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Research Article

Origin of the Stone Varieties used in the Cultural Heritage Buildings of Lumbarda, Island of Korčula, Croatia

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Abstract

The aim of this paper is to determine the possible origin of the stone used for the construction in five cultural heritage buildings dating from the different historical epochs in Lumbarda, on the island of Korčula, Croatia. Micropetrographic determination of limestone samples taken from the Roman Villae Rusticae, the old apse of St Križ Church, the Venetian Tower, the Bishop's Summer House and St Barbara Church, was done. For comparison, micropetrographic analysis on the rock samples taken from two abandoned quarries near Lumbarda: the Brendana Quarry in Lumbarda and Gornja Špilja Quarry at Sutvara islet, was also made. After comparison of their petrographic characteristics, it was concluded that the stone for construction of the Roman Villae Rusticae and St Križ Church was quarried in Brendana Quarry, while for the other three investigated buildings the material was quarried on Sutvara islet in Gornja Špilja Quarry. Accordingly, petrographic analysis proved to be useful tool for determination of the origin of stone and useful for restoration purposes.

Keywords: Lumbarda; island of Korčula; origin of stone; limestone; petrographic analysis; Sutvara islet; cultural heritage; Croatia

Introduction

There is a long tradition of stone quarrying, processing, and its utilization [1-3] in Croatia. Many different natural stone varieties, mostly limestones, are well-known and used worldwide in the past [4,5]. Local examples of their usage are the City of Zagreb, the capital of Croatia,[6]as well as many old medieval towns along the Adriatic coast, such as Trogir, Split and Dubrovnik. Moreover, prominent Croatian regions with stonemasonry traditions are Istria and Dalmatia, especially the islands of Brač and Korčula[1-3,7,8]. Island of Korčula (Figure 1a) was particularly an area of overlapping of different cultures and peoples during history since prehistoric times, through the Illyrian, Greek and Roman colonization of the island. The island is famous for the exploitation of extremely quality decorative building stone [9-11]. The exploitation, as well as the processing of decorative stone was very active especially in Lumbarda. Lumbarda today is a small municipality[12]. Stone quarrying and stonemasonry was especially evidenced by the Korčula Statute from the year 1214. According to the Statute, everyone who exports the stone from the island of Korčula is required to report it to the government, write it down in the municipal office and pay the municipality [7,10]. In addition, in the Middle Ages, the exploitation and processing of decorative stone was very significant, especially during the rule of the Venetian Republic in this area, since 1420 [13].Particularly, a small group of islets, so-called Škoji islets, in the Pelješac Channel (Figure 1b) near Lumbarda, are known for their white Cretaceous limestones. Demand for this limestone peaked in the 15th and 16th centuries and it was exploited until the mid-20th century in a significant number of small quarries. The most famous old quarries are located on the islets: Vrnik, Badija, Kamenjak, Planjak and Sutvara (Figure 1b). Since exploitation is nowadays prohibited, all these quarries are abandoned. The stone was used for the construction and decoration of many buildings and houses in the Town of Korčula, in Lumbarda itself and even was exported to Dalmatia, especially to Dubrovnik, Venice (Italy) and even to Constantinople (today Istanbul, Turkey) [10]. All these quarries, due to long history of stone quarrying, represent the mining heritage of Lumbarda and the island of Korčula [14].

