno brojni, zahvaćajući velike površine krajolika, no budući da se mnogi koriste i u kasnijim razdobljima, antički tragovi ekstrakcije sirovine često su uništeni novijima. Sličan je slučaj i s kamenolomima pronađenim u Starogradskom zaljevu. Na sjevernoj strani zaljeva nalazi se šest lokacija na kojima su vidljivi tragovi ekstrakcije kamena. Prirodne, izrazito velike slojnice kamena dale su naslutiti da je riječ o antičkim kamenolomima iz kojih su vađeni veliki blokovi za gradnju bedema grčkog Fara. Proučavanju kamenoloma pristupilo se koristeći više metodoloških pristupa i na multidisciplinarni način. Na svim lokacijama učinjen je površinski pregled terena, zračna prospekcija, analiza arhivskih fotografija i katastra. Učinjena je komparativna analiza tehnologije ekstrakcije sirovine, mikropaleontološka analiza uzoraka kamena iz kamenoloma i bedema, a sve je kartirano u geografskom informacijskom sistemu (GIS).

KLJUČNE RIJEČI: *Far, bedemi Fara, antički kamenolom, industrijski krajolik, tehnologija ekstrakcije kamena, mikropaleontološka analiza, zračna fotografija, GIS*

UVOD

Antički gradovi na našoj obali, pa čak i gradinska naselja koja su im prethodila, građeni su gotovo isključivo upotrebom kamena. Kamenolomi, kao i način eksploatacije kamene sirovine, vrijedan su svjedok o industrijskoj prošlosti jednog pros-

THE QUARRIES IN STARI GRAD BAY: DECIPHERING THE PROVENANCE OF STONE USED FOR BUILDING THE CITY WALLS OF ANCIENT PHAROS

Archaeological investigations are usually focused on areas with the highest concentration of the remains of the material culture of a community, such as the settlements and cemeteries, while landscapes, including the industrial ones, often remain on the margins of research. This is the case with quarries, which testify to the industrial past of an area and provide an insight into social organization of a society in a given period. In the Mediterranean region, including our coast and islands, ancient quarries are numerous, which extend over large areas of landscape, but since many are used in subsequent periods, traces of extraction of raw material from antiquity are often destroyed. Similar is the case with the quarries found in Stari Grad Bay. Along the northern side of the bay there are six locations with visible traces of stone extraction. Extremely large contour lines of the rock suggested that these are ancient quarries from which large blocks were extracted and used in construction of city walls of the Greek Pharos. Multidisciplinary approach to the study of the quarries included using multiple methods of research. Surface surveys were conducted on all six locations, as well as aerial prospection and analysis of historical imagery and cadastral maps. A comparative analysis of the technology of extraction of raw material and micropaleontological analysis of samples from the quarries and city walls were also conducted, and everything was mapped in geographic information system (GIS).

KEY WORDS: *Pharos, city walls of Pharos, ancient quarry, industrial landscape, technology of stone extraction, micropaleontological analysis, aerial photography, GIS*

INTRODUCTION

Ancient cities on our coast, even fortified settlements that preceded them, were built almost exclusively using the stone. Quarries and quarrying techniques are a valuable witness to the industrial past of an area and provide an insight into social organization of a

tora te daju uvid i u socijalnu organizaciju društva određenog vremena. Na Hvaru je otkriveno šest dosada nepoznatih kamenoloma primjenom nede-struktivnih metoda poput zračnog i terestrijalnog rekognosciranja prostora. Izradom detaljne dokumentacije, koja uključuje kartiranje u geografskom informacijskom sistemu, proučavanjem arhivskih prostornih podataka i mikropaleontološkom analizom stijena pokušalo se zaključiti da li se iz njih dobivao kamen za gradnju bedema Fara. Ovaj metodološki pristup rezultirao je novim saznanjima o eksploataciji kamena na otoku Hvaru.

BEDEMI FARA

Datiranje bedema Fara već je dugo predmetom rasprave. Pri istraživanjima se za datacije zidanih struktura, zbog njihovih vrlo složenih odnosa, nerijetko oslanjalo na kriterij tehnike gradnje koja se razlikuje među periodima. To je često dovodilo do netočnih zaključaka, budući da su varijacije u načinu gradnje i upotrebi materijala česte i unutar pojedinog vremenskog razdoblja. S druge strane, arheološki ostaci su mnogo puta bili interpretirani temeljem povijesnih izvora. Tako se za dataciju arhitekture grčkog grada Fara ponajviše oslanjalo na Diodora koji piše kako 385/4. godine pr. Kr. Farani, nakon bitke s Ilirima, osnovani grad utvrđuju bedemima.¹ Dugo se za masivne bedeme u konobi Gramotorov smatralo da je riječ upravo o tom prvom, izvornom bedemu Fara i temeljem toga se raspravljalo o položaju i veličini utvrđenog grčkog grada.² Tek su arheološka istraživanja 1993. godine dokazala da je riječ o masivnim fortifikacijama koje su građene nakon sredine 3. stoljeća po. Kr., ponovnim korištenjem blokova grčkog bedema.³ Najnovija istraživanja 2012. godine u Starome Gradu dokazala su da niti ostaci bedema na lokalitetu Sv. Ivan-Remete vrt, za koje se do sada smatralo da su izvorni bedemi koji zatvaraju jugoistočni ugao grada Fara (Sl. 1), nisu fortifikacije iz vremena osnutka grada.⁴ Za izgradnju tih bedema također je sekundarno korišten kamen klesan za neku drugu građevinu ili za starije, izvorne fortifikacije čija

society in a given period. Six previously unknown quarries were discovered on the island of Hvar, using non-destructive methods such as aerial and terrestrial survey of the area. By creating detailed documentation that includes mapping in the geographical information system, study of archival spatial data and micropaleontological analysis of the rocks, an attempt was made to conclude whether they were the source for the stone used in construction of the city walls of Pharos. This methodological approach has resulted in new insights about stone exploitation on the island of Hvar.

CITY WALLS OF PHAROS

Dating of the city walls of Pharos has long been the subject of debate. Research conducted for the dating of masonry structures, because of their very complex relationships, was often relied upon the criteria of construction techniques that differ between periods. This often led to incorrect conclusions since the variations in the construction and use of materials are common even within a particular period of time. On the other hand, many times the archaeological remains have been interpreted according to historical sources. Thus, dating the architecture of the Greek city of Pharos relied mostly on Diodorus who wrote that in 385/384 BC Pharians fortified their newly established city with walls after the battle with the Illyrians.¹ It has long been considered that the massive walls in the cellar of Gramotorov house were the remains of the first, original walls of Pharos and discussions about the position and size of the fortified Greek city were conducted based upon that belief.² It is not until 1993 that archaeological excavations proved that those were massive fortifications built by reusing blocks of the Greek walls, after the mid-3rd century AD.³ Recent research in Stari Grad, conducted in 2012 showed that remains of the walls on the site of Sv. Ivan – Remete vrt, previously thought to be original walls that enclosed south-eastern corner of Pharos (Fig. 1), are in fact not from the time of foundation of the city.⁴ The stones used for these walls were hewn for some other building or older, original fortification whose

1 DIODOR, *Bibliothèque Historique* XV, 14, 1 u: V. GAFFNEY et al., 1997, 225; B. KIRIGIN, 2004, 82-88.

2 N. DUBOKOVIĆ-NADALINI, 1960; B. KIRIGIN, 1991, 25-29.

3 S. FORENBAHER et al., 1994, 20-28.

4 Voditeljica istraživanja je autorica ovih redaka, a rad o navedenoj tematici je trenutno u pripremi.

1 DIODORUS, *Bibliothèque Historique* XV, 14, 1 in: V. GAFFNEY et al., 1997, 225. B. KIRIGIN, 2004, 82-88.

2 N. DUBOKOVIĆ-NADALINI, 1960; B. KIRIGIN, 1991, 25-29.

3 S. FORENBAHER et al., 1994, 20-28.

4 Director of the excavation was the author and the publication on this topic is currently under preparation.



SL. 1. / FIG. 1.

Bedem Fara (nacrt: S. Popović, foto: A. Devlahović).

City walls of Pharos (drawing: S. Popović, photo: A. Devlahović).



SL. 2. / FIG. 2.

Zvonik s detaljem zapadnog zida gdje su blokovi bedema Fara ostali bunjoliki (foto: S. Popović).

Bell tower with the detail of the west wall where the blocks with oval faces from the city walls of Pharos remained (photo: S. Popović).

točna lokacija još nije utvrđena. Kovačić prenosi zapis iz 18. stoljeća, iz knjige gradnje zvonika na trgu sv. Stjepana (Sl. 2), u kojemu stoji da je za gradnju korišten kamen iz zidova Fara, kopan u blizini crkve sv. Nikole.⁵ Na ovom mjestu neću detaljnije raspravljati o položajima i dataciji različitih fortifikacija grada Fara ili kasnije rimske Farije, već o provenijenciji kamena korištenog za njihovu gradnju. Jasno je da se za potrebe novih gradnji u Starome Gradu,

exact location has not yet been determined. Kovačić brings a record about building of the bell tower on St Stephen's Square (Fig. 2), from 18th century, which states that the stone used for the bell tower came from the walls of Pharos, and it was dug in the vicinity of the church of St Nicholas.⁵ At this point I will not discuss in detail the positions and dating of different fortifications of Pharos or later Roman Pharia, but the origin of the stone used in their construction. It

⁵ J. KOVAČIĆ, 1994, 364.

⁵ J. KOVAČIĆ, 1994, 364.

kao i drugdje, u više navrata iznova koristio dostupan građevinski materijal, no do sada je bila nepoznata lokacija kamenoloma iz kojeg su se mogli vaditi izuzetno veliki blokovi prvog bedema Fara, koji su toliko puta iznova korišteni te i danas čine temelje mnogih građevina povijesne jezgre grada.

