WP3

Platy limestone – geologic definition and its use as a mineral commodity

Appendix 2.3

Final report for the project area in Croatia

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CONTENT

Abstract

Hrvatski geološki institut – The Croatian Geological Survey (HGI-CGS) has contracts with all four Croatian RoofOfRock project partners: ZADRA (Zadar County), RERA SD (Split-Dalmatia County), DUNEA (Dubrovnik-Neretva County), and IDA (Istria County) to work on the project as external expert and to prepare the project outputs. The contracts requirements comprise all geological aspects of the RoofOfRock project that have been defined and supervised by the leading partner – Geological Survey of Slovenia (GeoZS).

Firstly, the database and the overview geological map of the RoofOfRock project area of Croatia at a scale of 1:250,000 have been compiled and used as a base for an overview on building limestone in general (Chapter 2). According to the potential as building limestone, geological units are classified into three categories: low potential, potential and high potential (Appendix 1). More than 40 of the most important types of building limestone outcropping in the project area are selected in the list, along with 74 typical quarries (Appendix 2).

HGI-CGS has been working in close collaboration with the project partners and other external experts in the process of setting up a common definition of platy limestone (PL) as well as with data acquisition and collection for the database and geological maps. After an extensive geological survey done by HGI-CGS teams, and according to recognized characteristics, spatial occurrence and general characteristics of selected types of PL are shown in Chapter 3. In accordance with the 1:50,000 scale lithostratigraphic maps and attribute tables, we review the importance of low potential, potential and high potential types. Considering the huge project area in Croatia, only the potential and high potential PL types were mapped (21 polygons, Appendix 3) at a scale of 1:50,000.

After reporting on the general occurrence of the platy limestone in the project area covered by the Croatian partners, we are focusing on PL as a mineral commodity (Chapter 4), with respect to general spatial limitations of usage and its natural heritage. The aim of this report is to identify possible sources of the most promising types of platy limestone (high potential PL units and localities) within the investigated parts of the Adriatic karst region in Croatia.

Show-case objects are described in Chapter 5. The aim of this part of the RoofOfRock project was to identify different types of building limestones (including platy limestone) used on the selected show-case objects, and to relate the limestones to geological units defined on the geological maps at 1:250,000 and/or 1:50,000.

Finally, we summarized all the results in Chapter 6, along with some recommendations and guidelines for all geological and some natural and cultural aspects related to platy limestone in the investigated part of the Adriatic region of Croatia.

Complete material (Excel tables, analytical results, photographs, and GIS database* in .shp file) is included and updated on the enclosed CD, along with the final report.

*The final version of the GIS-database will be prepared by the Lead Beneficiary – Geological Survey of Slovenia – RoofOfRock project partner responsible for building and maintaining the joint database and cross-border harmonization for the entire RoofOfRock project area.

1. INTRODUCTION

Hrvatski geološki institut – The Croatian Geological Survey (HGI-CGS) has contracts with all four Croatian RoofOfRock project partners: IDA (Istria County), ZADRA (Zadar County), RERA SD (Split-Dalmatia County), and DUNEA (Dubrovnik-Neretva County), to work on the project as an external expert and to prepare the project outputs. The contracts requirements comprise all geological aspects of the RoofOfRock project, which were organized through the project work packages (WP): WP3, partially WP4, WP5 and WP7.

After introductory work on the overview regarding the building limestone in the Croatian part of the project area (WP1 and 2), we focused on the main goal of the RoofOfRock project – the platy limestone (WP3). The aim is to identify possible different types of platy limestone (PL) within the investigated regions of the Adriatic karst. For this purpose, major sedimentological and paleontological characteristics, stratigraphic positions and the age of various platy limestone horizons were studied.

According to the recognized characteristics, the spatial occurrence of all types of PL were defined on maps at a general scale of 1:50,000, along with an assessment of its general potential as PL, which served as a basis for evaluation of listed types of platy limestone as a mineral commodity and for identification of potential quarrying areas. The WP3 also included the selection and geological expertise of show-case objects, while the natural and cultural heritage of platy limestone (WP4) are considered just from a geological point of view. Geological data collected within the survey is incorporated into excel tables as the basis for a GIS database (WP7).

The requirements of the RoofOfRock project are specified as follow:

- review of the existing relevant documents and data with the goal to prepare a detailed overview (list) of all types of limestone from the Adriatic region of **Croatia** that were used as building stone.
- fieldwork in the Project Area with the goal of defining source areas of all types of building limestone in the Adriatic region of **Croatia** and to present them on a geological map at a scale of 1:250,000.
- cooperation with the leaders of WP3 (LB GeoZS) and WP5 (FB5 DMG UniTS) in the process of setting up a common definition of platy limestone;
- collecting and editing available archive material (spatial occurrence, all available lithological and paleontological data, quarry areas etc.) of types of platy limestone for Istria and Zadar, as well as the Split-Dalmatia and Dubrovnik-Neretva counties;
- fieldwork - lithostratigraphic (formational) geological mapping of the selected areas in Istrian, Zadar, Split-Dalmatia and Dubrovnik-Neretva counties needed for relevant spatial identification of platy limestone according to the written geological standards;
- conducting detailed sedimentological and palaeontological laboratory analyses of samples from localities where the platy limestone was recognized as not sufficiently determined for use in the project (i.e. their age, paleontological and lithological characteristics, genesis etc.)
- preparation of a geological dataset for formational geological maps on the platy limestone (scale 1:50,000) of selected areas in Istrian, Zadar, and the Split-Dalmatia and Dubrovnik-Neretva counties;
- reviewing and evaluating of all paleontological historical data on platy limestone from the point of view of natural heritage;
- active cooperation with leaders of WP3 (LB GeoZS), WP4 (FB6 UP ZRS), WP5 (FB5 DMG UniTS) and WP6 (FB7 JZ PŠJ) to analyse and synthesize the limitations of use of platy limestone related to questions of land use and natural, physical, social and legislative limitations;

- active cooperation with leaders of WP3 (LB GeoZS) to estimate the quality and quantity of reserves of platy limestone in order to select locations of potential quarrying areas and set guidelines for its sustainable exploitation;
- review of the existing relevant documents and data with the goal to select a typical village and autochthonous houses in Dalmatia;
- review of the existing relevant documents and data, fieldwork in the Project Area, and petrological and palaeontological analyses that aim to identify source areas of building limestone for 10 selected houses in Dalmatia;
- detailed lithostratigraphical mapping of the selected parts of Dalmatia (provisional scale 1:50,000) for defining the provenance of building limestone used in selected houses;
- gathering and unifying of material from selected parts of the Croatian project area and the preparation of detailed geological maps (provisional scale 1:50,000) of provenance of building limestone used in 10 selected houses;
- collecting and unifying all geological data and maps on platy limestone (scale 1:50,000) from the Croatian part of the karstified project area (including data from Istrian, Zadar, Split-Dalmatia and Dubrovnik-Neretva counties, provided by the Contracting Authority) and continued feeding of the GIS database. Data is in the ESRI .shp file format and prepared according to the specific requirements of the WP3 leader (LB GeoZS).

Following the overview on building limestone in general in the project area of Croatia, we focused on the geological definition of platy limestone as the main subject of the RoofOfRock project. As a part of a regional building limestone heritage in general, the platy limestone is genuine regional natural heritage and a link between many common cultural and traditional practices.

During the preparation work, a review of the existing relevant documents and data from formal and informal archives located at the Hrvatski geološki institut – the Croatian Geological Survey (HGI-CGS) – were made. In terms of platy limestone, it should be noted that some parts of the project area in Croatia are still being investigated for the preparation of the official Basic geological (lithostratigraphic) map of the Republic of Croatia 1:50,000. However, most of the data is still in manuscript form and as yet unpublished. We gathered all of the archive data and used it for the project RoofOfRock. Furthermore, during the preparatory work stage, we recognized many areas characterized by the local occurrence of platy limestone. HGI-CGS has been collaborating closely with the Lead Beneficiary in the process of determining a common definition of platy limestone, as well as with collecting data for the database and for geological maps. A number of formal meetings (Matavun, Split, Trieste, Pula, Vodnjan, Međugorje, Piran), and many interviews with responsible representatives of the Contracting Authorities and their external experts, important for the successful implementation of the project, have been attended by key HGI-CGS experts. In close cooperation with the Contracting Authorities, we selected the most promising areas where platy limestone appeared in nature, and which were geologically investigated in detail during the fieldwork, i.e. during geological (lithostratigraphical) mapping (see chapter 3.1).

According to the recognized potential and spatial occurrence of all types of PL previously defined on maps at a general scale of 1:50,000, we evaluate selected types of platy limestone as a mineral commodity with the final goal to identify potential quarrying areas. On certain selected and most promising sites, detailed sedimentological and paleontological data was obtained for the purpose of a natural protection proposal (in terms of age, paleontological and lithological characteristics, genesis, etc.). In addition, we propose general guidelines for sustainable exploitation of platy limestone.

Following the fieldwork, the most interesting and relevant collected data is incorporated into excel tables and the GIS database.

1.1. OVERVIEW OF THE PROJECT AREA - GEOGRAPHIC DESCRIPTION

The Croatian part of the RoofOfRock project comprises Croatian counties situated along the north-eastern coastal region of the Adriatic Sea (Fig. 1.1). While an overview on building limestone in general has been prepared for whole the region, detailed investigations of platy limestone have been made only in selected areas that fall under the responsibility of the Croatian project partners in Istria (IDA), and Dalmatia: Zadar (ZADRA), Split-Dalmatia (RERA SD), and Dubrovnik-Neretva (DUNEA) counties, respectively.

Istrian County is situated in the north-western part of the project area, and shares a border with Slovenia in the north, along the mountain range of Ćićarija. The Adriatic coastal area comprises the whole of the Istrian peninsula.

Zadar County is situated in northern Dalmatia, the central part of the project area. The county shares a border with the Lika-Senj County in the north, and the Šibenik-Knin County in the southeast. The Adriatic coastal area comprises the broad and flat coastal mainland belt (Ravni kotari), four bigger islands (Pag, Ugljan, Pašman, Dugi otok), and many smaller islands.

Split-Dalmatia County is situated in central Dalmatia. The county shares a border with the Šibenik-Knin County in the west, Bosnia and Herzegovina in the north, and the Dubrovnik-Neretva County in the east. The Adriatic coastal area comprises the broad Split-Trogir area, an elongated coastal mainland belt in front of the mountain range along the coast, and the islands of Šolta, Brač, Hvar, and Vis, along with many smaller islands in central Dalmatian archipelago.

Dubrovnik-Neretva County is situated in southern Dalmatia, i.e. in the south-easternmost part of the project area. The county borders the Split-Dalmatia County in the west, Herzegovina in the north and Montenegro in the east. The Adriatic coastal area comprises the narrow mainland belt along the coast, the elongated Pelješac peninsula, three bigger islands (Korčula, Mljet and Lastovo), and many smaller islands in southern Dalmatian archipelago.

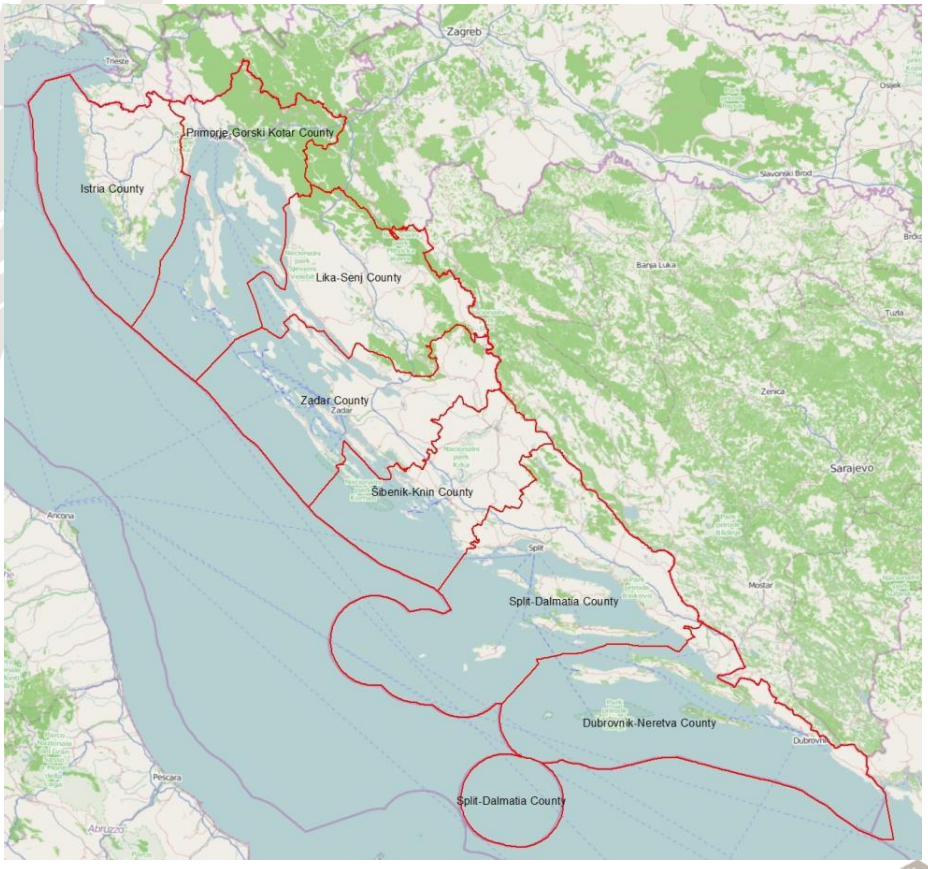


Fig. 1.1. Overview map of the Adriatic region showing Croatian counties within the RoofOfRock project area.

2. COMMON GEOLOGICAL DEFINITION OF (PLATY) LIMESTONE IN THE ADRIATIC REGION OF CROATIA

2.1. DEFINITION, OCCURRENCEAND DEPOSITIONAL ENVIRONMENTS OF LIMESTONE

According to some of the most widely cited geological classifications (TREFETHEN, 1950) limestone is a carbonate sedimentary rock that is characterized by content of more than 90% of calcium carbonate (CaCO3), while platy limestone is very thin-bedded limestone that is characterized by a bed thickness of 1-10 cm (cf. McKEE & WEIR, 1953; CAMPBELL, 1967; combined in KORBAR et al., 2012). According to such classification, we further consider laminated rock (<1 cm in thickness), thin-bedded (10-30 cm), medium thick-bedded (30-60 cm), thick-bedded (60-120 cm), very thick-bedded (>120 cm), and massive rocks.

The north-eastern Adriatic coastal area belongs to the Dinaric Karst region, the world renowned area of typical karstic geomorphological features developed within tectonically deformed and eroded sedimentary rocks (mostly limestone and dolomite), deposited within a broad Adriatic/Dinaric carbonate platform. The majority of the carbonates cropping out in the region were deposited during the Mesozoic era, some 200 to 66 million years (My) ago, from the Late Triassic to the end of the Cretaceous (VLAHOVIĆ et al., 2005 and references therein) eras. The entire region was part of the Adria, a northern promontory of the African continent, which was located during the Mesozoic approximately 2000 kilometres to the south, within a (sub)tropical climate belt. Younger carbonate and siliciclastic rocks were deposited later, at the beginning of the Cenozoic period (66 My ago) when Adria collided with Europe, and the material began to accumulate over the carbonate platform deposits within the so-called foreland basins (KORBAR, 2009, and references therein).

During the Cretaceous, shallow water spread over the Adriatic/Dinaric carbonate platform, and was encompassed by intervening deep marine basins within the Tethys Ocean (the present day Mediterranean), similar to the present day Bahamas. A variety of depositional environments could be found within the area (Fig. 2.1), and various limestone lithotypes (DUNHAM, 1962) could be deposited. Within the shallow-water, carbonate mud and peloids (micritic sediment), as well as carbonate skeletal sands (grainy sediment) were deposited at the bottom of shallow (up to a few meters deep) and warm tropical sea, while algal (microbial or cyanobactrial) laminites were deposited on broad intertidal areas in surrounding lowlands (islands) or within the shallow intraplatform depressions. In specific environments (lagoons, intraplatform depressions and basins), the deposits sometimes appeared thin-bedded or platy, and in places *fish, lizard* or even *plant* fossils were preserved. At the coastal areas of the lowlands, some *dinosaur tracks* have been preserved. Microscopic organisms living on the bottom (*benthic foraminifera and algae*) were the main producers of the carbonate mud and sand. *Mollusc shells* (mostly extinct *rudist* and *chondrodont bivalves*) could also appear within the sediment, and were especially abundant along the basin/platform margins, either deposited during storm events on the platform or redeposited as huge masses of broken shells (bioclasts) downslope to the basin. Within the basin, tiny skelets of *planktonic* (floating) *foraminifera* and *calcispheres* (both also made up of calcium-carbonate), sank to the bottom when an organism died. The material accumulated on the bottom, along with a fine carbonate mud (micrite, calcilutite), sporadically interrupted by deposition of fine- to coarse-grained detrital material (calcarenite=”sandstone”) redeposited from the marginal environments. In specific environments, especially during the deposition in Paleogene foreland basins, fossil tracks and traces of moving or feeding bottom-dwelling animals (crabs, worms...), so called *ichnofossils*, appeared during periods of non- or slow-deposition.

Over geological time, soft sediments lithified and limestone and dolomite beds formed from mud (mudstone or micrite, wackestone, packstone), sand (grainstone or calcarenite = “sandstone”), and gravel (rudstone, conglomerate), and became stacked one on top of another, forming a thick (up to a few kilometres) “layer cake” of the Adriatic/Dinaric carbonate platform and the overlaying foreland basin deposits.

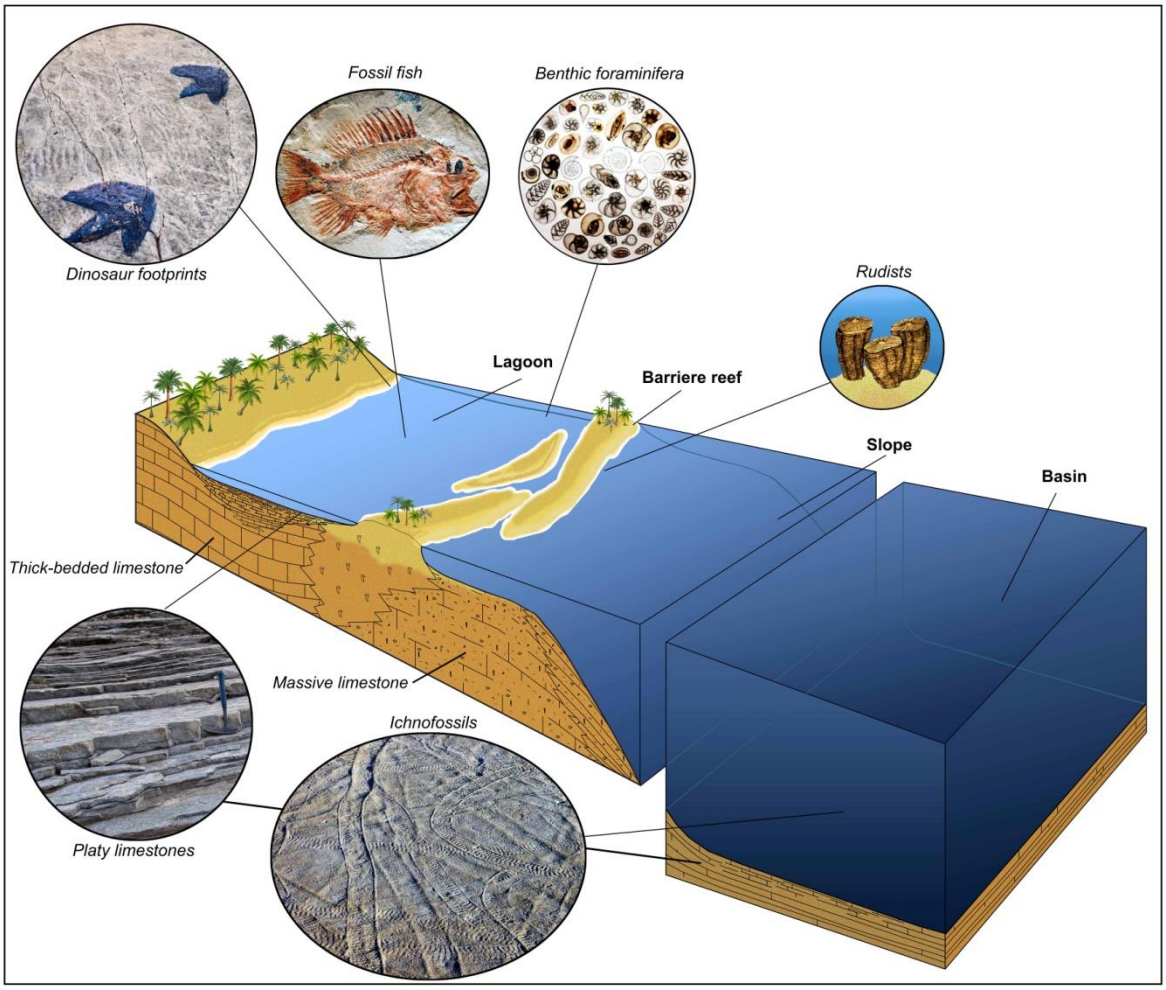


Fig. 2.1. Schematic block-diagram of depositional environments of thin-bedded (platy), thick-bedded and massive limestones within a shallow-water carbonate platform (including lagoon), platform margin (barrier reef), adjacent slopes and a deep marine basin.

During the Cenozoic era, the carbonate "layer cake" platform passed through a period of strong but slow tectonic deformation (faulting and folding), because of the collision between the Adria (African promontory) and the European plate. The carbonates and associated sediments were uplifted and eroded, forming External Dinarides (Dinaric mountain range and most of the Adriatic islands), and the associated and slightly deformed Adriatic foreland (most of Istria, and the islands of Vis, Lastovo, and Mljet) – all belonging to the Dinaric Karst region (see Chapter 2.2).

2.2. GEOLOGICAL SETTING

The Adriatic karst area of Croatia investigated for the RoofOfRock project belongs to the Dinaric Karst located in the NE Adriatic region (Fig. 1.1). The Croatian part of the region is characterized by a more or less deformed "layer cake" succession of Adriatic/Dinaric carbonate platform carbonates (80%), along with various underlying and overlying carbonate-siliciclastic (20%) sedimentary rocks (Fig. 2.3a). Most of the rocks that are highly deformed belong to the External Dinarides, while the outer, slightly deformed SW belt belongs to the Adriatic foreland (most of Istria, and some of the outermost Adriatic islands, KORBAR, 2009, and references therein). The External Dinarides are characterized by folds (anticlines and synclines), reverse and normal faults, which strike mostly in the NW-SE direction, the so-called Dinaric trend. The carbonate sedimentary rocks there are mostly well bedded limestones and

dolomites of the long lasting Adriatic/Dinaric carbonate platform (VLAHOVIĆ et al, 2005); thin-bedded platy limestone (PL) can also be found in places.

The whole NE Adriatic region is made up of different deposits characterized by a very large stratigraphic range – from the oldest Carboniferous sedimentary rocks to the youngest Quaternary deposits (Fig. 2.3b). The oldest rocks are found in the central part of the region, on the Velebit Mt. and its hinterland. The Upper Carboniferous to Permian clastic rocks (some 300 million years ago) crop out in the hinterland, while along the main crest of the mountain, thinly- to thickly-bedded grey dolomites of the Upper Permian age are exposed. Relatively large areas in the central mountainous and hinterland part of the region are built of various rocks of Triassic age, which can be divided into the Lower Triassic, predominantly of clastic rocks, followed by carbonates, clastic rocks and pyroclastic (volcanic) rocks (Middle Triassic) and Upper Triassic dolomites (Hauptdolomit). In normal successions there are the Jurassic peritidal carbonates with Lithiotis bivalves (Lower Jurassic), along with abundant benthic foraminifera and calcareous algae, which are rare in the Middle but again abundant in the Upper Jurassic carbonates.

In Istria, which belongs mainly to the gently tectonized Adriatic foreland, the carbonate rock succession spans the Upper Jurassic to the Eocene and is exposed on the surface in the limbs of a broad antiform with the oldest Upper Jurassic carbonates at the core (central coastal area of W Istria – Rovinj), and the Lower to Upper Cretaceous up to the Eocene, further to the north, east and south. PL appears mostly in the middle Cretaceous part of a succession, in the Upper Albian (Pula Formation) and the Cenomanian (Rušnjak Formation). Owing to its gently tectonized structure, and a relatively low angle of bedding, even thin intercalations of the PL within the succession (see chapter 3.2) resulted in relatively broad outcrops of PL in the field.

Most of coastal Dalmatia (lowland coastal areas, the islands) is built of Cretaceous to Paleogene carbonates. The Lower Cretaceous carbonates are rich in benthic foraminifera and calcareous algae. The middle part of Cretaceous is especially interesting because of many platy limestone (PL) horizons (Fig. 3.2). Thus, the Upper Albian horizons contain peritidal platy limestones, while certain Cenomanian units are characterized by PL deposited in shallow intraplatform basins, especially on the central Dalmatian islands. However, most of the Upper Cretaceous is characterized by peritidal limestones with numerous rudist and chondrodont bivalve fragments, benthic foraminifera and calcareous algae. These carbonate rocks cover a wide area along the coastal part of the region and the majority of the islands. Cenomanian deposits are characterized by platy limestones with stromatolites of the Milna Formation (Milna PL). Significant bodies of PL are also found within the lower part of the Gornji Humac formation (Fig. 3.2).

During the Upper Cretaceous age, tectonic movements caused a long-term emersion (terrestrial phase) and the uppermost part of the deposits were karstified and eroded. A shallow sea flooded the region again during the Early Paleogene. Thus, the karstified Upper Cretaceous platform carbonates are covered by younger sediments, Foraminiferal limestones (shallow-marine) in the lower and Flysch siliciclastics and carbonate clastics (deep marine) in the upper part (Fig. 3.2).

Basinal (deep marine) to fluvial (river) Promina deposits (Late Paleogene) cover the central lowland part of the Ravni kotari region, in the wider area of Benkovac (NE of Zadar). Benkovac platy limestones are identified in the lower part of the 2000 m-thick Promina succession (Fig. 3.2). The Promina geological unit represents a sedimentary infill of a complex basin developed above the deformed carbonate platform during the Paleogene.

Huge areas on the southern slopes of the Velebit Mt. and its hinterland are built of carbonate breccias (Oligocene-Neogene age) also known as the “Jelar breccias”. Neogene lacustrine (lake) deposits are found in places in the central part of the region. Quaternary deposits are found as small and thin patches, and can be either colluvial (slope) deposits, aeolian (wind derived) sands, lacustrine (lake) or residual (terra rossa) deposits.

2.3. GEOLOGICAL OVERVIEW ON BUILDING LIMESTONE

The database and the overview map of the Adriatic region of Croatia in scale 1:250,000 (Figures 2.3a, b) are based on the formal data shown on related sheets of the Basic geological map 1:100,000 (CROATIAN GEOLOGICAL SURVEY, 1951-1978), compiled on the overview geological map of Croatia in scale 1:300,000 (CROATIAN GEOLOGICAL SURVEY, 2009). Some data has been extracted from a professional book on Croatian Mineral Deposits (MARKOVIĆ, 2002). A huge amount of unpublished data has also been collected mostly from informal materials gathered by the HGI-CGS team members, and from the unpublished (Archive) formal regional mining-geological studies in the region (JELASKA et al., 2006, MIKO et al., 2008, 2013). For the final overview of the data, we used several official documents of the Government of Republic of Croatia (see http//: pages at the end of the REFERENCE LIST). These studies contain plenty of geological data on mineral deposits in the project area. However, for the purpose of the project, basic unification and harmonization of geological units and data was performed. The overview map in scale 1:250,000 was, in the end, harmonized in cooperation with Lead Beneficary GeoZS.

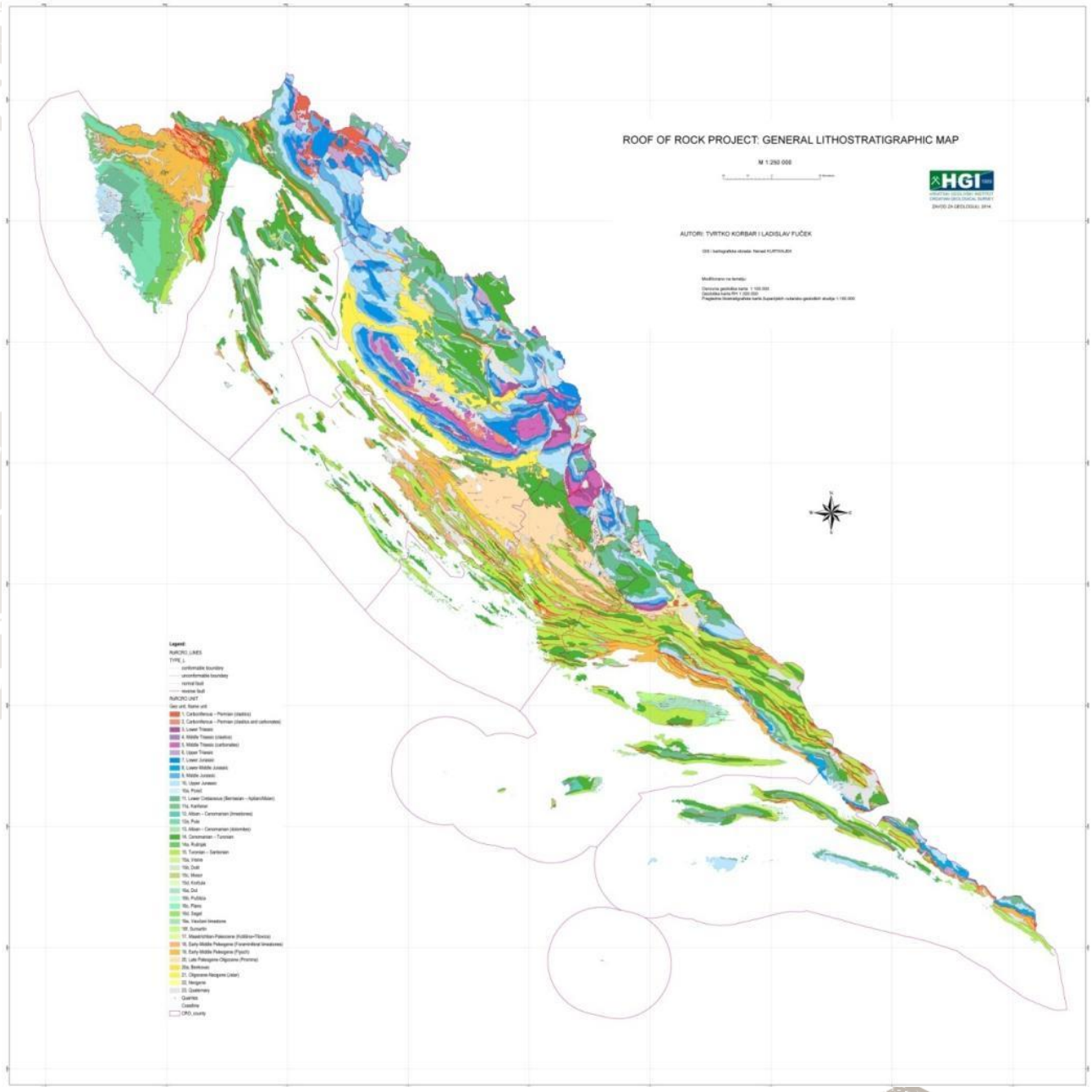


Fig. 2.3a. Geological overview map of the Croatian part of the RoofOfRock project area.

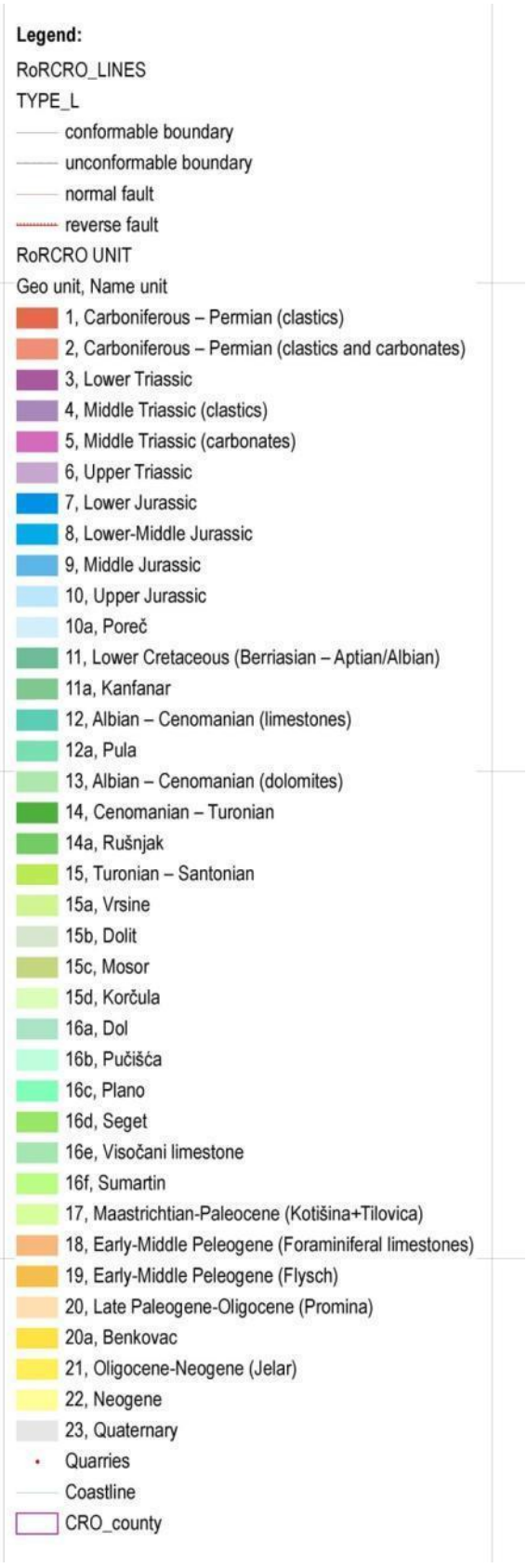


Fig. 2.3b. List of the geological units and the legend of the geological overview map (1:250,000) of the Croatian part of the RoofOfRock project area.