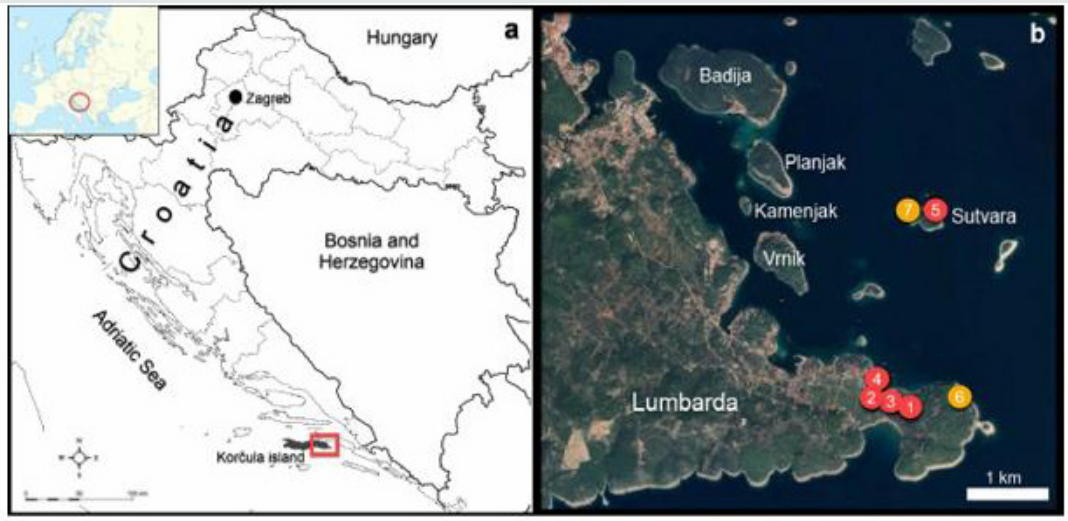

Figure 1: a) Map of the Republic of Croatia with the marked position of Korčula island (red rectangle), and b) Map of Lumbarda and Škoji islets (captured from Google Maps®), with marked sampling locations: 1. Villae Rusticae, 2. St Križ Church, 3. Venetian Tower, 4. Bishop's Summer House, 5. St Barbara Church on the Sutvara islet, 6. Brendana Quarry, 7. Gornja Špilja Quarry on the Sutvara islet.

There are several significant old buildings or building remains in Lumbarda that represent cultural heritage from the different historical periods (especially in the period from 15thto 18thcentury, when many summer houses were constructed). It is assumed that local valuable, decorative, and quality stone was used for their construction, although here are presented the first published petrographic analysis results for the samples taken from these buildings. Accordingly, the aim of this paper is to determine the possible origin of the stone used for the construction of five old cultural heritage buildings or their remains. Therefore, seven samples of limestones were taken for macroscopic and microscopic analysis from the Roman Villae Rusticae, the old apse of St Križ Church, Venetian Tower, Bishops Summer House, all located in Lumbarda, and from the St Barbara Church that is located on the islet of Sutvara(Figure 1b). In addition, three samples from two old quarries (one sample from Brendana Quarry in Lumbarda and two samples from Gornja Špilja ("Upper Cave") Quarry on the Sutvara islet – Figure 1b) were also analyzed. Based on the mutual comparison of petrographic characteristics of these samples, an attempt was made to determine from which quarry the stone for the construction of these buildings was quarried.

Geographical and geological overview

The island of Korčula is one of the largest islands in the Adriatic Sea, located about 1200 m away from the mainland (Figure 1a). The island stretches in an east-west direction for about 47 km, and together with the surrounding islets occupy the area of 271 km^2[15]. Around 15,500 inhabitants in a dozen larger settlements live there. Lumbarda is a small municipality on the east end of the island of Korčula, which cherishes long tradition of decorative stone exploitation and stonemasonry. Apart from the island itself, the stone was excavated on the nearby islets located in the Pelješac Channel (Figure 1b).The island of Korčula is a part of the Outer Dinarides belt, and it is built of limestones and dolomites deposited from the Lower to the Upper Cretaceous period, which are in places covered with terra rossa and sands of Quaternary age. The characteristics of limestones and dolomites indicate their deposition in a relatively shallow, turbulent environment, with variable currents, salt concentrations, temperatures, and water depths [15,16].The youngest part of the Cretaceous deposits of the island of Korčula are Upper Cretaceous rudist limestones [17]. The stratigraphic affiliation of these limestones was mainly determined from numerous analyzed rudist specimens[16]. The massive limestones have an average thickness of about 700 m in total. Most of the deposits belong to the stratigraphic range Santonian – Lower Campanian [16]. Due to its mineralogical and petrographic features, its fabric, easy processing and its decorativeness, it is a common and widely used stone for construction purposes [18].