SREDNJODALMATINSKI ANTIČKI KAMENOLOMI

Potencijal za vađenje arhitektonsko-građevnog kamena na području srednje Dalmacije je velik. Brojni su aktivni kamenolomi u kontinentalnom dijelu Dalmacije kao i na srednjodalmatinskim otocima, od kojih su najpoznatiji oni s otoka Brača. Mnogobrojni kamenolomi u kojima se vadi brački "mramor" (koji je zapravo vrsta vapnenca) imaju dugu tradiciju. U doba Rimskog carstva eksploatacija bračkog kamena iz kamenoloma Plate, Stražišće i Rasohe između Splitske i Škripa bila je važna za šire područje Dalmacije, npr. za gradnju Dioklecijanove palače u Splitu i teatra u Solinu.⁶ Ciccarelli 1802. godine piše o dvije milje uokolo vidljivim, nekoliko metara visokim, živim odlomima stijena s kojih se brao kamen.⁷ Teško je, međutim, sa sigurnošću odrediti kada se radilo o izvozu obrađenog, gotovog proizvoda, a kada o sirovini u blokovima koja je kasnije obrađena na odredištu.⁸ Po kamenu je poznat i otočić Vrnik kraj Korčule na kojemu se nalazi nekoliko danas neaktivnih kamenoloma. Najstarijim antičkim kamenolomom u nas do sada je smatran onaj u uvali Srebrna na otoku Visu, iz kojeg je vađen kamen za izgradnju bedema i druge arhitekture grčke Ise.⁹ Teško je zamisliti da bi Farani, grčki kolonisti s Para, otoka koji je u antici bio znamenit po kvaliteti svog mramora¹⁰ i po razvijenom kamenoklesarskom znanju, na Hvaru, koji ima potencijal za eksploataciju kamene sirovine, morali uvoziti kamen sa susjednog otoka.

is clear that for the purpose of recent constructions in Stari Grad, as elsewhere, available building material was reused, but until now location of the quarries from which it was possible to extract large blocks for the first walls of Pharos, which were often reused and still form the basis of many buildings in the historic centre of the town, was unknown.

ANCIENT QUARRIES OF CENTRAL DALMATIA

The potential for the extraction of architectural stone in central Dalmatia is great. There are many active quarries in continental part as well as on the islands, most notably those on the island of Brač. Numerous quarries where Brač "marble" (which is actually a type of limestone) is extracted have a long tradition. In the time of Roman Empire the exploitation of Brač quarries Plate, Stražišće and Rasohe between Splitska and Škrip was important for the broader region of Dalmatia, for example for the construction of Diocletian's Palace in Split and the theatre in Solin.⁶ Ciccarelli in 1802 writes about visible breaks in the bedrock from which stone was extracted, about two miles around and several metres high.⁷ Admittedly, it is difficult to determine with certainty when it was exported as processed, finished product, and when as a raw material later processed at the destination.⁸ Island of Vrnik near Korčula is also known for its stone, with several now inactive quarries. Until now the oldest known quarry was considered the one in Srebrna bay on the island of Vis, from where the stone for construction of Greek Issa was extracted.⁹ It is hard to imagine that Pharians, Greek colonists from Paros, the island notable in antiquity for the quality of its marble¹⁰ and knowledge in stonemasonry would have to import the stone from a neighbouring island when Hvar has the potential for stone exploitation.

6 P. DIDOLIĆ, 1957, 98-106; D. VRSALLOVIĆ, 1960, 72-74; B. KIRIGIN, 1979, 132; Z. STANČIĆ et al., 2004, 163.

7 P. DIDOLIĆ, 1957, 99; D. VRSALLOVIĆ, 1960, 73.

8 N. CAMBI, 2004, 241.

9 V. BILIČIĆ, D. RADIĆ, 1990, 39; B. KIRIGIN et al., 2006, 14; M. KATIĆ, 2009, 28-34.

10 PLINIJE STARIJI, *Naturalis Historia*, 36.14, u: J. HUMPREY et al., 1999, 196. Zbornik radova o parskom mramoru i kamenolomima: D. U. SCHILARDI, D. KATSONOPOULOU (ur.) 2000.

6 P. DIDOLIĆ, 1957, 98-106; D. VRSALLOVIĆ, 1960, 72-74; B. KIRIGIN, 1979, 132; Z. STANČIĆ et al. 2004, 163.

7 P. DIDOLIĆ, 1957, 99; D. VRSALLOVIĆ, 1960, 73.

8 N. CAMBI, 2004, 241.

9 V. BILIČIĆ, D. RADIĆ, 1990, 39; B. KIRIGIN et al., 2006, 14; M. KATIĆ, 2009, 28-34.

10 PLINY THE ELDER, *Naturalis Historia*, 36.14, u: J. HUMPREY et al., 1999, 196. Proceedings of a conference on Parian marble and quarrying: D. U. SCHILARDI, D. KATSONOPOULOU (eds.) 2000.

POTENCIJAL ZA EKSPLOATACIJU KAMENA NA OTOKU HVARU

Iako je geološka građa otoka Hvara obrađena još 50-ih godina 20. stoljeća,¹¹ nikada nije detaljnije ispitana mogućnost iskorištavanja njegove kamene osnove. Poznata (moderna) eksploatacija arhitektonskog kamena uvijek se svodila samo na dvije lokacije: prva na južnoj strani otoka, u blizini grada Hvara, s kamenolomima u Pokonjom dolu, Križnoj luci i Mikićevici, te druga kod Bogomolja.¹² U literaturi se uz kamenolom u Mikićevici vezao i termin "grčka kava"¹³ no ostaje nepoznato je li doista riječ o starijem kamenolomu, te ako i jest, koliko starom. Za bedeme Fara se sa sigurnošću jedino pisalo da su izgrađeni od autohtonog kamena.¹⁴ Dimenzije arhitektonsko-građevnog kamena koji je stoljećima korišten u gradnji hrvatskih priobalnih gradova variraju. Manji je dio ugrađenih kamenih elemenata znatnih i izrazito velikih dimenzija, a najčešći su klesanci korišteni za gradnju zidova koji su se mogli vaditi iz stjenske mase koja nema izražene slojnice. Od prije su poznati manji kamenolomi u središnjem dijelu otoka Hvara iz kojih su dobivani klesanci za gradnju kuća (poput Škudljivca) i malog kamenoloma u uvali Paklina otvorenog za vađenje grubog kamena korištenog u gradnji zvonika na trgu sv. Stjepana,¹⁵ no ne i kamenolomi pogodni za vađenje velikih blokova od kakvih su građeni bedemi Fara. Ležište za dobivanje blokova većih dimenzija mora imati velike i međusobno približno paralelne i okomite razmake između tektonskih diskontinuiteta u stjenskoj masi, a takvih je u prirodi mali broj.¹⁶ Na lokalitetu Remete vrt bedem Fara je očuvan u visini od jednog do četiri reda kamena, pri čemu visina pojedinog bloka varira od 35 cm do 55 cm, dok u širinu sežu i preko 2 m. Blokovi bedema ponovno korišteni za gradnju zvonika također su takvih dimenzija, što znači da je slojnica kamena u prirodi morala biti iste visine, a to nije čest slučaj.

POTENTIAL FOR STONE EXPLOITATION ON ISLAND HVAR

Although the geological structure of the island of Hvar was studied in 1950s,¹¹ the possibility of exploitation of its stone foundation was never further investigated. Known (modern) exploitation of dimension stone has always been reduced to just two locations: first on the southern side of the island, in the vicinity of town Hvar with quarries in Pokonji dol, Križna luka and Mikićevica and second one near Bogomolje.¹² In the literature, the term "Greek quarry" is tied with the quarry in Mikićevica,¹³ but it remains unknown whether it is an older quarry, and if so, how old. For the walls of Pharos it had always been written that they were built using local stone.¹⁴ Dimensions of architectural stone which had been used for centuries in the construction of Croatian coastal towns vary. A smaller part of the incorporated stone elements is of substantial and extra large dimensions. Most common are masonry stones used for the walls of the houses and they could be extracted from rock mass that has no pronounced contour lines. Smaller quarries are known in the central part of the island of Hvar from which masonry stones were extracted for the construction of houses (like Škudljivac) and a smaller quarry in Paklina that was opened for the extraction of coarse stone for the bell tower on St Stephen's Square,¹⁵ but not quarries suitable for the extraction of large blocks like the ones used for the construction of the city walls of Pharos. Stone deposit for obtaining larger blocks must have large and approximately parallel and vertical spacing to each other between tectonic discontinuities in the rock mass and such deposits are rare in nature.¹⁶ At the site of Remete vrt, the city wall is preserved in the height of one to four rows of stones and the height of each block varies from 35-55 cm while they can be over 2 m wide. Blocks from the city walls reused for the bell tower are of the same size, which means that the contour line of natural rock had to be of the same height, and this is not often the case.

11 M. HERAK et al., 1976, 5-11.

12 S. MARINČIĆ, 1995, 52.

13 V. MAJER, B. CRNKOVIĆ, 1977, 23.

14 S. DUNDA et al., 2001, pogl. 2.

15 J. KOVAČIĆ, 1994, 364.

16 S. DUNDA et al., 2001, pogl. 4.

11 M. HERAK et al., 1976, 5-11.

12 S. MARINČIĆ, 1995, 52.

13 V. MAJER, B. CRNKOVIĆ, 1977, 23.

14 S. DUNDA et al., 2001, Ch. 2.

15 J. KOVAČIĆ, 1994, 364.

16 S. DUNDA et al., 2001, Ch. 4.

TIJEK I METODOLOGIJA ISTRAŽIVANJA

Slučajan nalaz jednog polukružnog otiska dljeteta na stijeni¹⁷ potakao je 2012. godine sustavno rekognosciranje Starogradskeg zaljeva s ciljem definiranja prostora na kojemu se eksploatirala kamena sirovina. Istraživanja su koncentrirana na sjevernu stranu zaljeva koja ima naglašene slojnice stijena, dok je obala južne strane razmrmljena i vrlo strma. Terestrijalno su pregledani svi dostupni dijelovi obale, a dužina obalnog dijela, do kojeg se ne može prići zbog guste i neprohodne vegetacije, oplovila se brodom s kojega se silazilo na odabranim lokacijama koje su imale potencijal za ekstrakciju sirovine. Na mjestima na kojima su pronađeni tragovi eksploatacije uzeti su uzorci stijene. Ovim je načinom otkriveno šest dosada potpuno nepoznatih kamenoloma. Sve lokacije i očuvani pojedini tragovi otisaka alata na stijeni su dokumentirani.¹⁸ Po tipu otiska alata pokušala se rekonstruirati tehnika ekstrakcije sirovine koja bi stvorila okvir za datiranje kamenoloma.