For the purposes of accessing potential as building limestone, geological units are classified into three categories: **low potential, potential and high potential.** Low potential types include lesser-quality limestone, used not commercially but only locally. Potential types include relatively quality building limestone that could be also be commercially used, where abandoned quarries exist. High potential types include types that are/were widely commercially used, from a number of active quarries, and the occurrence of the high potential types is usually presented on more detailed lithostratigraphic maps (subunits a, b, c... in Figure 2.3b, and in the list of the geological units in **Appendix 1**). Geological units with **"no potential"** (e.g. flysch, igneous rocks, quaternary etc.) are not shown in the potentiality overview map (Figure 2.3c).

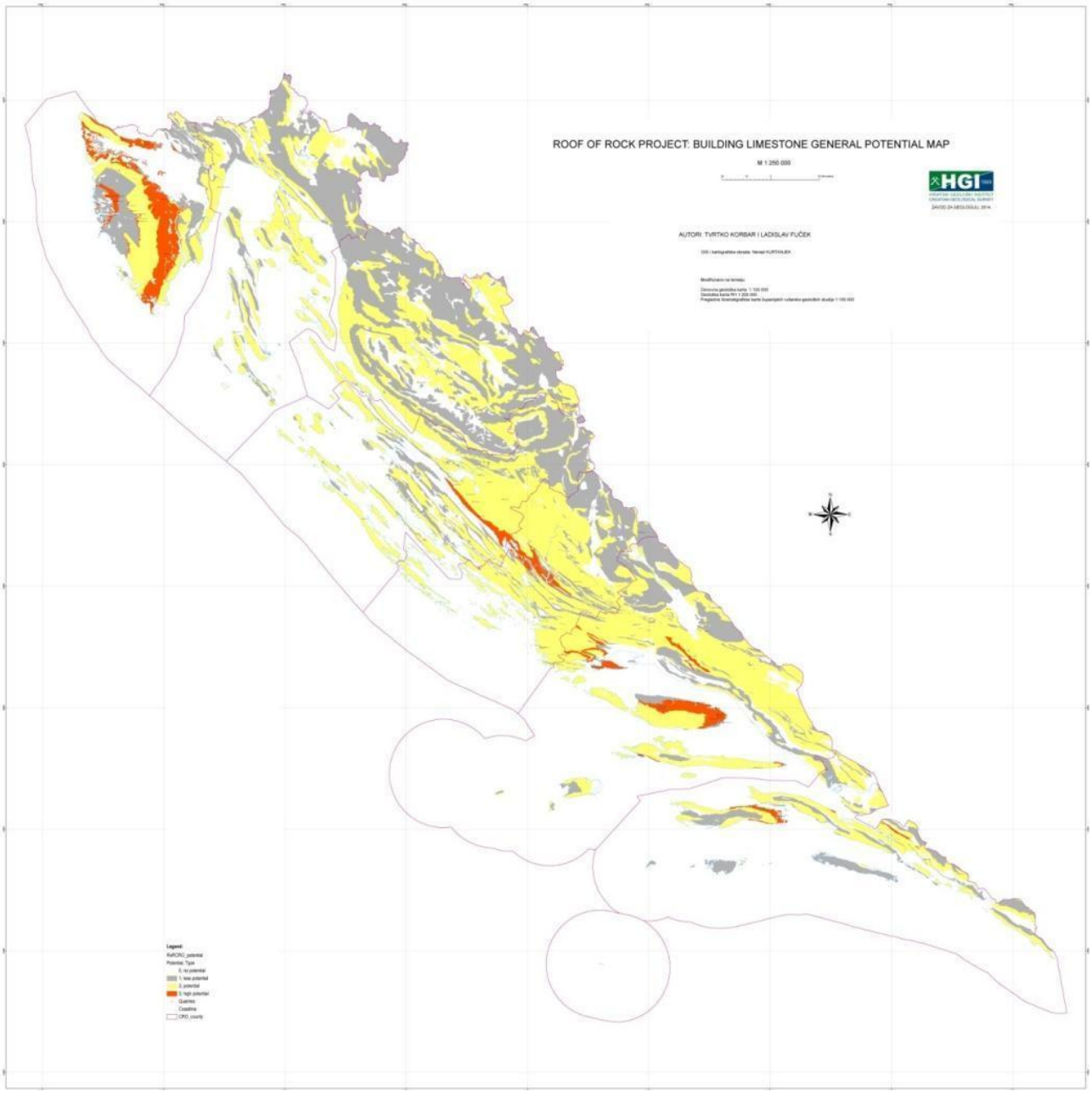


Fig. 2.3c. Overview map of general building limestone potential of the Croatian part of the RoofOfRock project area (grey – low potential, yellow – potential, orange – high potential).

The most important types of building limestone appear in certain areas within the Adriatic region of Croatia, because of specific depositional environments that have existed in the region throughout geological history (see Chapter 2.1). The majority of building limestones are massive limestones, suitable for exploitation as limestone blocks. More than 40 of the most important types of building limestones in the project area are selected in the list (**Appendix 1**), along with 74 typical quarries of building limestones (**Appendix 2**). However, there are also widely used platy limestones that are investigated in more detail within the project RoofOfRock.

3. GEOLOGICAL RESEARCH ON PLATY LIMESTONE IN THE PROJECT AREA

3.1. METHODOLOGY OF DETAILED GEOLOGICAL INVESTIGATION AND MAPPING

Following a comprehensive analyses of the existing maps and mostly unpublished geological archive data of the HGI-CGS, field research teams started with preparation of fieldwork and geological mapping within the project RoofOfRock. Apart from the project areas in Croatia that have already been investigated by the HGI-CGS for the production of the official Basic geological (lithostratigraphic) map of the Republic of Croatia 1:50,000, we focused on the areas that were recognized as potential for platy limestone and for additional detailed lithostratigraphic (formational) geological mapping according to the written standard (KORBAR et al., 2012). Different types of platy limestone within the investigated regions of the Adriatic karst are identified. Each team prepared their fieldwork according to the specific characteristics of the target area based on both previous detailed stratigraphy, as well as recent stratigraphical research on selected outcrops comprising the successions of the most interesting platy limestones.

During the logging of the most interesting sedimentary successions, major sedimentological and paleontological characteristics, stratigraphic position and the age of various platy limestone horizons were studied, both in situ and during subsequent laboratory analyses. Thus, detailed sedimentological and paleontological data from localities where the platy limestone appear has been collected for use in the project (related to age, paleontological and lithological characteristics, genesis, etc.)

The major part of the fieldwork included extensive and detailed geological mapping of the units recognized after stratigraphical research at a scale of 1:50,000. Each geologist from the team usually mapped 0.5-1.5 km^2 per day. The distribution of various lithostratigraphic units that resulted from mapping was then plotted on a topographical map. This working/central geological map was improved/updated daily after fieldwork by the team.

Alongside the geological data, the quality and quantity of single types of platy limestone were observed during the mapping. The most representative samples were collected from both the outcrops and the buildings. Estimations as a basis for the evaluation of platy limestone as a mineral commodity and for identification of the potential quarrying areas were discussed among the members of the team.

Furthermore, there was continuous collaboration with the WP4 (cultural heritage) team leader and external experts, since the use of PL in the past also helped us to define areas that should be investigated in detail within the broader project region.

After all the data had been collected and unified and the maps of platy limestones prepared, office work continued and GIS-based databases were prepared. The data was converted into ESRI .shp file format and processed according to the specific requirements of the project.

Finally, the team used the database and the maps for the preparation of the reports.

Appearances of platy limestone recognized as valuable for the project are shown on the maps in this chapter, while an assessment on the most promising occurrences as a mineral commodity are described in detail in Chapter 4. All other local PL occurrences and buildings are included in Excel tables and the database in GIS.

3.2. GENERAL AND SPATIAL OCCURRENCEOF PLATY LIMESTONE

An approach to the spatial definition of the PL depends significantly on the scale of the geological map. Following the first findings on PL in the project region, obtained during analyses of existing maps within the process of compilation of general geological map 1:250,000 (250K), for the purpose of showing the general occurrence of various types of building limestones, we recognized various potentials of platy limestone units on a very general scale. However, according to a general approach agreed on in the coordination meetings, as well as during the more detailed fieldwork on PL (lithostratigraphic mapping at a scale of 1:50,000), we recognized three categories of PL potentiality, primarily defined according to the main criterion – a certain percentage of PL within the lithostratigraphic unit thickness. Namely, every stratigraphical unit that is defined spatially during lithostratigraphical mapping is characterized by a substantial thickness of the sedimentary succession (in average up to a few tens of meters). Every sedimentary succession is a stack of sedimentary strata (beds) of different thickness (one centimetre up to a few meters). In most of the cases only a certain portion of the succession is characterized by platy occurrence (beds 1-10 cm thick). This means that plates appear only in a restricted part of the unit, at the surface (outcrops), though some units can be completely characterized by a platy occurrence (100 %). Thus, we assigned the PL units to the following categories:

1. LOW POTENTIAL (<10% of PL, not shown on the maps),
2. POTENTIAL (10-30% of PL, yellow colour on the maps),
3. HIGH POTENTIAL (>30% of PL, orange colour on the maps).

For purposes of the project, the potential and high potential units (**Appendix 3**) are spatially defined and shown on the topographic maps (OpenStreetMap), according to detailed geological maps prepared by mapping teams during the fieldwork. It should be noted that these PL units cover more than 500 km^2 of the Croatian project territory. The low potential units are not shown on the maps, due to a significant number of restricted and dispersed local occurrences of such thin (mostly <1m thick) intercalations, largely within thickly-bedded geological units outcropping in a large project region in Croatia. Almost all limestone units shown on the 250K general map can be considered low potential PL units, especially units: 7, 10, 12, 12a,13, 14, 15, 16a, 16f, 18, and 20a. However, some important local occurrences within the units are marked and geologically described, especially in cases where these less important PL occurrences were used as local building stone.

The PL sequences belong to various geological (lithostratigraphical) units (Fig. 3.2), or sometimes represent a separate unit themselves. In the Croatian part of the project area, platy limestones (PL) appear within sequences which could be up to a few tens of meters thick. It must be noted that most of the PL sequences are only a few meters thick, in some places less than a meter, but the superficial spatial occurrence of PL depends considerably on the relation of the geological (bed dip angles) and morphological (flat or steep relief) features: as concordant as these two geometrical issues are, as broad is occurrence of a PL unit on the surface. This same criterion was used as a secondary criterion for the characterization of PL in the three categories.

The majority of the surface occurrences of PL are found within the Adriatic/Dinaric carbonate platform succession (see chapter 2) within mostly shallow-water carbonate sequences of the Early Cretaceous (Albian) and Late Cretaceous age (Cenomanian, Turonian, and sporadically Campanian and Maastrichtian). There is also the well-known and commercially widely used platy limestone from the Benkovac area (“Benkovac Stone”), which was deposited in a basin developed above the carbonate platform in the Benkovac region during the late Paleogene.

In Istria, 2 main Cretaceous PL types characterized by a significant amount of platy limestone are

recognized and defined (Pula PL and Rušnjak PL, see chapter 3.3.). Both platy limestone types have been deposited in shallow water on the carbonate platform. The Pula platy limestone is recognized in the lower part of the Pula Formation of Albian age. The Rušnjak platy limestone is recognized in the middle part of the Rušnjak Formation of Cenomanian age.

In the Benkovac (Zadar) area (northern Dalmatia), there is the major PL occurrence of the so-called "Benkovac Stone"), where three Paleogene types of PL were recognized during this survey in higher Promina unit: Debelo brdo, Benkovac PL, and Otavac. There are also local occurrences of Cretaceous PL, e.g. the Cenomanian Milna PL on the island of Dugi otok (see chapter 3.4.).

In the Trogir area and the islands of Šolta, Brač, Hvar, Vis, Korčula, and Pelješac peninsula (central and southern Dalmatia), five main Cretaceous lithostratigraphic units include also a number of various PL types defined stratigraphically and spatially (see chapters 3.5., and 3.6.): Crna Formation of Albian age (only local occurrences on Vis and Korčula-Vela Luka), Milna Formation of Cenomanian age (Klačina, Milna PL, Rogač, and Vrboska sub-types), Gornji Humac Formation of Turonian-Coniacian age (includes Gračišće PL and Gornji Humac PL sub-types), Dol Formation of Turonian-Campanian age (Vinišće and Jelinak sub-types, and some local occurrences of PL on the island of Brač), and Sumartin Formation of Maastrichtian age (locally on the island of Brač). The PL have been deposited either in lagoons (Milna, Vrboska, Gračišće, Gornji Humac, and Sumartin Formation in general), or in intraplatform basins (Rogač, Vinišće, Jelinak and Dol in general).

No	area	ID polygon	Name of PL	Age	Area of occurrence (descriptive)	PL potential
1	Istra	3010	Pula PL-Istria	Albian	Between Pula and Savudria (Istria).	high-potential !
2	Zadar	3110	Debelo brdo-Zadar	Late Eocene	Between Islam Grčki - Smilčići villages and Debelo brdo to Mejanica hill.	potential
3	Zadar	3120	Benkovac PL-Zadar	Late Eocene-Lower Oligocene	NW-SE trending belt located between Smilčići village and Mejanica hill and extending more than 5 km toward SE.	high-potential
4	Zadar	3130	Otavac PL-Zadar	Late Eocene-Lower Oligocene	Two larger areas: northeastern slopes of Kukalj hill and southwest of Pliskovo village.	high-potential
5	Trogir	3310	Milna PL-Trogir	Cenomanian	Between Svinca and Gustirna (W of Trogir).	high-potential
6	Trogir	3320	Vinišće-Trogir	Turonian	East of Vinišće (SW of Trogir) and northern part of Veli Drvenik island.	potential
7	Trogir	3330	Jelinak-Trogir	Turonian-Santonian	Between Bristivica and Blizna at Jelinak Mt. hinterland (NW of Trogir).	high-potential
8	Šolta	3410	Klačina PL-Šolta	Cenomanian	Koludrovi doci. Between Stomorska and Gornje Selo (Šolta).	high-potential
9	Šolta	3420	Klačina PL-Šolta	Cenomanian	In Stomorska village and Nečujam cove (Šolta).	potential
10	Šolta	3440	Rogač-Šolta	Cenomanian	Central part of Šolta island.	potential
11	Šolta	3430	Milna PL-Šolta	Cenomanian	Kupište. W of Gornje Selo (Šolta)	high-potential
12	Hvar	3510	Vrboska-Hvar	Cenomanian	Between Vrboska and Stari Grad	potential
13	Hvar	3520	Vrboska PL-Hvar	Cenomanian	Northern part of Starogradsko polje, between Vrboska and Stari Grad	high-potential
14	Brač	3610	Vrboska-Brač	Cenomanian	Westernmost part of the island of Brač.	potential
15	Brač	3620	Gračišće-PL-Brač	Turonian	Central-southern part of the island of Brač.	potential
16	Brač	3630	Gornji Humac-PL-Brač	Turonian	Central-southern part of the island of Brač.	high-potential
17	Korčula	3810	Milna-PL-Pupnat	Cenomanian	In the eastern part of the island of Korčula (east of the Pupnat village).	high-potential
18	Korčula	3820	Milna-PL-Žrnovo	Cenomanian	In the eastern part of the Island of Korčula; (Žrnovo-(Postrana).	high-potential
19	Korčula	3830	Gornji Humac-PL-Vela Luka	Turonian - Santonian	In the NW part of the island of Korčula; from Prigradica, to the eastern tip of the island.	high-potential
20	Pelješac	3910	Gornji Humac PL - Pelješac	Turonian-Santonian	Westernmost part of the Pelješac peninsula (around Lovište).	high-potential
21	Pelješac	3920	Gornji Humac PL - Pelješac	Turonian-Santonian	Westernmost part of the Pelješac peninsula (around Lovište).	potential

Table of potential and high-potential PL polygons in project areas of Istria, Zadar, Split-Dalmatia and Dubrovnik-Neretva

counties (Croatia).

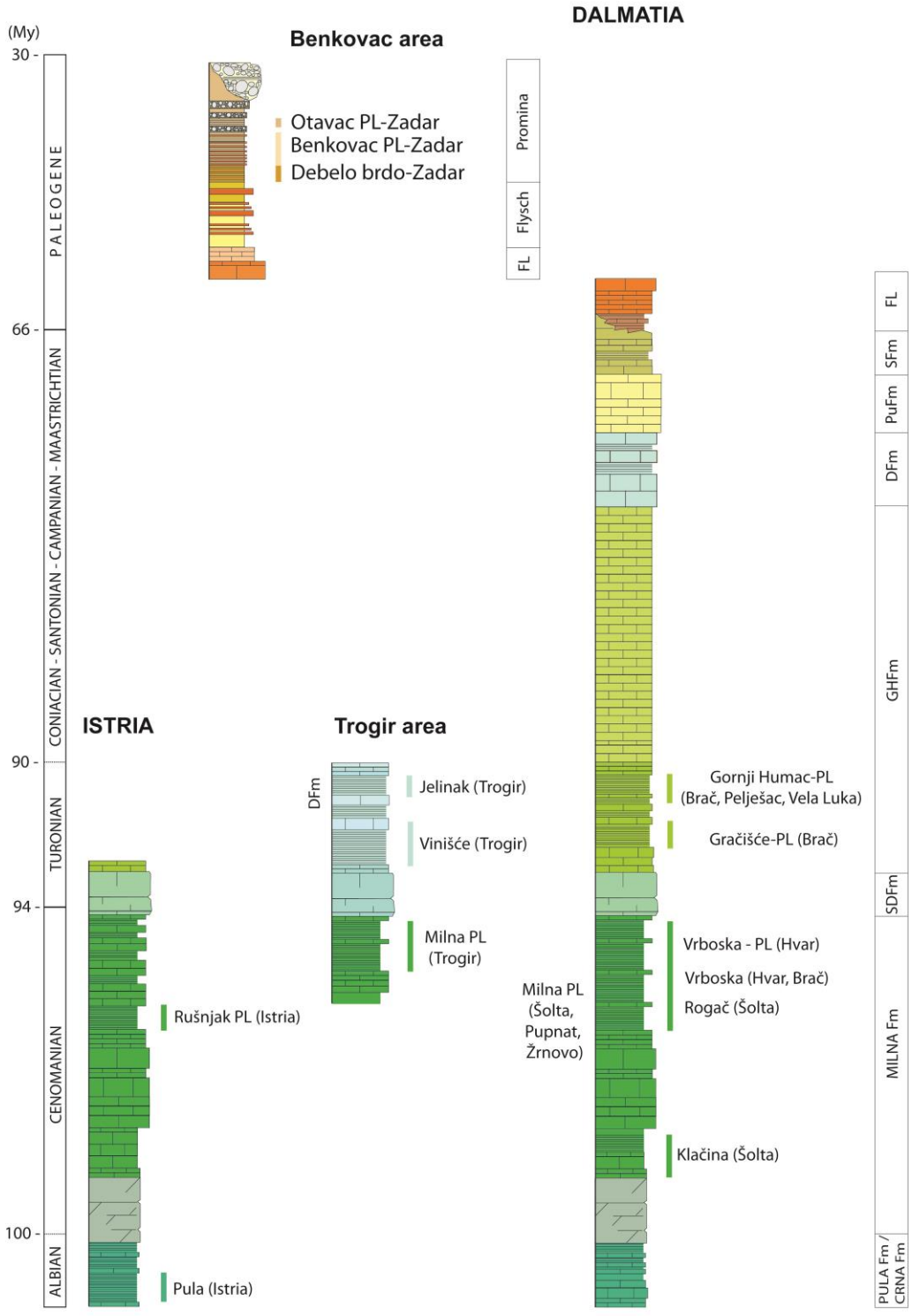


Fig. 3.2. Schematic correlation of sedimentary successions which include major PL occurrence in the Adriatic belt of the Dinaric karst region of Croatia (the upper part of a "layer-cake" of sedimentary rocks some few km thick). Cretaceous carbonate units in the lower part (Albian to Maastrichtian in age, green: shallow-water limestone, blue: deeper-water limestones, grey: dolomites). Paleogene carbonate and siliciclastic units in the uppermost part (orange to brown: shallow- to deep-water units). Appearances of platy limestone are marked by closely spaced lines, while the units shown on the detailed maps as polygons are marked by vertical bars and names (not to scale). My-Million year old (age of the rocks), PL-platy limestone, Fm-Formation=sedimentary units: SD-Sveti Duh, GH-Gornji Humac, D-Dol, Pu-Pučišća, S-Sumartin, FL-Foraminiferal Limestones.

3.3. ISTRIAN COUNTY

3.3.1. MAP OF OCCURRENCE OF PLATY LIMESTONE

In the investigated area of Istria, there is a major occurrence of PL within the Pula Formation and within a small but interesting area of the Rušnjak PL east of Buje, in the vicinity of Oprtalj.

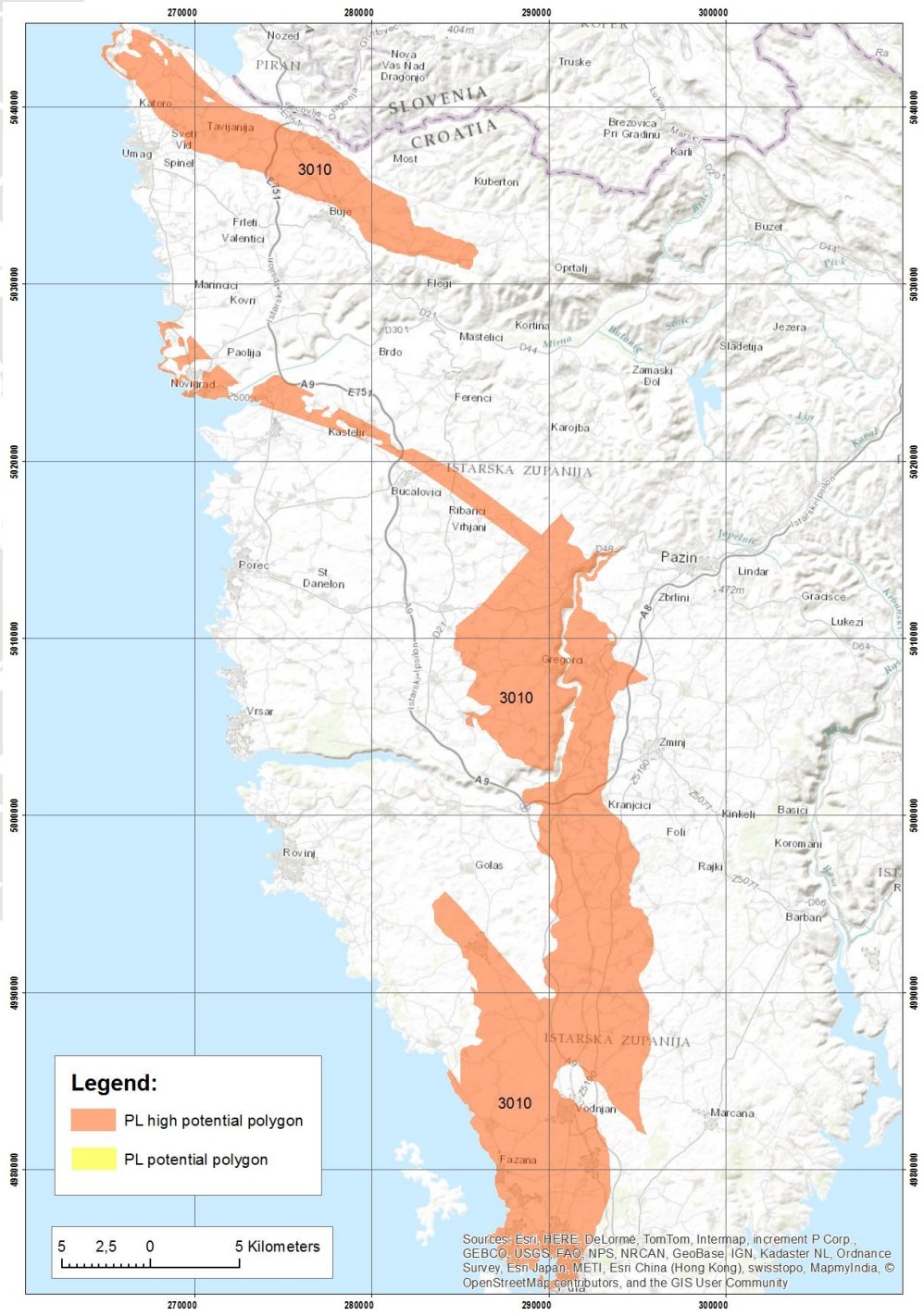


Fig. 3-3-1. Overview map of platy limestone occurrence in the investigated area of Istria.

3.3.2. APPEARANCE

The Pula PL (Fig. 3.2.) appears in places along a generally continuous zone stretching S-N from Pula to Novigrad, and along a SE-NW-oriented zone from Buje to Savudrija (Fig. 3-3-1, polygons 3010). PL occurrence within the unit is rather discontinuous (e.g. locality 3025).

In the northern part of Istria (Oprtalj area), PL outcrops are found in the Rušnjak PL zone (Localities 3021, 3022, and 3023). The PL of the locality ID 3021 is found only in abandoned houses near the village of Hrastići. The locality ID_3022 is near the village of Laganisi. The locality 3023 is in the village Ćabrnica.

3.3.3. LITHOLOGY

The lithology of both platy limestone types reflects deposition in protected lagoons. The rock generally consists of peloids (carbonate mud grains) and small particles of eroded limestone and fragmented carbonate fossil shells. Thin bedding is mostly the consequence of a short break in sedimentation of the material (marked with black laminae of bio material in an anoxic environment), or a change of water energy that caused deposition of various particle grain sizes.

3025_P1*. Subhorizontal bedding in Pula PL.

The platy limestone is mostly gently recrystallized. Along the exposed bedding planes, which mark the different lithology or thin lamina which represent the anoxic conditions, the rock is usually disintegrated into “plates”.

* Figure captions are marked by photo ID_numbers from the GIS database; more data on these photos and localities can also be found in web-application.

3023_P2. Rušnjak PL outcrop at Ćabrnica village.

3.3.4. STRATIGRAPHY AND AGE

According to the relative stratigraphic position in a wider context, the Pula PL is of late Albian age (Fig. 3.2). According to its relative stratigraphic position and well known microfossil and macrofossil content (benthic foraminifera and chondrodont bivalves), Rušnjak PL is of Middle to Upper Cenomanian age (Fig. 3.2).

3.4. ZADAR COUNTY

3.4.1. MAP OF OCCURRENCE OF PLATY LIMESTONE

The most significant occurrences of platy limestone in the Zadar County are recognized in the wider area of Benkovac.

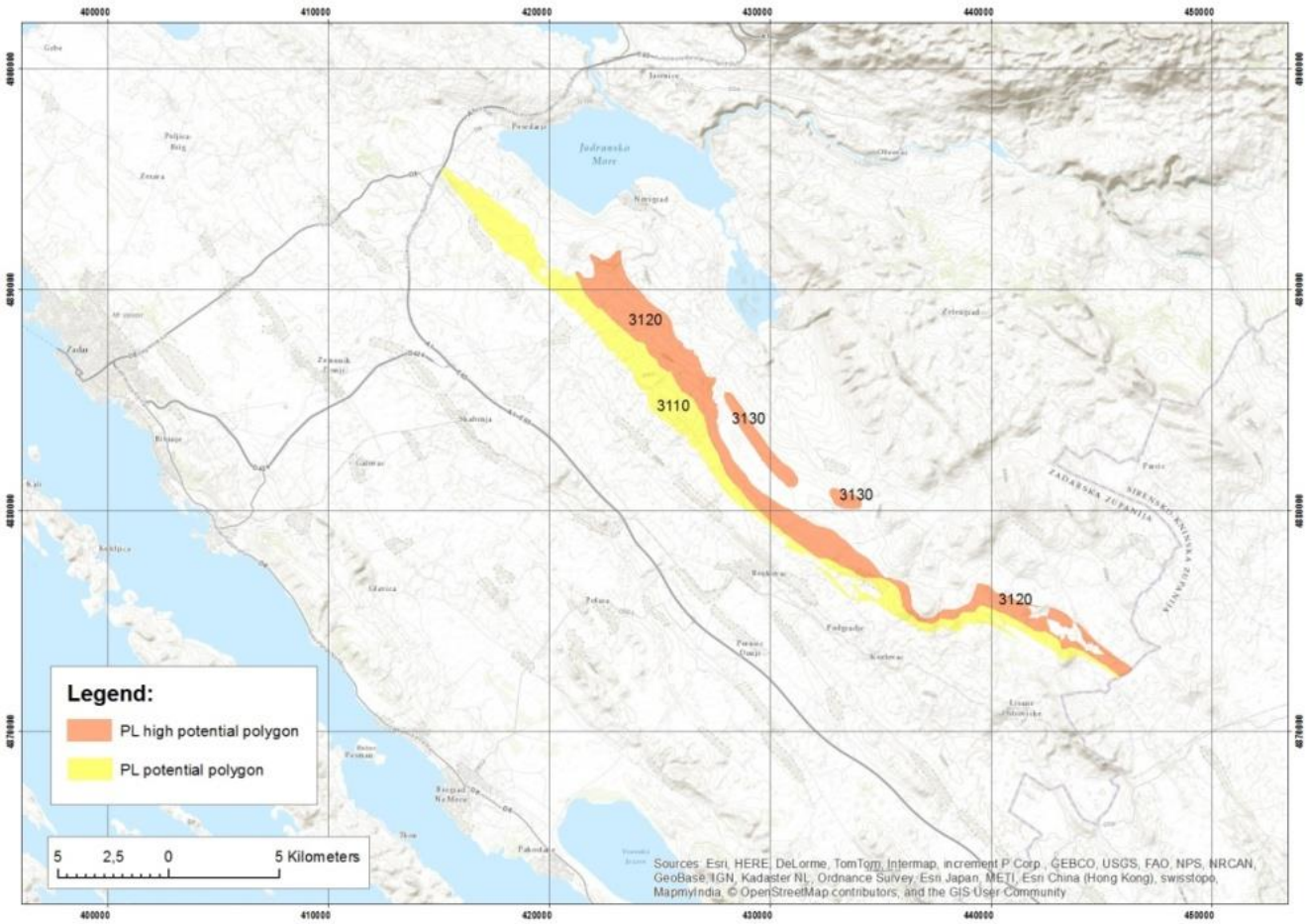


Fig.3-4-1. Overview map of the platy limestone occurrence in Zadar county (Benkovac area).

In addition, the Zadar County also features low potential platy limestone types characterized by local distribution. This is the case with the Albian-Cenomanian limestones (ID geol. unit 12) and the Cenomanian-Turonian limestones (ID geol unit 14) e.g. on the island of Dugi otok (Savar and Božava), and partly in the succession of the Promina deposits (ID geol. Unit 20), where PL crops out in a wide area several kilometres NE of Benkovac (e.g. Medviđa). These are very important horizons with 10-30 % (even more) platy limestone lithotypes, but with restricted occurrences and for local use only (e.g. for rural stone houses and roofs). In these areas only smaller abandoned quarries can be found that were once exploited as roof coverings of local houses.

3.4.2. APPEARANCE

In the Benkovac area PL was investigated and mapped in several areas (Fig.3-4-1). In the area between the villages of Islam Grčki - Smilčići and Debelo brdo to Mejanica hill **Debelo brdo** PL type was determined (ID_polygon 3110).

In the NW-SE trending belt located between the village of Smilčići and Mejanica hill (and extends toward SE) the **Benkovac PL** type was investigated and described (ID polygon 3120).

The **Otavac PL** type (ID polygon 3130) was investigated and described in two larger separate areas on the northeastern slopes of the Kukalj hill and southwest of the village of Pliskovo.

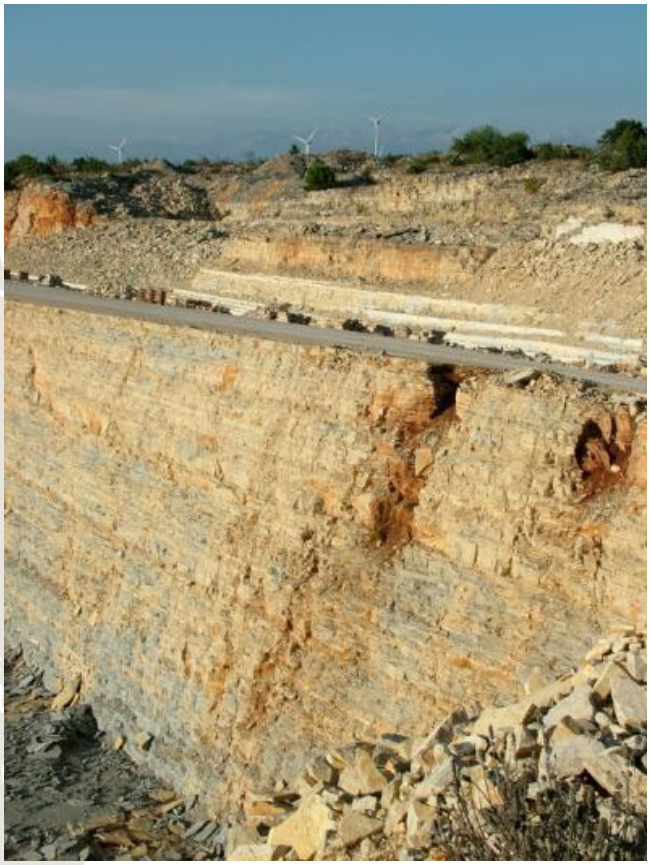
3.4.3. LITHOLOGY

The **Debelo brdo** PL consists of a thin-bedded light brownish to yellowish fine-grained to clayey limestone and a rare medium coarse-grained limestone in alteration (3107_P1).