Cultural heritage of Lumbarda

Many of the old buildings from Lumbarda, as Villae Rusticae building from Roman times and medieval summer houses and churches, were built of stone that was exploited from the quarries in Lumbarda and on the Škoji islets. Therefore, special attention is paid to five old buildings and building remains which represent the cultural heritage of Lumbarda.The oldest building in Lumbarda is Roman Villae Rusticae (Figure 2a), which is partly built in the technique of "opus reticulatum", mentioned by Radićin 1885 [19]. The small stone blocks, one side is 10 to 11 cm long, have a quadrangular face and are set at an angle (Figure 2b). The remains

of the walls of an ancient square elongated building with unusual span and its foundations seem to be composed of many rooms [20]. According to the locals, these were allegedly prison or dungeons erected by the Roman emperor Diocletian, the sworn persecutor of the Christians. These Christians, brought and imprisoned there, worked in nearby quarries [20]. Remains of Roman Villae Rusticae is the only Roman period building on the eastern part of Korčula island. On the St Križ Church (Križ means Cross in Croatian) (Figure 2c), that is surrounded with the vineyards, the year 1774 was engraved. Church was expanded and decorated in 1881, with lodge built in front of the church [20]. The church was built on the foundations of a much older church. Today the foundations of the apse of the old church are visible (Figure 2d).

Near the remains of Roman Villae Rusticae, at the distance of about 100 m, it is located the Venetian Tower, remains of it, (Figure 2e) surrounded by famous Lumbarda vineyards. We were unable to find the data in the literature on the history of its construction. It is assumed that Tower had a reconnaissance and defensive function and used as an observatory for the channel and shipping way between Pelješac peninsula and Korčula island.In addition, fifteen country complexes built between the 15th and 18th centuries, are located in Lumbarda [21]. Therefore, Lumbarda was the country destination of the bishops and nobles from the Town of Korčula in 17thand 18thcenturies. The first preserved summer house belonged to the Bishop (Figure 2f) and it was built in the 15thcentury with its northern wall's "sprout" from the sea, and the southern ones (Figure 2g) located next to the vineyard [21]. Remains of small church of St Barbara are located on the islet of Sutvara(Figure 2h) [22,23]. Church is 8 m long and 4.5 m wide, with polygonal-hexagonal apse typical for Byzantine architecture of the 6thto 7thcenturies in Asia Minor. The three-sided broken outer line of the apse floor plan is a crucial mark for its dating to the 6thcentury [23]. The way the church was built is typically late antique. The stone material was not carved with delicate tools, but it was roughly cut and selected from the quarry waste. The walls were thus made with two separate raised faces and strengthened by the abundant throwing of mortar and small sharp stone into the inner width. But more than the ignorance or negligence of the masons, it seems that on the islet where stonemasons worked even before the construction of the church, this can be explained by the late antique or early Christian efforts to plaster the walls. On the side walls, other parts were built in the "fishbone" style (Figure 3). Front door was oriented at the west and entrance lintel, 153 cm long and 26 cm high, had a cross in the middle of the face. This form is rare, according to known examples it dates mainly from the 9thto 11thcentury, so its appearance here is enigmatic [23]. The cult of St. Barbara was conceived in the early Christian East, and from Syria from the IV century it spread with the movements of the monastic orders. It reached the West in the 13th to 14th centuries. According to Skok[24], Sutvara is a Latin-Greek hybrid toponym, which contains the adjective sanctus = Sut and the Byzantine pronunciation of the name of Santa Barbara.

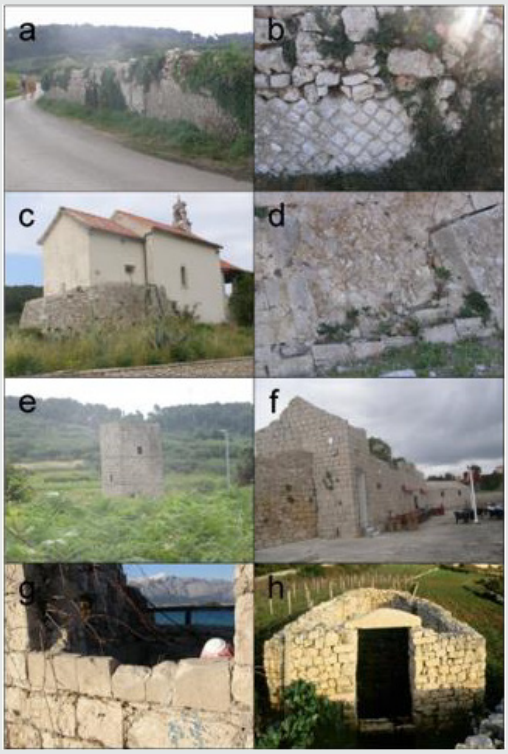

Figure 2: Figures of a) remains of Roman Villae Rusticae, that is b) made of small stone blocks, c) St Križ Church with d) visible apse of the old church, e) Venetian Tower, f) Bishop's Summer House, and g) southern wall of the House, h) remains of St Barbara Church on Sutvara islet (Photo of St Barbara church remains by N. Fazinić).