Kartiranje je izvedeno u geografskom informacijskom sustavu gvSIG (u daljnjem tekstu GIS) koji je omogućio georeferenciranje odnosno smještanje svih geografskih podataka u isti koordinatni sustav što omogućuje pregled i analize zajedno s drugim geografskim podacima.¹⁹ Kreirana baza podataka omogućila je korelaciju različitih setova prostornih podataka: lokacije kamenoloma su korelirane s arhivskim katastrom i arhivskim fotografijama. Zračne fotografije iz sredine 20. stoljeća, uzimane za različite namjene, dragocjen su izvor o stanju krajolika prije velikih promjena nastalih nakon 70-ih godina u korištenju zemljišta, urbanom širenju i vegetaciji.²⁰ Uz proučavanje historijskih zračnih fotografija, arheolozi vrijedni podaci o multi-temporalnom krajoliku mogu se dobiti i novom zračnom prospekcijom.²¹ Ciljano se zračnim rekognosciranjem pregledao prostor Staroga Grada, Starogradskeg polja i zaljeva. Letjelo

WORKFLOW AND RESEARCH METHODOLOGY

Incidental find of semicircular chisel mark on the rock¹⁷ instigated a systematic survey of Stari Grad bay, conducted in 2012, with the aim of defining the area where raw material was exploited. Research was concentrated on the northern side of the bay which has accentuated rock contour lines, while the southern side is crumbled and very steep. Terrestrial prospection covered all accessible parts of the coast, and the length of coastal area that could not be approached because of the dense and impenetrable vegetation, was prospected offshore. Landing was done at selected locations that had the potential to be used for the extraction of raw material and rock samples were taken where traces of exploitation were found. Using these methods six quarries were found, up to now completely unknown. All locations are documented as well as preserved tool marks on the rock.¹⁸ According to type of the tool marks, an attempt was made to reconstruct the extraction technique that would create a framework for the dating of the quarries.

Mapping was conducted in a geographical information system gvSIG (hereafter GIS) which allowed the georeferencing i. e. aligning geographic data to a known coordinate system so it can be viewed, queried, and analyzed with other geographic data.¹⁹ The created database allowed the correlation of different spatial data sets. For example: locations of the quarries were correlated with archival cadastre and archival imagery. Aerial photographs from the mid-20th century, taken for a different purpose, are a valuable source on the condition of the landscape before major changes after the 1970s in land use, urban expansion, and vegetation.²⁰ In addition to the study of historical aerial imagery, valuable archaeological information about the multi-temporal landscape can be obtained with new aerial prospection.²¹ Tar-

17 Na prve tragove otisaka alata upozorio me ravnatelj Muzeja Staroga Grada g. Aldo Čavić, što je potaklo istraživanje koje je rezultiralo otkrivanjem još pet kamenoloma. Ujedno mu zahvaljujem što je učinio dostupnim arhivski katastar i povijesne fotografije korištene za ovaj rad.

18 O standardu za dokumentiranje kamenoloma: T. HELDAL, E. BLOXAM, 2008, 13.

19 Općenito o geografskim informacijskim sistemima: K. KVAMME et al., 1997. Prvi primjer primjene GIS-a u arheologiji: V. GAFFNEY, Z. STANČIĆ, 1991.

20 O korištenju historijskih zračnih fotografija u arheološke svrhe: D. COWLEY et al. (ur.), 2010.

21 O zračnoj arheologiji: K. BROPHY, D. COWLEY, 2005.

17 The traces of tool marks were first brought to my attention by Mr. Aldo Čavić, director of the Museum of Stari Grad, which initiated research that has resulted in discovery of another five quarries. I would like to thank him for this information, as well as for making accessible historic cadastral maps and archival imagery used for this paper.

18 On standard for documenting quarry landscapes: T. HELDAL, E. BLOXAM, 2008, 13.

19 Generally on geographic information system: K. KVAMME et al., 1997. First application of GIS in archaeology: V. GAFFNEY, Z. STANČIĆ, 1991.

20 About application of historic aerial imagery in archaeology: D. COWLEY et al. (eds.), 2010.

21 On aerial archaeology: K. BROPHY, D. COWLEY, 2005.



Sl. 3. / FIG. 3.

Položaji kamenoloma kartirani u GIS programu (gvSIG), na podlozi ortofota iz arhive Muzeja Staroga Grada (kartirala: S. Popović).

Locations of the quarries mapped in GIS (gvSIG) overlapped with orthophoto from the archive of the Museum of Stari Grad (author: S. Popović).

se u svrhu pronalaska kamenoloma na prostoru gdje se rasprostire litološka jedinica determinirana mikropaleontološkom analizom uzoraka bedema (o kojoj će biti više riječi kasnije).

LOKACIJE KAMENOLOMA

Na šest lokacija duž sjeverne strane Starogradskog zaljeva (Sl. 3) rekognosciranjem su otkriveni tragovi eksploatacije kamena: dvije lokacije su na rtu Dugi rat (koji lokalno stanovništvo naziva rt Baba), a preostale su na gotovo cijeloj zapadnoj strani uvala Brizenica (koja se u povijesnom katastru naziva uvala Dugi rat) te na istočnim stranama uvala Zavala, Zapaš bok i Veli Zelenikovac. Po kategorizaciji, riječ je o površinskim, nizinjskim, plitkim kamenolomima. Zbog konfiguracije terena na ovom prostoru nije bilo moguće otvoriti dugotrajan, dubinski kamenolom poput onih na Braču ili Visu, već se sirovina, koja je zadovoljavala kriterije za gradnju, tijekom vremena vadila

getet aerial prospection was conducted in the area of Stari Grad, Stari Grad Plain and Stari Grad bay, in the search for the quarries in the area where the lithological unit is spread, determined by micropaleontological analysis of the samples of the city walls (discussed later).

QUARRY SITES

At six locations along the northern side of the Stari Grad bay (Fig. 3) prospection yielded traces of stone exploitation: two on cape Dugi rat (known to local population as cape Baba), almost entire western shore of Brizenica cove (named Dugi rat cove on historical cadastral maps) and eastern sides of Zavala cove, Zapaš bok cove and Veli Zelenikovac cove. By categorization these are surface, low-lying shallow quarries. Because of the terrain configuration of this area it wasn't possible to open long-lasting, deep quarry such as those on the islands of Brač and Vis. Here, the raw material that met the construction cri-

duž obale. To ostavlja mogućnost da će se ubuduće pronaći još lokacija s ostacima eksploatacije kamena. Upravo kratko trajanje pojedinih kamenoloma je i jedan od razloga zašto površinskim pregledom terena, uz mnogobrojne dokaze o vađenju kamena, nije pronađeno gotovo nikakvog pokretnog materijala, ni grčko-helenističkog niti ikojeg drugog razdoblja (osim nekoliko ulomaka tegula koje se ne mogu pobliže datirati), dok je drugi razlog sigurno izloženost jakim morskim strujama koje su mogle isprati materijal. Zbog nedostatka materijala pomoću kojeg bi se datirali ovi kamenolomi istraživanje se usmjerilo na uspoređivanje tehnika ekstrakcije sirovine te mikropaleontološku analizu uzoraka kamena.

TEHNIKA VAĐENJA KAMENA

Tehniku eksploatacije kamena opisuju autori članka *Povijest dobivanja prirodnog kamena*: "Cijepanje kamena je operacija kojom se od stijenske mase odvajaju veliki blokovi koji se naknadno obrađuju. Za cijepanje su se rabili suhi drveni klinovi nabijeni u prirodne diskontinuitete, koji su nakon toga polijevani s vodom. Natopljeno je drvo počelo bubriti čime je narastao tlak kojim se kamen cijepa duž ravnine najmanjeg otpora."²² Od pojave kovanih željeznih alatki rupe u stijeni počele su se izrađivati ručno dljetom i čekićem, uz zakretanje dljeta u rupi. Tako se radilo do druge polovine 19. stoljeća, kada počinje primjena strojnog bušenja.²³ S obzirom na to da visine blokova odgovaraju debljinama slojeva vapnenca možemo zaključiti da su u plitkim, površinskim kamenolomima jednostavnim podizanjem pomoću poluge blokovi odvajani duž prirodnih diskontinuiteta, slojnica (Sl. 4). Ostale su se ploče ploha najvjerojatnije odvajale duž pukotinskih diskontinuiteta, obično prilično okomito na slojevitost. Takvo dobivanje blokova je moguće tamo gdje su naslage vapnenca horizontalne ili neznatno nagnute. Daljnje dotjerivanje ploča je bilo jednostavno, oklesavanjem okomito na slojevitost. Tehnologija dobivanja blokova iz stijenske mase je zajednička svim antičkim kamenolomima u Hrvatskoj, kao što im je zajedničko i to da su svi u vapnencima. Prvo su okomito na slojnicu, dljetom i čekićem ili pijukom, izrađivani kanali ili "pašarini" koji mogu biti

terea was acquired along the shore during a certain period of time. That leaves the possibility that in the future more locations with evidence of stone exploitation will be found. Short duration of these quarries is one of the reason why surface survey, in spite of the numerous evidence of quarrying, yielded no archaeological material, Greco-Hellenistic or any other (except few shards of tegulae which cannot be closely dated), while the second reason is certainly exposure to strong marine currents that could wash away the material. Due to the lack of the material that could help in dating these quarries, research is focused on comparative analysis of extraction techniques and micropalaeontological analysis of stone samples, whose results have encouraged further study.