Microfacies description: Intercalation of thin layers of calcareous mudstone and very fine-grained calcareous “sandstone” characterized by horizontal and cross lamination. Sediment was transported from the shelf and deposited in the deeper basinal environment (3107_S1).

3107_P1. The outcrop of Debelo brdo platy limestone in one of the abandoned quarries.

The **Benkovac PL** is predominantly thin-bedded (platy) yellowish to light brownish fine-grained limestone to clayey limestone with grayish medium- to coarse-grained types of limestones (3109_P2, 3111_P1) in alternation with numerous trace fossils (ichno-assemblages).



3109_P2. Outcrop of a typical Benkovac platy limestone in ADRIA-KAMEN active quarry.

3111_P1. Outcrop of a typical Benkovac platy limestone in LISIČIĆ quarry.

Microfacies description: Graduated intercalation of very fine-grained calcareous “sandstone” and calcareous mudstone contains well-preserved burrowing traces (ichnofossils). Sediment was transported from the shelf and deposited in the deeper environment. Very rare globigerinid (planktonic) foraminifera can be found (3109_S1).

The **Otavac PL** (in two separate areas) is fine-grained limestone, alternating with medium- to coarse-grained types of limestone (3123_P1, 3123_P2), but intercalated within thick-bedded multi-coloured carbonate conglomerates (3111_S1).

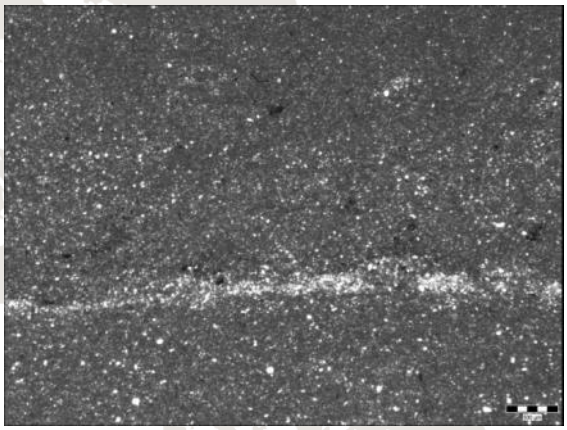
3123_P1. Otavac PL in PLISKOVO Quarry.

3123_P2. Outcrop of a typical Otavac PL. Alternations of light-brown to grey, mainly coarse-grained, calcareous sandstones with medium- to very fine-grained varieties. Quarry near the Pliskovo village.

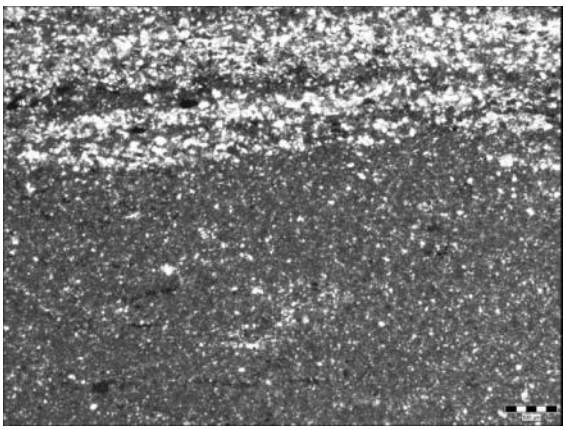
Microfacies description: Calcareous mudstone with intercalations of thin horizontal and wavy laminated very fine-grained calcareous “sandstone” (similar to 3109_S1). The sediment was transported from the shelf and deposited in the deeper environment. Rare radiolarians are indicative of a deeper and more open environment. The second lithotype is conglomerate built up of rounded clasts of older rocks deposited in an aquatic environment. Diverse clasts are made dominantly from Cretaceous limestones.

3.4.4. STRATIGRAPHY AND AGE

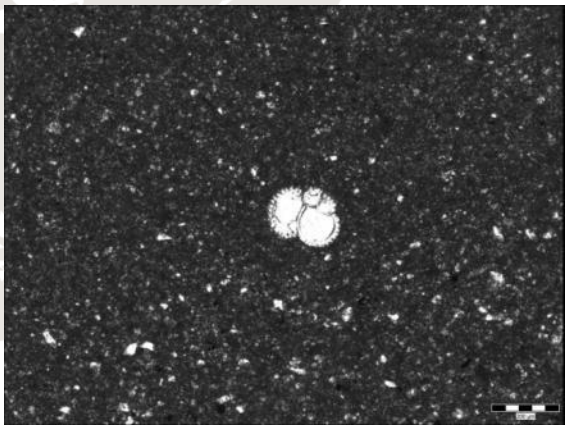
All of the three types of platy limestone units (Debelo brdo, Benkovac PL and Otavac PL) belong to the Late Paleogene (Late Eocene and possibly to the Early Oligocene) age. Their age was determined on the basis of large benthic foraminifera (nummulitids, discocyclinids) and small pelagic globigerinid foraminifera, deposited within the basin (see 3107_S1).



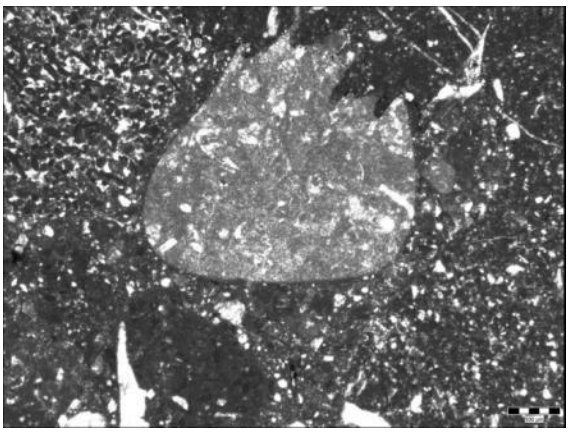
3107_S1. Microphotograph of detrital calcareous mudstone (Debelo brdo).). Scale bar 500 µm.



3109_S1. Microphotograph of detrial calcareous mudstone and fine-grained calcareous “sandstone” in alternation (Benkovac PL).). Scale bar 500 µm.



3109_S1. Microphotograph of Late Paleogene planktonic (globigerinid) foraminifera *Subbotina linaperta* (Benkovac PL).). Scale bar 200 µm.



3111_S1. Microphotograph of conglomerate (Otavac PL). Scale bar 500 µm.

3.5. SPLIT-DALMATIA COUNTY

3.5.1. MAP OF OCCURRENCE OF PLATY LIMESTONE (Split-Dalmatia County)

The PL stratigraphical intervals (Fig. 3.2.) appear in many places in the investigated part of the county. Significant spatial occurrences of PL are recognized in the Trogir area and the islands of Šolta, Brač and Hvar (Fig.3-5-1), along with local occurrence on the island of Vis.

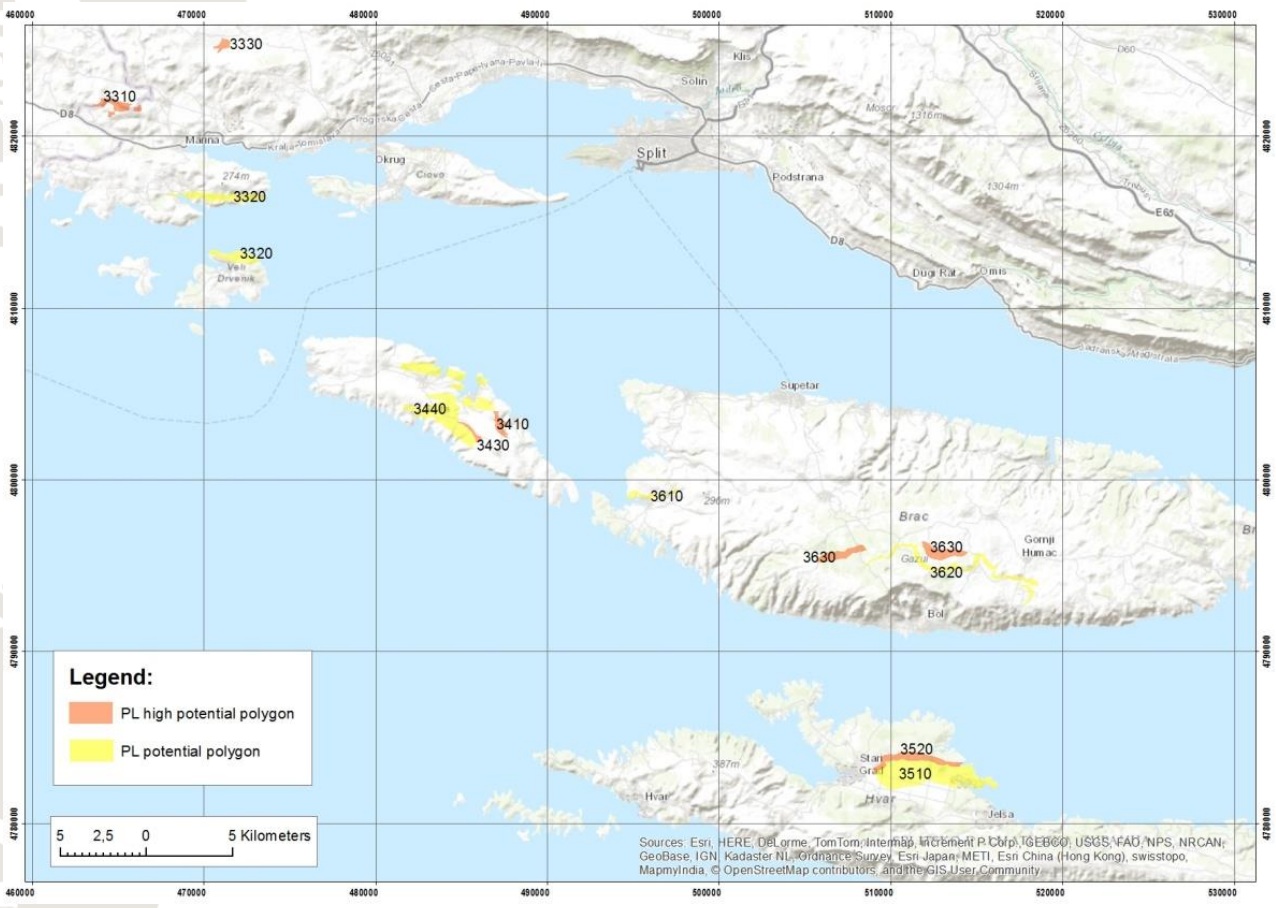


Fig.3-5-1. Overview map of the platy limestone occurrence in the Trogir area and the islands of Šolta, Brač, and Hvar.

3.5.2. APPEARANCE

In the Trogir area (Fig. 3-5-2a) PL was investigated and described east of Vinišće (SW of Trogir), on the northern part of the island of Veli Drvenik, between Svinca and Gustirna (W of Trogir) and between Bristivica and Blizna at the Jelinak Mt. hinterland (NW of Trogir).
At the coastal outcrops near the village of Vinišće and at the northern part of the island of Veliki Drvenik the Vinišće-Trogir PL type appears (ID_polygon 3320). At Kmećalovica (Pločurine) an area of the Milna-PL-Trogir PL type is exposed (ID_polygon 3310). The Jelinak-Trogir PL type is exposed at the village of Begovići (ID_polygon 3330).

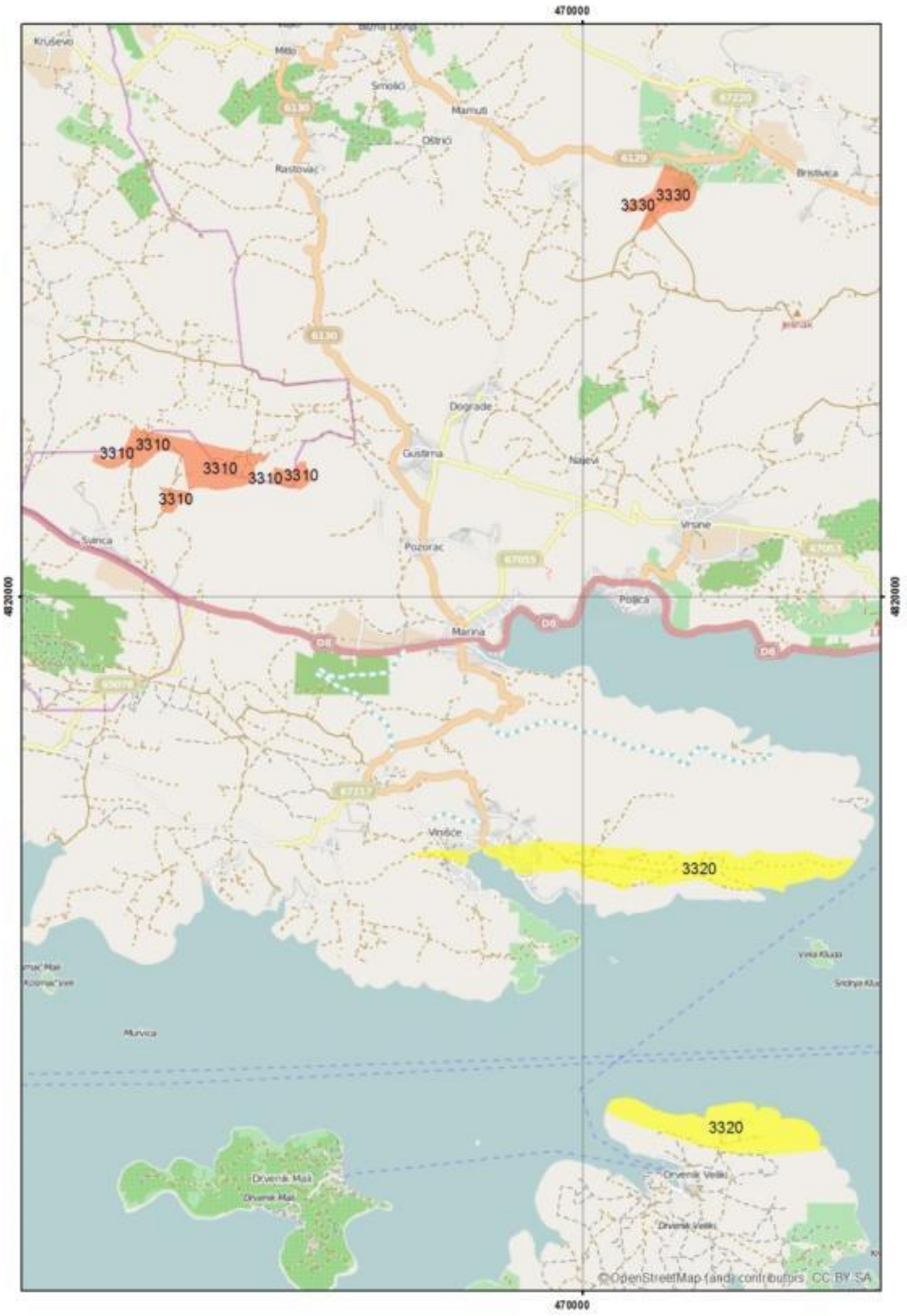


Fig. 3-5-2a. Detailed map of the platy limestone occurrence in the Trogir area.

On the island of Šolta (Fig.3-5-2b) PL was investigated in several areas such as the Koludrovi doci between Stomorska and Gornje Selo (Šolta), the village of Stomorska and Nečujam cove (Šolta), the central part of the island of Šolta and Kupište W of Gornje Selo (Šolta).
A platy limestone type named Klačina PL-Šolta (ID_polygon 3410) was mapped at Stomorska-Koludrovi doci and at Stomorska (ID_polygon 3420). PL type named Milna PL-Šolta was mapped at G.Selo-Kupište (ID_polygon 3430). PL type named Rogač-Šolta was defined at Trzavica (ID_locality 3443) and Straža (ID_polygon 3440).

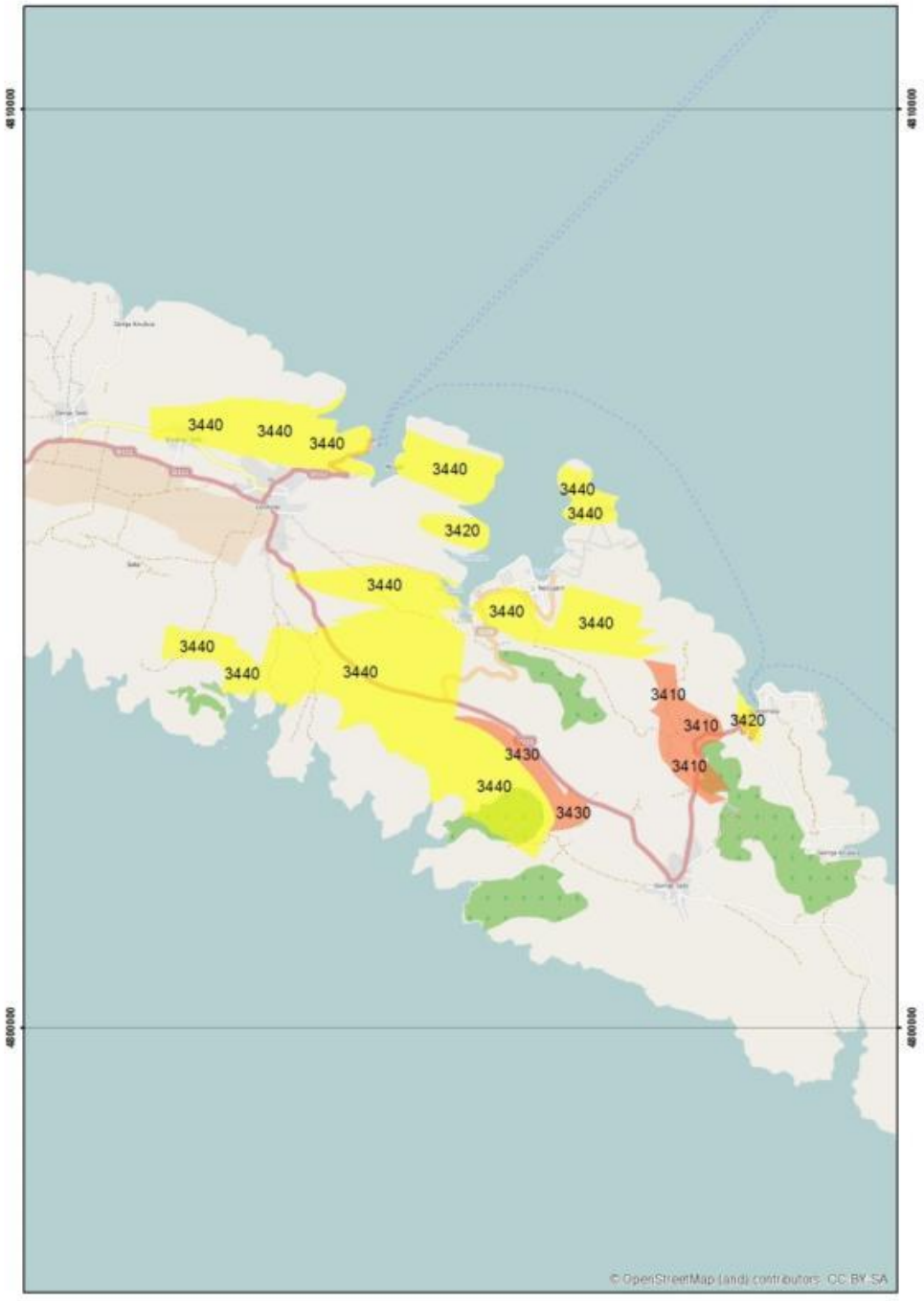


Fig.3-5-2b. Detailed map of the platy limestone occurrence on the island of Šolta.

On the island of Brač PL was investigated and mapped in several areas. Vrboska PL type was mapped on the western part of the island of Brač (Fig. 3-5-2c), north of Milna (ID_polygon 3610).

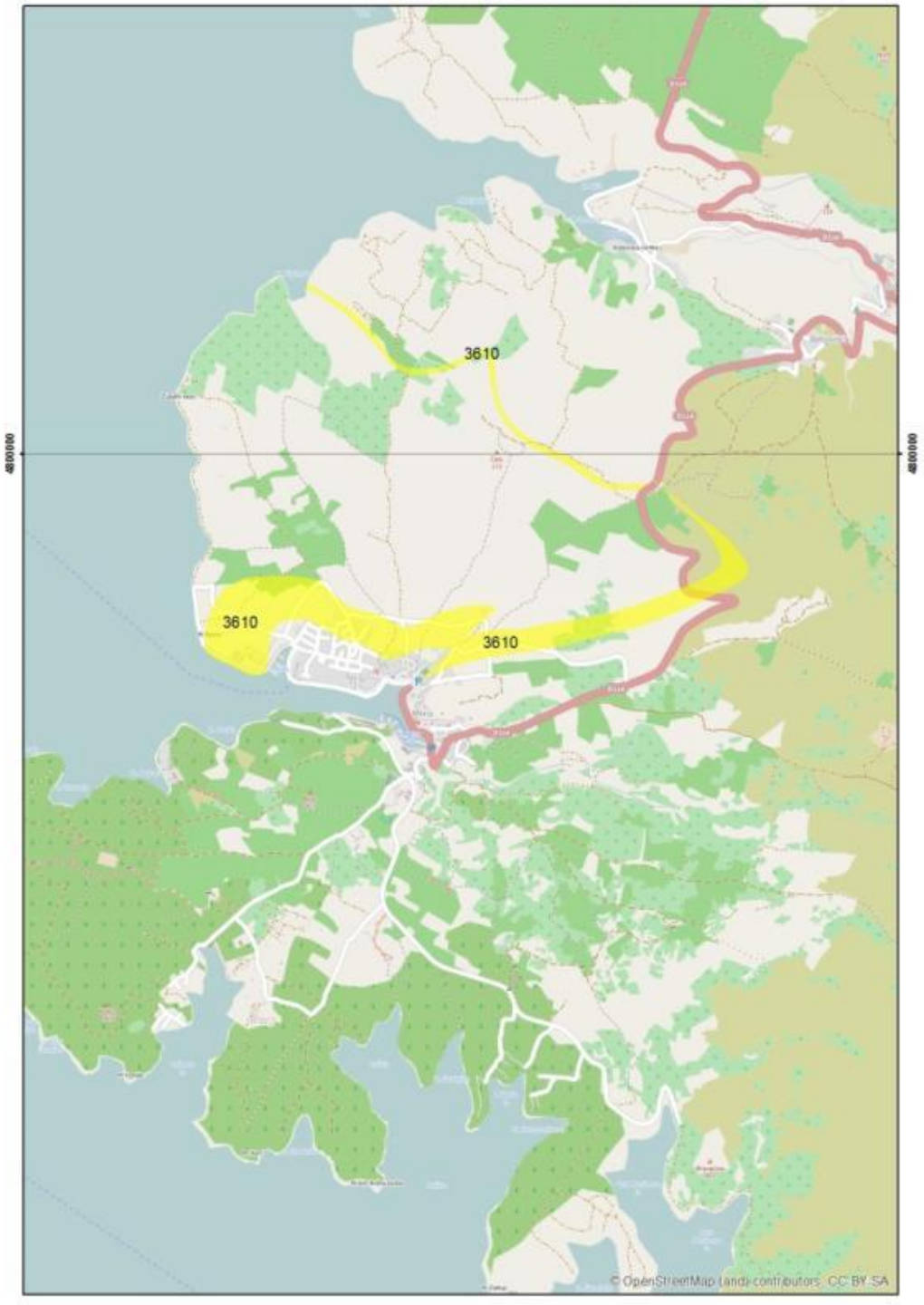


Fig.3-5-2c. Detailed map of the platy limestone occurrence in the western part of the island of Brač at Milna.

In the central-southern part of the island of Brač (Fig.3-5-2d), in the area of Kalina, Vestac and Podgažul, Gračišće-PL (Brač) PL type was mapped (ID_polygon 3620). A type of PL named Gornji

Humac-PL is located at Fantovi doci and Podgažul (ID_polygon 3630).

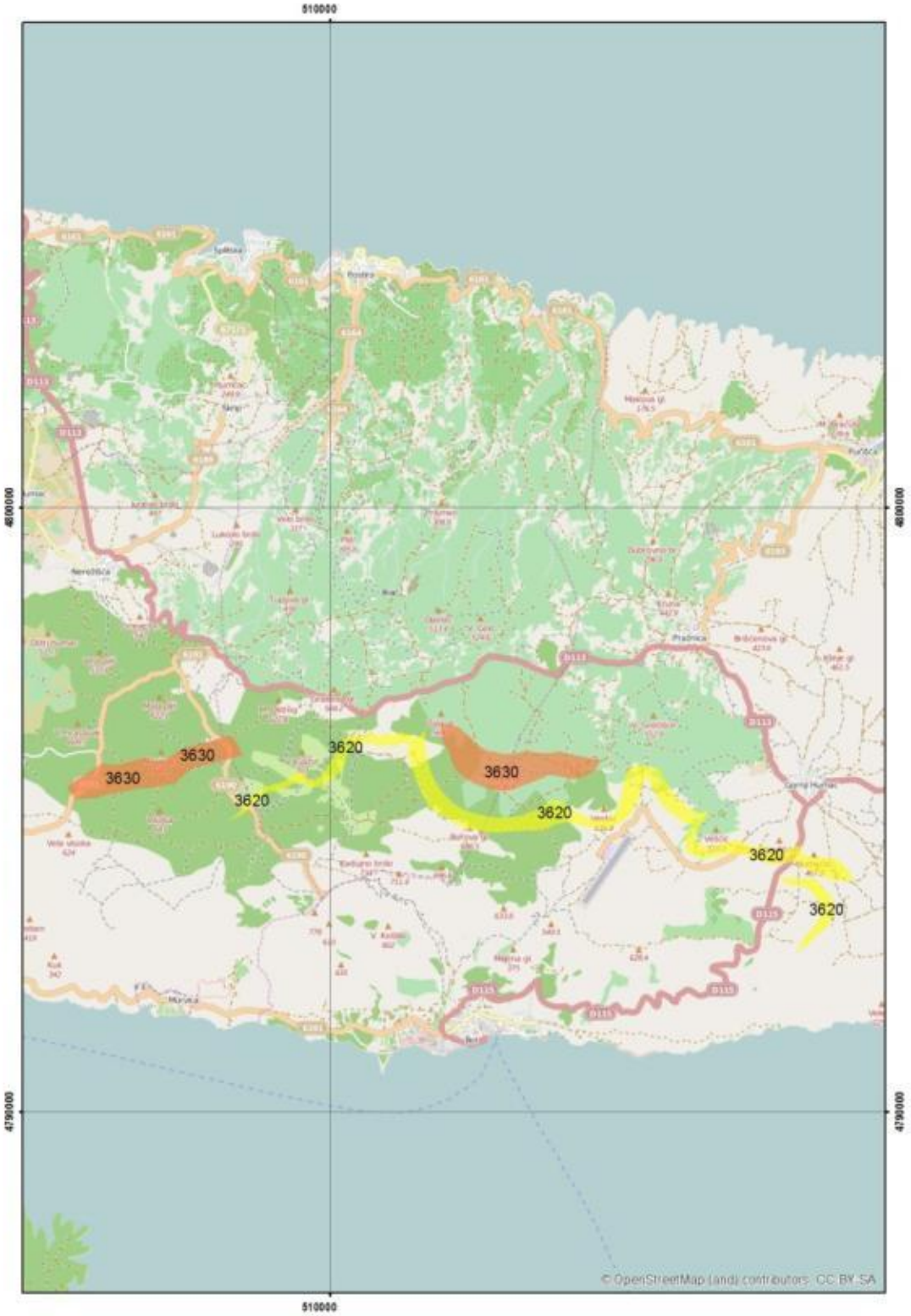


Fig.3-5-2d. Detailed map of the platy limestone occurrence in the central part of the island of Brač at Gornji Humac and Vidova gora.

On the island of Hvar (Fig.3-5-2e) PL was investigated and mapped in the northern-central part of the island in the area between Stari Grad and Vrboska. The Vrboska (Hvar) unit (10-30% of

PL) stretches north of the main field called Starogradsko polje (ID_polygon 3510). The Vrboska PL (Hvar) is characterized by more than 30 % of PL, and is located north of the Vrboska unit (ID_polygon 3520).

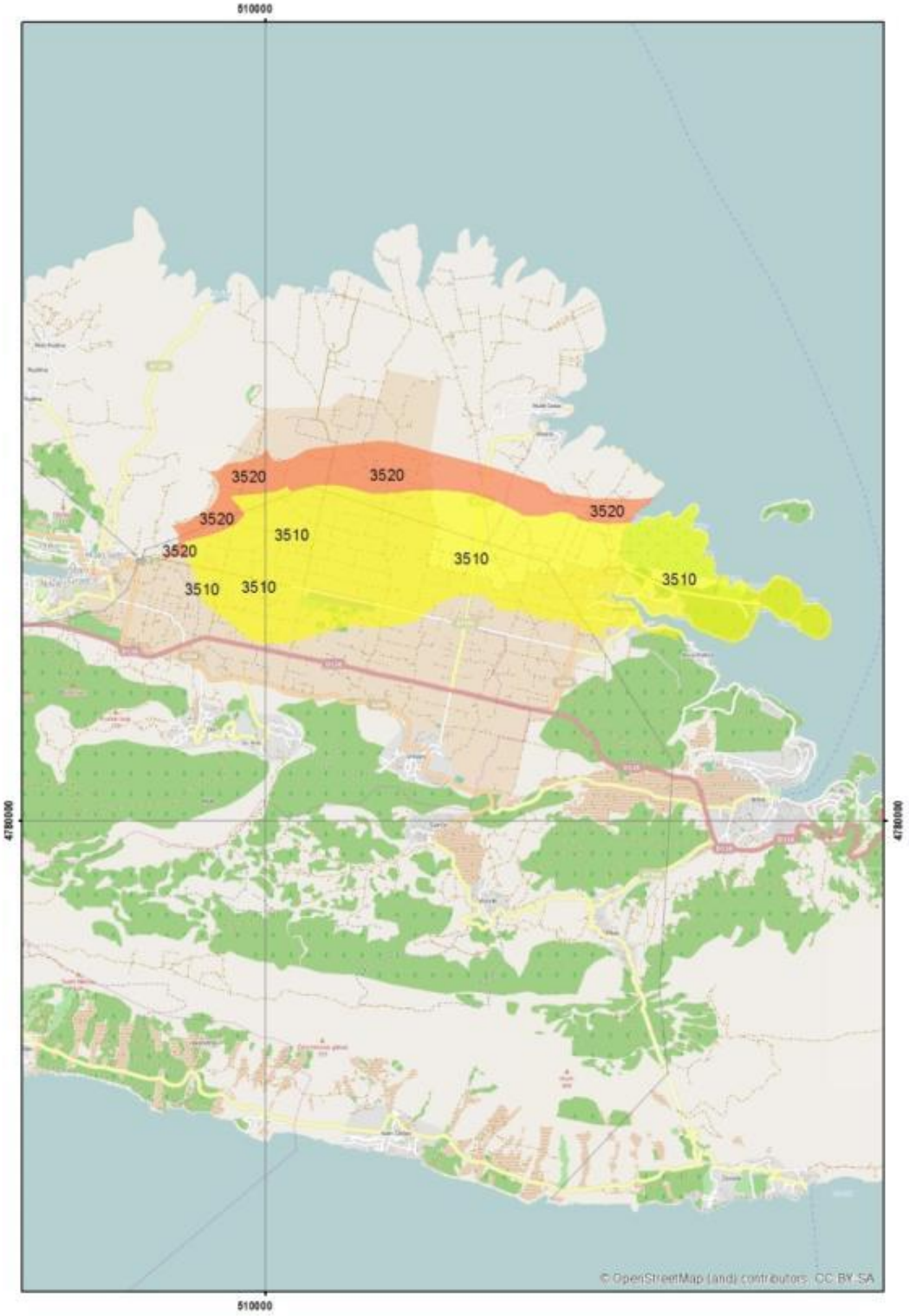


Fig.3-5-2e. Detailed map of the platy limestone occurrence in the central part of the island of Hvar at Vrboska.

3.5.3. LITHOLOGY

The Milna PL (Trogir) type is mostly well-bedded micritic to grainy skeletal limestone. The platy ones (>30%) are mainly composed of laminated stromatolitic limestones.

3306_P1. Outcrop of Milna PL-Trogir at Kmećalovica.

The Vinišće (Trogir) PL type is medium- to thin-bedded, platy and laminated. The platy ones (<30%) are mainly composed of benthic and planktonic microfossils and are mud-supported with rare reddish microbial laminas.

3302_P1. Coastal outcrop of steeply dipping Vinišće platy limestone.

The Jelinak (Trogir) PL type is medium- to thin-bedded, fine-grained calcisphere packstone.

3314_P1. Outcrop of Jelinak (Trogir) platy limestone.

The Klačina PL (Šolta) type is mostly well-bedded micritic to grainy skeletal limestone. The platy ones (>30%) are mainly composed of laminated stromatolitic limestones.

3413_P2. Platy limestone outcrops of Koludrovi doci on the island of Šolta.

The Rogač (Šolta) PL type is an alternation of medium- to thin-bedded, platy and laminated limestones. The platy ones (<30%) are mainly composed of fine-grained skeletal packstones and cyanobacterial laminites.

3444_P3. Outcrop (abandoned quarry) of Rogač (Šolta) PL at Trzavica.

The Milna PL (Šolta) type is very similar to other Milna PL types (Trogir, Brač, Hvar).

3431_P1. Milna PL at Kupište (Šolta island).

The Vrboska (Hvar) unit (<30%) as well as the Vrboska PL (Hvar) (>30%) are composed of medium- to thin-bedded, platy and laminated alternations of mudstones, cyanobacterial laminites and very rare, fine-grained skeletal packstones.