Figure 3: Side walls of the St Barbara Church built in the "fishbone" style (Photo by N. Fazinić).

Old quarries

Samples from two quarries – Brendana Quarry in Lumbarda and Gornja Špilja (Croatian for "Upper Cave") Quarry on the islet of Sutvara(Figure 1b) – were also chosen for the petrographic analysis. Brendana Quarry, located by the sea (Figure 4a, b) about 600 m east of Villae Rusticae. It is assumed that the quarry was

active in antiquity because today part of the quarry is flooded (Figure 4b). Traces of manual stone extraction or "chisel marks" are still visible. Brendana Quarry was abandoned in the 20thcentury and some family houses in Lumbarda are built of stone from that quarry, according to the locals[10].According to Gjivoje[9], both surface (external) and underground (gallery) methods of stone exploitation was applied, same from the antiquity to modern age. The largest underground quarries are located on the islet of Sutvara: DonjaŠpilja (Lower Cave) Quarry near the sea, whose ceiling collapsed in year 1950, and Gornja Špilja (Upper Cave) Quarry, which extends 25 m in depth, 13 m in width and a floor-to-ceiling height of 2 to 3 m (Figure 4c, d). Three layers of stone were removed here. These allegations would need to be reconsidered. In antiquity, stone was quarried on the islets of Korčula exclusively by the mining method of underground excavation[9]. Although some other authors also state this [25-27], that has not been exactly proven. The top surface layer of poor-quality stone was not removed, because the top layer of low-quality material reached a thickness of 1 to 3 m and removing a few meters thick mass without the use of explosives would require a lot of effort and time. Therefore, according to the same author, the stone was mined by underground gallery method. For the presented theses,[9] did not present convincing evidence for ancient exploitation of the stone on Sutvara islet. Namely, throughout the Middle Ages until the year 1950, stone was sporadically extracted from these galleries.

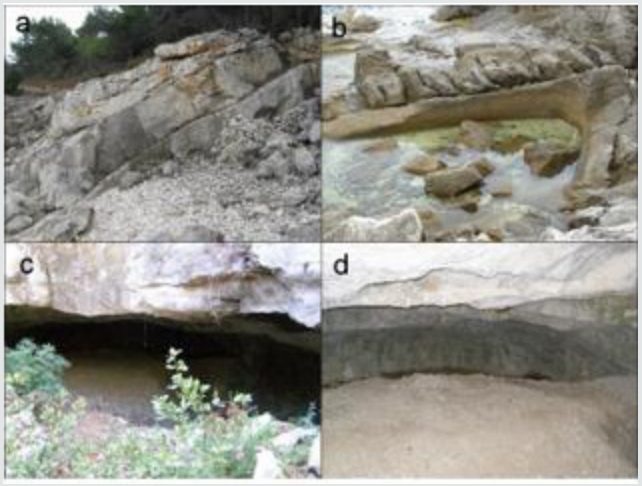

Figure 4: a) Brendana Quarry located by the sea, and b) flooded part of Brendana Quarry, c) Gornja Špilja Quarry on Sutvara islet, d) and inside of Gornja Špilja Quarry.

Methodology and Sampling

For distinguishing and description of carbonate rocks, classifications after Dunham [28] with the modifications after Embry and Klovan[29] and Flügel[30], were applied. For micropetrographical analysis of the thin sections, classifications after Folk [31,32] were used. In addition, thin sections were treated with Alizarin Red S and K-Ferricyanide chemicals, to distinguish and describe different carbonate particles and cements, according to the procedures described by Müller [33]. Thin sections were analyzed with the polarizing microscope Leica DM LSP, while microphotographs were taken with digital camera Canon EOS 1300D at the Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb. To determine possible origin of the building stone, samples for petrographic analysis were taken from five cultural heritage buildings. Additionally, samples for comparison were also taken from two old quarries. Sample locations and sample labels are marked in Table 1, according to Figure 1b.