QUARRYING TECHNIQUE

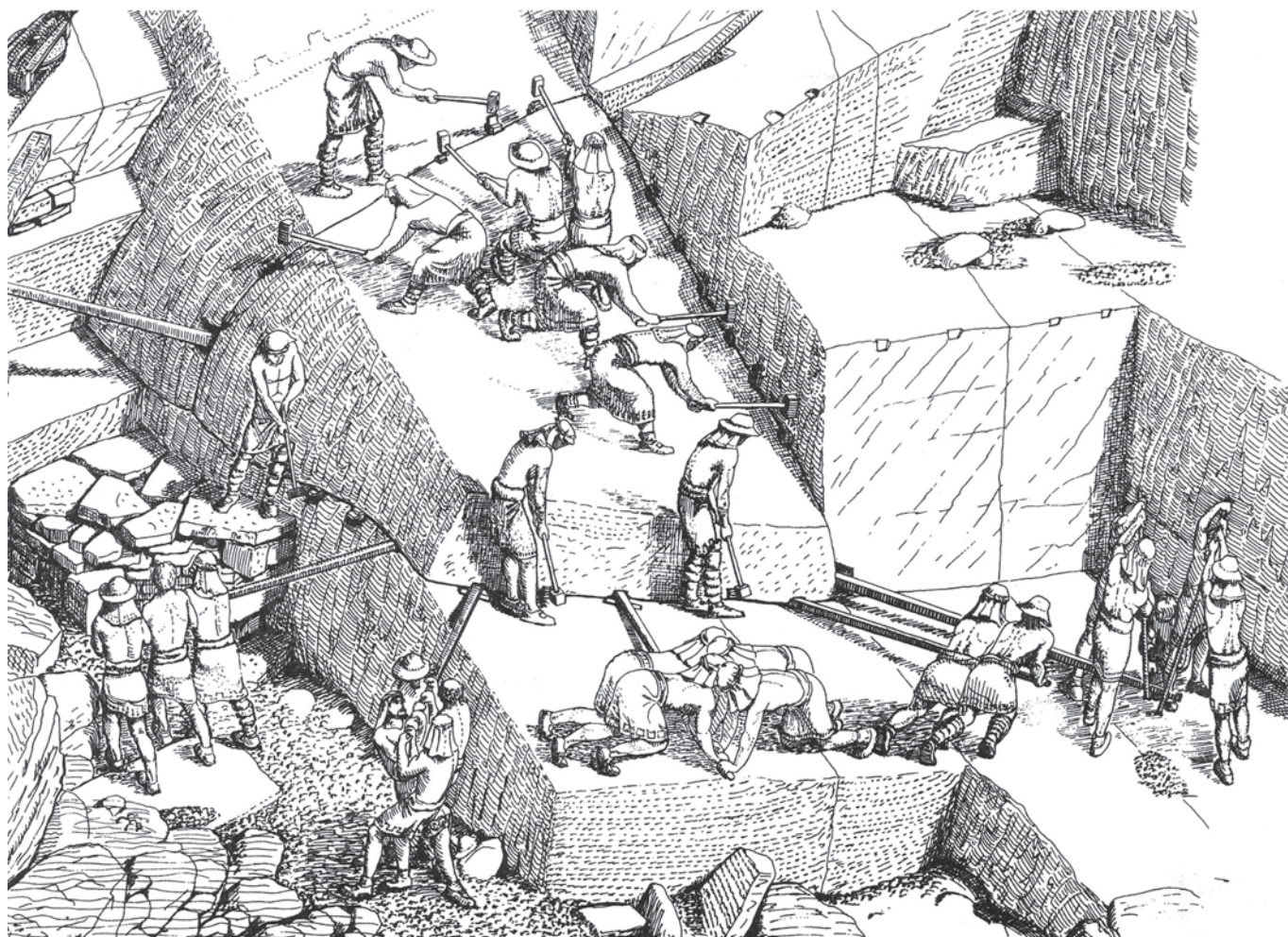
Stone exploitation technique is described by the authors of the paper *History of extracting natural stone*: "Stone splitting is an operation to detach subsequently processed large blocks from the rock mass. Dry wooden wedges placed into natural discontinuities and then soaked with water were used for splitting. Waterlogged wood would become swollen which increased the pressure with which the stone was split along the plane of least resistance".²² Since the appearance of wrought iron tools, holes in the rock were prepared by hand with a chisel and a hammer, by rotating the chisel in the hole. This was done up to the second half of 19th century when the application of drilling machines begun.²³ Since the height of the blocks corresponds to the thickness of the limestone layers, in shallow surface quarries simple lifting with a lever would separate the blocks along the natural discontinuities, that is, the contour lines (Fig. 4). Other surface plates were probably separated along the fissure continuities, usually quite perpendicular to the layers. This kind of block extraction is possible where the layers of the limestone are horizontal or slightly inclined. Further refinement of the plates was simple, done by hewing perpendicularly to the layers. The technology of block extraction from the rock mass is common to all ancient quarries in Croatia, as is the fact that they are all in the limestone. Channels were being carved first, with a chisel and a hammer or a pick-

22 S. DUNDA et al., 1997, 83.

23 S. DUNDA et al., 1997, 84.

22 S. DUNDA et al., 1997, 83.

23 S. DUNDA et al., 1997, 84.



SL. 4. / FIG. 4.

Prikaz načina ekstrakcije kamena korištenjem poluge i kvadratnog klina (K. HELLMANN, 2002, 76).

Depiction of stone extraction using levers and square wedges (K. HELLMANN 2002, 76).

impozantnih dubina poput onoga u kamenolomu Splitska na Braču. Šesta ploha bloka je obično horizontalno položena, duž naglašene slojnice i oslobađa se izradom utora ili "formela" i pobijanjem klinova uloženi u njih.²⁴ Način postavljanja klinova, njihova međusobna udaljenost i veličina variraju obzirom na to kakvu će namjenu imati ekstrahirani blok kamena. Grci su u klasično doba primjenjivali tehniku vađenja blokova korištenjem kvadratnih klinova,²⁵ ali nije postojala uniformnost u njihovoj veličini, niti razmaku u njihovom postavljanju. Standardizacija postupka i veličine klinova javlja se u rimskom

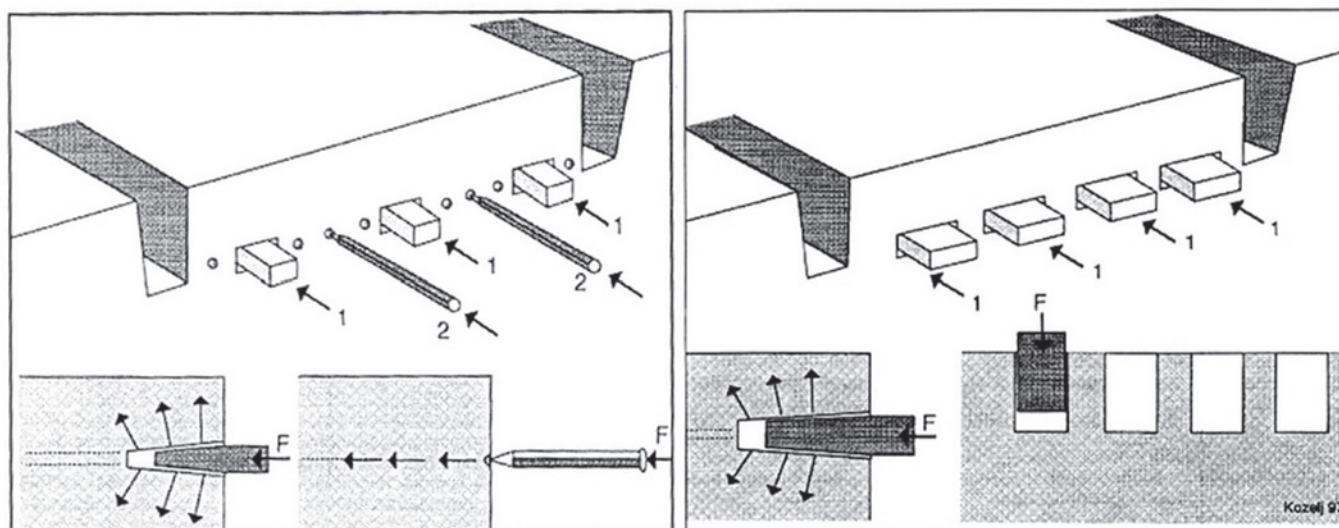
axe, perpendicular to the contour line. They can be impressive in depth like the one in Splitska quarry on the island of Brač. Sixth surface of the block is usually positioned horizontally, along the accentuated contour line and is released by carving grooves and inserting wedges into them.²⁴ The method of inserting the wedges, the distance between them and their size, vary depending on the purpose the extracted stone block will have. Greeks in the Classical Antiquity applied extraction technique using square wedges,²⁵ but there was no uniformity in their size or spacing between them. Standardization of the proc-

24 S. DUNDA et al., 1997, 86-87.

25 M. C. HELLMANN, 2002, 76.

24 S. DUNDA et al., 1997, 86-87.

25 M. C. HELLMANN, 2002, 76.



SL. 5. / FIG. 5.

Prikaz parske i klasične grčke tehnike vađenja kamenog bloka (T. KOZELJ, 2000, 418, 419).

Depiction of Parian and classical Greek techniques of the stone block extraction (T. KOZELJ, 2000, 418, 419).

periodu.²⁶ Od grčke "klasične tehnike" razlikuje se "parska tehnika" ekstrakcije kamena (Sl. 5).²⁷ Otok Par je bio poznat u antičkom svijetu po kvaliteti mramora te kamenoklesarskom znanju, poznavajući čak i tehniku izrade podzemnih kamenoloma.²⁸ Upravo su se u kamenolomima otoka Para, kao i onima njegove kolonije na Tasu te otocima Naksu i Eubeji, sačuvali ostaci parske tehnike vađenja kamena. Ona podrazumijeva umetanje okruglih dlijeta između četvrtastih klinova.

Debljina slojeva u vapnencima Hvara varira od 5 cm do 150 cm, a slojne plohe su jasno izražene, što je od posebnog značaja za odvajanje blokova duž slojnih ploha i za njihovu debljinu.²⁹ Budući da visina očuvanih blokova bedema grčkog Fara varira od 35 do 55 cm, to podrazumijeva velike i "zdrave" prirodne slojnice stijene kojih na otoku nema mnogo. Na mnogim dijelovima duž sjeverne strane Starogradske zaljeva jasno su vidljive velike slojnice kamena koje su blago nagnute prema moru i koje zadovoljavaju kriterije za ekstrakciju blokova kakvi su korišteni za gradske bedeme.

ess and the sizes of the wedges occur in the Roman period.²⁶ Greek "classical technique" differs from "Parian technique" of stone extraction (Fig. 5).²⁷ Island of Paros was renowned in the ancient world for the quality marble and stonemasonry, even for the construction of the underground quarries.²⁸ It was precisely in the quarries of Paros, as well as in those of its colonies on the islands of Thasos, Naxos and Euboea, where traces of "Parian" stone extracting technique that involves inserting round chisels between square wedges are preserved.