3507_P2: Vrboska PL outcrop in Maslinica Cove (N of Vrboska on the island of Hvar).

The Vrboska (Brač) PL type is medium- to thin-bedded, platy and laminated alternations of mudstone, fine-grained skeletal packstones, and cyanobacterial laminas.

3606_P1. Vrboska platy and laminated type at Milna (island of Brač).

The Gračišće-PL (Brač) PL type is thick- to thin-bedded limestone composed of micritic limestone in places with algal balls and rudist bivalves.

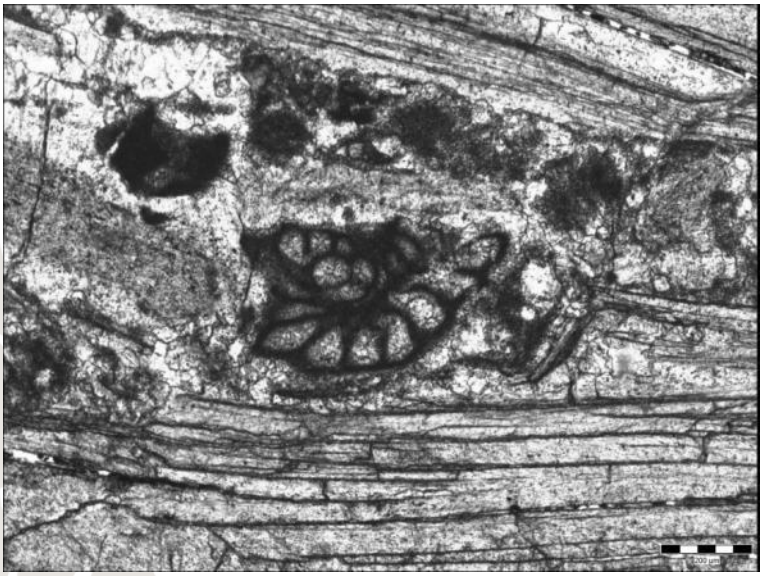
3607_P1. “Kalina” quarry of platy and laminated Gračišće PL type (island of Brač).

The Gornji Humac-PL (Brač) PL type consist of alternating medium- to thin-bedded platy limestones mainly composed of fine-grained skeletal particles in a micritic matrix.

3611_P2. Gornji Humac PL at Fantovi doci (island of Brač).

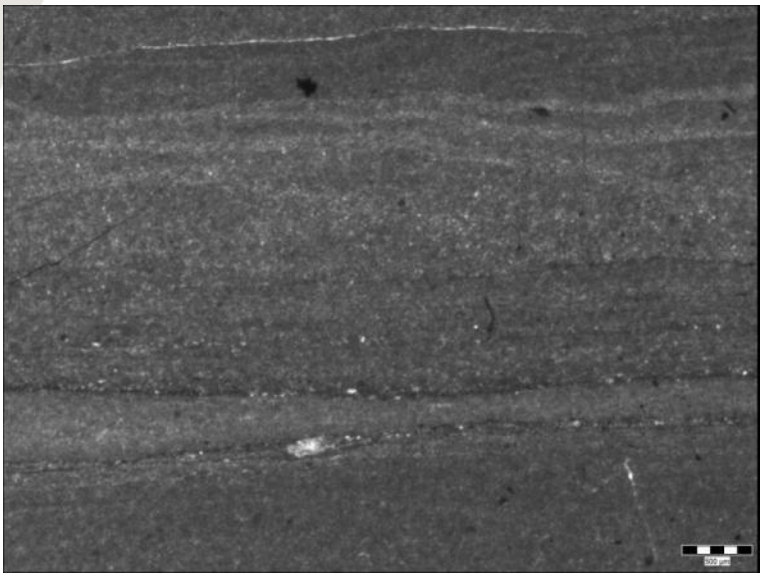
3.5.4. STRATIGRAPHY AND AGE

Three types of platy limestone were found in the area of Trogir (Fig. 3.2.). The Milna PL, Trogir type, is of Cenomanian age. Common are Cenomanian microfossils, mostly benthic foraminifera, and macrofossils such as rudist and chondrodont bivalves.



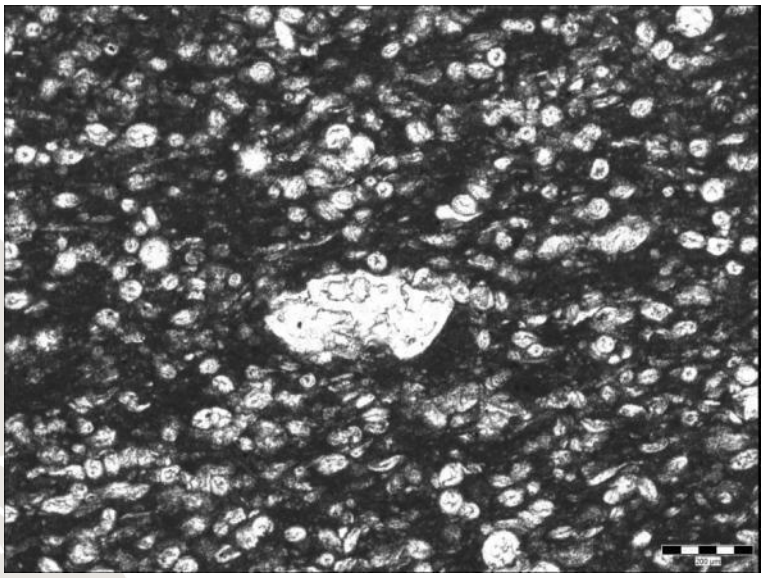
3308_S1. Microphotograph of the Milna PL Trogir type. Coarse-grained bioclastic limestone made of rudist bivalve fragments and Cenomanian benthic foraminifera *Nezzazata simplex*. Scale bar 200 µm.

The Vinišće (Trogir) type of PL corresponds to the Turonian (field description). It contains tiny microfossils (*Decastronema, Thaumatoporella*, calcispheres) and in some beds very rare rudists.



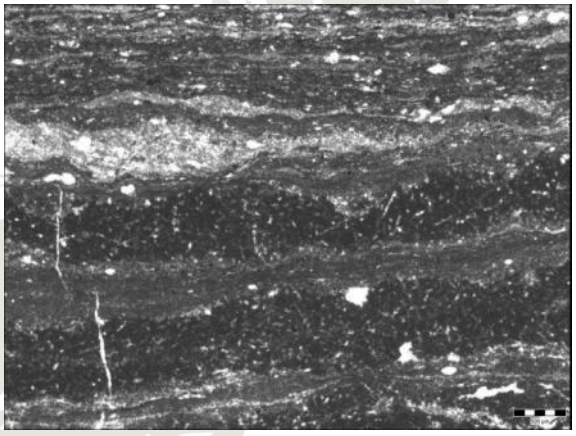
3301_S1. Microphotograph of the Vinišće PL Trogir type. Very fine lamination of calcareous mudstone. Scale bar 500 µm.

The Jelinak type of PL (Trogir) is of Turonian-Santonian age, and contains microfossils such as *Marginotruncana* sp. and *Dicarinella* sp.

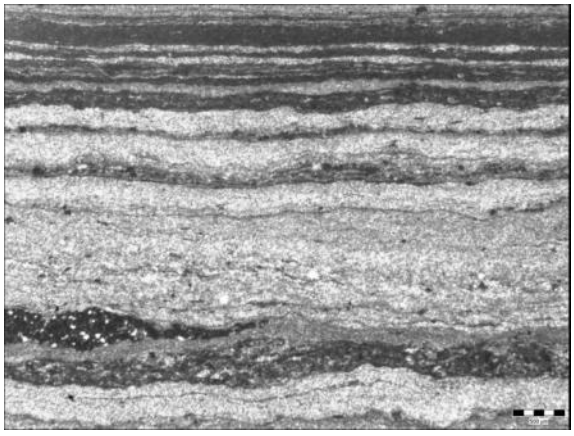


3313_S1. Microphotograph of the Jelinak PL (Trogir) type. Micrite limestone with a large portion of very small planktonic microfossils calcisphere and a planktonic foraminifera *Marginotruncana* sp. Scale bar 200 µm.

On the island of Šolta three types of platy limestone were distinguished (Klačina-Šolta, Rogač-Šolta and Milna PL-Šolta; Fig. 3.2.) which are all of Cenomanian age (field description).

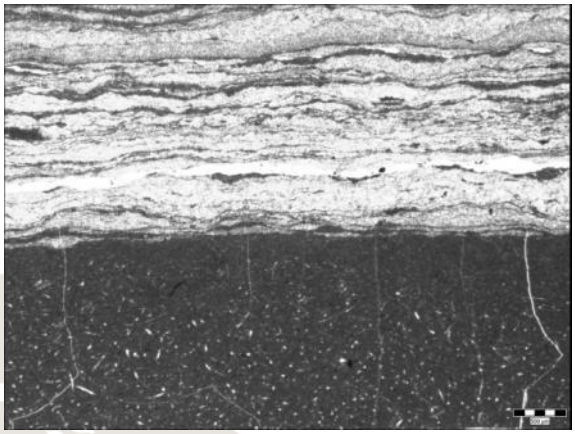


3431_S1. Microphotograph of the Milna PL, Šolta type. This bindstone shows fine lamination of micrite particles with tubes of cyanobacteria. Scale bar 500 µm.

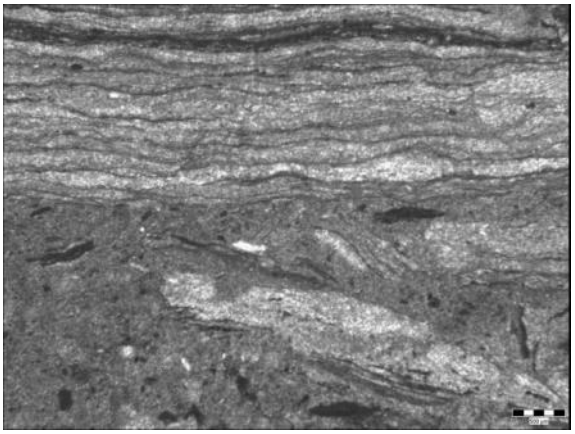


3444_S2. Microphotograph of the Rogač PL type (Šolta). Thin micrite laminae of microbial origin and slightly thicker microcrystalline laminae, originated from early litification in the intertidal environment. Scale bar 500 µm.

On the island of Hvar two types of platy limestone were distinguished (Fig. 3.2.).
Both the Vrboska-Hvar as well as the Vrboska PL-Hvar types are of Cenomanian age (field description).

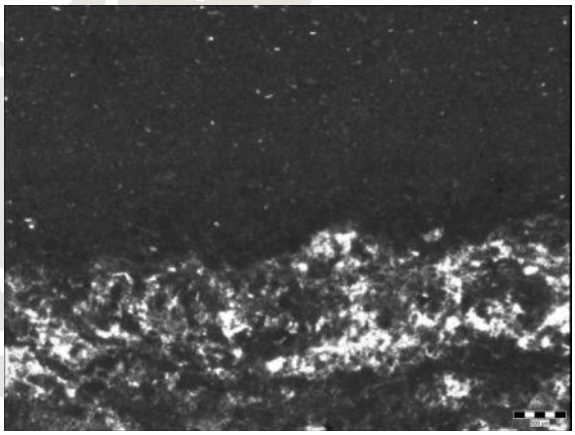


3504_S2. Microphotograph of the Vrboska PL-Hvar type. This bindstone (stromatolite) shows various types of laminae with diverse small carbonate particles trapped and bind by cyanobacterial mats in the intertidal zone. Scale bar 500 µm.

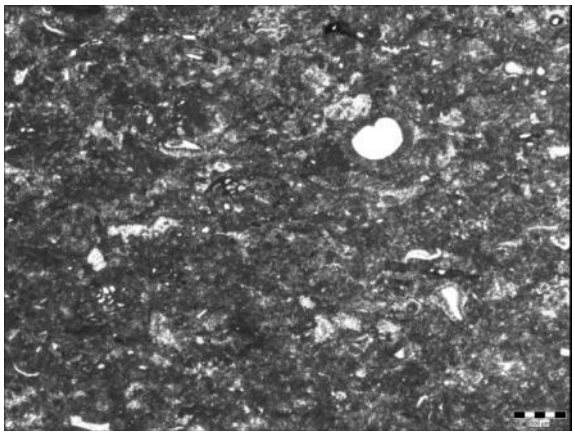


3505_S2. Microphotograph of the Vrboska PL-Hvar type. This microfacies is represented by bindstone (stromatolite) as well, but shows very fine intercalations of microcrystalline and micrite laminae of stromatolite origin. A thin layer of stromatolite fragments destroyed in a storm (tempestite) is visible as well. Scale bar 500 µm.

On the island of Brač three types of platy limestone were determined (Fig. 3.2.).
The Vrboska PL, Brač type is of Cenomanian age, and similar to the same unit on Hvar (Fig. 3-5-4-1). Cenomanian microfossils (mostly benthic foraminifera) and macrofossils (rudist and chondrodont bivalves) were determined in the intercalations.
The Gračišće-PL and Gornji Humac-PL types are of Turonian age (field description). They contain microfossils (cyanobacteria and benthic foraminifera) and rare radiolitid rudist bivalves.



3607_S1. Microphotograph of the Gračišće-PL-Brač PL type. Laminae of micrite sediment trapped and bind by cyanobacterial mats. Scale bar 500 µm.



3612_S2. Microphotograph of the Gornji Humac-PL-Brač PL type. Intraclastic-bioclastic limestones made of carbonate micritic intraclasts and small fossil fragments. Scale bar 500 µm.

3.6. DUBROVNIK-NERETVA COUNTY

3.6.1. MAP OF PLATY LIMESTONE OCCURRENCE (Dubrovnik-Neretva County)

Significant occurrences of the Milna PL and Gornji Humac PL are recognized on the island of Korčula and the Pelješac peninsula (Fig. 3-6-1).

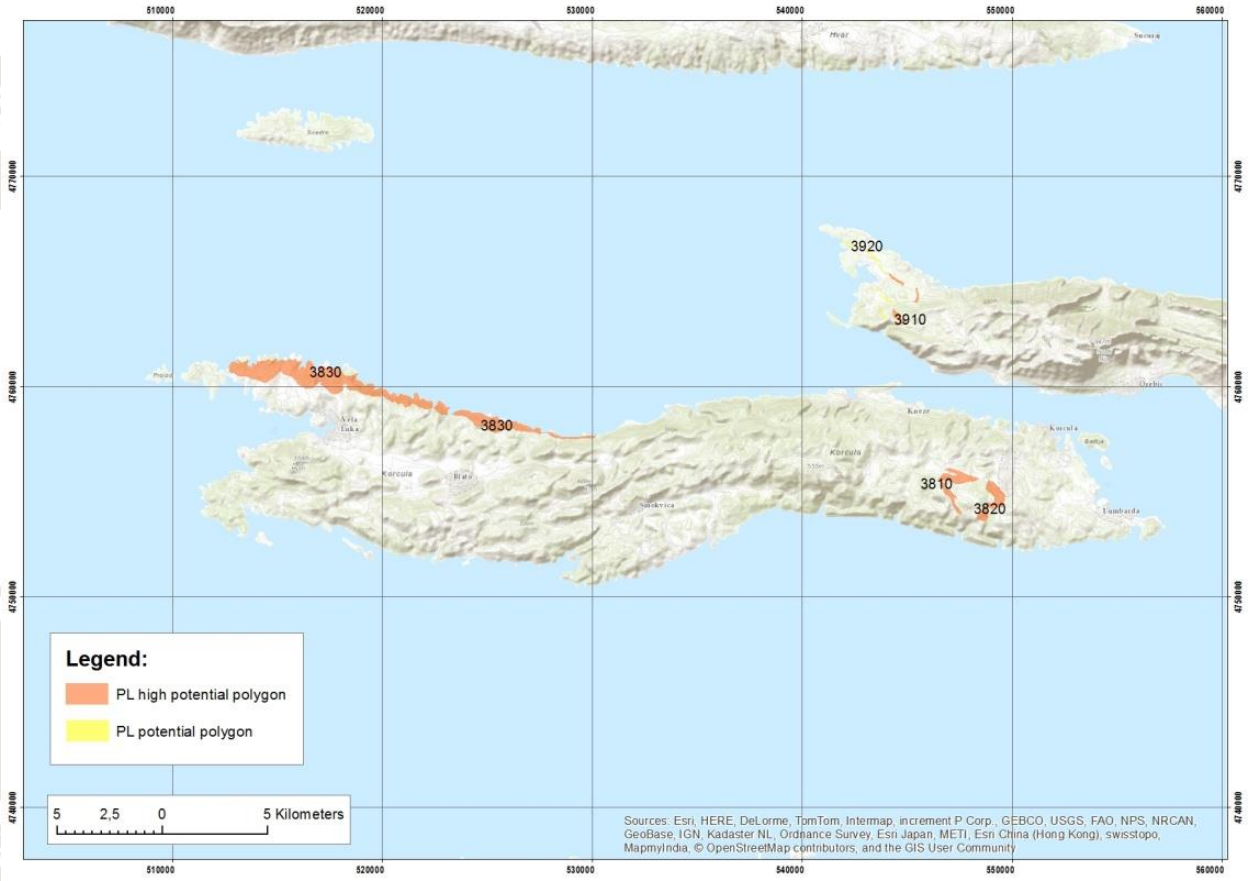


Fig. 3-6-1. Overview map of the platy limestone occurrence on the island of Korčula and the Pelješac peninsula.

3.6.2. APPEARANCE

On the Island of Korčula the Gornji Humac-PL (ID_3830) was investigated and mapped on the NW part of the island in the vicinity of Vela Luka (Fig. 3-6-2a).

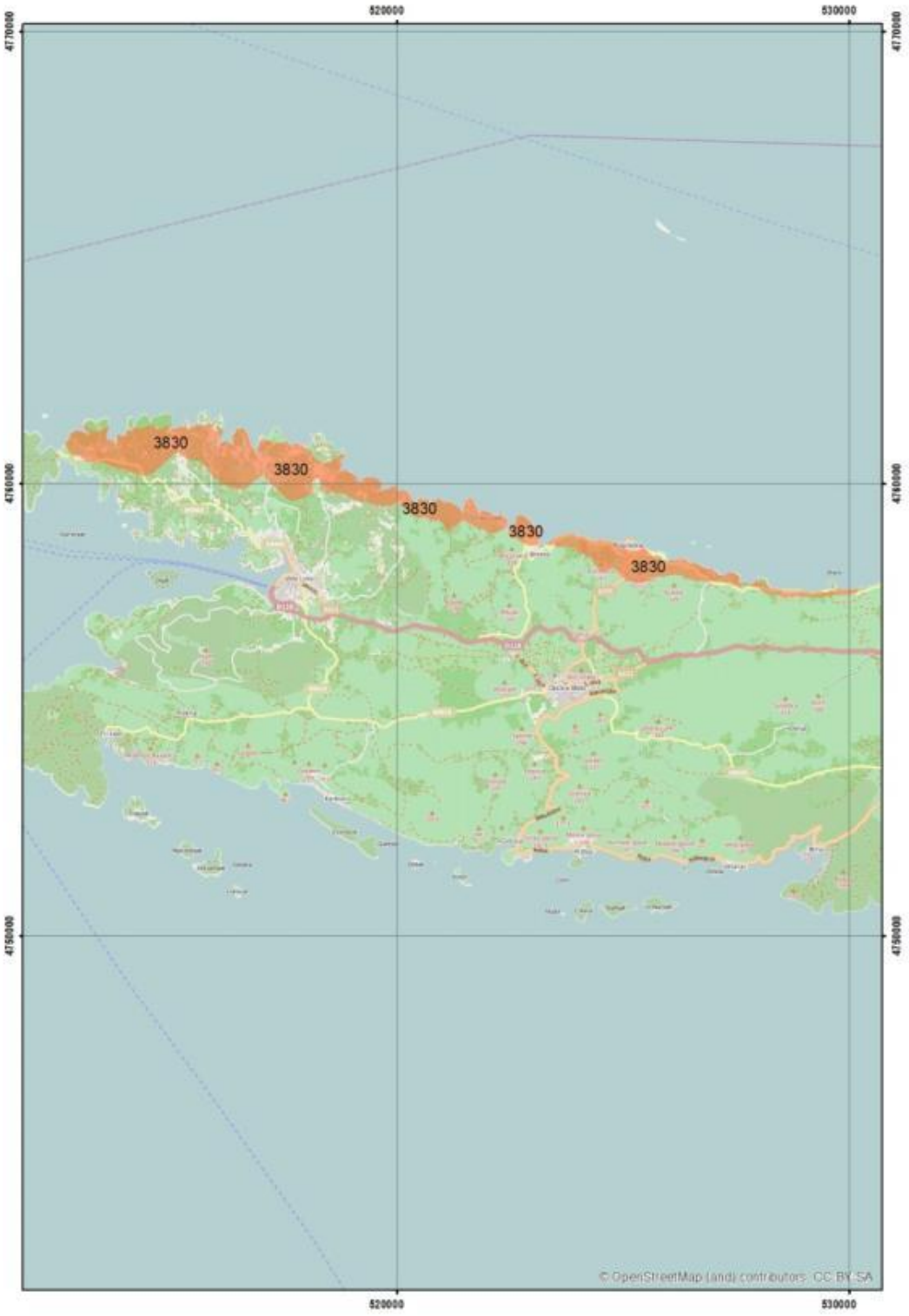


Fig. 3-6-2a. Detailed map of the Gornji Humac PL occurrence in the vicinity of Vela Luka (Korčula island).

Two subtypes of Milna PL (Pupnat – ID_3810, and Žrnovo – ID_3820) appear in the central-eastern part of the island of Korčula (Fig. 3-6-2b).

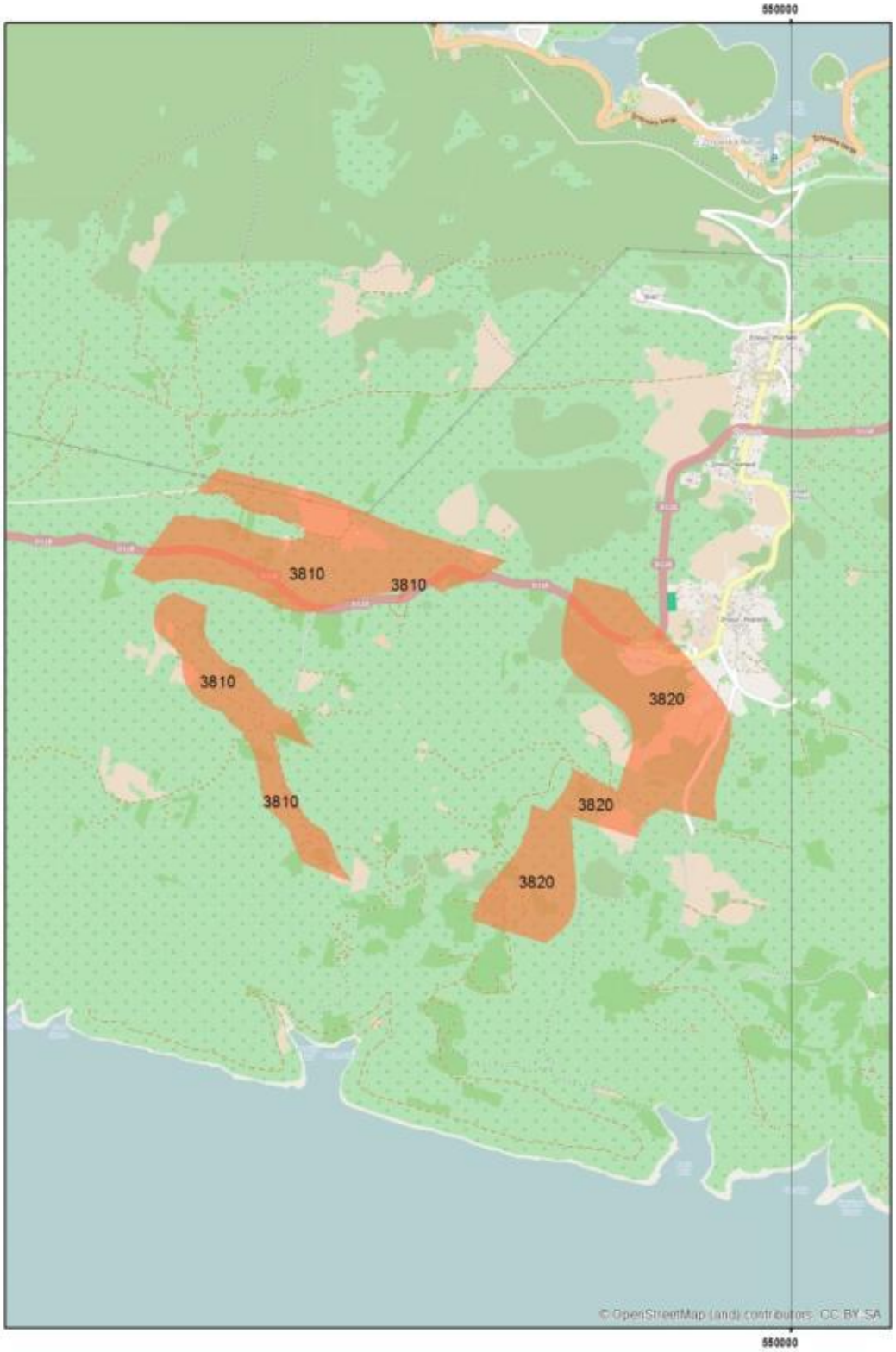


Fig. 3-6-2b. Detailed map of the Milna PL (Pupnat and Žrnovo types) in the surroundings of Žrnovo (Korčula).

On the Pelješac peninsula Gornji Humac PL (>30% ID_3910, <30% ID_3920) was investigated and mapped in the W part of the island, in the surroundings of Lovišta (Fig. 3-6-2c).

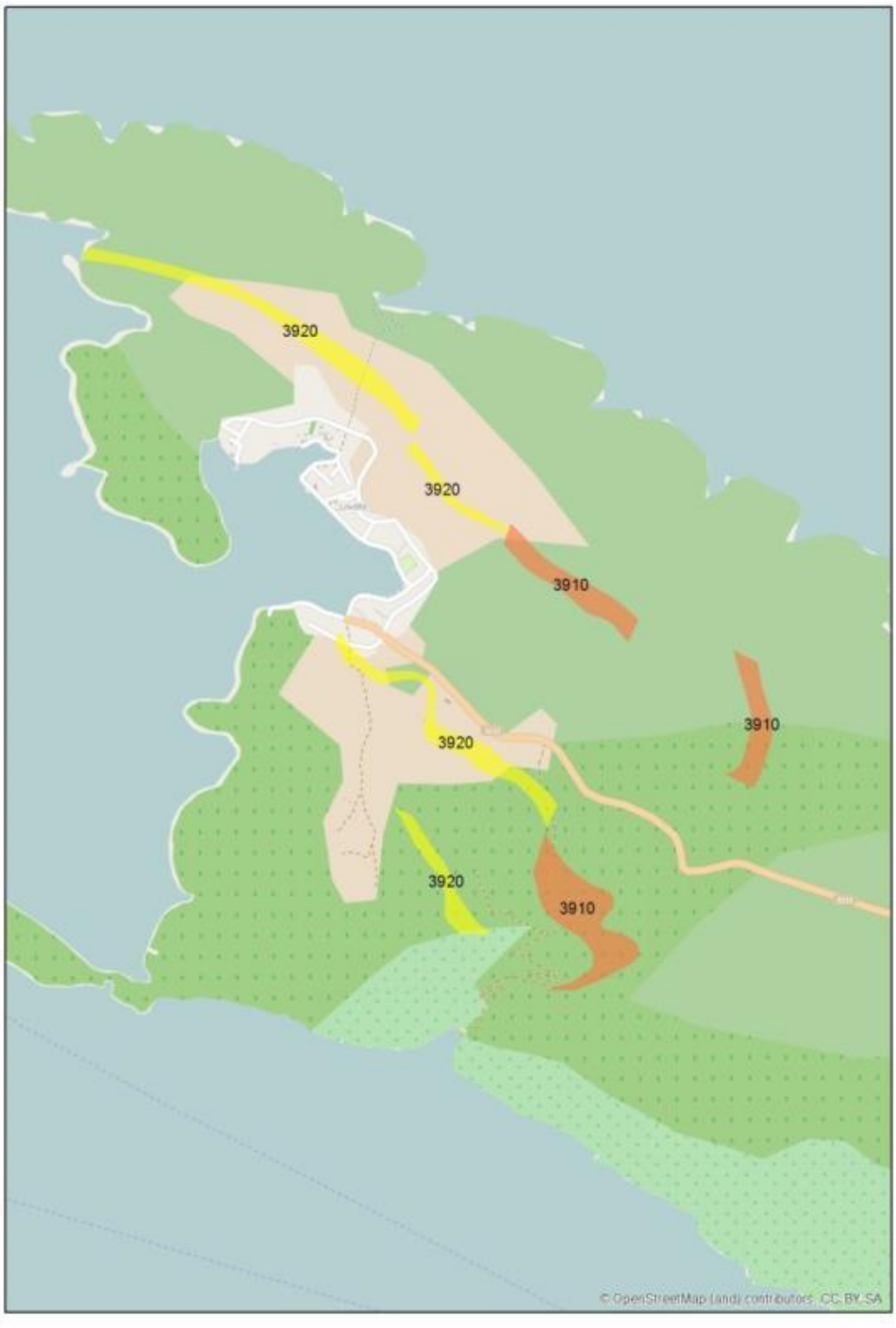


Fig. 3-6-2c. Detailed map of the Gornji Humac PL occurrence in the surroundings of Lovišta (Pelješac peninsula).

3.6.3. LITHOLOGY

On the Island of Korčula three different types of platy limestones or three different lithostratigraphic units were mapped which contain PL sequences: the Milna-PL-Pupnat, the Milna-PL-Žrnovo and the Gornji Humac-PL at Vela Luka.

Milna-PL-Pupnat is composed of alternating layers of medium- to thin-bedded, platy mostly micritic limestones. Platy limestones (about 20% of the unit) are mainly represented with skeletal wackestones, the laminated ones are mudstones and wackestones with rare cyanobacterial laminas.

3812_P1. Quarry of Milna-PL-Pupnat limestones in Zlo Polje on the Island of Korčula.

Milna-PL-Žrnovo is composed of alternating medium- to thin-bedded, platy and thick-bedded bioclastic limestones with rudists. Platy limestones (about 20% of the unit) are mainly composed of skeletal wackestones and packstones.

3813_P1. Quarry of Milna-PL-Žrnovo (Podstrana) on the Island of Korčula.

Gornji Humac-PL at Vela Luka is composed of alternating layers of medium-, thin-bedded and platy limestones. Platy limestones (more than 30% of the unit) are mainly represented by laminated fine-grained limestones characterized by microbial laminae.

3816_P1. Outcrop of Gornji Humac PL (Zaklopatica, Vela Luka, the Island of Korčula).

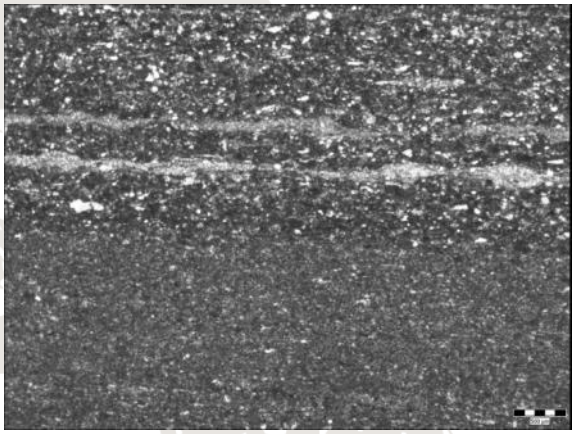
One lithostratigraphic unit of PL was mapped on the Pelješac peninsula, the Gornji Humac-PL. This type of PL limestone is largely composed of well-bedded (medium, thin-bedded and platy limestones) skeletal micritic to peloidal limestones with lithosomes of rudists. In places micritic limestones with calcispheres are present. Locally, this unit can be thick-bedded to massive (especially beds with rudist bivalves).

3901_P1. Outcrop of Gornji Humac PL at Lovišta on the Pelješac peninsula.

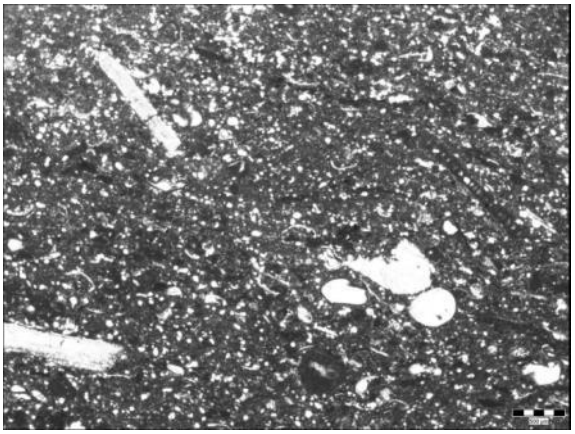
3.6.4. STRATIGRAPHY AND AGE

The Milna-PL-Pupnat limestones (on Korčula Island) are of Cenomanian age and contain the Cenomanian fossil association, mostly benthic foraminifera and other marine microfossil fauna.

The Milna-PL-Žrnovo limestones (on Korčula Island) are also of Cenomanian age and contain the Cenomanian fossil association, mostly benthic foraminifera and other marine microfossils as well as macrofossils of rudist bivalves.