Table 1: Sampling locations and sample labels.

Sampling location	Sample label
1. Villae Rusticae – northern wall	Su2
2. The St Križ Church – the upper part of the vertical threshold from the old apse	Su1
3. Venetian Tower – facade stone taken from the left side of the entrance	Su3
4a. The Bishops Summer House – left part of the lower threshold of the south window	Su4
4b. The Bishops Summer House – fragment of the facade stone under the roof on the south side	Su5
5a. The St Barbara Church on the islet of Sutvara – threshold of the church	Su8
5b. The St Barbara Church on the islet of Sutvara – the outer facade stone, the north side of the church	Su9
6. Brendana Quarry	Su7
7a. Gornja Špilja Quarry on the islet of Sutvara – the southern top of the cave	Su11
7b. Gornja Špilja Quarry on the islet of Sutvara – filled material from the inner part of the cave	Su12

Petrographic characteristics of the stone samples

Macroscopic determination and microscopic analysis have been made on ten limestone samples, seven among them taken from the buildings and remains, and three samples taken in two quarries, in order to compare their petrographic characteristics (Figure 5 & 6). Sample Su2 is limestone, determined as packstone/biomicrite (Figure 6a). According to its visible macroscopic characteristics (white-yellowish color and small, densely packed bioclasts), and to its microscopic characteristics (predominantly rudist fragments, and subordinately echinoid bioclasts within micrite and carbonate matrix), this sample is almost identical with the sample Su1. Intergranular primary porosity is more pronounced, comparing with the sample Su1. Sample Su1 is determined as packstone/biomicrite type of limestone (Figure 6b). Its white to yellowish color, together with small (<2 mm), densely packed and equally distributed bioclasts, are the main macroscopic characteristics of this stone. Microscopic analysis showed predominance of rudist fragments among bioclasts, and echinoid fragments appear subordinately within micrite and carbonate matrix. Small primary porosity is also visible.

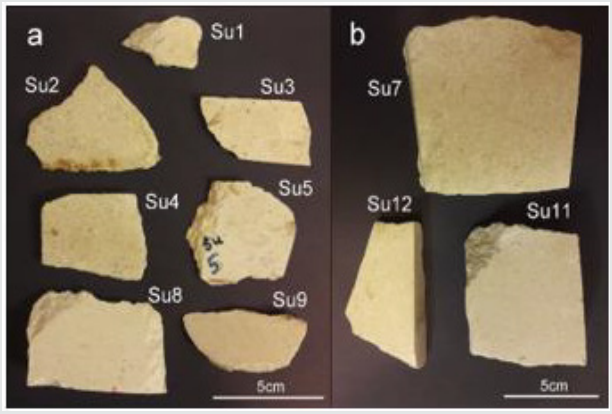

Figure 5: Samples of limestones, taken from: a) buildings, and b) quarries.