The thickness of the limestone layers of the island of Hvar ranges from 5-150 cm and the bedding planes are clearly distinct which is of special importance for the block separation along the bedding planes and their thickness.²⁹ The height of the preserved blocks of the Greek city walls of Pharos varies from 35-55 cm which implies large and "healthy" rock contour lines that are scarce on the island. In many areas along the northern side of Stari Grad Bay are clearly visible rock contour lines that are slightly inclined towards the sea, and they meet the criteria for block extraction as was used for the city walls.

26 T. KOZELJ, 1988, 36.

27 T. KOZELJ, 2000, 417.

28 M. KORRES, 2000, 82.

29 V. MAJER, B. CRNKOVIĆ, 1977, 25.

26 T. KOZELJ, 1988, 36.

27 T. KOZELJ, 2000, 417.

28 M. KORRES, 2000, 82.

29 V. MAJER, B. CRNKOVIĆ, 1977, 25.

Teško je reći koliko je kamena bilo potrebno za izgradnju bedema Fara jer je nepoznata veličina opasanog gradskog područja. Za takav pokušaj prvo treba uzeti u obzir dinamiku mjenjaanja veličine opasanog dijela grada jer, kako je već navedeno, istraženi su samo segmenti dvije (od tri) kronološki različite fortifikacije Fara. Ako se pokuša izračunati koliko je m^3 kamena potrebno za jedan metar dužine bedema (ne računajući ispunu od sitnijeg grubog kamena) treba uzeti u obzir da je prosječna dubina pojedinog kamenog bloka na lokalitetu Remete vrt 0,6 m. Ako u to uračunamo dva lica zida doći ćemo do rezultata od $1,20 m^3$, odnosno za pretpostavljenu visinu bedema od 5 do 7 m (širina bedema je 2.7 m), koju zid mora imati da bi imao obrambenu funkciju,³⁰ potrebno je 6 do $8.4 m^3$ kamena. Tek kada se utvrde granice opasanog dijela grčkog Fara moći će se izračunati koliko je kamena bilo potrebno za gradnju i detaljnije zaključivati o logistici potrebnoj za ovaj poduhvat. U tom slučaju čak i za najmanju dosada pretpostavljenu veličinu opasanog dijela grada od 1,5 ha (teza koja danas više ne stoji)³¹ trebalo bi $3000-4.200 m^3$ obrađenog kamena. Usporedbe radi, otkriveni kamenolom u uvali Zapaš bok ima površinu od $885 m^2$ i prosječnu dubinu od 2 m, što bi značilo da je njegova zapremina $1770 m^3$ kamena. U tu količinu raspoloživog kamena treba uračunati otpad pri ekstrakciji i obradi blokova čiji se postotak razlikuje ovisno o geološkoj podlozi, tehnici ekstrakcije i tipu gradnje za koju su blokovi namijenjeni. U kamenolomima Delfa postotak odbačenog materijala od vađenja i klesanja doseže čak i do 80% volumena kamenoloma no na tom se mjestu vadio kamen za finiju gradnju od ove potrebne za gradske bedeme.³²

Šest otkrivenih starogradskih kamenoloma mogu se odvojiti u dvije skupine na osnovi očuvanih tragova na preostalom dijelu stijene koji svjedoče o različitoj tehnici cijepanja kamena. Prvu skupinu po tehnici vađenja kamena čine kamenolomi u uvalama Zapaš bok (Sl. 6) i Veli Zelenikovac (Sl. 7). Budući da je riječ o površinskim, niskim kamenolomima s izraženim slojnicama, za vađenje blokova nije bilo potrebno izrađivati kanale odnosno pašarine. Na obje lokacije nisu vidljivi otisci kružnog dlijeta već otisci kvadratnih klinova. U kamenolomu Veli Ze-

It is difficult to know the amount of stone necessary for the construction of the city walls of Pharos because the size of the enclosed area is unknown. For such an attempt one should first take into the account the dynamics of altering the size of the walled city, because, as noted above, only two segments (out of three) of chronologically different fortifications of Pharos have been studied. If we try to calculate how many cubic meters of stone is needed for one metre of the city wall (not including the filling of smaller coarse stone) it should be taken into the account that the average depth of each stone block on the site of Remete vrt is 0.6 m. Taking into the account the two faces of the wall, the result is $1.2 m^3$. For the supposed height of the city wall of 5 to 7 m (width of the wall is 2.7 m) which wall should have for fortification purpose,³⁰ the result is 6 to $8.4 m^3$. Only after determining the boundaries of the walled city of Pharos, it will be possible to calculate how much stone was needed for the construction. Then the correct conclusions about the logistics required for this venture can be drawn. In this case, even for the smallest so far assumed size of the walled city of 1.5 ha (this thesis is no longer valid³¹) $3000 m^3$ of worked stone would be needed. For comparison, a quarry discovered at Zapaš bok cove has an area of $885 m^2$ and average depth of 2 m, which means that it has volume of $1770 m^3$ of stone. This amount of stone also includes debris from the extraction and processing of blocks whose percentage varies depending on the geological base, extraction technique and the type of construction for which the blocks are intended. In the quarries of Delphi the percentage of rejected material from extraction and hewing reaches up to 80% of the volume of the quarry, but on that site the extracted stone was used for finer construction than the one needed for the city walls.³²

Six locations of Stari Grad quarries can be separated in two groups, based on the preserved tool marks on the remaining part of the rock which testify to the differences in the stone splitting technique. The first group consists of quarries in coves Zapaš bok (Fig. 6) and Veli Zelenikovac (Fig. 7). Since these are surface, low-lying quarries with distinct contour lines, block extraction did not require channels. At both locations traces of square wedge holes

30 N. FIELDS, 2006 navodi primjere fortifikacija na osnovu kojih je hipotetski određena visina bedema Fara.

31 N. DUBOKOVIĆ-NADALINI, 1960.

32 J. PAPAGEORGAKIS, E. KOLAITI, 1992, 38.

30 N. FIELDS, 2006, provides examples of different fortifications on which the hypothetical height of the city walls of Pharos is presumed

31 N. DUBOKOVIĆ-NADALINI, 1960

32 J. PAPAGEORGAKIS, E. KOLAITI, 1992, 38.



SL. 6. / FIG. 6.

Kamenolom u uvali Zapaš bok i prikaz tragova od klinova na preostalim slojnicama (foto: S. Popović).

Quarry in Zapaš bok cove and the wedge marks on the remaining contour lines (photo: S. Popović).



SL. 7. / FIG. 7.

Kamenolom u uvali Veli Zelenikovac i trag ekstrakcije na jednom ostavljenom bloku (foto: S. Popović).

Quarry in Veli Zelenikovac cove and the extraction mark on one stone block that is left in the quarry (photo: S. Popović).

lenikovac ostavljen je jedan blok kamena koji ima očuvane ostatke kanala od vađenja bloka. Zapaš bok je veći kamenolom gdje se na preostalim slojnicama kamena uočavaju tragovi umetanja klinova. Po sredini kamenoloma se nalaze veliki ostavljeni blokovi koji očito nisu zadovoljavali kriterije za gradnju, kao i velike gomile manjeg kamena odnosno otpada od klesanja.

Drugu skupinu po tehnici ekstrakcije kamena čine kamenolomi obalnog područja rta Dugi rat i oni u uvalama Brizenica i Zavala. Za vađenje blokova ovdje, kao i kod prve skupine kamenoloma, nije bilo potrebno izrađivati pašarine, već rupe okomite na slojnicu, postavljene u određenim razmacima. Upravo su tragovi u preostalom dijelu stijene dali zaključiti da je riječ o kamenolomima. Na području Dugog rata (Sl. 8), na lokaciji gdje su prvo pronađeni ostaci eksploatacije kamena, jasno se ra-

are visible, not of round ones. One stone block, left in the quarry at Veli Zelenikovac, has the remains of a channel. Zapaš bok is a larger quarry, where traces of the wedge insertion are visible on the remaining contour lines. In the centre of the quarry are few large blocks, obviously left because they did not meet the construction criteria, as well as large piles of smaller stones i.e. debris slides.

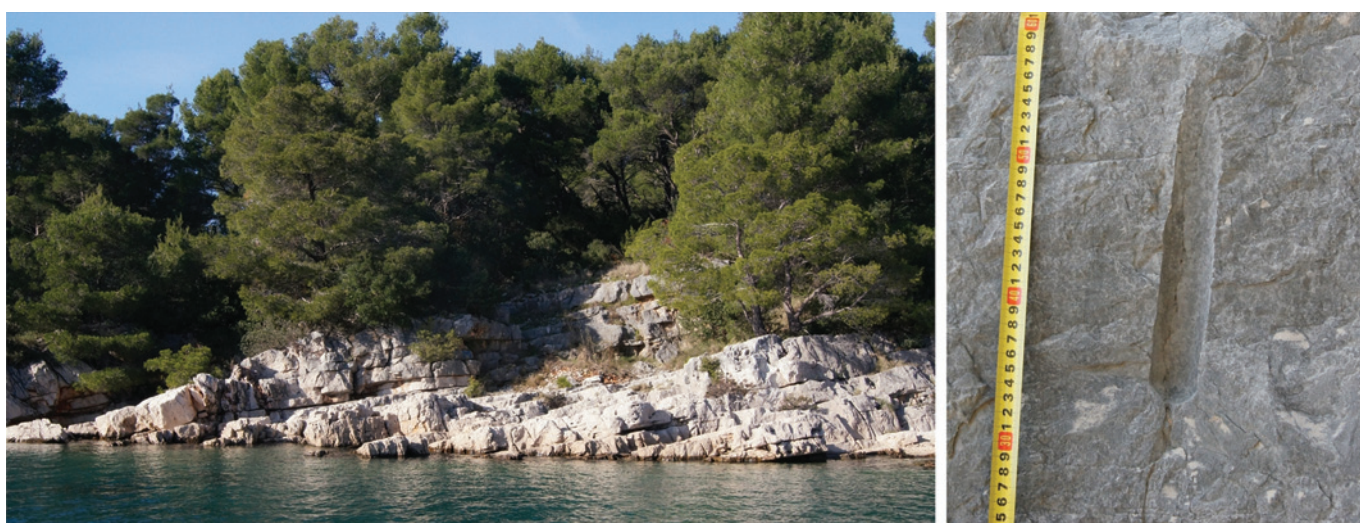
The second group consists of the quarries on the coastal line of cape Dugi rat and those in coves Brizenica and Zavala. As in the first group, block extraction did not require a channel construction, but rather holes positioned with certain spacing, perpendicular to the contour lines. It is precisely these traces in the remaining portion of the rock that indicated the existence of the quarries. In the area of Dugi rat (Fig. 8), where the remains of the stone exploitation were first discovered, at least eight rock



SL. 8. / FIG. 8.