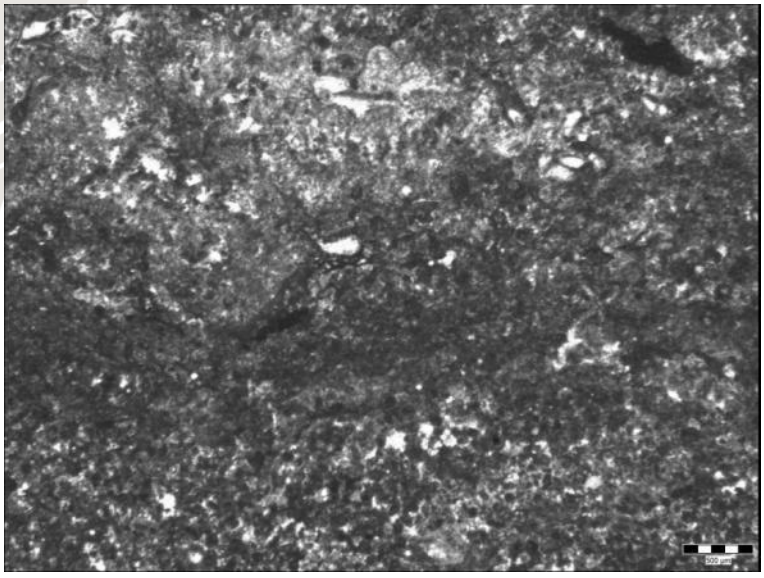


3812_S1. Microphotograph of laminated mudstone from Milna-PL-Pupnat limestones (on Korčula Island). Scale bar 500 µm.



3813_S2. Microphotograph of bioclastic wackestone-packstone from the Milna-PL-Žrnovo limestones (on Korčula Island). Scale bar 500 µm.

The Gornji Humac-PL at Vela Luka (on Korčula Island) and Gornji Humac-PL on the Pelješac peninsula contain Turonian-Santonian microfossil association (mostly benthic foraminifera, algae - aeolisacus and thaumatoporellas) and macrofossils (rudists).



3905_S1. Microphotograph of laminated mudstone and fine-grained peloidal packstone from Gornji Humac-PL (on the Pelješac peninsula). Scale bar 500 µm.

3.7. HISTORICAL USE OF PLATY LIMESTONE

It must be pointed out that PL was traditionally exploited for local use. People used the stone plates without any significant impact on the natural environment, mostly by gathering by hand (*branje kamena*) or picking it up with a hand tools.

In the **Istria County** PL has been extensively used mostly for roofs (churches, chapels, rural houses and field shelters and local water catchments, mostly in the area around Vodnjan and Oprtalj (Buje), i.e. in areas where the Pula PL and Rušnjak PL appear (Fig. 3-3-1). A special type of round field shelter built with PL is locally called a *kažun*. Locality 3024 in the small village of Ćabrnice is especially interesting, since this is the only house still covered with Rušnjak PL and has been chosen to be protected as an ethnological monument.

In the **Zadar County**, PL has been extensively used mostly for roofs (churches, chapels, rural houses and field shelters), and local water catchments (*gustirna*).

The most widely used (all over Dalmatia, recently even in surrounding regions of Croatia) is the "Benkovac stone" (polygons: Debelo brdo, Benkovac PL and Otavac PL), which was the most plentiful, naturally platy stone in the region. Therefore, the history of the exploitation of the Benkovac stone (in a broad sense) dates back to ancient times, when people started to inhabit these areas. Evidence of early Benkovac stone is seen in the Liburni-Roman city of Asseria (fourth century BC) near the village of Podgrađe, and many other historic buildings as well as numerous sacral objects from medieval times. More significant and intensive exploitation of Benkovac stone in the area began in the mid-20th century. The most common methods of exploitation of this platy limestone is quarrying or collecting from the surface. At present this is the most commonly used platy limestone (Benkovac PL and Otavac PL), used as a building material for local as well as commercial use: for rural stone houses, roofs, walls and fences, and as decorative stone wall cladding and paving.

In the **Split-Dalmatia County** PL has been extensively used for roofs (churches, chapels, rural houses and field shelters, and local water catchments called *gustirna*).

On the island of Brač all of the old settlements are characterized by extensive application of the PL (web page Brač). Here a special type of round field shelter built with PL is locally called a *bunja*.

On the island of Hvar platy limestone is of very good quality and of high potential. The name of the major PL source is Vrboska PL. There are numerous abandoned quarries of PL which were used already in ancient times. Today there are remains of uninhabited shepherd's villages with well preserved rural architecture (e.g. locality 3508_U1 at the Greek fortification Maslinovik). The roofs were built of platy limestone excavated from nearby quarries (ID_localities are 3504, 3505 and 3506). A special type of rounded field shelter is locally called a *trima,* while *a* quadrangular field shelter built of PL is locally called a *teza* (3509_U1, 3506_U1). There is also use of the Vrboska PL in some distant historical villages (e.g. Humac, locality 3501_U1), along with the use of unidentified local occurrences of Milna PL (e.g. Malo Grablje village, locality 3503_U1).

Locality 3503_P1. Old village of Malo Grablje on the island of Hvar.

Locality 3506_P2. A special type of quadrangular field shelter built of PL on the island of Hvar is called a *teza*.

On the island of Vis, Milna PL has been used in Okljućna village, while Gornji Humac-PL has been used for building houses in the villages of Plisko polje and Rukavac, especially in the village of Podhumlje-Privcovo (especially for roofs).

In the **Dubrovnik-Neretva County** PL has been extensively used mostly for roofs (churches, chapels, rural houses and field shelters), and local water catchments (*gustirna*).

On the island of Korčula, the platy limestone of the Milna-PL-Pupnat type from a small quarry in Zlo polje has been used for building houses in the Pupnat village (especially for roofs). The platy limestone of the Milna-PL-Žrnovo type, taken from a few small abandoned quarries near the Žrnovo-Postrana locality, has been used for building old houses, especially for roofs (today partly destroyed). The platy limestone of the Gornji Humac-PL-Vela Luka type from the quarry in Zaklopatica cove has been used for building houses (especially for roofs) and fences throughout history and is probably still in use today. A special type of round field shelter built from PL is locally called a v*rtujak*. The platy limestone of the Gornji Humac-PL-Vela Luka type from a small quarry in the vicinity of the Punta od Žukove hilltop has been used for building houses (especially for roofs) and fences throughout history and is probably still in use today.

On the Pelješac peninsula, the platy limestone of Gornji Humac-PL-Pelješac type from two quarries east of the village of Lovište (ID-3909 and ID-3911) has been used throughout history for building houses (especially for roofs) and for fences in the village of Zajut. The platy limestone of the Gornji Humac-PL-Pelješac type from two quarries near the village of Lovište (ID-3901 and ID-3905) has been used throughout history for building houses and field fences and is probably still in use today. Furthermore, platy limestone from these two localities was used in ancient times for building elsewhere, not only on the Pelješac peninsula. According to locals, in ancient times the platy limestone from these two quarries was exported from Pelješac to Dubrovnik and Venice by boat. The platy limestone of the Milna-PL-Pelješac type from one of the small abandoned quarries near the village of Nakovana (ID-3917) has been used for building houses (especially for roofs) in the villages of Donja and Gornja Nakovana.

3.8. SUMMARY FOR GEOLOGICAL RESEARCH ON PLATY LIMESTONE

Hrvatski geološki institut – The Croatian Geological Survey (HGI-CGS) has contracts with all four Croatian RoofOfRock project partners: IDA (Istrian County), ZADRA (Zadar County), RERA SD (Split-Dalmatia County), and DUNEA (Dubrovnik-Neretva County), to work on the project as an external expert and to prepare the project outputs. The contract requirements comprise all geological aspects of the RoofOfRock project, which were organized through the project work packages (WP): WP3, partially WP4, WP5 and WP7.

HGI-CGS has been closely collaborating with the project partners and other external experts in the process of determining a common definition of platy limestone and in the work of assembling data for the database and the geological maps. After an extensive geological survey carried out by the HGI-CGS teams, and according to certain recognized characteristics, the spatial occurrence of all types of PL were indicated on maps at a general scale of 1:50,000, along with an assessment of each of their general potential as PL. Platy limestone occurrences of recognized value for the project are shown on the maps in Chapter 3, while more detailed descriptions of PL occurrences as mineral commodity, which also include natural protection and other spatial restrictions, are covered in Chapter 4. All other local PL occurrences and buildings are included on the **enclosed CD** (Excel tables, analytical and photo material, along with the database in .shp file format).

The entire NE Adriatic region is made up of different deposits characterized by a very wide stratigraphic range – from the oldest Carboniferous to the youngest Quaternary. The karstic (coastal) part of the region is characterized by a largely deformed “layer cake” succession of Adriatic/Dinaric carbonate platform carbonates (80%), along with various overlying carbonate-siliciclastic sedimentary rocks (20%). However, the most interesting PL horizons were observed within Cretaceous lagoonal and intraplatform basin deposits, and within basinal (deep marine) Promina deposits (Late Paleogene).

In accordance with the 1:50,000 map and POLYGONS attribute tables, we review the importance of low potential, potential and high potential types, as shown on the maps. However, low potential types are distributed sparsely in thin horizons within the region, as parts of the units shown on the general geological map 1:250,000 (Chapter 2), but without significant platy limestone content. This is the case with the Albian-Cenomanian (ID geol. unit 12), Cenomanian-Turonian(ID geol unit 14), Turonian-Santonian (ID geol. unit 15) limestones in general as well as Dol (ID geol. unit 16a) and Sumartin units (ID geol. unit 16f). Considering the huge project area in Croatia, only the potential and high potential PL types were mapped in the scale 1:50,000 (**Appendix 3**).

On the multicolour topographic base map, the **POTENTIAL** polygons are shown in **yellow**, while **HIGH POTENTIAL** types are shown in **orange**. The data served as a basis for the evaluation of listed types of platy limestone as mineral commodity and for identification of potential quarrying areas. In the Croatian part of the project area most of the PL sequences are only a few meters thick, in some places less than a meter, but their spatial occurrence depends immensely on the relation of the geological (bed dip angles) and morphological (slope angles) features.

In Istrian county two main Cretaceous PL types characterized by a valuable amount of platy limestone are recognized in the high-potential Pula PL unit, along with some occurrences within the Rušnjak geological unit. The Pula PL is only of general potential owing to the very thin PL horizons that are sparsely distributed within the units.

In Zadar county (northern Dalmatia) a major PL occurrence is the so-called "Benkovac Stone", where three Paleogene types of PL were recognized during this survey in a higher Promina unit. Debelo brdo and Benkovac PL units are of excellent quality, since the PL is mostly densely packed micrite and fine-grained calcarenite, which is uniformly thin-bedded.

In Split-Dalmatia county (central Dalmatia), in the Trogir area and on the islands of Šolta, Brač, and Hvar, six main Cretaceous lithostratigraphic units characterized by platy limestone are recognized and mapped: Klačina (Šolta), Milna PL (Trogir, Šolta), Vrboska PL (Hvar), Gornji Humac PL (Brač), Vinišće (Vinišće and Veliki Drvenik), and Jelinak (Trogir).

In Dubrovnik-Neretva county (southern Dalmatia), on the island of Korčula and Pelješac peninsula, two main Cretaceous lithostratigraphic units characterized by platy limestone are recognized and defined as high potential: Milna PL (Pupnat and Žrnovo on Korčula) and Gornji Humac PL (Vela Luka on Korčula and Lovišta on Pelješac).

4.

PLATY LIMESTONE AS A MINERAL COMMODITY AND ITS NATURAL HERITAGE

4.1. INTRODUCTION

After reporting on the general occurrence of platy limestone (PL) in the Croatian part of the project area, we are focusing on PL as a mineral commodity with respect to the general spatial limitations of usage and its natural heritage. The aim of this section is to identify possible sources of the most promising types of platy limestone (high potential PL units and localities) within the investigated regions of the Adriatic karst. For this purpose, the stratigraphic position, age, and major sedimentological and paleontological characteristics of various platy limestone units were studied, both in situ and during subsequent laboratory analysis. According to the recognized potential and spatial occurrence of all types of PL previously defined on maps at a general scale of 1:50,000, we evaluate selected types of platy limestone as a mineral commodity with the final goal of identifying potential quarrying areas. The quality of selected samples was assessed according to the field observations combined with geomechanical laboratory analyses of flexural strength. In the selected and most promising sites, detailed sedimentological and paleontological investigations were undertaken for the purpose of natural protection proposal (in terms of age, paleontological and lithological characteristics, genesis, etc.)

A study of platy limestone as a mineral commodity and the identification of potential quarrying areas required gathering of data from WP3 (Act. 3.3) as well s WP4 and WP5 data, with the aim of analysing and synthesizing the limitations on the use of platy limestone. It means that land usage, as well as natural, physical, social and legislative limitations should be included, taking into account the results of action 3.4. In these report, we use only working materials from WP4 and WP5 to propose locations for potential quarrying areas. However, it was necessary that all data be unified and incorporated into a joint GIS database (activity of WP7), where they were covered on geological maps illustrating the spatial occurrence of platy limestone. Following the conclusions agreed at the coordination meetings in Trieste (February, 2014), Split (April, 2014), Međugorje (June, 2014), Matavun (October, 2014), and Piran (December, 2014), we evaluated the general spatial limitations of PL usage, proposed the most interesting natural heritage sites, and estimated the quality and quantity of reserves of PL, either as selected high potential polygons, or selected locations proposed for potential quarrying. We estimated in this report that surface quarrying could extend down to 5 m from the surface. In addition, we propose general guidelines for sustainable exploitation of platy limestone.

4.2. ASSESSMENT OF PL AS A MINERAL COMMODITY IN GENERAL

Different types of platy limestone (PL) are shown and briefly described in the report on PL in general (see Chapter 3). The quality and quantity of each type of PL was observed during the fieldwork. The most representative samples were collected from both the outcrops and the buildings. Furthermore, crucial issues for the evaluation of PL as a mineral commodity and for identification of the potential quarrying areas were discussed among the members of the team, as well as with the local inhabitants. After all the data was collected and unified and the maps of platy limestones prepared, office work continued and GIS-based databases were prepared. The GIS data was used to assess the quantity of each high-potential type of PL. Finally, the maps and the database were used the for preparation of this report.

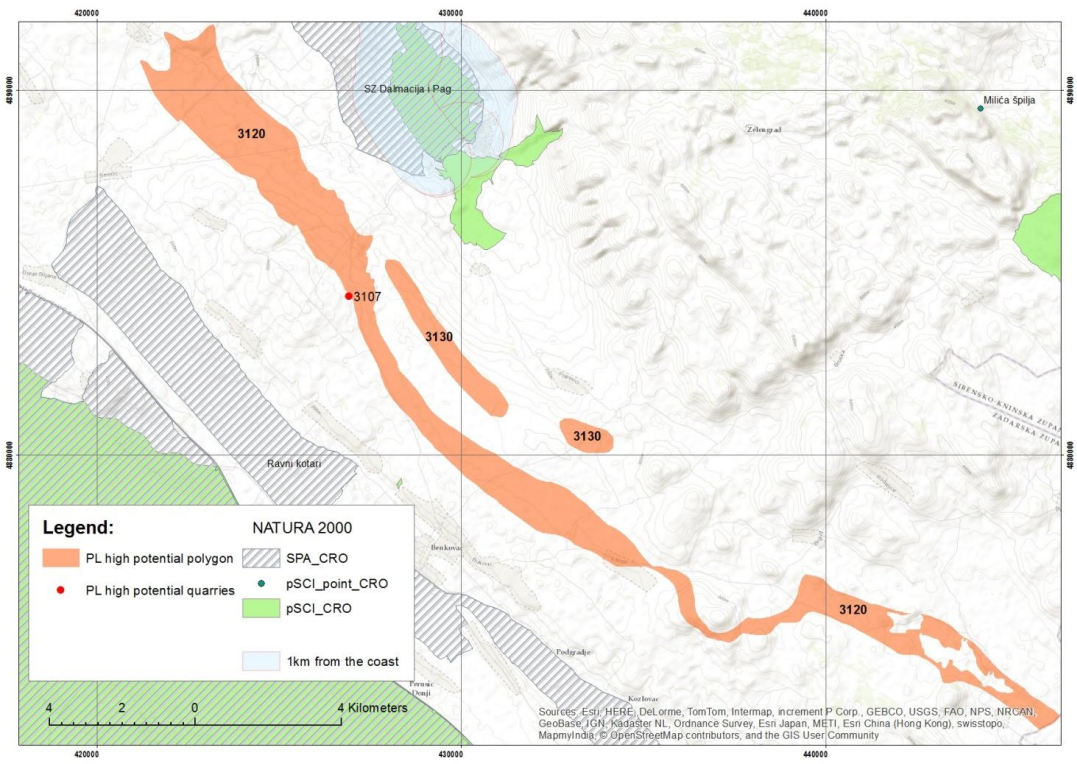
For the purpose of assessing PL as a mineral commodity with the aim of possible future sustainable exploitation, and taking into account the possible impact on the natural environment, we **focused only on high potential units and localities**. According to the current mining

regulations in Croatia, there is a protection zone 1,000 m wide along the coastline, and 500 m from a human settlement. In addition, **there are special restrictions on any mining activity on most of the islands**. Regardless the fact that most of the PL polygons and localities are on the islands, we reported on all of the high-potential types. Although there are significant limitations, there is still a need for restricted use of PL. Thus, it should be proposed that in some cases a local traditional gathering of plates using only simple hand tools (non-motorized) should be allowed for the renovation of existing traditional houses and cultural (sacral) objects. Nevertheless, realization of any commercial exploitation of PL ultimately depends on the current national mining regulations in place. It is supposed that the formal Croatian regulations (which should be listed in the WP6 report) could be modified in the future, and for that reason we decided to assess the general quantities according to the complete natural (geological) occurrence of PL within high potential units and localities. Thus, on the maps we show zones that are generally protected (according to **Natura2000 and a zone 1 km from the sea coast**), which could be included in more detailed possible future assessments on PL potential as a mineral commodity, in accordance with future regulations.

4.3. HIGH-POTENTIAL PL APPEARANCE, LIMITATIONS AND GEOLOGICAL ASSESSMENT

4.3.1. ZADAR COUNTY (ZADRA)

In the Benkovac (Zadar) area (northern Dalmatia), there is a major PL occurrence in the Benkovac region (see Chapter 3), where two high potential Late Paleogene PL units (Benkovac PL - ID 3120 and Otavac PL - ID 3130) and one high potential locality (Debelo brdo locality - ID 3107) were identified during this survey in higher Promina unit.



Detail map of high potential PL units and PL localities in the Zadar County project area.

In the area between the villages of Islam Grčki to Smilčići and Debelo brdo to Mejanica hill the potential platy limestone type named Debelo brdo (ID 3110) was determined. However, because of <30% PL content within the unit thickness, we selected only one local occurrence (an abandoned quarry) as high potential, situated in the **Debelo brdo locality** (ID 3107).

The major PL occurrence is the high potential platy limestone type named **Benkovac PL** (ID polygon 3120), which is mapped along the NW-SE trending belt located between the village of Smilčići and Mejanica hill (extends further toward SE).

High potential platy limestone type named **Otavac PL** (ID polygon 3130) was investigated and defined in two larger separate areas: the northeastern slopes of the Kukalj hill and southwest of the village of Pliskovo.

It should be noted that within the lower part of the Late Paleogene there is also a wide area of occurrence of the potential Debelo brdo unit (ID polygon 3110) characterized by many local occurrences of the PL.
There are also local occurrences of Cretaceous PL (e.g. the Cenomanian Milna PL on the island of Dugi otok). We do not recommend it for any commercial exploitation because of the small quantities of PL and its proximity to the sea coast. However, it is suitable for local use (stone gathering of PL on the surface or excavation in small delves) for renovation of parts of traditional houses as a good practice.

It is noteworthy that 28 official commercial quarries of platy limestones are situated in the Zadar County, within the area of occurrence of the high potential PL units (Benkovac PL and Otavac PL) of the "Benkovac Stone" (Table 3.2, after the Ministry of Economy, Mining Sector 2012.). All of these commercial quarries have excellent quality platy limestone and exhibit great potential for further exploitation.

	Name of exploitation field (quarry)	Area (ha*)	Authorized concessionaire
1	ANTE	12.76	Obrt Kamenoklesar
2	BUKOVIĆ GAJ	8.45	Obrt Čerinka
3	BUKOVIĆ GAJ -ZAPAD	4.56	Mediteran Kamen d.o.o.
4	BUKOVIĆ GAJ II	2.62	Obrt Čerinka
5	GRADIĆ	2.95	Saal d.o.o.
6	GRADIĆ II	6.33	Obrt Gradina
7	KUKALJ KAVE	296.81	Adria Kamen d.o.o.
8	KUKALJ	11.71	Obrt TGP Karlo
9	KUKALJ KAVA -JAMAR	19.28	Jamar d.o.o.
10	LISIČIĆ	2.00	Obrt Autoprijevoznik
11	MAČKOVAČA	3.99	Saal d.o.o.
12	MARIĆI	10.30	Kamen d.o.o
13	MATAN KAMEN	8.60	Obrt Matan Kamen
14	PLISKOVO	7.64	Obrt kamenoklesar Rogić

15	ROMANOVAC	7.65	Kamen d.o.o.
16	STAZICE -ADAM	5.75	Geofon d.o.o.
17	TORINE	5.39	Zio Commerce d.o.o.
18	TORINE 2005	8.58	Kamen Benkovac d.o.o.
19	TORINE II	4.77	Obrt Žilić kamen d.o.o.
20	TORINE-AMADEUS	3.62	Obrt Amadeus
21	TORINE-AMADEUS II	15.51	Obrt Amadeus
22	TORINE-GRANIT	7.74	Granit-Tokić d.o.o.
23	TORINE-MAMINJO	11.79	Maminjo d.o.o.
24	TORINE-SJEVER	37.13	Grič-3 d.o.o.
25	TORINE-ZAPAD	3.80	Grič-3 d.o.o.
26	TORINE-VIKTOR	18.24	Obrt Viktor
27	USKOK	4.00	Obrt Uskok
28	VLAČINE	9.07	Benkamen d.o.o.
	TOTAL (ha*)	**541.04**	**"Benkovac Stone"**

Table 3.2. Commercial quarries of platy limestone in Zadar County (Ministry of Economy, Mining Sector, 2012. * 1 ha = 10,000 m^2).

None of the polygons and localities recognized as high potential for PL as a mineral commodity are under Natura2000 protection.

4.3.1.1. Debelo Brdo (abandoned quarry): ID locality 3107

The Debelo Brdo abandoned quarry is one of a few quarries in the uppermost part of the Debelo Brdo unit. The PL at this location makes 100% of the stratigraphic succession, while the estimated thickness for surface exploitation is at least 5 meters*. Bedding surfaces are almost horizontal or slightly inclined to the northeast (5-10 degrees).

**Surface quarrying is estimated in this report down to 5 m from the surface in all of the low-relief areas.*

3107_P5: Debelo brdo abandoned quarry.

At this locality, the succession is characterized by an alternation of 10-40 cm thick beds of calcilutites with thin laminae of fine to coarser grained calcarenites, and beds 1-5 cm thick of very fine grained calcarenites. However, platy occurrence was predisposed by the laminae even in thicker beds, resulting in thicknesses of most plates at 1-5 cm throughout the whole succession. This is a general principle of plating within all types of "Benkovac Stone".

The plates could be easily gathered from outcrops or excavated from shallow (up to 5 m deep) quarries. The plates are of irregularly quadrangular shape, mostly 20x30 cm, rarely up to 50 cm long. The best quality plates are characterized by a homogenous lithology, either muddy or grainy (without any laminae within the plate). Of a lesser quality are plates characterized by alternation of the fine- to coarser grained material because of possible further plating during exposure on the surface or an object (e.g., as a building material). However, all the lithotypes are in use. The average thickness of the plates used on roofs is 3-5 cm.

Usage of platy limestone is similar to the Benkovac PL, considering the fact that the locality is situated close to that major occurrence and quarries of the PL in the area.

On the Debelo brdo locality, the slopes are gentle and covered by shallow vegetation, in places cultivated for vineyards and olives. Outcrops are accessible because of the proximity to the main Benkovac-Karin road, and many wide macadam roads (all in use) in this area.

Considering the general concordance of the gentle topography and gentle bedding angles, it is estimated that the Debelo Brdo unit (100% platy) covers approx. 200,000 m^2, while the quantity suitable for exploitation is estimated at 1 billion m^3.

4.3.1.2. Benkovac PL: ID polygon 3120

This unit consists of 100% of PL. For this reason most of the commercial quarries of "Benkovac stone" are located within this unit. The stratigraphic succession is approx. 120 m thick. The

Bedding surfaces are slightly inclined to the northeast (7-16 degrees) or subhorizontal, and slightly undulated. The estimated thickness for surface exploitation at each locality is at least 5 meters.

3109_P1_Benkovac PL quarry Adria-kamen.

Within this unit, succession is characterized by an alternation of grey fine- to coarser grained calarenites and yellowish-grey calcilutites. The thickness of the calcarenite beds varies 0.5-3 cm, mostly 5-10 cm, and rarely up to 30 cm. Calcilutites (calcareous mudstones) range from a few mm to 30 cm thick, but are intercalated by very thin (1-5 mm) grainy laminae which predispose plating.

The plates are of an irregular quadrangular shape, mostly 50 x 50 cm, and can be up to 1 m^2. The plates are broadly used in the area, as well as all over Dalmatia (see Chapter 5), and in continental Croatia. The average thickness of the plates on roofs is 2-5 cm.

The best quality plates are homogenous calcarenites or calcilutites, in average 2-5 cm thick.

3106_P1: Example of the usage of the Benkovac PL - Žilići village near Lisičić.

Of slightly lower quality are plates characterized by alternation of fine- to coarser grained material.

3101_P2: Example of the usage of the Benkovac PL - church of Sv. Ivan Krstitelj (Medviđa).

The most promising area for the exploitation of PL is on the NE slopes of Debelo Brdo and NE of Benkovac (many active and abandoned quarries are located there). The area is characterized by gentle topography (small hills) and is covered by shallow vegetation. All the outcrops are highly accessible because of the Benkovac-Karin-Pliskovo-Lisičić road network, and wide local roads used

by both past and active stone-masons.

Considering the general concordance of the gently inclined slopes and gentle bedding angles, it is estimated that 100% of Benkovac PL unit surface occurrence of 29.83 km^2 and approximate thickness of at least 5 m, can be calculated for general exploitation of approx. 150 billion m^3.

4.3.1.3. Otavac PL: ID polygon 3130

The Otavac PL stratigraphic succession is 25-30 m thick (100% of the unit thickness is PL). The Otavac PL unit is intercalated as a huge lens within the higher and thicker Otavac conglomerate unit. Beds are slightly inclined to the northeast (5-15 degrees), but are also gently undulated, and the estimated PL succession thickness over the entire area is at least 5 meters.

3123_P3_Pliskovo quarry within the Otavac PL unit.

The Otavac PL succession is characterized by an alternation of fine- to coarser grained grey calcarenites and yellowish-grey calcilutites, like the Benkovac PL. Calcarenite beds are 10-150 cm thick, and are characterized by planar lamination that causes plating every 5 to 15 cm. Calcilutite beds (calcareous mudstone) are 5 to 30 cm thick, and contain very thin intercalations of grainy calcarenite (1-5 mm thick) which are also predisposed to plating.

In the quarries and on the surface, the plates are of irregular quadrangular shape, mostly 30 x 50 cm, rarely to $1m^2$. The best quality plates are homogenous calcarenites (5-15 cm thick) or calcilutites (3-10 cm thick), while thin-laminated alternations cause secondary plating susceptible to damage on the buildings. All lithotypes are in use, mostly on roofs and as pavement.

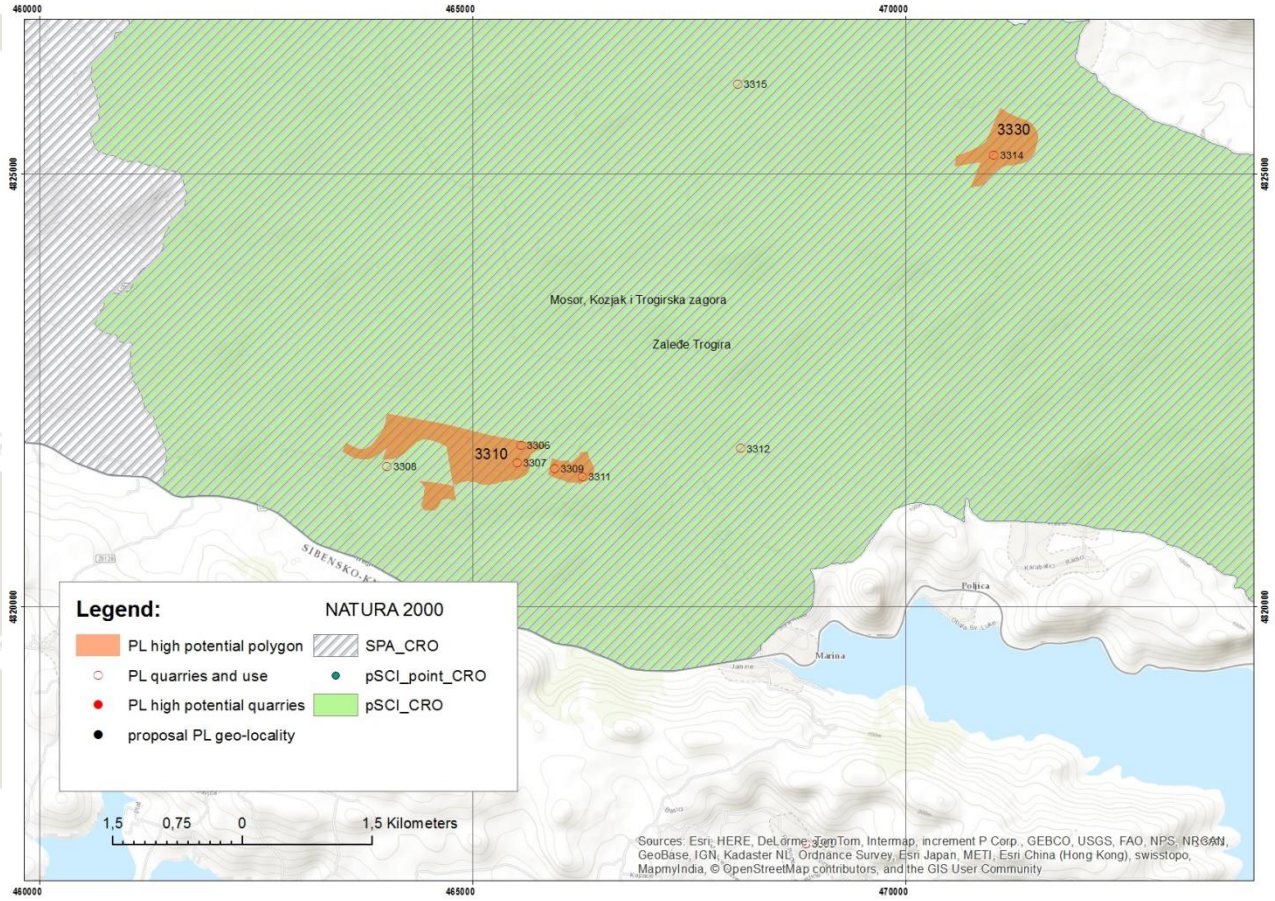
There are two polygons of the Otavac PL: one bigger polygon on NE slopes of Kukalj hill, and one smaller SW of the village of Pliskovo. The latter is characterized by several active and abandoned quarries. Outcrops and quarries are easily accessible, because of the gentle topography, shallow vegetation and a network of local macadam roads. There is a local main road from Benkovac to Pliskovo.

The Otavac PL unit (both polygons together) covers 3.97 km^2. Taking the estimated average PL succession thickness of minimum 5 m, the quantity suitable for exploitation is estimated to 19.87 billion m^3.

4.3.2. SPLIT-DALMATIA COUNTY

In Split-Dalmatia County (central Dalmatia), there are numerous, relatively small high potential PL polygons in the Trogir area and on the islands of Šolta, Brač and Hvar, along with a few local high-potential localities, and a number of largely abandoned quarries, all within the Cretaceous sedimentary succession (see Chapter 3).

In the **TROGIR** area high potential PL is defined at **Kmečalovica** hill ("Pločurine"), situated NW of Marina, and is characterized by outcrops of the Milna PL type (ID_polygon 3310), while in a flat area close to the **Begovići** village, NW of Marina, the Jelinak PL type is exposed (ID_polygon 3330).