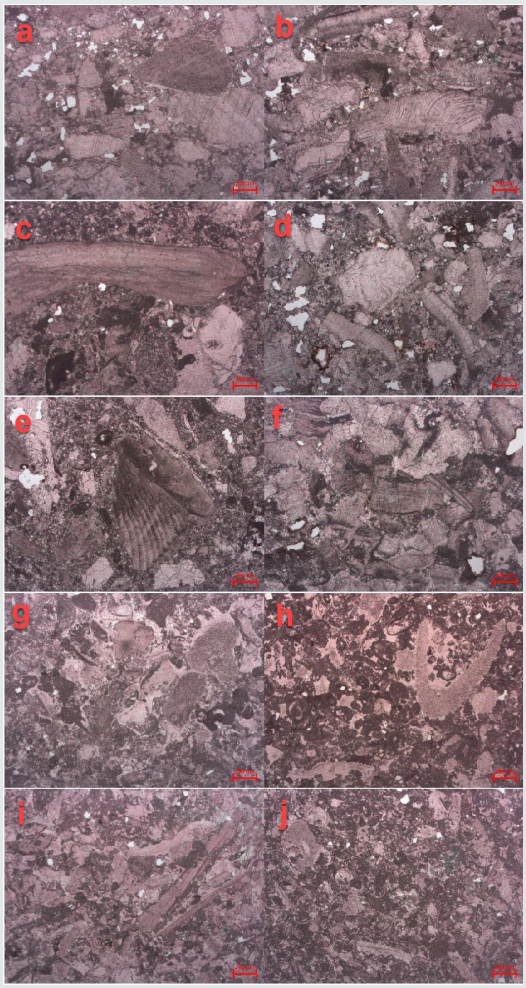

Figure 6: Microphotographs of limestone samples: a) Su2 – packstone/biomicrite; b) Su1 – packstone/ biomicrite; c) Su3 – packstone-to-floatstone/biomicriteto-biomicrudite; d) Su4 – packstone-to-floatstone/ biomicrite-to-biomicrudite; e) Su5 – floatstone/ biomicrudite; f) Su8 – packstone/ biomicrite; g) Su9 – packstone/biomicrite; h) Su7 – packstone/biomicrite i) Su11 – packstone/biomicrite; j) Su12 – packstone/ biomicrite.

Limestone sample Su3 is determined as packstone-to-float stone/biomicrite-to-biomicrudite (Figure 6c). White color of this stone, together with the significant amount of large (>2 mm) grey bioclasts, are their distinguishing characteristics from the two previously described limestone lithotypes (Su1 and Su2). Microscopic characteristics are also different, showing predominance of large chondrodite bioclasts (up to several millimeters long), accompanied with small miliolid foraminifera, bryozoans and some small intraclasts, all together bounded with micrite and carbonate matrix. Sample Su4 is also determined as packstone-to-float stone/biomicrite-to-biomicrudite (Figure 6d). Its color is white to yellowish, and predominant bioclasts are again poorly sorted (there are some bioclasts larger than 2 mm, among predominantly smaller) and equally distributed within the stone. Microscopic analysis showed again predominance of rudist bioclasts bounded with micrite and carbonate matrix. Primary intergranular porosity is significant, and it is more pronounced than in the sample Su3. Only sample that is determined precisely as floatstone/biomicrudite limestone is the sample Su5 (Figure 6e). According to its macroscopic characteristics (color and fabric), it is similar as the sample Su4, together with some larger rudist fragments, as significant distinguishing characteristic. Its fabric and composition at the microscopic scale showed predominance of larger (>2 mm) rudist bioclasts, accompanied with some small benthic foraminifera, green algae and intraclasts, all together bounded with micrite and carbonate matrix. Porosity is generally smaller than in sample Su4.

Limestone sample Su8 is determined as packstone/biomicrite (Figure 6f). Its color is white to light grey, and small bioclasts are densely packed and equally distributed throughout the sample. At the microscopic scale, predominantly rudist bioclasts are recognized, accompanied with echinoids and small benthic foraminifera, bounded together with micrite and carbonate matrix. Sample Su9 is also determined as packstone/biomicrite (Figure 6g). The color of this stone is also white to light grey, as in the sample Su8, and their macroscopic and microscopic are also similar, except that microscopic analysis showed more intraclasts in the sample Su9, as well as some more pronounced porosity, comparing with the sample Su8. Su7 limestone sample is determined as packstone/biomicrite (Figure 6h). White to light grey color, together with small (<2 mm), densely packed and equally distributed bioclasts, are its main macroscopic characteristics. Microscopic analysis showed predominance of rudist fragments among bioclasts, and echinoid fragments appear subordinately within micrite and carbonate matrix. Large pores are present in this stone. Limestone sample Su11 is determined as packstone/biomicrite (Figure 6i). Main macroscopic characteristics are its white to pale/light grey color, as well as small (< 2 mm), densely packed and equally distributed bioclasts. Microscopic analysis identified predominantly rudist bioclasts, accompanied with some echinoid fragments, bounded

together predominantly with micrite. Intraclasts are also subordinately observed. Small intergranular pores are present in this stone.Limestone sample Su12 is determined as packstone/biomicrite (Figure 6j). Its macroscopic characteristics, white to yellowish color, small grain size (<2mm), and densely packed fabric, are almost identical as in the sample Su11. At the microscopic scale, beside predominantly rudist bioclasts, some small benthic foraminifera, bryozoans and intraclasts appear as well. Small intergranular pores are present in this stone.