Kamenolom na rtu Dugi rat i trag eksploatacije koji je djelomično ispod razine mora (foto: S. Popović).

Quarry on Dugi rat cape and the exploitation mark, partially below the sea level (photo: S. Popović).



SL. 9. / FIG. 9.

Kamenolom u uvali Brizenica i jedan od tragova ekstrakcije kamena (foto: S. Popović)

Quarry in Brizenica cove and one stone extraction mark (photo: S. Popović).

zaznaje barem osam slojnica stijene. U svakoj od slojnica mogu se uočiti brojni polukružni otisci alata. Ostaci vidljivih tragova u stijeni mogu doseći dubinu i do 70 cm, iako češće ne ostane otisak cijele dužine alata. Promjeri variraju između 2,5 cm i 4 cm. Na više mjesta vidi se lomljenje kamena pod pravim kutem, a za sada je teško sa sigurnošću potvrditi je li riječ o uporabi klinova. Druga lokacija, zapadnije na Dugom ratu plića je od prve, odnosno nema veliki

contour lines are clearly visible. In each of them are numerous semicircular tool marks. Visible traces in the rock can reach depths of up to 70 cm, although traces of the entire tool length are rare. Diameters vary between 2.5 and 4 cm. Splitting of the stones at the right angle can be observed in several places, but for now it is difficult to say with certainty if those are wedge marks. The second location on Dugi rat is shallower than the first one and has less contour



SL. 10. / FIG. 10.

Kamenolom u uvali Zavala i ostaci dvaju tragova ekstrakcije kamena (foto: S. Popović).

Quarry in Zavala cove and the remains of two stone extraction marks (photo: S. Popović).



SL. 11. / FIG. 11.

Kamenolom u uvali Paklina i trag ekstrakcije kamena (foto: S. Popović).

Quarry in Paklina cove and the stone extraction mark (photo: S. Popović).

broj slojnica u visinu kao prva lokacija. Na ovom mjestu vidi se da je u većoj širini cijepana samo jedna ili možda dvije slojnice kamena. Pronađeno je šest polukružnih tragova, od kojih su zanimljiviji ostaci onih položeni na istoj visini, relativno blizu jedan drugoga. Na trećoj lokaciji u uvali Brizenica (Sl. 9) nalazi se ponešto dublji kamenolom, s više slojnica, koji nalikuje prvoopisanome. U njemu i duž cijele zapadne strane uvale nađeni su ostaci 25 polukružnih otisaka. Gotovo ista tehnika primjenjena je u najvećem kamenolomu onome duž zapadne obale uvale Zavala (Sl. 10). Ovdje se zbog veličine prostora i brojnosti ostataka, otisci nisu ni brojali. U

lines height wise. It can also be seen that only one or two contour lines were cut here, but at the greater width. Six semicircular tool marks were found, with ones at the same height, relatively close to one another being most interesting. At the third location in Brizenica cove (Fig. 9), the quarry is somewhat deeper and with more contour lines, resembling the first one in Dugi rat. In it and along the western shore of the cove the remains of 25 semicircular tool marks were found. Almost the same technique was applied in the largest quarry, along the western shore of Zavala cove (Fig. 10). Here, because of the size of the area and abundance of extraction traces, tool marks

danas borom pošumljenom dijelu uvale, iznad ploča koje se blago spuštaju u more, također se vide ostaci ekstrakcije kamena kao i velike gomile otklesanog sitnijeg kamena.

Iako je prva pomisao, promatrajući polukružne otiske na stijinama druge skupine kamenoloma, navela na razmišljanje o dlijetima koja su se koristila u parskoj tehnici ekstrakcije kamena, jedini od prije poznati kamenolom u uvali Paklina (Sl. 11) dokazao je suprotno. Otvaranje tog kamenoloma spominje se u knjizi gradnje zvonika iz 1753. godine.³³ Na ovom mjestu nema izraženih slojnica kamena kao u svim ostalim kamenolomima (služio je za vađenje grubog kamena), ali su očuvani polukružni otisci ručnog svrdlanja identični onima u kamenolomima druge skupine. Upravo se po tipologiji ostataka na stijeni, koji svjedoče o istoj tehnici vađenja kamena, može zaključiti da su kamenolomi Dugog rata, Brizenice i Zavale korišteni u novome vijeku.³⁴

KARTIRANJE KAMENOLOMA U GIS SISTEMU

U nedostatku pokretnog materijala koji bi stvorio točniji vremenski raspon eksploatacije kamena na ovom prostoru, a nakon komparativne analize tragova ekstrakcije sirovine, studirani su arhivski prostorni podaci ovog industrijskog krajolika.

Lokacije ubiciranih kamenoloma kartirane su u GIS programu (Sl. 12) i preklapljene s arhivskim katastrom (nastalim u vrijeme Austro-Ugarske monarhije) koji između ostalih podataka sadrži i one o načinu korištenja tla. Tom se metodom ustanovilo da se u prvoj polovici 19. stoljeća znalo za kamenolome duž rta Dugi rat i Paklina. Na tim je parcelama ucrtan podatak o korištenju tla slovom C – *cave di pietra*. Budući da je Paklina izuzetno mali kamenolom (polukružnog oblika, promjera cca. 20-30 m i visine 2 m) vjerujem da je bio korišten kratko vrijeme i samo za navedenu namjenu, te da njegova eksploatacija nije mogla trajati do 1830-ih godina kada je ucrtan u katastar. Time se dovodi u pitanje jesu li kamenolomi duž rta Dugi rat bili aktivni u vrijeme izrade katastra (što je vjerojatnije iz razloga ubiranja poreza) ili je postojalo znanje o njihovoj minuloj eksploataciji. Ti se kamenolomi, naime, ne spominju

were not counted. In forested area of the cove, above the plates that slope gently into the sea, traces of stone extraction are also visible as well as the large debris slides.

Although the first observation of the semicircular marks in the quarries of the second group led to the consideration about usage of chisels like those in the Parian stone extraction technique, the only previously known quarry in Paklina (Fig. 11) cove proved otherwise. Establishment of this quarry is mentioned in the book about the construction of the aforementioned bell tower from 1753.³³ In this quarry contour lines are not distinct as in all others (it was used for the extraction of rough stone) but the preserved semicircular marks of hand augering are identical to the ones in the quarries of second group. Based on the typology of the tool marks on the rock, which testify to the same technique of stone extraction, it can be concluded that the quarries in Dugi rat, Brizenica and Zavala were used in modern times.³⁴

MAPPING THE QUARRIES IN GIS

In the absence of archaeological material that would create a more accurate time scale of the exploitation of this area, after a comparative analysis of extraction marks of raw material, archival spatial data of this industrial landscape was studied.

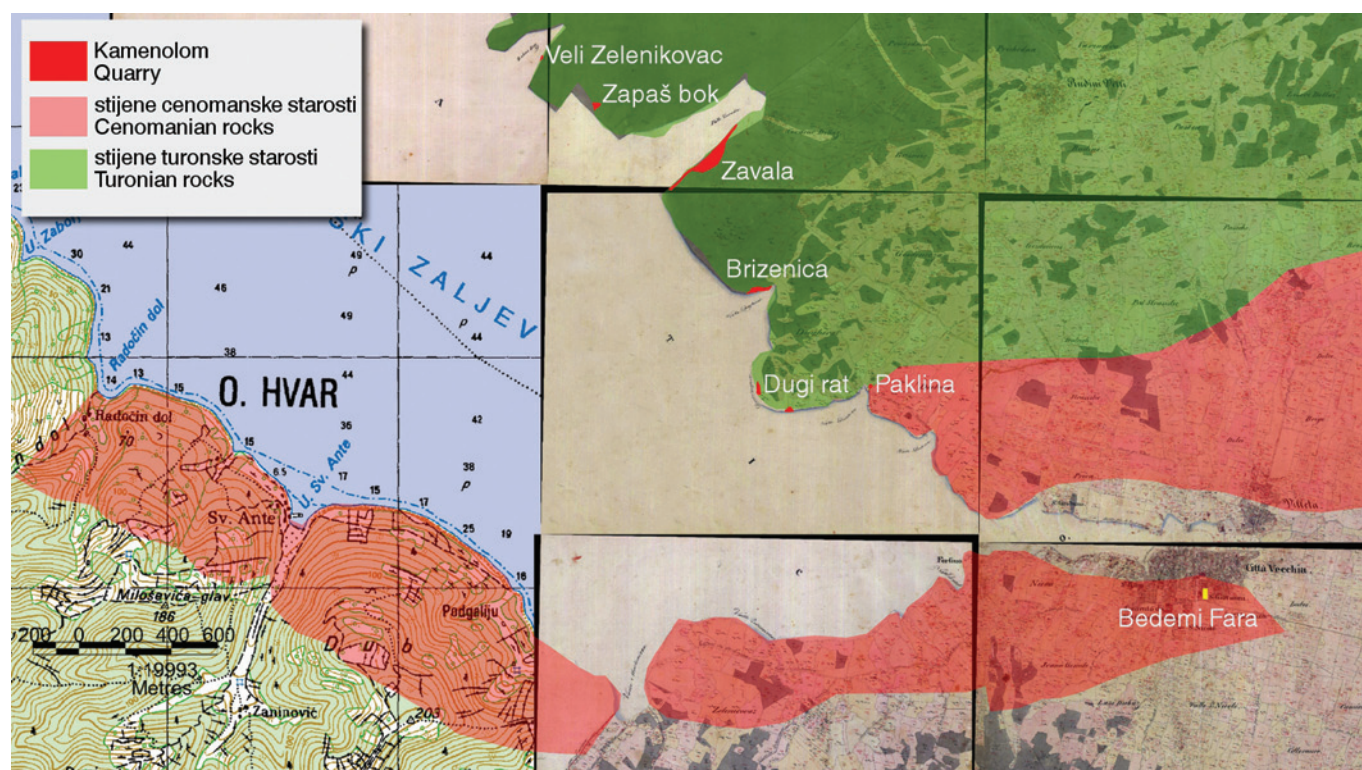
Locations of the quarry sites were mapped in GIS (Fig. 12) and overlapped with historic cadastral maps (created at the time of Austro-Hungarian Empire), which among other data contains those about land use. Using this method it was established that in the first half of the 19th century the quarries in Dugi rat and Paklina were known. These plots are marked with letter C – *cave di pietra*. Since Paklina is actually a small quarry (semicircular in shape, with diameter of about 20-30 m and 2 m of height) I believe that it was used for a short period of time and only for the stated purpose and that its exploitation could not last until 1830s when it was plotted in the cadastral map. This calls into question whether the quarries along Dugi rat were active at the time of creating the cadastre (which is more likely because of the tax revenue collection) or that there existed