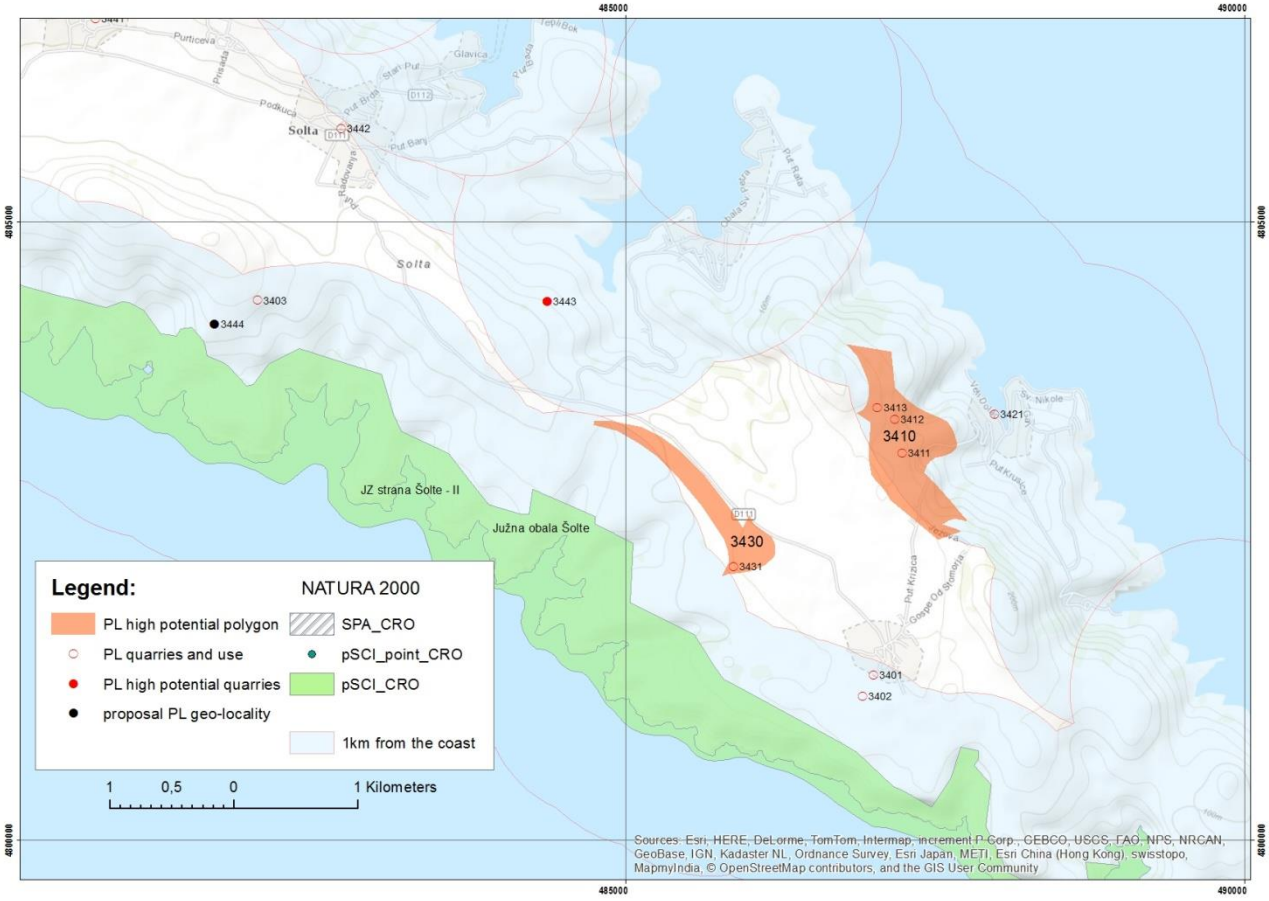


Detailed map of high potential PL units and PL localities in the Trogir (Marina) project area.

It should be noted that relatively large PL polygons are situated east of Vinišće (SW of Trogir), and on the northern part of the island of Veli Drvenik, but these are mostly steeply dipping beds (plates) which are not suitable for any commercial exploitation.

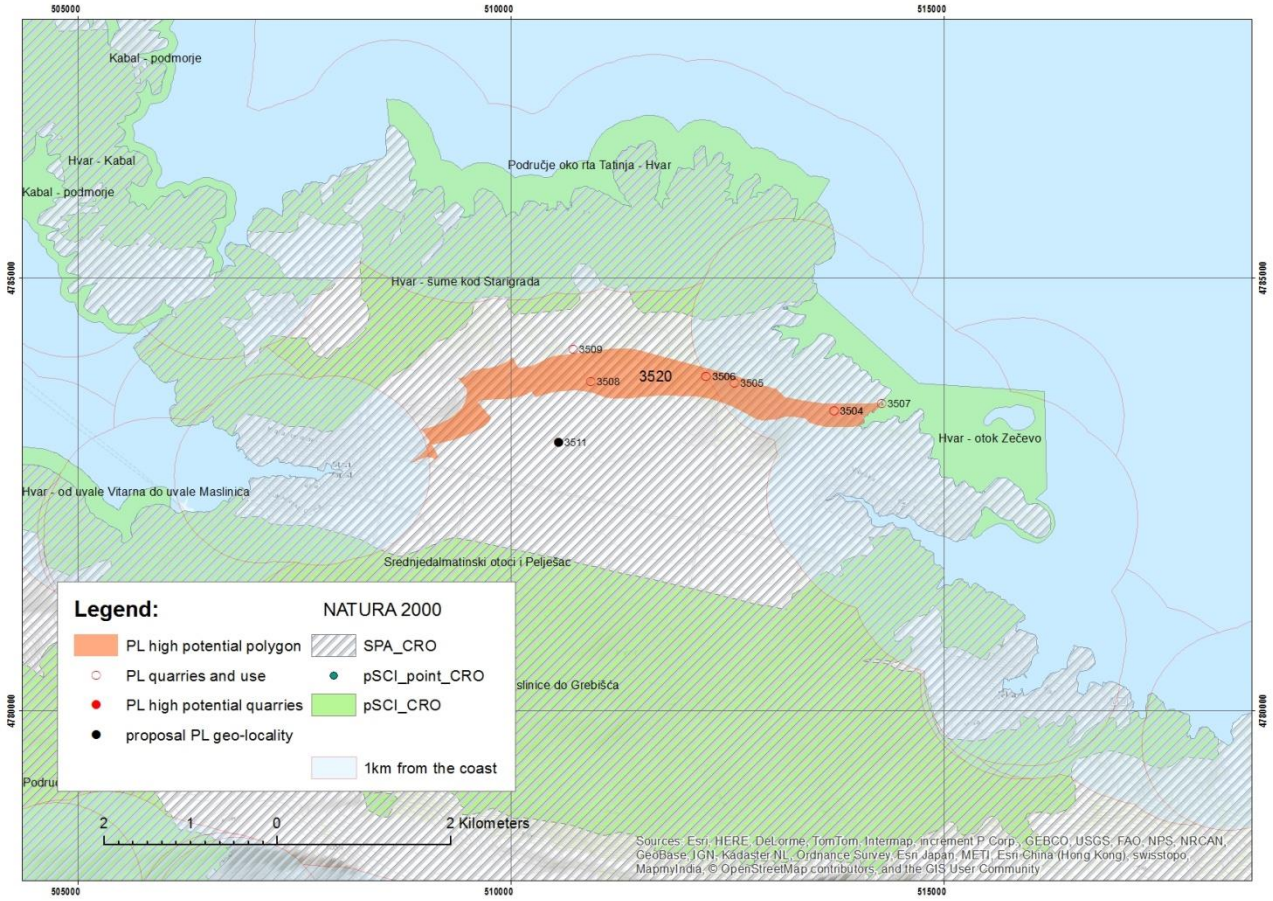
On the island of **ŠOLTA** high potential PL is defined in several areas: in **Koludrovi doci** flat area between Stomorska and Gornje Selo characterized by the Klačina PL (ID_polygon 3410), and

between the villages of Gornje Selo and Grohote in the central part of the island of Šolta, at **Kupište,** where the Milna PL appears (ID_polygon 3430). A high potential local occurrence is also defined between Grohote and Nečujam, at **Trzavica** (ID_locality 3443), within Rogač-Šolta PL unit.



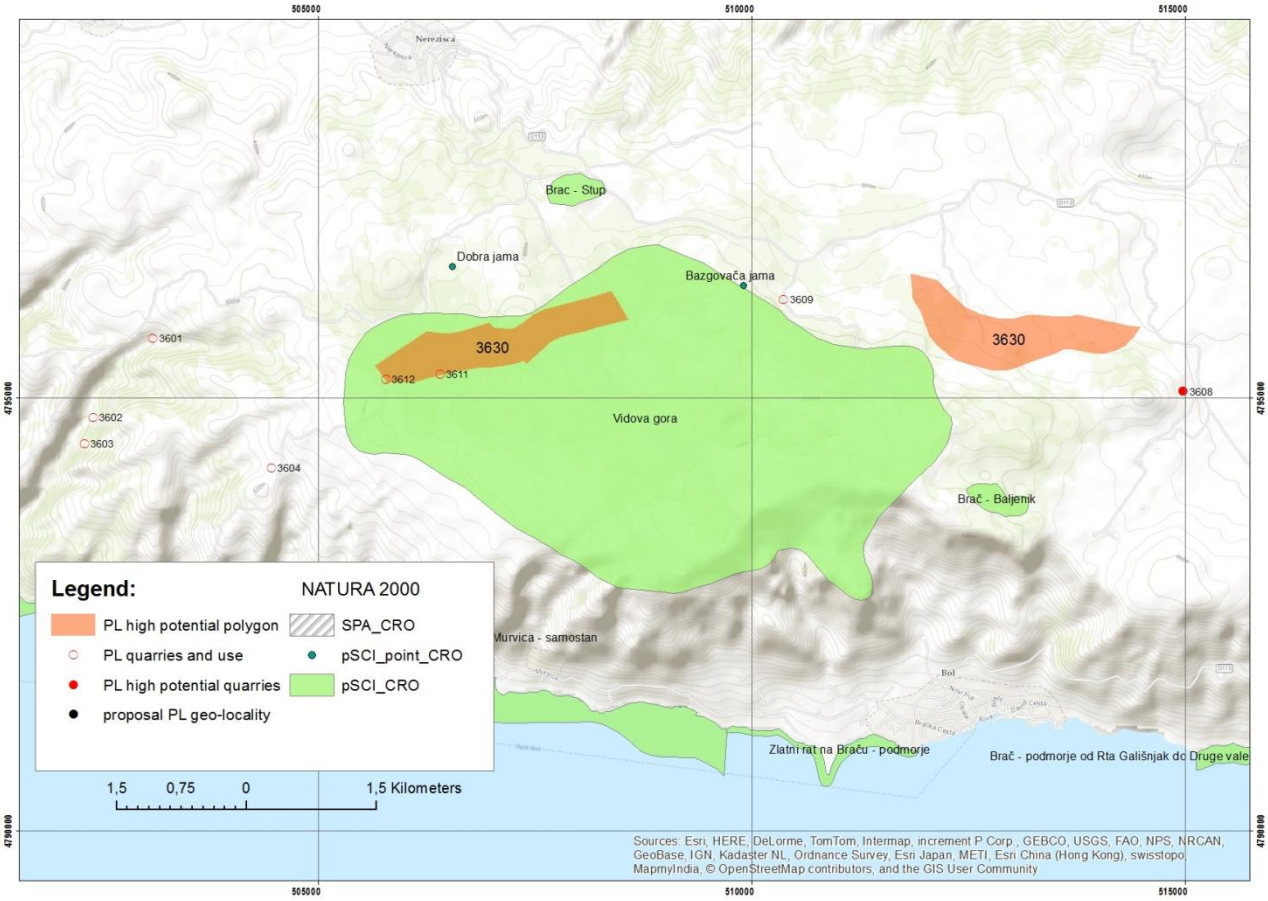
Detailed map of high potential PL units and PL localities on the island of Šolta project area.

On the island of **HVAR** high potential PL is defined in the northern-central part of the island in the area between Stari grad and **Vrboska**, where the Vrboska PL unit is located north of Starogradsko polje (ID_polygon 3520).



Detailed map of high potential PL units and PL localities on the island of Hvar project area.

On the island of **BRAČ** high potential PL is defined in the central-southern part of the island of Brač, in the area of Vidova gora, where two polygons are situated near **Podgažul** and **Fantovi doci** (ID_polygon 3630). One high potential locality (quarry) is defined in the area of Gornji Humac, at the locality called **Vestac** (ID_locality 3608).



Detailed map of high potential PL units and PL localities on the island of Brač project area.

Noteworthy, both former commercial quarries (last data from 2012) of platy limestones are situated on the island of Brač, south of the village of Gornji Humac (informal "Brač Platy").

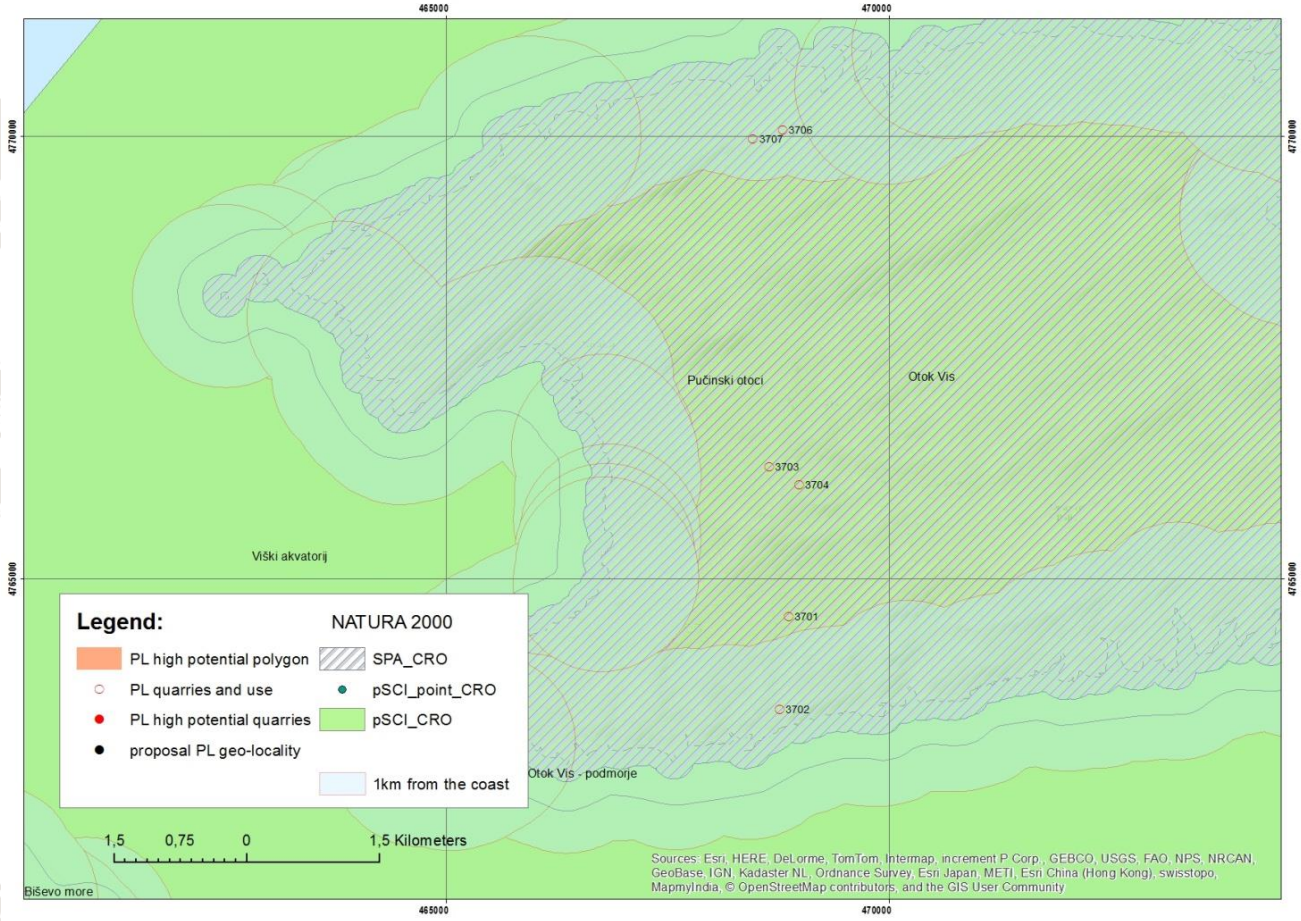
	Name of exploitation field (quarry)	Area (ha*)	Authorized concessionaire
1	KALINA I	0.61	Obrtnik Siniša Šesnić, Gornji Humac
2	KALINA II	0.23	Obrtnik Vjekoslav Šesnić, Gornji Humac
	TOTAL (ha*)	**0.84**	**"Brač Platy""**

Commercial quarries of platy limestone in the Split-Dalmatia County, the island of Brač (Ministry of Economy, Mining sector, 2012., * 1 ha = 10,000 m^2).

It should be noted that we recommend only high-potential polygons and localities for possible commercial exploitation, while others were not recommended because of small quantities of PL on the surface, bad quality and/or proximity to the coast or a settlement. However, all the others (potential and less potential) occurrences could be suitable for local use (stone gathering of PL on the surface or excavation in small delves), but for renovation of traditional houses only. We recommend such local use as good practice.

As examples of low potential localities, we propose two relatively small abandoned

quarries/delves of PL on the island of **VIS** (3702 and 3706). However, considering the small quantities and the high level of protection on the off-shore islands (including Natura2000 and proximity to the coast), this material potentially could be used only for renovation of local traditional houses in the villages of Podšpilje, Oključna etc.



Detailed map of PL localities on the western part of the island of Vis.

4.3.2.1. Kmečalovica (Trogir area NW of Marina): ID_polygon 3310

Kmečalovica hill ("Pločurine") is characterized by outcrops of the Milna PL type of Cenomanian age. There is a near concordant relation between the low-angle dipping beds (10-20 degrees) to the northern quadrant, and the northern slopes of the hill, resulting in relatively large area characterized by PL appearing at the surface. Thicknesses for surface exploitation at this locality extends up to 5 meters*.

**Surface quarrying is estimated in this report down to 5 m below the surface.*

3309_P3: Kmečalovica area.

More than 30% of PL appears within succession a few tens of meters thick of medium to thick-bedded limestones characterized by chondrodont and rudist bivalve shells. PL is characterized by alternation of grey micritic and very fine-grained laminated limestones and microbial (algal) laminites, brownish-grey skeletal limestones rich in benthic foraminifera, and light-grey fine-grained bioclastic limestone with shell fragments. Predominating microbial laminites usually form undulating plates (reflecting depositional algal hummocks and synsedimentary plastic deformations which laterally form synsedimentary breccias), while micitic and fine-grained plates are usually flat. Micritic plates are characterized by smooth natural surfaces, while harsh surfaces in grainy materials reflect selective corrosion.

The plates are of irregular shape, usually 20x30 cm, although some thicker plates (5-10 cm) of microbial laminites can be as large as 50x100 cm. The plates are used for dry walls and field shelters in the Kmečalovica olive yards and for roofs on traditional Dalmatian houses in surrounding villages (Gustirna, Dograde, Vrsine, Svinca etc.).

3311_P1: Example of usage of the Milna PL that alternate with medium-thick limestone in Kmečalovica olive yard.

The high variety of lithologies alternating within the PL succession resulted in various qualities of plates. According to the field assessment, plates of micritic limestone represent the best quality plates.

The northern slopes of the Kmečalovica hill are characterized by olive groves surrounded by many well preserved dry stone walls and field shelters characterizing typical rural Dalmatian architecture. The whole area is characterized by particularly fine landscapes, and could justify reasonable spatial restrictions on possible exploitation of PL as a mineral commodity. Access to the area is possible by narrow local roads from the south (from the village of Svinca) and from the east (from the village of Gustirna).

Considering the general concordance of the gently inclined slopes and gentle bedding angles, and the estimated 30% PL content within the Milna PL succession that covers approx. 1 km^2 surface quarrying* quantities are estimated at 1.5 billion m^3 of PL.

4.3.2.2. Begovići (Trogir area NE of Marina): ID_polygon 3330

A few hundred meters SW of Begovići village, NW of Marina, there is a polygon of the Jelinak PL type of Turonian age, characterized by a rather concordant relation between the subhorizontal bedding and the flat morphology.

3314_P3: Jelinak PL type area near the village of Begovići.

More than 30% of PL appears within the >10 m thick succession of platy limestones overlain and underlain by medium- to thick-bedded calcisphere limestones. The Jelinak PL is also very fine-grained yellowish-grey calcisphere limestone with reddish microbial laminae. The laminae occur at every 2-20 cm within the beds, thus predisposing plating. Rare mollusk fragments up to a few mm long can be found within the limestones.

The plates are of irregular quadrangular shape, mostly 15x25 cm, up to 30x40 cm large. The plates are used in the area for roofs on traditional Dalmatian houses (villages of Bristivica and Blizna).

**Surface quarrying is estimated in this report down to 5 m below the surface.*

3315_P1: Example of usage of Jelinak PL type on traditional Dalmatian house in Oštrići village.

The quality of the typical Jelinak PL type can be limited because of the macroscopically observed porosity in some horizons. Besides, higher portions of reddish microbial laminites appear in some horizons, which can causes the forming of very thin, rather fragile plates.

The whole area is characterized by low relief and minor vegetation, as well as very good accessibility by a wide local road built for the purpose of accessing a new wind power plant at the crest of Jelinak Mt. There is a joint with Bristivica-Blizna main road a few hundred meters to the north. The only possible spatial limitation for potential exploitation would be the vicinity of the village of Begovići (less than 500 m).

Taking into consideration the general concordance of the flat topography and subhorizontal bedding, and the estimated portion of 30% of PL within the Milna PL succession that covers approx. 0.4 km^2, the quantity for potential exploitation for surface quarrying up to 5 m deep is estimated to be 0.6 billion m^3 of PL.

4.3.2.3. Koludrovi doci (Šolta island): ID_polygon 3410

The Koludrovi doci area between Stomorska and Gornje Selo is characterized by lower Cenomanian Klačina PL, which are mostly well-bedded micritic to grainy skeletal limestones. The platy ones (>30%) are mainly composed of laminated stromatolitic limestones.

3413_P1: Koludrovi doci area (W of Stomorska on the island of Šolta).

Approximately 30% of PL appears within successions a few tens of meters thick of predominantly thick-bedded Klačina PL. The Klačina PL is an alternation of micrite containing tiny ostracods and very fine-grained light grey peloidal and skeletal limestones characterized by horizontal parallel lamination. The laminae are up to a few mm thick. Thin microbial laminae cause plating in the outcrops. Small groups or horizons of mollusc shells (requieniid rudists) can be found within the limestones.

The plates are of irregular quadrangular shape, mostly 15x25 cm, up to 25x50 cm large. The plates are used for roofs on traditional Dalmatian houses (villages of Stomorska and Gornje Selo).

3421_P1: Example of the usage of Klačina PL type on traditional Dalmatian house in Stomorska village.

The quality of typical Klačina PL type is very good, although some horizons can be dark grey in places owing to local dolomitization.

The whole area is characterized by low relief and vegetation, and is isolated from exposure to the sea by the surrounding hills. There is good accessibility via a net of wide macadam roads with a connection to the Gornje Selo-Stomorska main road. The main abandoned quarry in Koludrovi doci recently became a site for the controlled deposition of building waste (under video monitoring). The only possible spatial limitation for potential exploitation would be the vicinity to the sea coast (mostly within 1000 m from the coast).

Considering the general concordance of the flat topography and subhorizontal bedding, and the estimated portion of 30% of PL within the Milna PL succession, which covers approx. 0.65 km^2, potential exploitation for quarrying down to 5 m below the surface is estimated at approx. 1 billion m^3 of PL.

4.3.2.4. Kupište (Šolta island): ID_polygon 3430

In the central part of the island of Šolta in the locality of Kupište is a polygon of Milna PL, which is lithologically very similar to other Milna PL types (Trogir, Brač, Hvar).

Approximately 30% of PL is intercalated within medium- to thick-bedded limestones of Cenomanian Milna formation, characterized by chondrodont and rudist bivalve shells. Milna PL is mostly microbial (algal) laminites in alternation with grey micritic and very fine-grained laminated limestones, brownish-grey skeletal limestones rich in benthic foraminifera, and light-grey fine-grained bioclastic limestone with shell fragments.

The plates are of irregular quadrangular shape, mostly 10x20 cm, up to 20x30 cm large. The plates

are used in the area for roofs on field shelters and on traditional Dalmatian houses (village of Gornje Selo).

3431_P2: Example of the use of Milna PL type on a traditional Dalmatian field shelter.

The quality of typical Milna PL type is very good, although some plates are undulating because of the natural occurrence of algal laminites.

The locality is on a gentle slope inclined to the south. There is good accessibility via a narrow macadam road with a connection to the Gornje Selo-Grohote main road. Spatial limitations to potential exploitation is an open view to the sea, and the fact that there is a waste deposit facility nearby.

The estimated portion of 30% of PL within the Milna PL succession, which covers approx. 0.3 km^2, for potential exploitation quarrying down to 5 m below the surface* is estimated at approx. 0.5 billion m^3 of the PL.

4.3.2.5. Trzavica (Šolta island): ID_locality 3443

A high potential local occurrence of a PL type named Rogač was identified at Trzavica. The Rogač (Šolta) PL type is an alternation of medium- to thin-bedded, platy and laminated limestones that are characterized by alternating brownish-grey peloidal fine-grained skeletal limestones and cyanobacterial laminites, in places with intercalations of chert nodulae.

At the Trzavica locality it is estimated that >30 % is suitable for exploitation in 35x45 m abandoned quarry and the surrounding area of approx. 200x100 m.

**Surface quarrying is estimated in this report down to 5 m below the surface.*

3443_P1: Trzavica abandoned quarry (E of Grohote on the island of Šolta).

The plates are of irregular quadrangular shape, mostly 10x20 cm, up to 25x35 cm large. The plates are used in the area for dry walls, roofs on field shelters and on traditional Dalmatian houses (village of Grohote).

3444_P6: Example of use of Rogač PL type on traditional water catchment at Straža locality.

The beds are slightly inclined to the south, opposite to the northern slopes of the island. That is why we recommend this specific locality for possible quarrying of PL in future, rather than the entire polygon of the Rogač PL, which covers the biggest PL area on the island of Šolta (see the map in Chapter 3 on PL in general). There is good accessibility to the locality of Trzavica via a narrow white road Grohote-Nečujam. One spatial limitation for potential exploitation is its proximity (less than 1000 m) to the coast.

Considering the portion of 30% of PL within the Rogač PL succession that covers 20,000 m^2 at Trzavica, the potential quantity of PL for exploitation down to 5 m below the surface is estimated at 30000 m^3.

4.3.2.6. Vrboska (Hvar island): ID_ polygon 3520

A PL named Vrboska PL is located in the northeastern part of Starogradsko polje (the island of Hvar). The Vrboska (<30%) as well as the Vrboska PL (>30%) are composed of medium- to thin-

bedded, platy and laminated alternations of mudstones, microbial (algal) laminites, and very rare fine-grained skeletal limestones of Cenomanian age. Predominating microbial laminites can form flat or undulating and folded plates (reflecting synsedimentary plastic deformations).

3505_P1. A quarry of Vrboska PL on the island of Hvar.

The plates are of irregular quadrangular shape, mostly 15x25 cm, up to 25x35 cm large. The plates are used in the area for roofs on field shelters and on traditional Dalmatian houses (mostly in the surroundings but even in the distant village of Humac).

3501_P1: Example of good practice with Vrboska PL on traditional Dalmatian houses in the ethno-village of Humac on the island of Hvar.

The quality of the typical Vrboska PL type is very good, although some plates are undulated and folded. The folded plates can be used as roof crests and for water catchments.

The eastern part of the polygon is situated on a flat forested area, while the western part lies on the slopes north of Starogradsko polje. There is good accessibility to a few abandoned quarries via a net of narrow macadam roads with a connection to the Vrboska-Basina blacktop road. The abandoned quarries are also sites of past findings of fossils (fish, lizards etc., see chapter 5.). Some quarries are partly filled with waste building material.

Spatial limitations to potential exploitation are the cultural heritage of Starogradsko polje

(UNESCO SITE) for the western part of the polygon, and proximity to the sea coast at the eastern part of the polygon, which includes all abandoned and historical quarries (less than 1,000 m from the sea coast). Additionally, the polygon lies entirely within Natura2000, so without possible special permission there is no potential for future exploitation of Vrboska PL on the island of Hvar.

The bed dips to the NNE (15-25 degrees), and this is also a limiting factor for successful surface exploitation. In general, according to the estimated portion of 30% of PL within the Vrboska PL succession that covers approx. 2 km^2, potentially suitable quantities for quarrying down to 5 m below the surface* is estimated at approx. 3 billion m^3 of PL. HOWEVER, THE ENTIRE AREA IS UNDER CULTURAL AND NATURAL PROTECTION. One possible solution might be to select one abandoned quarry for non-commercial exploitation of PL for the renovation of traditional houses.

4.3.2.7. Vestac (Brač island): ID_locality 3608

At the locality called Vestac (SW of Gornji Humac) the Gračišće-PL type of Turonian age is characterized by thick- to thin-bedded (including platy), mostly micritic limestone in places with algal balls (oncolite) and rudist bivalves. Approximately 30% of PL appears within succession of a few tens of meters thick.

3608_P1. “Vestac” quarry of platy and laminated Gračišće PL type (island of Brač)

The plates are of irregular quadrangular shape, mostly 20x30 cm, up to 40x100 cm large. The plates are used in the area for roofs on traditional Dalmatian houses (Gornji Humac and surroundings). There was also commercial exploitation of the plates as building material for houses, pavements and dry walls in other parts of the island and even on neighbouring islands as well.

**Surface quarrying is estimated in this report down to 5 m below the surface.*

3605_P1: An example of good practice using Gračišće PL type on traditional Dalmatian houses ("Hacienda") between the villages of Gornji Humac and Selca on the island of Brač.

The quality of the typical Gračišće PL type is excellent, as recognized by past activity in the area ("Kalina" quarries south of Gornji Humac, so-called "Brač platy").

The locality is situated on the eastern slopes of the Vestac hill, in an area protected from exposure to the sea by the surrounding hills. There is good accessibility via a wide macadam road with a connection to the Gornji Humac-Bol main road.

The beds are inclined slightly to the NNE (10 degrees), while the zone crops out on the southern slopes of Vestac hill, which is not a suitable location for extensive surface exploitation. A better location lies in the surroundings of the quarry, where the morphology is more or less flat. The quarry dimensions are some 40x50 m, while the broader area for possible exploitation is estimated at 100x100 m.

Considering the estimated portion of 30% of PL within the succession that covers approx. 10,000 m^2, quantities of high-quality limestone plates down to 5 m below the surface for suitable for quarrying are estimated at approx. 15,000 m^3 of PL.

4.3.2.8. Podgažul and Fantovi doci (Brač island): ID_ polygon 3630

The Gornji Humac-PL type of Turonian age is characterized by alternating medium- to thin-bedded and platy limestone. There is a near concordant relation between the low-angled dipping beds (up to 10 degrees, generally to N), and the gentle NW and N slopes of Vidova gora, resulting in a relatively wide zone characterized by PL occurrences at the surface. Thicknesses for surface exploitation at this locality is up to 5 meters*.

**Surface quarrying is estimated in this report down to 5 m below the surface.*

Photo: 3611_P1: Fantovi doci site at Brač.

More than 30% of PL appears within a succession of medium- to thick-bedded limestones tens of meters thick, and characterized by light-grey fine-grained and laminated skeletal and micritic (peloid) particles in a micritic matrix, and small rudist bivalve shells in places.

The plates are of irregular shape, usually 15x30 cm, although some thicker plates (5-10 cm) of microbial laminites are up to 30x50 cm large. The plates are used on roofs for field shelters and for roofs on traditional Dalmatian houses in surrounding villages (Fantovi doci, Obršje, Podgažul, Dragovode, Blaca etc.).

Photo: 3604_P1: Example of the usage of Gornji Humac PL in Obršje village.

The high variety of lithologies alternating within PL succession resulted in varying qualities of plates. According to the field assessment, plates of micritic limestone represent the best quality plates.

The SW slopes of Vidova gora (Fantovi doci polygon) lie in a nicely forested area characterized by a fine landscape, which could pose a reasonable spatial restriction for possible exploitation of PL as a mineral commodity (as recognized in Natura2000). However, the northern slopes of Vidova gora (Podgažul polygon) are more suitable for possible exploitation, since they are situated in a flat area without any settlement and out of view from the main road. Access to the area is possible via

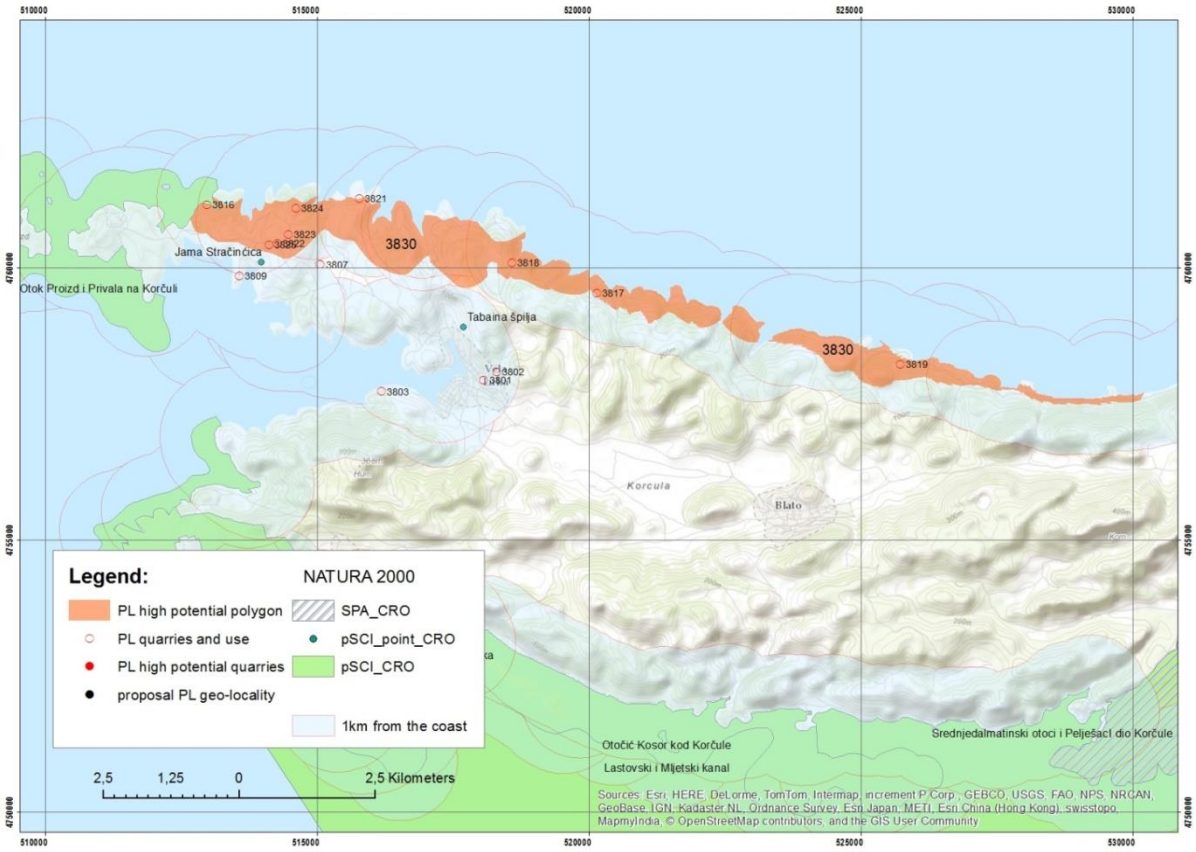
narrow local roads from the north (from the main road Nereižišća-Gornji Humac).