Discussion and Conclusion

The exploitation and processing of dimension and building stone on the island of Korčula, especially in Lumbarda and the surrounding islets, has a long tradition [1,2,7-11,18]. This decorative, high-quality stone suitable for processing was used for building and decoration in many villas, summer houses, in Lumbarda and in the Towns of Korčula, Dubrovnik and Constantinople, as well as in Italy [10]. It is assumed that the stone used in Lumbarda cultural heritage buildings was locally quarried. Therefore, to determine origin of the stone, petrographic analysis of seven samples taken from five old buildings, were performed. In addition, three samples were taken from two old quarries for analysis and compared with the samples taken from buildings. According to the results of petrographic analysis, all limestone samples are similar in composition and consists predominantly of bioclasts bounded together with micrite and carbonate matrix. In all samples, bioclasts are predominantly rudist fragments that are mainly small (<2 mm). In addition, the fragments of echinoids (in samples: Su1, Su2, Su7 and Su11) and foraminifera tests (in samples: Su3, Su5, Su8 and Su12) can be found. Green algae (in sample Su5), bryozoans (in samples: Su3 and Su12) and intraclasts (in samples: Su3, Su5, Su9, Su11 and Su12), were also observed. The samples were mainly determined as packstone (28) or as biomicrite (31, 32). Only sample Su5 is determined as floutstone/biomicrudite, while samples Su3 and Su4 are determined as transitional types: packstone/biomicrite-to-floutstone/biomicrudite.

Stone varieties from two quarries, as main building materials, slightly differ in petrographic properties. Variety from Brendana Quarry has a significant amount of rudist, and echinoid fragments bounded in micrite and carbonate matrix, mainly with the size of bioclasts <2 mm. Samples from Gornja Špilja have smaller bioclasts (mostly rudist fragments), together with significant amount of intraclasts. According to the similar composition as well as type and amount of bioclasts or other allochers, their dimensions, and ratio of bioclast to micrite were the main criteria for determining origin of stone material. Analyzed samples are determined as bioclastic limestones with mainly small (<2 mm) fragments (packstones/biomicrites) and occasionally with large (2 mm) fragments (floatstones/biomicrudites) having similar bioclasts (predominantly rudists, and subordinately echinoids and small benthic foraminifera), which implies their origin from the same geological formation – Upper Cretaceous rudist limestones – appearing along Korčula island, as well as in investigated quarries nearby Lumbarda. This conclusion, made by micropetrographical analysis and comparison of these building stones, imply local origin of the stone, with possible limitation of this determination to the stones deposited along the strike of similar beds throughout the island (not only to the beds quarried in the investigated quarries). Origin of the stone from some other quarries (if such quarries even existed) in the same geological formation at the island of Korčula is possible, but not highly probable, and needs to be further investigated.

Therefore, according to the obtained results, it can be assumed, with great certainty, that the stone used to build all cultural heritage buildings in Lumbarda was exploited in the vicinity. In terms of petrographic characteristics, it can be assumed that stone used for construction of two oldest buildings in Lumbarda – Roman Villae Rusticae and old apse of St Križ Church, was taken from Brendana Quarry (Table 2). In addition, if also considered the mode of stone material transport, it can be concluded that during the Roman Period the stone was excavated in nearby local quarry. In contrast, stone used for construction in three other buildings from later periods (Venetian Tower, Bishops Summer House and St Barbara Church) was quarried on Sutvara islet, in Gornja Špilja Quarry (Table 2). Accordingly, quarries on Sutvara islets had to be active in the Middle Ages and especially from the 15th to 18th century, when numerous summer houses in Lumbarda were being built, unlike previous allegations that the Sutvara Quarries date back to ancient time[9,25-27]. It should be noted that Sutvara Quarries were active until the 1950s, when it was prohibited to quarry the stone on all surrounding islets.Although the quarries are no longer active, the stone could be used for restoration purposes. In addition, given that Korčula island is famous for its long tradition of quarrying and stonemasonry, this is an opportunity for geological and mining heritage, together with related cultural heritage, to be presented for (geo)tourism purposes.

Table 2: Linking of building stone with the quarry.

Cultural Heritage Building/Remains	Quarry
Roman Villae Rusticae	Brendana
Old apse of St Križ Church	Brendana
Venetian Tower	Gornja Špilja
Bishops Summer House	Gornja Špilja
St Barbara Church	Gornja Špilja

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