33 J. KOVAČIĆ, 1994, 364.

34 Na konzultacijama se zahvaljujem kolegi Mati Parici s Odjela za arheologiju Sveučilišta u Zadru koji piše doktorsku disertaciju o problematici kamenoloma od prapovijesti do novoga vijeka.

33 J. KOVAČIĆ, 1994, 364.

34 I would like to thank a colleague Mate Parica from the Department of Archaeology, University of Zadar, who is preparing doctoral dissertation on the issue of quarries from prehistory to the modern age for consultations.



SL. 12. / FIG. 12.

Primjer usporedbe položaja kamenoloma s drugim georeferenciranim podacima poput arhivskog katastra i karte s geološkim podacima (u GIS programu kartirala S. Popović).

Example of comparison of the position of the quarries with other georeferenced data such as historical cadastral map and map with geological data (author: S. Popović using gvSIG).

ni u kakvim spisima, a ni danas u Starome Gradu ne postoji ikakvo znanje o njima.³⁵ Također, ne postoji pisani trag niti znanje o ostalim pronađenim kamenolomima, što je tim više interesantno kada je riječ o velikom prostoru duž cijele južne strane uvala Zavala i uvala Brizenica koje su eksploatirane istom tehnikom, a nisu ucrtane u arhivski katastar. Da su nastali nakon izrade katastra, bili bi ucrtani u kasnijim reambulacijama i vjerojatno bi se sačuvalo znanje o njima. Literatura o srednjovjekovnim ili novovjekovnim kamenolomima (koja donosi opise tragova alata) u nas je manjkava pa je tehniku upotrebe ručnog svrdlanja teško datirati. S druge strane, na Dugom ratu ostaci puntaruna (otiska ručnog svrdlanja) čije je dno 30 do 40 cm ispod razine mora (Sl. 8) govore o starosti kamenoloma koji se nikada nisu eksploatirali u morskoj razini.

the knowledge about their past exploitation. Those quarries are not mentioned in any records and no knowledge exists about them today in Stari Grad.³⁵ Also, there is no written record or knowledge of the other quarries which is more than interesting considering a large area along the southern side of Zavala cove and Brizenica cove that were exploited using the same technique, but are not plotted in historical cadastre. If they became active after the time of production of the cadastral map, they would be plotted in later revisions and knowledge about them would probably exist today. The literature about medieval or modern quarries (which describes the tool marks) in Croatia is deficient, so the technique of hand augering is hard to date. On the other hand, augering marks found in Dugi rat have bottoms at about 30-40 cm below sea level (Fig. 8) which indicates antiquity of the quarry, since the stone was never extracted at sea level.

35 Ovaj zaključak izveden je iz razgovora s voditeljem ispostave Hrvatskog državnog arhiva u Hvaru dr. sc. Joškom Kovačićem, koji najbolje poznaje pisanu arhivsku građu otoka, razgovora s hvarskim akademskim kiparom Slavomir Drinkovićem koji poznaje hvarski kamen, a ima iskustva i u radu u bračkim kamenolomima te s drugim upućenim ljudima na otoku Hvaru.

35 This conclusion is derived from interviews with the Head of Section of the Croatian State Archives in Hvar, Ph.D. Joško Kovačić, who is an expert on archival records of the island, academic sculptor Slavomir Drinković who is an expert on the stone from the island of Hvar and has experience in working in the quarries of the island of Brač and as well as talking with other knowledgeable people on the island.

MIKROPALEONTOLOŠKA ANALIZA KAMENA

S pet (od šest) lokacija na kojima su pronađeni tragovi eksploatacije kamena uzeti su uzorci za mikropaleontološku analizu koju je učinio L. Fuček, dipl. ing. geol. s Hrvatskog geološkog instituta. Istovremeno je poslano i pet nasumično odabranih uzoraka blokova bedema Fara s lokaliteta Remete vrt. Od uzoraka su u Institutu načinjeni izbrusci za mikroskopsku analizu, sa svrhom da se utvrdi relativna starost tj. odredi mikrofosilna zajednica relevantna za određeno geološko razdoblje. Uzorci bedema kao i oni kamenoloma vapnenačke su građe, no različitih geoloških starosti unutar razdoblja gornje krede. Svi izbrusci bedema odgovaraju istoj starosti – cenomanu (osim jednog izbruska koji se ne može detaljnije odrediti), dok uzorci kamenoloma imaju mikrofosilnu zajednicu karakterističnu za razdoblje gornjeg turona do kampana. Nakon rezultata analize, Institut mi je ustupio još neobjavljene pa time i neformalne podatke o rasprostiranju cenomanske litojedinice u okolici Staroga Grada, odnosno potencijalnog prostora za kamenolom s kojega su mogli biti vađeni analizirani blokovi bedema.³⁶

Iscrtavanjem položaja stijena cenomanske starosti u GIS programu taj podatak je uspoređen s drugim georeferenciranim podacima poput već spomenutog arhivskog katastarskog plana i arhivskih zračnih fotografija iz 1952. i 1968. godine (Sl. 12). Fotografije su vrijedan dokument koji svedoči o stanju krajolika prije velikih izgradnji Staroga Grada (od 1970-ih godina do danas) i prije pošumljavanja otoka, te bi se na njima lako uočio prostor na kojem se eksploatirala kamena sirovina. Dio potencijalnog prostora za kamenolom na južnoj strani Starogradskog zaljeva, od uvale Maslinica do uvale Radočin dol (za koji nedostaje arhivski materijal) pregledan je iz zraka (Sl. 13). Analizom zračnih fotografija zaključeno je da na tom prostoru uz more ne postoje slojnice stijene koja se mogla koristiti za gradnju, niti su vidljivi ostaci kakve eksploatacije krajolika koji se ovdje prilično strmo spušta u more. Uvala Maslinica pregledana je i terestrijalno i nije pokazala ikakav potencijal za vađenje velikih blokova kamena. Nakon pregleda terena (terestrijalnog i brodom), zračne prospekcije, te analize arhivskih zračnih fotografija i katastra cijelog prostora koji sadrži stijene cenomanske starosti, jedini poznati kamenolom ostaje onaj, ranije spomenut, na položaju Škudljivac.

MICROPALEONTOLOGICAL ANALYSIS OF THE STONE

Samples for the micropaleontological analysis were taken from five (out of six) locations where the traces of the stone acquisition were found. The analysis was conducted by L. Fuček B.Sc. from the Croatian Geological Survey (CGS). Five randomly selected samples of the blocks from the city walls of Pharos, on the site of Remete vrt, were also sent for analysis. Scrapings for the microscopic analysis were acquired from those samples in order to determine the relative age i.e. to determine microfossil assemblage relevant to a specific geological period. Samples of the city walls as well as those from the quarries are calcareous, but of different geological age within Upper Cretaceous period. All scrapings from the city walls correspond to the same age – Cenomanian (except one which cannot be determined precisely) while samples from the quarries have microfossil assemblage typical of the Upper Turonian to Campanian. After the results of the analysis, CGS also provided me with unpublished and thus informal data on the distribution of Cenomanian lithic unit around Stari Grad i.e. potential quarrying area from where analyzed blocks of the city walls could have been extracted.³⁶

After mapping the position of Cenomanian age rocks in GIS the data was compared with the other georeferenced data such as the aforementioned historical cadastral maps and historical aerial imagery from 1952 and 1968 (Fig. 12). Photographs are a valuable record attesting to the condition of the landscape before the large constructions in Stari Grad (from 1970s onward) and before the reforestation of the island, and the stone acquiring area should be easily recognized. Part of the potential quarrying area on the southern side of Stari Grad Bay, from Maslinica cove to Radočin dol cove (for which historical data is missing) was prospected from the air (Fig. 13). Analysis of the aerial imagery did not determine contour lines by the sea that could be used for the construction or any indication of landscape use, which here quite steeply descends into the sea. Terrestrial prospection in Maslinica cove did not indicate any potential for the extraction of large stone blocks. After terrestrial and offshore prospection, aerial prospection and analysis of the historical aerial imagery as well as the historical cadastral maps of the entire area containing rocks of Cenomanian

36 Zahvaljujem kolegama Ladislavu Fučeku i Tvrtku Korbaru iz Hrvatskog geološkog instituta na ustupljenim podacima.

36 I would like to thank colleagues Ladislav Fuček and Tvrtko Korbar from the Croatian Geological Survey for the given data.



SL. 13. / FIG. 13.

Zračna fotografija prostora uz uvalu Radočin dol
(foto: S. Popović).

*Aerial photograph of the area of Radočin dol cove
(photo: S. Popović).*

On se nalazi na sjevernoj strani Starogradskeg polja, ucrtan je u katastar, ali se odatle mogao vaditi samo kamen manjih dimenzija za gradnju kuća. Jedina mogućnost ostaje da su veće slojnice (kojih danas više nema) ranije bile eksploatirane. U svakom slučaju, na prostoru cenomanske starosti stijena nema vidljivih kamenoloma, što ide u prilog tezi da je možda samo manji dio zidina građen od blokova kamena te starosti.