Considering the general concordance of the gently inclined slopes and gentle bedding angles, and the estimated portion of 40% of PL within the Gornji Humac-PL succession that covers approx. 2.5 km^2, quantities for potential quarrying down to 5 m below the surface are estimated at 5 billion m^3 of PL. However, Fantovi doci polygon lies completely within Natura2000 (1.2 km^2), and the end-potential would very likely be some half the estimated quantity.

4.3.3. DUBROVNIK-NERETVA COUNTY

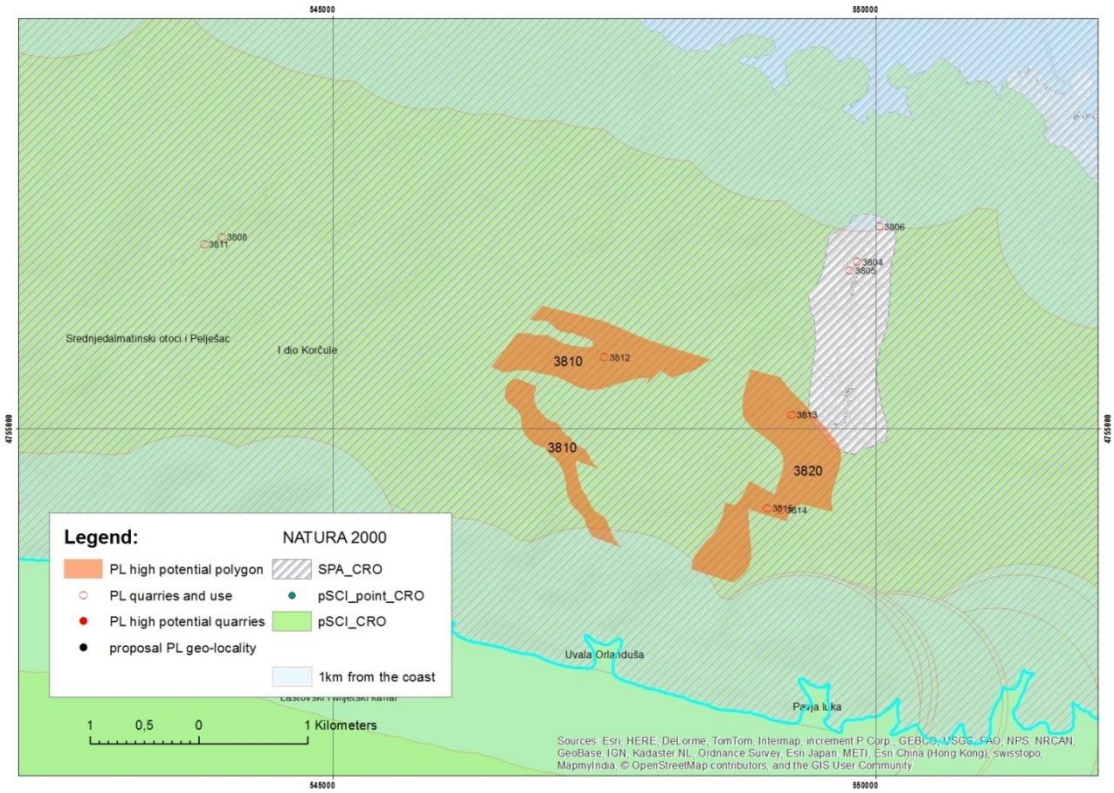
In Dubrovnik-Neretva County (southern Dalmatia), there is a single large polygon and two relatively small high-potential PL polygons on the island of Korčula, and a few small polygons on the Pelješac peninsula, along with a few local occurrences, all within the Cretaceous sedimentary succession in Upper Cretaceous lithostratigraphic units (see Chapter 3).

On the Island of KORČULA there is a major occurrence of high-potential Gornji Humac PL (ID_polygon 3830) on the NW part of the island in the surroundings of Vela Luka. There are two examples of small active potential quarries in the vicinity of the hilltop Punta od Žukove (ID_locality 3824) and in Zaklopatica Cove (ID_locality 3816).



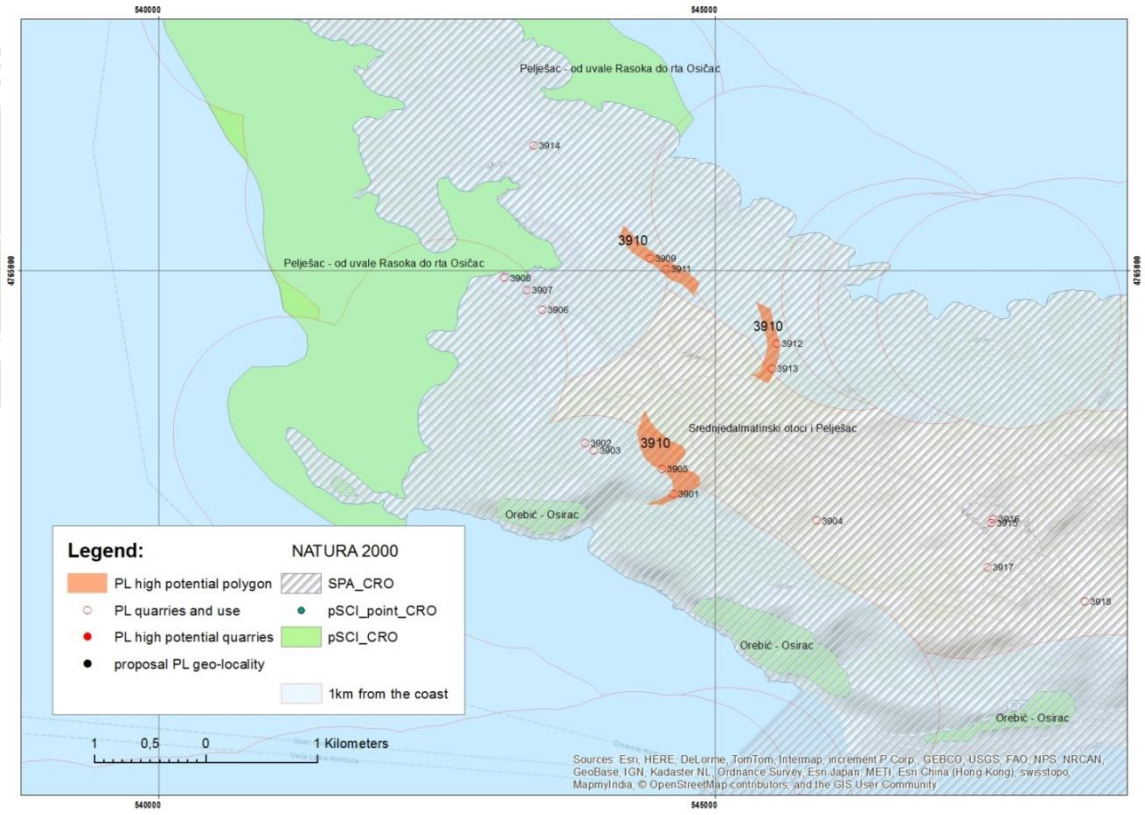
Detailed map of high potential PL units and PL localities in the surroundings of Vela Luka (Korčula island).

Furthermore, on the island of Korčula there are two high-potential subtypes of Milna PL (Pupnat – ID_polygon 3810, and Žrnovo – ID_polygon 3820) on the central-eastern part of the island. Milna PL-Pupnat unit (ID_polygon 3810) is well exposed in one potential small quarry near the main road in Zlo Polje (ID_locality 3812). Milna PL-Žrnovo unit (ID_polygon 3820) was exploited in at least 3 abandoned quarries (20x30 m) near the village of Žrnovo-Postrana (ID_locality 3813).



Detailed map of high potential PL units and PL localities in the vicinity of Žrnovo (Korčula island).

On the PELJEŠAC peninsula high-potential Gornji Humac PL (>30% ID_ polygon 3910) appears in the W part of the peninsula, in the surroundings of Lovišta, and is represented by a few small PL quarries on localities ID_3905, 3909 and 3911.



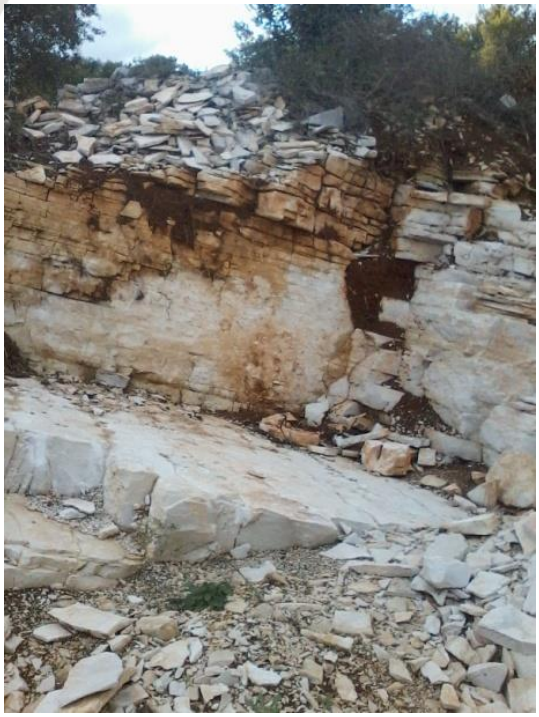
Detailed map of high potential PL units and PL localities in the surroundings of Lovišta (Pelješac peninsula).

It should be noted again that only high-potential polygons and localities on the island of Korčula and Pelješac peninsula are recommended for possible commercial exploitation. However, other occurrences (see Chapter 3) could be suitable for local use, for the renovation of traditional houses (especially roofs).

4.3.3.1. Vela Luka (NW part of the island of Korčula): ID_polygon 3830

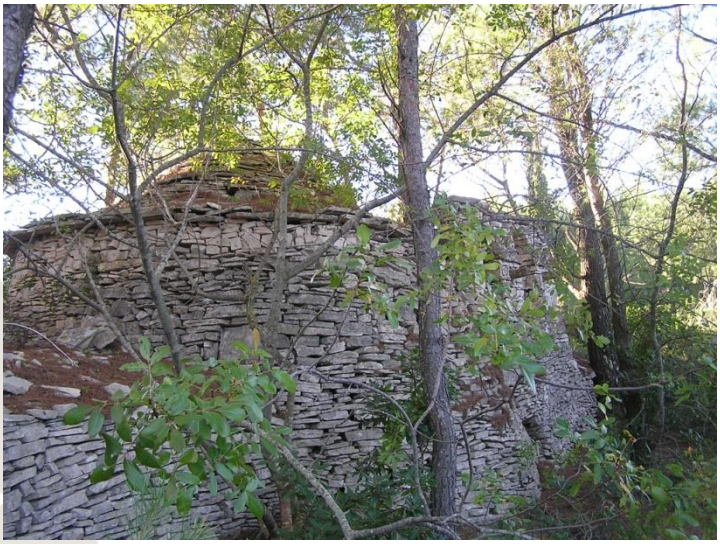
NW part of the island of Korčula (surroundings of Vela Luka) is characterized by many outcrops of the Gornji Humac PL of Turonian-Santonian age. This unit appears on the surface in a coastal zone, N of the city of Vela Luka, stretching 5-6 km from the NW tip of the island east to the village of Prigradica village, where the zone thins out significantly. Gornji Humac PL-Vela Luka is composed of alternations of medium-, thin-bedded and platy limestones. PL are mainly represented by skeletal fine-grained limestones containing microbial laminae, rich in thaumatoporellas and aeolisacus, small benthic foraminifera, etc. Other parts of the unit Gornji Humac PL-Vela Luka (not platy, but medium- and thin-bedded limestone) contain Turonian-Santonian microfossil association (mostly benthic foraminifera, algae - aeolisacus and thaumatoporellas) and macrofossils (rudists).

PL is exploited in one small active quarry in the vicinity of the hilltop Punta od Žukove (ID_locality 3824) and one small quarry in Zaklopatica Cove (ID_locality 3816). The plates are of irregular quadrangular shape, mostly 15x25 cm, up to 20x35 cm large.



3824_P1: Žukova quarry.

The quality of the Gornji Humac PL-Vela Luka unit as building material is good. This PL is usually used for roofs and walls on typical local field shelters (VRTUJAK) and rural houses, as well as dry stone walls (ID_localities: 3818, 3822, 3825).



3818_P1: Strmena locality – characteristic local field shelter (vrtujak).

3825_P1: Rural PL architecture in a rural touristic resort.

The northern slopes of the NW part of the island of Korčula are characterized by a very nice landscape and typical Dalmatian rural architecture, which could be a reasonable spatial restriction to possible exploitation of PL as mineral commodity. Access to the area is possible by a network of local roads from Vela Luka.

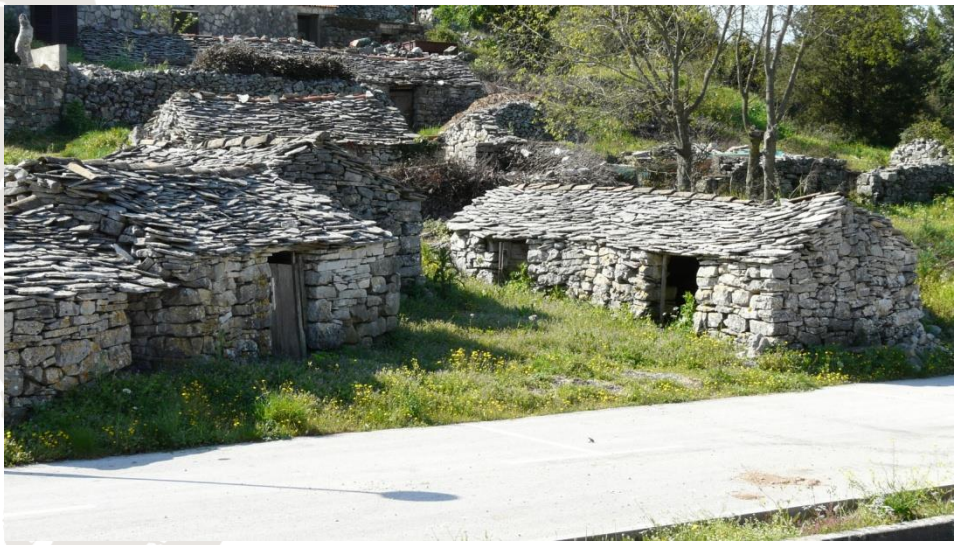
Considering the general concordance of the topography and bedding (subhorizontal or dipping to the north), and the estimated portion of 30% of PL within the succession that covers approx. 9 km^2, quantities for potential quarrying down to 5 m below the surface are estimated at 13.6 billion m^3 of PL. However, most of the area lies within 1 km of the sea, and only the western part can be considered for further investigation.

4.3.3.2. Pupnat (central-eastern part of the island of Korčula): ID_polygon 3810

A few kilometers to the east of village of the Pupnat, in the vicinity of Zlo polje and Crnića dolac, is a surface occurrence of the Milna PL-Pupnat type of Cenomanian age. It is composed of alternations of medium- to thin-bedded, and platy (approx. 40%), mostly micritic and fine-grained skeletal limestones, with rare cyanobacterial laminae. Other parts (not platy) of the unit Milna PL-Pupnat are represented by thin-, medium- and thick-bedded micritic, fine-grained and coarse-

grained, and laminated limestones, containing bioclast and various tiny microfossils (benthic foraminifera) and macrofossils (rudists and/or chondrodont bivalves). Locally, dolomites are found in alternation with limestones.

The platy part of the Milna PL-Pupnat unit was exploited in one small quarry near the main road in Zlo Polje (ID-locality 3812). The plates are of irregular quadrangular shape, mostly 15x25 cm, up to 20x30 cm large. The quality of the platy limestone as building material is good. The plates are durable, as can be seen in their implementation in constructing old cattle barns (stables) in the village of Pupnat, especially for roofs (example of use of this material for building: ID_locality 3808).



3808_P1: Pupnat cattle barns.

Considering the general concordance of the topography and bedding (gentle bedding in the core of the Korčula anticline), and the estimated portion of 40% of PL within the succession that covers approx. 1.1 km^2, quantities for potential quarrying down to 5 m below the surface are estimated at 2.2 billion m^3 of PL. However, the polygon lies entirely within Natura2000, where any future exploitation is possible only with special permission.

4.3.3.3. Žrnovo (central-eastern part of the island of Korčula): ID_polygon 3820

At the village of Žrnovo (Postrana), there is a zone of Milna PL-Žrnovo type of Cenomanian age. This unit is composed of alternations of medium- to thin-bedded, platy and thick-bedded bioclastic limestones. Platy beds (30%) are mainly composed of fine-grained skeletal limestone. Other parts (not platy) of the unit Milna PL-Žrnovo are represented by thin-, medium- and thick-bedded micritic, fine-grained and coarse-grained limestones, containing bioclast and various tiny microfossils (benthic foraminifera) and macrofossils (rudists and/or chondrodont bivalves). Milna PL-Žrnovo contains Cenomanian fossil association, tiny microfossils - mostly benthic foraminifera, and other marine microfossils as well as macrofossils of rudist bivalves (radiolitid rudists).

The platy part of the Milna PL-Žrnovo unit was exploited in at least 3 abandoned quarries (dimension 20x30 m) near the Žrnovo-Postrana village (ID-locality 3813). This sequence represents the lower part of the succession. The plates are of quadrangular shape, mostly 15x25 cm, up to 20x35 cm large. The quality of Milna PL-Žrnovo limestone as building material is good and people used material from these quarries for building old rural houses, especially for roofs (examples of use of this material for building: ID_locality 3813, ID_locality 3814 and ID_locality 3815).

3813_P1: One of Žrnovo-Podstrana PL quarries.

3813_P2: Žrnovo-Podstrana rural house in the PL quarry area (show-case object).

Considering the general concordance of the topography and the bedding, and the estimated portion of 30% of PL within the succession that covers approx. 1 km^2, quantities for potential quarrying down to 5 m below the surface are estimated at 1.5 billion m^3 of the PL. However, the main occurrence is less than 500 m from the settlement of Žrnovo-Podstrana.

4.3.3.4. Lovišta (W part of the Pelješac peninsula): ID_polygon 3910

In the surroundings of the Lovišta village there are a few zones of the Gornji Humac PL-Pelješac type of Turonian-Santonian age. Gornji Humac PL-Pelješac is composed of alternations of medium-, thin-bedded and platy limestones. Localy the limestones can be thick-bedded to massive. Platy beds (more than 30% of the unit) are mainly represented by fine-grained limestones with tiny microfossils (thaumatoporellas and aeolisacus). Other parts of Gornji Humac PL-Pelješac (not platy, but medium-, thin-, and thick-bedded limestone) are represented mostly by well-bedded

skeletal micritic to peloidal limestones with intercalations of rudist-bivalves. This type of PL contain Turonian-Santonian microfossils association (mostly benthic foraminifera, aeolisacus and thaumatoporellas) and macrofossils (rudists). In places micritic limestones contain calcispheres (pelagic microfossils).

Gornji Humac PL-Pelješac (ID_polygon 3910) has a major occurrence within a series of ridges and mounds a few hundred meters long and some tens of meters wide built of PL plates (probably as a result of historical exploitation), SE of the village of Lovišta (ID_localities 3901 and 3905).

3905_P2: Small quarry and Gornji Humac PL ridge (Lovišta, Pelješac).

Further, around Lovišta village there are also a few small quarries of this PL type at other locations (ID_locality 3905, ID_locality 3909 and ID_locality 3911).

3909_P1: Small quarry of Gornji Humac PL (Lovišta, Pelješac).

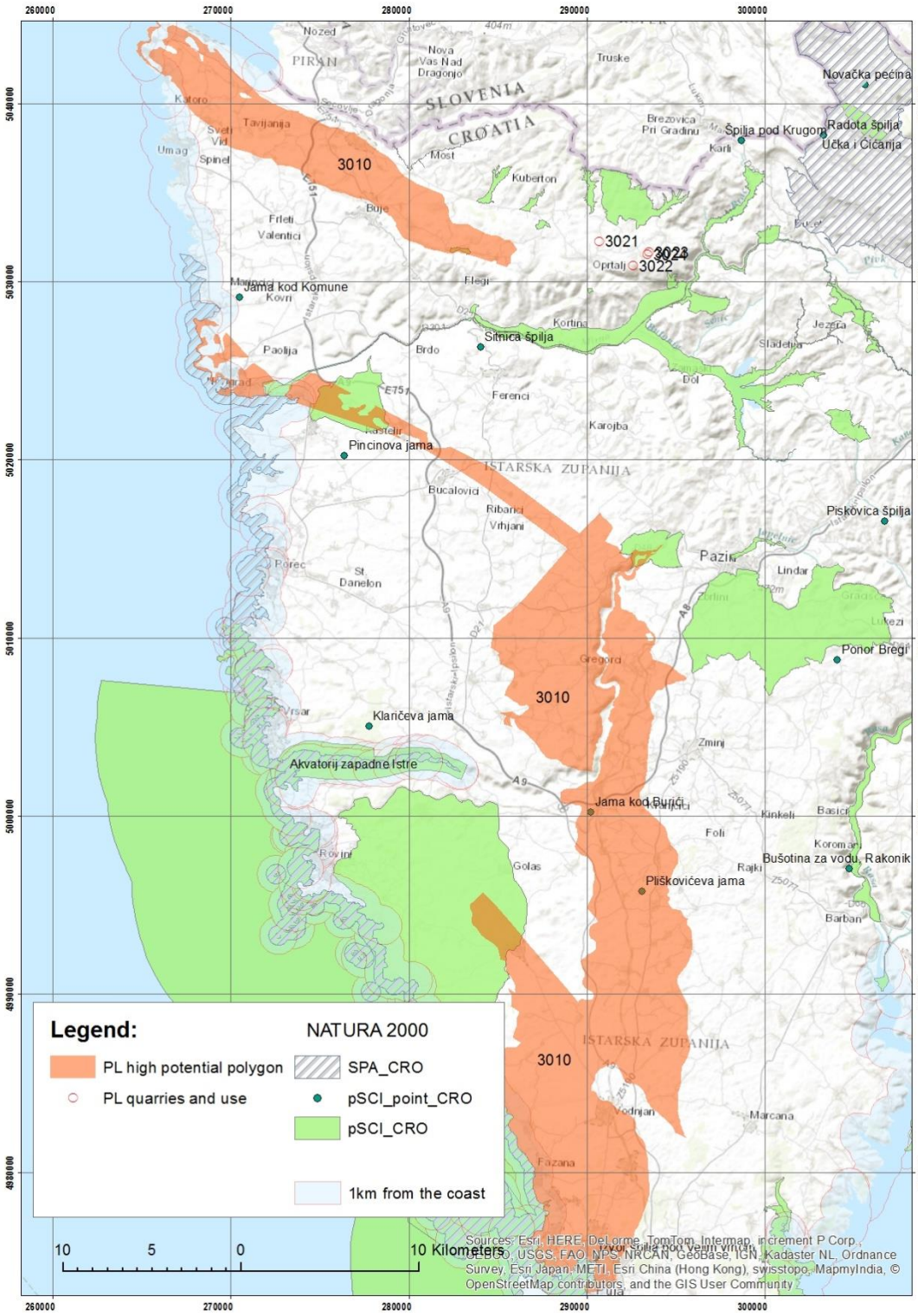
The plates are of irregular quadrangular shape, mostly 20x30 cm, up to 30x50 cm large. The quality of the Gornji Humac PL-Pelješac type of limestone is very good. Local people used PL for rural houses, roofs, fences, water cisterns, shelters in fields, etc. (examples of uses of this material for buildings: ID_locality 3912 and ID_locality 3913).

3912_P4_Zajut water cistern covered with PL (Lovišta, Pelješac)

Considering the estimated portion of 40% of PL within the succession that covers approx. 0.36 km^2, quantities for potential quarrying down to 5 m below the surface are estimated at 0.73 billion m^3 of PL. However, most of the area lies within 1000 m of the sea, and only small parts can be considered for possible PL exploitation if restrictions are to be observed.

4.3.4. ISTRIAN COUNTY

In the Istrian County, investigations within the RoofOfRock project were focused on Cretaceous units of Albian age, i.e. the lithostratigraphic unit Pula shown on the general geological map of the region (see Chapter 2.3). Within the general research on PL (see Chapter 3.3) the lower part of the Albian unit is defined as the Pula PL unit (ID_3010), stretching across central Istria from Pula, over Žminj to Novigrad in the northwest (see Figure 1). Also, a few high-potential PL localities (IDs 3021, 3022, 3023) of Cenomanian age (Rušnjak PL type) were found near Oprtalj.



Detailed map showing high potential PL polygon and PL localities in the Istrian County project area

Given the huge spatial occurrence of the most promising unit ID 3010, only small parts of it lie within Natura2000 protection.

4.3.4.1. Pula PL: ID_polygon 3010

The **Pula PL (ID_polygon 3010)** is of Albian age, and is characterized by an average bed thickness of 4 to 60 cm. Lithologically it is characterized by alternations of different structural types of rocks: mudstones, wackestones, packstones and grainstones, which are the result of the water energy changes that brought the carbonate particles into the depositional environment. The carbonate particles represent the fragments of broken foraminiferas, shells, algae, or fragments of already lithified mud. The alternations of lithofacies are very important, since the contacts represent discontinuities which disintegrate the rock into plates.

3025_P1: Small delve where the local people exploit the platy limestone for their own needs.

The Pula PL unit ID_3010, is characterized by alternating platy and thick-bedded limestones. Thus, thicker beds were used for building the massive elements (e.g. walls, corner stones, doorposts) of traditional rural houses and field shelters (*kažun*), while thinner beds have been used for covering the roofs. People still use this stone to build *kažuns* – small round houses in the fields where they kept tools and protected their cattle in the past. In their own special traditional way they still also use thinner parts of the unit for covering the roofs.

LOCALITY_UNKNOWN: Field shelters *kažuns* in Istria (Vodnjan vicinity).

In general, the bedded limestone from the Pula unit is used today, mostly as a technical stone. Considering the occurrence of PL, this polygon (ID_3010) is generally of high potential, since it is estimated that the unit contains more than 30 % of PL. However, Pula PL (polygon ID_3010) is exposed over a broad area, which is why geological research has been focused only on locations where PL was most widely used for roofing. We investigated some localities within the Pula PL unit and existing quarries of technical stone to analyse the structural types of rocks and to understand the reason for the lateral disappearance of PL – which is why PL occurrence, without extensive mapping, cannot be shown on the detailed map of PL as more precisely defined polygons.

Within the Pula PL polygon there are known quarries where the stone is mainly used for technical purposes, and only in small delves were plates excavated for covering roofs in the surrounding villages. For example, in the area east of Baderna (**Locality ID_3025**), there are several small delves where the local people are still using PL for their own purposes. At this specific locality, PL represents more than 90 % of stratigraphic succession that is at least 10 m thick. Bedding surfaces are smooth and strait and are gently inclined to the north-northeast. Most of the succession is characterized by the alternation of 2-15 cm thick beds, and rare intercalations of thicker beds (40-55 cm). The delves are up to 2 meters deep and in fact represent the pits where the PL is excavated. People use hammers to pick at the plates, so they are of irregular shape and usually up to 50 cm in size. The plates are characterised by a homogenous lithology. We estimate that PL in the area of Baderna covers approx. 600.000 m2.

4.3.4.2. Oprtalj localities (ID_localities: 3021, 3022, 3023)

Detailed investigations were focused on Cenomanian limestones (Rušnjak PL type), in the area of Oprtalj (Bujština), the northernmost part of the Istrian peninsula. According to the general assessment of potential (see chapter 3.1.) this unit holds less potential because here the occurrence of PL is less than 10 %, and appears in rather narrow zones. However, during the

investigations it was found that this platy material has been used for hundreds of years to cover roofs, and whole villages still exist here (Hrastići, Laganisi, Ćabrnica) that deserve to be preserved as ethnological and architectural heritage.

The Rušnjak PL appears in relatively thin and laterally discontinuous horizons/layers within thicker-bedded limestones, which is why it could not be shown on the map as a polygon of occurrence of PL. In these localities the PL occurrence is the result of sedimentation in the protected, rather small lagoons where fine-grained sediment accumulated locally in laminas one millimetre to one centimetre thick, and in thin beds due to frequent changes of water energy. Thus, usually it is very fine-grained bioclastic grainstone to packstone that alternates vertically with thin layers of muddy sediment rich in organic material and cyanobacterial laminites. PL is, in places, gently dolomitised. The stone is of a light grey to yellowish colour. Along the contacts of alternating lithologies, the stone splits into plates of PL, and thus can easily be dug up. The intercalations of PL are usually less than 1 m thick and stretch laterally some tens of meters, since they are intercalated within the thick-bedded succession of mudstones, packstones and grainstones composed of pellets, shell fragments, intraclasts and bioclasts. The beds on all localities are gently inclined toward the east-southeast, or horizontal.

The PL on **Hrastići** locality (ID 3021) is found only in abandoned houses near the village Hrastići. The PL is lithologically similar to other two localities. This locality has long been abandoned, and the roofs covered with the PL are largely ruined.

The **Laganisi** locality (ID_3022) lies near the village of Laganisi, where the inhabitants have been digging up the PL plates for their roofs. A lot of waste material was discarded in their search for usable plates, since only the best materials have been used for the roofs.

3022_P2. The delve near the village Laganisi.

3022_P1. The largely abandoned village of Laganisi, but rather well preserved old architectural style of building and house coverings.

This locality in the village of **Ćabrnica** (ID-Locality 3023) is characterized by an old house that is chosen to be protected as ethnological and old architectural heritage. It is a cloister covered with the PL. The plates were dug up from the pits in nearby fields. The bedding is almost horizontal. At first sight, the outcrops do not even look like PL, but the plates are easily split with a hammer, which is the traditional way rural people used to dig up the PL, by hand, for their own purposes, in the traditional way with hand tools (without machinery).

3023_P1. Digging the plates of PL in Istria the traditional way.

In the village of Ćabrnica (ID_3023) a house more than one hundred years old covered with the aforementioned plates of PL is proposed for protection as cultural heritage.

3023_P1. The house in Ćabrnica which is proposed for protection.

None of the occurrences of Rušnjak PL from these localities is suitable for a commercial quarry, as they appear within the mostly thick-bedded succession, and PL thickness is less than 1 m. However, this local material could be used for the reconstruction of traditional houses.

On the other hand, there are very interesting houses in certain localities surrounding Oprtalj, built partly of Rušnjak PL type of Cenomanian age (localities ID 3021, 3022, 3023). And the old house in the village of Ćabrnica has been chosen for protection as ethnological and architectural heritage. Thus, there is an open option to protect the area of the outcrops from which the plates of PL have been dug up, rather than recommend it for extensive exploitation. The same applies to the village of Laganisi, which is hoped will be protected in future for the same reason – the village is abandoned, but still well preserved and represents outstanding cultural heritage.

4.4. LABORATORY ANALYSES OF PLATY LIMESTONE MECHANICAL CHARACTERISTICS

Within the project RoofOfRock a set of selected PL samples was analysed in the geomechanical laboratory with the aim of numerically assessing the quality of the samples through measurement of their flexural strength (see Table 4.4.1).

PROJECT ROOFOFROCK, WP3 – MECHANICAL PROPERTIES OF PLATY LIMESTONE
Laboratory: METRIS – Materials Research Centre, Laboratory 4
Operators: mag. ing. Mech. Davor Mandić, dott.ssa mag. Tea Zubin Ferri
Equipment: Universal testing machine 250kN Messphysik Beta 250
Method: Flexural Strength

ID_SAMPLE	FLEXURAL STRENGTH (MPa)	PL unit ID/locality and name (lithology)	FLEXURAL STRENGTH (descript.)	FIELD QUALITY ASSESS.	NOTES
3107_S4	19.21	3110 Debelo brdo – Benkovac (M)	excellent	excellent	outcrop
3109_S3	9.57	3120 Benkovac PL- Benkovac (M-P)	good	excellent	outcrop
3303_S1	17.02	3320 Vinišće (M-Bi)	excellent	very good	outcrop + use
3308_S1	6.69	3310 Milna-PL (G-R biokl.)	good	good	outcrop
3308_S2	13.45	3310 Milna-PL (Bi)	very good	very good	outcrop
3313_S1	8.31	Prapratnica (P kalc. Lam.)	good	bad	outcrop
3314_S1	6.70	3330 Jelinak (P kalc.)	good	good	outcrop
3444_S1	3.89	3440 Rogač (W)	bad	very good	outcrop+use
3444_S2	15.21	3440 Rogač (Bi)	excellent	very good	outcrop + use
3431_S1	3.04	3430 Milna PL (Bi)	bad	very good	outcrop
3502_S1	9.53	Milna - M. Stiniva (M)	good	very good	outcrop
3504_S1	9.72	3520 Vrboska PL (Bi)	good	excellent	outcrop
3505_S1	7.10	3520 Vrboska PL (Bi)	good	excellent	outcrop
3506_S1	8.46	3520 Vrboska PL	good	excellent	outcrop
3607_S1	4.56	3620 Gračišće-PL (Bi)	bad	excellent	outcrop
3608_S1	15.80	3620 Gračišće-PL (Bi)	excellent	excellent	outcrop
3609_S1	8.46	3620 Gračišće-PL (Bi)	good	excellent	outcrop
3612_S1	7.20	3630 Gornji Humac-PL (P)	good	good	outcrop
3612_S2	9.47	3630 Gornji Humac-PL (P)	good	good	outcrop
3612_S3	6.51	3630 Gornji Humac-PL (P)	good	good	outcrop
3702_S1	2.25	Gornji Humac PL - Vis (P)	bad	very good	outcrop
3807_S1	15.85	Milna-PL (Vela Luka. M/W/P)	excellent	good	outcrop
3813_S1	9.21	3820 Milna-PL (Žrnovo. P)	good	good	outcrop+use
3813_S3	7.68	3820 Milna-PL (Žrnovo. P)	good	good	outcrop+use
3905_S1	8.79	3910 Gornji Humac PL (P/M)	good	very good	outcrop+use
3917_S1	8.31	Milna PL - Nakovana (Bi)	good	very good	outcrop
3918_S1	10.62	Milna PL – Nakovana (M)	very good	very good	use
descriptive categories for flexural strength	**1-5 bad**	In red are samples from the same outcrop or similar lithology with significantly different results!?	**QUALITY ASSESMENT FROM BOTH METHODS (in scale of grey)**		**bad**
	5-10 good				**good**
	10-15 very good				**very good**
	15-20 excellent				**excellent**

Bi-laminated mudstone, M-mudstone, W-mudstone + fine grains, P-fine grains, G-grains, R-coarse grains

Table 4.4.1. Comparison of flexural strength and a field assessment on the PL quality of the selected PL types.