U grčkoj praksi izgradnje gradova kamen se dobivao uz istovremeno prilagođavanje morfologije terena za gradnju.³⁷ To je slučaj i s gradnjom Ise koja je smještena na padini brda koje se klešuci pripremao za gradnju, a na taj način dobiveni blokovi su se odmah koristili.³⁸ Blokovi bedema Fara na lokalitetu Remete vrt ne leže direktno na živoj stijeni već

age, the only known quarry remains the one on the site of Škudljivac. It is located on the northern side of Stari Grad Plain and plotted in cadastre, but only the stone of smaller dimensions, for construction of the houses could be extracted from there. The only other option is that the larger contour lines (which no longer exist) have already been used. In any case, in the area of Cenomanian rocks there are no visible quarries which support the thesis that perhaps only a small part of the city walls were built with the stone blocks of that age.

Greek practice of constructing the cities included extracting the stone and at the same time adapting the morphology of the terrain.³⁷ This is also the case in the construction of Issa, which is located on the hillside that was prepared for the construction during the flattening of the rock, and the resulting blocks were immediately used.³⁸ Situation with the city walls of Pharos differ because the blocks on the site of Remete vrt do not lie directly on the bedrock,

37 E. KOLAITI, L.G. MENDONI, 1992, 29; J. PAPAGEORGAKIS, E. KOLAITI, 1992, 38.

38 M. KATIĆ, 2009, 29-30.

37 E. KOLAITI, L.G. MENDONI, 1992, 29; J. PAPAGEORGAKIS, E. KOLAITI, 1992, 38.

38 M. KATIĆ, 2009, 29-30.

na kulturnim slojevima, no ostaje mogućnost da su starije još neotkrivene fortifikacije u blizini crkve sv. Nikole građene na zaravnjenom kamenu živcu. To je moguće tim više što se cijeli prostor Fara nalazi na prostoru cenomanske litojedinice, odnosno stijeni iste starosti kao što su i blokovi bedema poslani na analizu. Moguće je da se kamen vadio u samoj blizini grada, uz obalu čiji nam je izvorni izgled nepoznat, jer je današnja linija obale nasipana u vrijeme Austro-Ugarske monarhije.

ZAKLJUČNA RAZMATRANJA

Za dataciju kamenoloma eksploatiranih za potrebe gradnje multiperiodnih naselja, ili onih u kojima, kao u slučaju Staroga Grada, život traje i danas, treba uzeti u obzir više kriterija, a time i metodoloških pristupa. Komparativnom analizom tehnika vađenja kamena može se zaključiti da su kamenolomi na rtu Dugi rat i uvali Brizenica nedvojbeno srednjovjekovni ili novovjekovni zbog velikog broja polukružnih otisaka istovjetnih onima u uvali Paklina. Valja napomenuti da se pri popravljaju rive u Starome Gradu 2003. godine uočilo da je građena od velikih kamenih blokova, koji su se pripisali blokovima Fara jer je nekima lice bilo klesano na bunju. Budući da je današnja linija obale izgrađena nasipavanjem u vrijeme Austro-Ugarske monarhije i ucrtana u kasnijoj reambulaciji katastra, ostaje mogućnost da su se upravo za tu namjenu otvorili kamenolomi na Dugom ratu i Brizenici.³⁹ Osim rive, niti jedna građevina u Starome Gradu nije građena od tako velikih blokova, koje zbog nemogućnosti kontroliranja pucanja kamena, prije modernih metoda, nije bilo moguće rezati na manje blokove. S druge strane, antički kamenolomi su se znali opetovano koristiti u kasnijim razdobljima, pa ponekad tragovi novije ekstrakcije zasjene one starije. To je moguć slučaj u uvali Zavala gdje je izuzetno velik prostor eksploatiran, a na nekim dijelovima, gdje je vidljivo da su odstranjene slojnice kamena, nedostaje ikakvih tragova novijeg korištenja prostora. Također je indikativno da dva kamenoloma najudaljenija od Staroga Grada, u uvalama Zapaš bok i Veli Zelenikovac, nemaju tragova kasnije eksploatacije.

Da su se mikropaleontološkom analizom podudarili uzorci bedema i kamenoloma, opet bi trebalo razmatrati razlike u tehnici ekstrakcije

but on the cultural layers. The possibility remains that the older, still undiscovered fortifications near the church of St Nicholas were built on leveled bedrock. This is possible because the whole area of Pharos is located on the Cenomanian lithic unit, on the rock of the same age as the blocks from the city walls sent for analysis. It is possible that the stone was extracted near the town, along the coast whose original morphology (due to the major change by filling in the time of Austro-Hungarian monarchy) is unknown to us.

CONCLUDING REMARKS

To date the quarries exploited for the purpose of construction of multi-period settlements, or those which, as is the case with Stari Grad, still live today, we must take into account a number of criteria and with them multiple methodological approaches. After the comparative analysis of the stone extraction techniques it can be concluded that the quarries on the cape Dugi rat and in Brizenica cove are undoubtedly medieval or modern, because of the large number of the semicircular marks identical to those in Paklina cove. It should be noted that during the reconstruction of the waterfront in Stari Grad in 2003 it was discovered that it was built with large stone blocks, which have been attributed to the city walls of Pharos because some of them were hewn with oval faces. Since the present shoreline was built by filling, in the time of Austro-Hungarian monarchy, and was plotted in later revisions of the cadastre, the possibility remains that the quarries on Dugi rat and in Brizenica were established specifically for this purpose.³⁹ Besides the waterfront, no other building in Stari Grad is constructed with such large stone blocks. Due to the inability to control the cracking of the stone, before modern methods it was not possible to cut those blocks into smaller pieces. On the other hand, ancient quarries are known to be used repeatedly in subsequent periods, and sometimes traces of recent extractions hide the older ones. This is possible in the case of Zavala cove where extremely large area was exploited and in some parts it is evident that the contour lines were removed, but any traces of more recent use of the area are lacking. It is also indicative that the two quarries farthest from Stari Grad, in the coves of

39 Ovu tezu bi trebalo dalje razmotriti detaljnim proučavanjem cijelog arhivskog katastarskog operata.

39 This thesis should be examined by detailed study of the entire historical cadastral register.



SL. 14. / FIG. 14.

Zračne fotografije kamenoloma u uvalama Zapaš bok i Zavala (foto: S. Popović).

Aerial photographs of the quarries in Zapaš bok and Zavala coves (photo: S. Popović).

sirovine jer je svih šest otkrivenih kamenoloma otvoreno u različito vrijeme, a u istoj vrsti vapnenca i to stijeni istog geološkog razdoblja taloženja. Budući da su svi uzorci poslani na analizu uzeti s blokova bedema koji su međusobno blizu ugrađeni i čine jedan mali dio zidina Fara, velika je vjerojatnost da su potekli iz istog kamenoloma. I dalje ostaje mogućnost da je za velik pothvat u gradnji, kao što je izgradnja gradskih bedema, za koju je potrebna velika količina i to velikog kamena, u nedostatku adekvatnog prostora koji bi se duže iskorištavao, bilo potrebno otvoriti više manjih kamenoloma iz kojih se crpila sva odgovarajuća sirovina. Moguće je da presloženi blokovi bedema u konobi Gramotorov ili oni ugrađeni u zvonik upravo potječu s jednog od pronađenih kamenoloma. Zato je potrebno nastaviti geološka ispitivanja, a zračnim (Sl. 14) i terestrijalnim, dodati i podvodna istraživanja. Ako se i pokaže da otkriveni kamenolomi nisu služili za dobivanje sirovine za bedeme Fara, vrijedi odgonetnuti kada su i za kakvu gradnju bili u upotrebi.

Istraživanje kamenoloma može informirati o nizu drugih arheoloških pojavnosti u industrijskom krajoliku poput radionica i drugih ostataka čovjekove aktivnosti koja je vezana za eksploataciju sirovine. Također upućuju o logistici transporta kamena, pa time ako su uz more mogu uputiti na položaj istovremenih luka ili privremenih pristaništa, ako su u kopnenom dijelu, na ceste kojima se sirovina dopremala do odredišta. Mapiranjem njihovih položaja i detaljnim dokumentiranjem promjena u tehnici

Zapaš bok and Veli Zelenikovac, show no traces of recent exploitation. Had the micropaleontological analysis showed that the samples from the city walls and the quarries were identical, the differences in the technique of extraction of the raw material should be considered, because all six quarries were opened at a different time but in the same type of limestone rock and of the same geological age. Since all samples of the city walls were taken from the blocks that were built close together and were forming only a small part of the walls of Pharos, it is highly possible that they came from the same quarry. It is still possible that for a great construction enterprise, such as the construction of the city walls which require considerable amount of large stone, in the absence of adequate space that could be exploited over extended period of time, it was necessary to open several smaller quarries from which all of the appropriate raw material was extracted. It is also possible that the reused blocks in the cellar of Gramotorov house or those built into the bell tower came from one of these quarries. Therefore, it is necessary to continue with the geological survey and to conduct underwater research, in addition to aerial (Fig. 14) and terrestrial research. If it turns out that discovered quarries were not used for acquiring raw material for the city walls of Pharos, it would still be valuable to see when and for what purpose were they in use.

Study of the quarries can inform us on a number of other archaeological manifestations in the industrial landscape such as workshops and other remnants of human activity that is related to the exploitation of stone. They also indicate on the logistics of the stone transportation. If the quarries are by the sea they may refer to the position of contemporary ports or occasional harbours and if they are inland they may refer on the roads used to transport the material to its destination. Mapping their locations

ekstrakcije kamena stvorio bi se tipološki okvir za lakšu dataciju aktivnosti u prostoru. Upravo sva ova otvorena pitanja dobar su poticaj za razradu metodološkog pristupa za daljnja istraživanja ovakvog kulturnog krajolika.

and detailed documentation of changes in the technique of stone extraction would create a typological framework for the dating of activities in the landscape. These open questions are a good incentive for the development of methodological approach for further study of the cultural landscape.

Translation: Andrea Devlahović

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