It should be noted that most of the PL samples are not homogeneous, as a result of their genesis in the natural environment, which is why there is a broad range of numerical values for the flexural strength of samples. The samples are generally of the same material – a limestone, but with a variety of lithotypes: from muddy, compact and laminated lithotypes to grainy and porous. The strength reflects the structure of the limestone, i.e. a combination of the grain size, packing, lamination, cement quality in grainy limestones etc. However, some samples from the same outcrop or of the same lithology also display discrepancies (highlighted in red). Thus, the results are combined with the field observations on PL quality, and the final assessment is the result of a combination (intersection) of the descriptive quality produced by these two methods. **Generally, it can be concluded that the homogenous mudstones (M) and laminated mudstones (Bi) are of the best quality.**

Apart from such a tentative methodology and discrepancies, some of the most widely used materials (e.g. Benkovac stone, Rogač PL from Šolta, Gračišće PL from Brač, Vrboska PL from Hvar and some localities of Milna PL in general) are characterized as of best quality according to Table 4.1. The best way to assess PL quality would likely be an evaluation of long-term durability as or on existing objects, such as roofs.

4.5. NATURAL HERITAGE OF PLATY LIMESTONE

We reported a few localities in PL that deserve special attention as geo-localities (in ZADAR COUNTY and SPLIT-DALMATIA COUNTY). However, considering the limitations indicated on the maps, some polygons can be recognized entirely as natural protection sites, since almost everywhere PL occurrence on the surface is characterized by an outstanding landscape (dry walls, field shelters and traditional houses, olive groves etc.).

4.5.1. BENKOVAC STONE GEO-LOCALITY

We recommended one abandoned quarry in Benkovac PL for protection as a natural heritage site (geo-locality) because of its abundance of ichnofossils and interesting sedimentological features recognized in that PL unit.

4.5.1.1. General information about the proposed geo-locality

Proposed name of the area to be protected: Benkovac Stone (Croatian: “Benkovački kamen”)
Locality ID 3108: Vlačina (northwest of Benkovac)
Proposed protection category: Geological paleontological site
Area of the proposed locality: cca. 3250 m2
Coordinates: A - x = 5548396 y = 4881544
B - x = 5548349 y = 4881625

Benkovac Stone, lying close to the surface and covered with low vegetation, may generally not be readily observable. However, an abandoned quarry proposed for the presentation of the Benkovac Stone geo-heritage (marked “BENKOVAČKI KAMEN” on Fig. 1), situated alongside the road connecting Obrovac and Benkovac, is a convenient, illustrative and accessible representative of this geo-heritage (Fig. 2).

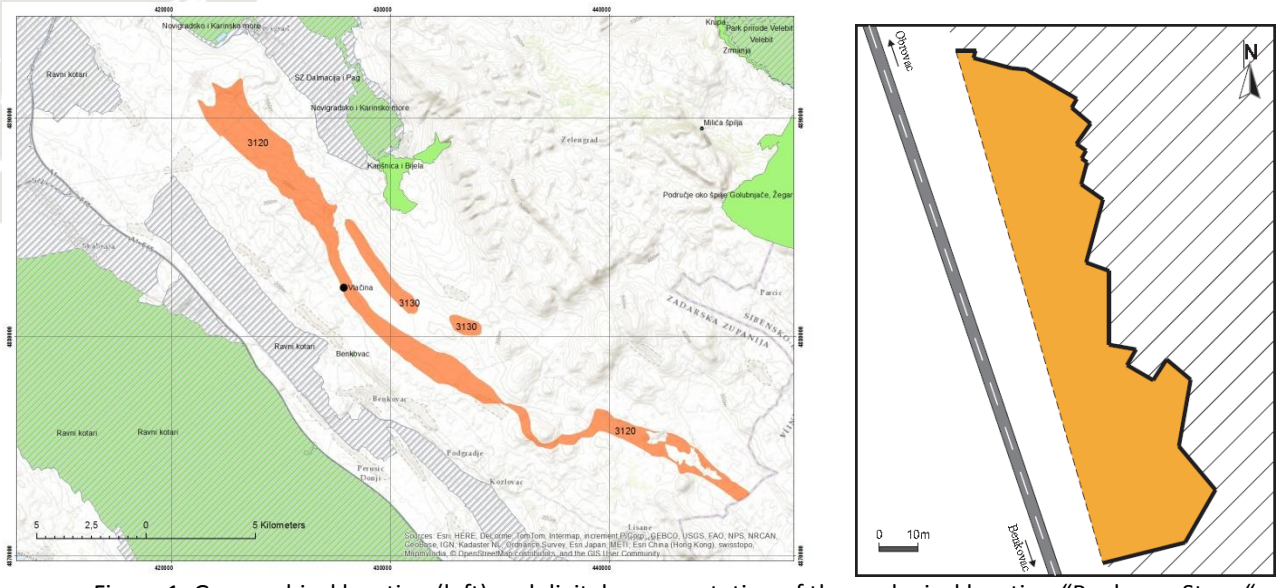


Figure 1: Geographical location (left) and digital representation of the geological location “Benkovac Stone“.

Figure 2: Field photographs (panorama above and the detail from red frame below) of the proposed geo-heritage site "Benkovac Stone" at Vlačina (locality ID_3108).

The "Benkovac Stone" geological site at Vlačina is located approx. 10 m from the Obrovac-Benkovac main road. It is situated below the surrounding surface line, and leans gradually downwards away from the road. With regard to such a position, it is suggested that it does not compromise the landscape nor the skyline, while it remains noticeable and intriguing to passers-by. The surroundings of this geological site consist of a generally mildly rough terrain with low vegetation, with no significant natural or artificial verticals.

4.5.1.2. Geological valorisation of the Benkovac Stone

The Late Eocene Benkovac Stone is a roughly 140 m-thick, thinly-bedded succession of alternating carbonate sandstones and calcareous mudstones. Its Late Eocene age was established on the basis of large benthic foraminifera (nummulitids, discocyclinids) and small pelagic globigerinids. The Benkovac Stone is exposed as a narrow, SE-trending outcrop belt best visible between Debelo Brdo and Mejanica, two small hills near the town of Benkovac in northern Dalmatia. The area has a low topographic relief covered with low vegetation and the general rock bedding here is gently inclined towards the northeast. The Benkovac Stone belongs to the Promina Beds, which are considered a proximal, wedge-top part of the Dinaric foreland. In northern Dalmatia this partition started in the late Middle Eocene with the formation of blind-thrust anticlines that split the foreland basin into the northeastern 'piggyback' Promina Basin and the southwestern 'Flysch' foredeep.

The Benkovac Stone, with its tabular bedding and platy splitting pattern, has long been an important local source of building stone (hence the succession's name), and the numerous small quarries enabled a detailed study of this calciclastic succession. The "sandstone" beds are up to 35 cm thick, but mainly thinner, and the sandstone-rich heterolithic succession is readily distinguishable from the underlying and overlying sediments. The carbonate "sandstones" are very fine- to fine-grained calcarenites, sporadically medium-grained, and consist mainly of various sparitic and micritic grains. Quartz grains are subordinate (less than 10 vol. %). The sand grains are

sub-rounded to rounded and generally well to very well sorted, forming a grain-supported framework with mostly pointed or planar grain contacts. Interstitial spaces are filled with a microcrystalline carbonate cement and/or fine-grained calcareous sediment. The beds are predominantly tabular and separated by mudstone layers, with relatively few beds amalgamated, stacked directly one upon another. The light-brown to grey sandstones are readily distinguishable from the pale yellowish–grey mudstones, even though their weathering patterns are not necessarily dissimilar. The sandstone beds vary considerably in thickness and have been classified into six facies and three subfacies:

S1 – tripartite sandstone beds with planar parallel stratification, hummocky cross-lamination and flat parallel lamination (Fig.3);
S2 – bipartite sandstone beds with hummocky cross-lamination and flat parallel lamination;
S3 – sandstone beds with convolute stratification;
S4 – amalgamated sandstone beds (Fig.5);
S5 – cross-laminated sandstone beds that can be divided into three subfacies: sandstone beds with translatory ripples (S5a), sandstone beds with climbing ripples (S5b), and sandstone beds with pinch-and-swell lamination (S5c) (Fig.6).
S6- massive sandstone beds with normal grading

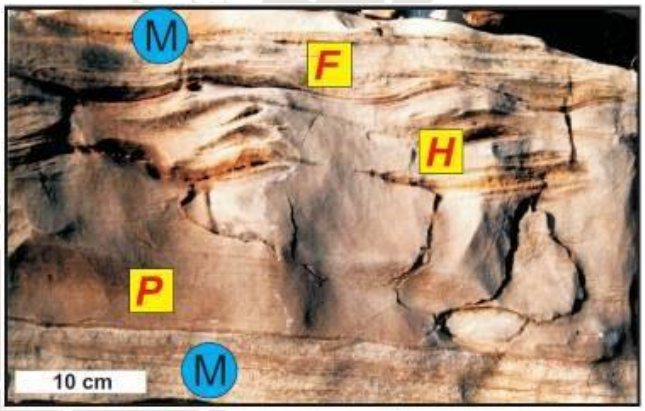


Figure 3: Close-up view of a carbonate sandstone bed of Facies S1. Note that the sandstone bed has a sharp, erosional base and consists of a planar parallel-stratified division P (6 cm thick) overlain by a hummocky cross-stratified division H (15 cm) and capped with an undulatory to flat laminated division F (3-4 cm). The underlying and overlying deposits are silt-streaked calcareous mudstones of Facies M.

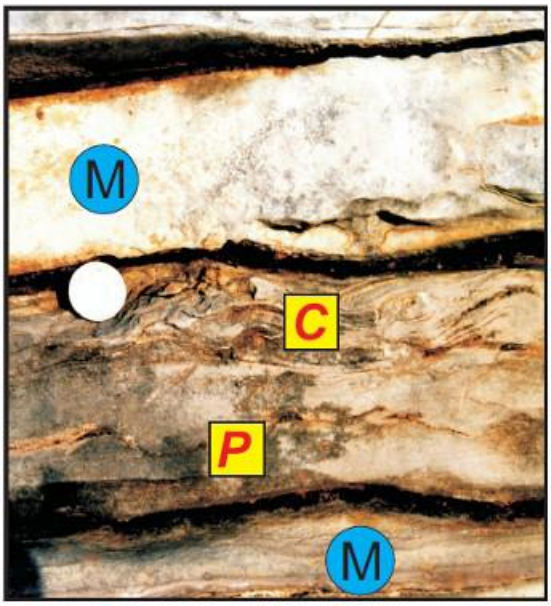


Figure 5.1/4: Convoluted sandstone bed of Facies S3. Note that the sandstone bed has a sharp, erosional base and consists of a planar parallel-stratified division P overlain by a convolute laminated division C. The underlying and overlying deposits are silt-streaked mudstones of Facies M. The coin (scale) is 2.2 cm in diameter.

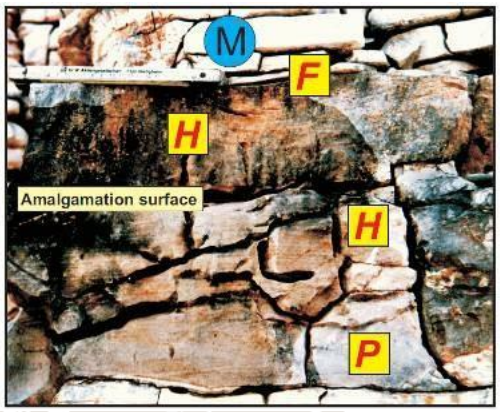


Figure 5: Compound, amalgamated sandstone bed of Facies S4. Note the sequence of component bed divisions, including planar parallel stratification P, hummocky cross-stratification H and undulatory to flat parallel lamination F. The lower division H shows broader, medium-scale hummocky cross-stratification (HCS), whereas the upper division H shows hummocky cross-lamination (ripple-scale hummocks). The underlying and overlying deposits are silt-streaked mudstones of Facies M.

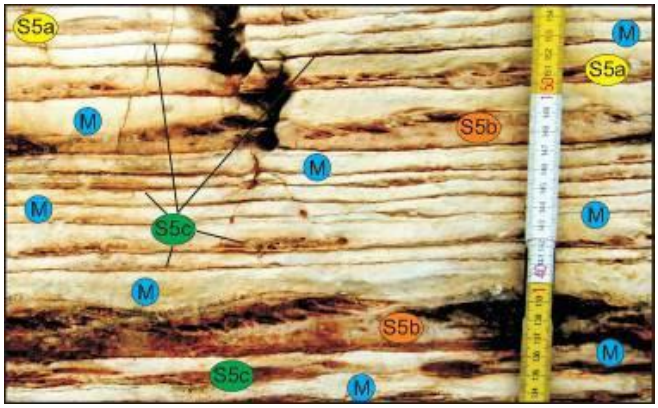


Figure 6: Close-up view of a carbonate sandstone bed of Facies S5a, S5b and S5c. The small translatory ripple forms in the sandstone beds of facies S5a have an amplitude of 1-1.5 cm, a wavelength of ca. 14 cm. The ripple forms in the sandstone beds of facies S5b have an amplitude of 2-3 cm, a wavelength of ca. 14.5 cm and a low angle of climb (>10°). The thin, solitary and lenticular sediment-starved translatory ripples with pinch-and-swell lamination (facies S5c) have an amplitude of 0.5-1cm and wavelength of ca. 12 cm. The underlying and overlying deposits are silt-streaked mudstones of Facies M.

The finer-grained interbeds are carbonate siltstones and mudstones, moderately to strongly burrowed. The siltstones are composed mainly of medium to coarse silt-sized carbonate grains and up to 10 vol. % of quartz grains. The calcareous mudstones are slightly clayey micrites with scattered silt-sized carbonate and quartz grains. The mudstone interbeds (Facies M) are common and laterally continuous on an outcrop scale, ranging in thickness from a few mm to 30 cm (Figs. 3, 4, 5 and 6). Most beds contain thin (0.2-1 cm) silty interlayers in the form of flat streaks and distinct lenses with signs of pinch-and-swell lamination, apparently representing sediment-starved small ripples of wave or tidal origin. The interlayers usually show normal grading from coarse to fine silt, and many have slightly erosional bases. The vertical spacing of these interlayers varies from a few centimetres to 20 cm or more, and are commonly disrupted and deformed by animal burrows.

The Benkovac Stone was deposited in a microtidal offshore transition zone characterized by muddy “background” sedimentation punctuated by discrete storm events. The observed spectrum of tempestite sandstone beds represents a wide range of storm events, varying in magnitude and in the mode of sand dispersal – from the pure action of oscillatory waves to pure geostrophic currents. The majority of tempestites are attributed to a combination of these two end-member factors, with the geostrophic currents often enhanced by a high load of sediment suspension (density-modified currents).

Exceptional trace fossils ichnoassemblages are preserved through all succession with more or less frequency. The Benkovac Stone shows more than 60 varieties of different ichnospecies, which is rather the result of different modes of preservation than the result of tracemaker biodiversity.

Most interesting is the occurrence of deep marine Nereites (*Palaeodictyon*, *Helminthoides*) ichnofacies (Fig.7) together with shallow shelf Cruziana (*Chondrites*, *Planolites*, *Thalassanoides*) (Fig.8) and Skolithos (*Ophiomorpha*) ichnofacies (Fig.9). This ichnofacies mingling is clear evidence

that the ichnofauna ecology factors are near-bottom hydraulic energy, sediment deposition rate, water turbidity, oxygen and salinity level and nutrient supply rather than bathymetry or distance from shoreline. In this respect, the storm-punctuated offshore-transition environment is very similar to the deep-marine turbiditic environment, whereby Nereites tracemakers might survive the rapidly evolving of deep-marine environments into shallow ones.

Figure 7: *Paleodictyon*.

Figure 8: *Chondrites*.

Figure 9: *Ophiomorpha*.

Figure 10: *Cosmorhaphe lobata* and *Hydrancylus* sp.

4.5.1.3. Conclusion

Benkovac Stone maintains prominent geological, construction and heritage characteristics, which need to be preserved, and appropriately presented to the public. The results of such efforts may take the form of new and improved educational and economic opportunities, as well as in environmental protection and the sustainable use of Benkovac Stone as the main local natural resource.

Further scientific research of the Benkovac Stone, as well as its protection and sustainable exploitation, as a public and local community interest – on the one hand – and economic interest for its further exploitation as a raw material and related service-sector business on the other make a rational and advantageous combination. This combination relies on the geological and heritage uniqueness and quality of the Benkovac Stone, and poses a clearly articulated opportunity for further economic and social development of the local community. The realization of these opportunities ultimately lies with the local community.

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4.5.2. PLATY LIMESTONE “FISH FACIES” OF CENTRAL DALMATIA

4.5.2.1. General Information about the proposed geo-localities

In this chapter we collected the most interesting macropaleontological material found in the past within certain geo-localities proposed for recognition as natural heritage sites, largely owing to the abundance of fish and lizard fossils. Further, there are some other fossils found within the so-called PL “fish facies”, as well as some extraordinary sedimentological features.

The Upper Cretaceous platy limestones (PL) along the Dalmatian coast and on the islands have been known as macrofossil-rich sediments since ancient times. Findings of attractive fossils of fish and reptiles (marine lizards) imprinted into huge slabs of PL provoked the curiosity of the local population, which used such natural art to decorate their homes. Later fossils were collected, mostly by the local population, by different collectors interested in natural attractions, and eventually some of these fossils found their way into the museums of Zadar, Zagreb, Vienna, Trieste and Milan, and thus became the object of scientific study.

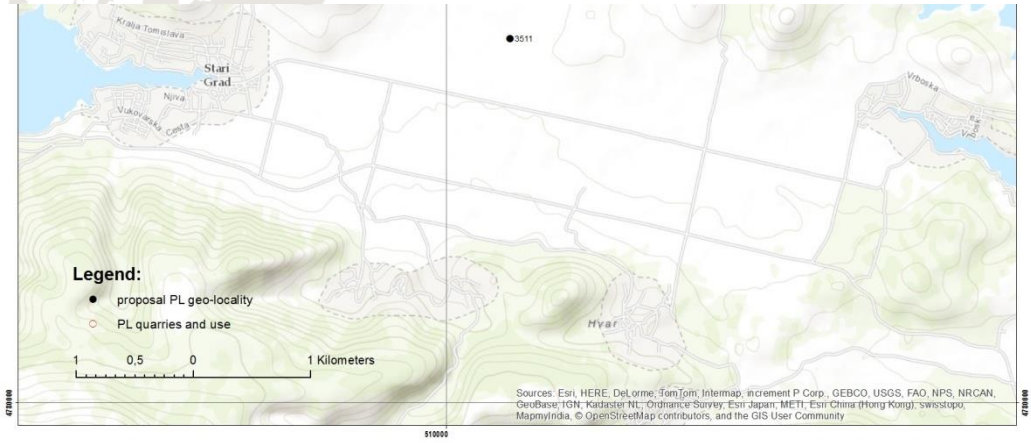
4.5.2.2. Geological valorisation of PL “fish facies”

Known sites featuring findings of fossil marine vertebrates in Split-Dalmatia County include the island of Hvar, Vidova Gora on the island of Brač, the island of Šolta (ID_3441_P2), Konjsko north of Split and Labištica hill east of Split (RADOVČIĆ, 1975).

On the island of Šolta in the vicinity of Grohote, in an area north of Mala Straža hill (ID_3441, see map in chapter 2.2), there is a nice landscape within Cenomanian Rogač PL. There local people found a fish fossil imprinted on the bedding surfaces of the PL.

3444_P2. Mala Straža fish fossil (collection of Mr. Nikola MATELJAN, Grohote, Šolta).

The historically most significant fossil locality in platy limestones (proposed as a geo-locality also in the scope of the RoofOfRock project) lies **between Stari Grad and Vrboska on the island of Hvar** (ID_3511, see map).



Location map of known vertebrate fossils site between Stari Grad and Vrboska on the island of Hvar.

Field research of the site described in literature revealed that the most numerous remains of fossil vertebrates have been found in a relatively small area characterized by the occurrence of a locally dolomitized Cenomanian Vrboska member, between the localities of Dračevice and Moće, 2.5 km east of Stari Grad and 500 m north of the Stari Grad – Vrboska road. This fossil site has been known for centuries. The famous Venetian traveller and writer Alberto FORTIS (1774) mentioned slabs of limestone with fossil fish that spotted on the island, and Austrian geologist SCHUBERT (1909) reports, in his book on the geology of Dalmatia, slabs of limestone with a very rich fossil fauna of fish and large petrified lizard precisely from this site. A series of authors that followed have described fossilized lizards and fish of the island, including HECKEL (1849), KORNHUBER (1873), BASSANI (1879, 1883) and others, but only with the systematic research of Croatian geologist and paleontologist Dragutin GORJANOVIĆ-KRAMBERGER (1881, 1892, 1895) did these findings become known throughout the world.

In the Upper Cretaceous platy limestone at the locality ID_3511 there are numerous well-preserved fossils of reptiles taxa *Pontosaurus* sp. (Fig. ID_3511_P1), *Opetiosaurus bucchichi, Aigialosaurus dalmaticus, A. novaki,* and fish, among which the most common being *Thrissops microdon, Belonostomus dalmaticus* (Fig. ID3511_P2) and *Holcodon lesinaensis* (Fig. ID_3511_P3). The species *Erugocentrus illyricus* RADOVČIĆ 1975 is also described as being from this locality. Remains of invertebrate and fossil plants can be found in these layers as well.

Most of these findings are stored in the Croatian Natural History Museum in Zagreb, and relatively rich collections exist in the collection of the Dominican monastery in Stari Grad, the Natural History Museum in Split and Natural History Museum in Vienna.

There is some doubt as to the possible protection of the sites, since the best findings (almost all the fossils) can be traced back to the time of greatest exploitation, when people used limestone plates to cover their houses. These platy limestones contain almost the entire fossil record. Eventual changes to controlled exploitation practices would encourage new findings that would enhance the museums and the larger scientific heritage – all of course with the necessary training of any future concessionaire.

3511_P1. Fossilized lizard *Pontosaurus* sp. (from JAPUNDŽIĆ et al. 2013).

3511_P2. Fossilized fish *Belonostomus dalmaticus* GORJANOVIĆ-KRAMBERGER, 1895.

3511_P3. Fossilized fish *Helcodon lesinaens*is (GORJANOVIĆ-KRAMBERGER, 1881).

The platy limestones featuring findings of fossil vertebrates belong to the broader Vrboska unit, made up of platy (<30%) and laminated light brown or grey limestones. Platy limestones are mainly composed of partly recrystallized wackestones and packstones while the laminated are madstones and wackestones with reddish laminas. Even better findings are possible within the Vrboska PL subunit (>30% of PL in the succession), in the topmost part of the Vrboska unit (recognized as a high-potential polygon for possible exploitation (see chapter 2.2, and the report on PL in general). Further, numerous interesting sedimentological features are also recognized within the unit, and should be properly presented to the public in future. Most of these are highly interesting folded intervals of platy limestones during synsedimentary tectonic tilting of the sea bottom and consequent sliding/slumping of the soft sediment. It should be noted that platy limestone sequences in particular were prone to such a synsedimentary processes, owing to the many potential sliding surfaces within such a sediment before cementation.

3507_P3. A chaotic slump (soft-sediment deformations) of Vrboska PL in Maslinica Cove (N of Vrboska on the island of Hvar).

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4.5.2.3. Conclusion

Some PL polygons and localities in Split-Dalmatia County maintain prominent geological, construction and heritage characteristics that need to be preserved, and properly presented to the public, as new and improved educational and economic opportunities. Furthermore, they are important in terms of both environmental protection and sustainable use of PL, and as a primary local natural resource.

Considering the general occurrence of these paleontological and sedimentological features within certain polygons, rather than in known localities, we proposed broader areas within the polygons for additional (geological) protection (e.g. Vrboska PL area on the island of Hvar and Rogač PL polygon on the island of Šolta).

Protection and sustainable exploitation of PL heritage is in the interest of both the general public and the local community. Specifically, possible further exploitation of PL as raw material would likely produce new fossil findings. Thus, this scenario represents a rational and advantageous combination, which relies on the geological and heritage uniqueness of the PL, and poses a clearly articulated opportunity for further economic and social development of the local community. The realization of these opportunities ultimately lies with the local community, but it must be pointed out that economic development need not always run contrary to positive social development: here some of the PL sites and larger areas could be used as both geo-touristic attractions and mineral resource sources simultaneously.

4.5.3. OUTSTANDING PL LANDSCAPES OF VELA LUKA (Korčula)

We have found neither literature nor new outcrops characterized by any extraordinary fossil that should be protected as a geo-locality in the Dubrovnik-Neretva County. However, we can particularly recommend the area of Vela Luka, which corresponds to the Gornji Humac PL unit (polygon 3830), as an outstanding landscape developed within the major PL occurrence. This unit

appears on the surface in a coastal zone, N of the city of Vela Luka, stretching from the NW tip of the island to 5-6 km east of the village of Prigradica village, where the zone thins out significantly. Access to the area is possible via a network of local roads from Vela Luka. There are several places (delves and small quarries) where local people still use small quantities of PL to renovate existing objects/structures, which is recognized as good practice.

The northern slopes of the NW part of the island of Korčula are characterized by a very nice landscape and typical Dalmatian rural architecture (dry walls, rural houses, olive groves, *vrtujak* field shelters etc.), and it could pose a reasonable spatial restriction on possible exploitation of PL as mineral commodity.

Photo-compilation of outstanding platy limestone landscape on the island of Korčula related to the polygon Gornji Humac PL (ID_3830), north of Vela Luka.

4.6. OVERVIEW OF PLATY LIMESTONE AS A MINERAL COMMODITY

4.6.1. ZADAR COUNTY

In Zadar County (northern Dalmatia) there is a major PL occurrence within the Late Paleogene succession of the Promina unit, which is commercially named **"Benkovac Stone"**. Two high potential types of PL were recognized and mapped in a higher Promina unit: Benkovac PL and Otavac PL, along with one locality in the lower Promina unit (Debelo brdo locality).

These PL types are of excellent quality, since the PL is mostly densely packed calcilutite (calcareous "mudstone") and fine-grained calcarenite, which is rather uniformly very thin-bedded. According to the estimations on the field, the most qualitative are plates characterized by a monotonous lithology, especially calcilutite (micrite), but also calcarenite, while thin-laminated alternations of calcilutite and calcarenite that contain microbial laminae within a single plate are predisposed to secondary plating, and thus susceptible to damage during use (on roofs, pavements etc.).

The only restriction on the use of the "Benkovac Stone" could be its yellowish colour, which differs from other (mostly Cretaceous) grayish lithotypes of PL that characterize other parts of the project area in Croatia. Thus, we recommend the use of an autochthonous material if available.

Alongside its widespread and celebrated cultural heritage, the "Benkovac Stone" maintains prominent geo-heritage features, which need to be preserved in an accessible place and properly presented to the public. That is why we proposed an abandoned quarry characterized by outstanding preservation of all the key sedimentological and paleontological (ichnofossils) features that can be found within the succession of "Benkovac Stone", for protection as a geo-locality.

As regards geological issues, we strongly recommend further detailed investigations and subsequent exploitations within the proposed high potential polygons. In 2012. there were 28 authorized concessionaires for "Benkovac Stone" quarrying in an area of 5.41 km^2. We strongly support an initiative that aims to allow restricted collecting of the plates from the surface in the field for necessary reconstruction of existing traditional houses or sacral objects that are located within the natural outcrops of platy limestones.

Considering Natura2000 limitations, all proposed high potential types in Zadar County are outside any protection category. As a final conclusion on PL occurrences exploited as a mineral commodity, all natural and social limitations and other spatial restrictions should be also integrated into the potentiality maps.

CRO area	ID polygon / locality	Name of PL	Koefic.= 100/% PL	Total surface (m^2)*	Estimated thickness (m)	Estimated volume (m^3)
Zadar	3107	Debelo brdo-Zadar	1	200,000	5	1,000,000
Zadar	3120	Benkovac PL-Zadar	1	29,831,758	5	149,158,790
Zadar	3130	Otavac PL-Zadar	1	3,974,343	5	19,871,715
ZADAR	**All**	**"Benkovac Stone"**	**approx. 34,000,000 m^2**			**170,000,000**

TABLE 4.6.1. General assessment on quantity of selected (high potential) PL types proposed to be considered as mineral commodity in Zadar County. *10,000 m2 = 1 ha

4.6.2. SPLIT-DALMATIA COUNTY

In the wider **TROGIR** area there are two occurrences of high-potential PL units. **Kmečalovica** hill ("Pločurine") is characterized by outcrops of the Milna PL type of Cenomanian age. Although the plates are of good quality, the whole area is characterized by a very nice and protected (Natura2000) landscape, which could pose a reasonable spatial restriction for possible exploitation of PL as a mineral commodity. A few hundred meters SW of the village of **Begovići**, NW of Marina, there is a polygon of the Jelinak PL type of Turonian age, characterized by a rather concordant relation between subhorizontal bedding and flat morphology. The quality of typical Jelinak PL type can be limited because of macroscopically observed porosity in some horizons.

On the island of **ŠOLTA** there are two high-potential polygons of PL and a local occurrence. The **Koludrovi doci** area is situated between Stomorska and Gornje Selo, and characterized by lower Cenomanian Klačina PL on the surface. The quality is very good, though some horizons can be dark grey in as a result of local dolomitization. The spatial limitation for potential exploitation would be its proximity to the coast. In the central part of Šolta island at **Kupište** locality there is a polygon of Cenomanian Milna PL. The quality of typical Milna PL type is very good, though some plates are undulating because of the natural occurrence of algal laminites. Spatial limitations to potential exploitation are an open view to the sea and the site of a waste deposit facility. A high potential local occurrence of a PL type named Rogač is found at **Trzavica**. The quality is very good but the site is less than 1000 m from the sea.

On the island of **HVAR** there is a high-potential polygon of PL named **Vrboska** PL, located in the northeastern part of Starogradsko polje, which is under cultural and natural protection.
On the island of **BRAČ** there is a high-potential polygon and one locality. At the locality called **Vestac** (SW of Gornji Humac) the Gračišće-PL type of Turonian age appears, a unit that was already exploited in the area ("Kalina" quarries south of Gornji Humac, so-called "Brač platy"). The Gornji Humac-PL type of Turonian age is of good quality and appears outside Natura2000 protection on the northern slopes of Vidova gora (**Podgažul** polygon), within a flat area without settlements and roads.

There are also other polygons and localities characterized by PL occurrence on the mainland and on the other islands (**VELIKI DRVENIK, VIS**) which can be used as local building material for the renovation of local typical Dalmatian houses, which has been assessed as good practice. These PL localities usually have very restricted and dispersed spatial occurrence. However, many PL polygons and localities in Split-Dalmatia County maintain prominent geological, construction and heritage characteristics that need to be preserved and properly presented to the public. The realization of these opportunities ultimately lies with the local community; and it must be pointed out that economic development need not always run contrary to social concerns, as some of the PL sites and areas are much more interesting for landscape protection and geo-tourism than for exploitation as mineral resource (e.g. Vrboska PL area on the island of Hvar and Rogač PL polygon on the island of Šolta).

It should be pointed out that most of the high-potential polygons of PL are situated on the central Dalmatian islands. However, current mining regulations in Croatia define special restrictions for the exploitation of mineral resources on islands in general.

CRO area	ID polygon / locality	Name of PL	Koefic.= % PL/100	Total surface (m^2)*	Estimated thickness (m)	Estimated volume (m^3)
Trogir	3310	Milna PL-Trogir	0.3	1,058,633	5	1,587,950
Trogir	3330	Jelinak-Trogir	0.3	401,181	5	601,722
Šolta	3410	Klačina PL-Šolta	0.3	652,921	5	979,382
Šolta	3430	Milna PL-Šolta	0.3	335,051	5	502,577
Šolta	3443	Rogač-Šolta	0.3	20,000	5	30,000
Hvar	3520	Vrboska PL-Hvar	0.3	2,004,418	5	3,006,627
Brač	3608	Gračišće PL-Brač	0.3	10,000	5	15,000
Brač	3630	Gornji Humac-PL-Brač	0.4	2,500,540	5	5,001,080
SPLIT-DALMATIA COUNTY	**All**	**Cretaceous PL**	**approx. 7,000,000**			**12,000,000**

TABLE 4.6.2. General assessment on quantity of selected (high potential) PL types proposed to be considered as mineral commodity in Split-Dalmatia County. *10,000 m2 = 1 ha. SHOULD BE CORRECTED FOR NATURA2000 AND 1 KM FROM THE COAST. SPECIAL RESTRICTION FOR THE ISLANDS IS NOT CONSIDERED IN THE TABLE.

4.6.3. DUBROVNIK-NERETVA COUNTY

On the island of **KORČULA** there are three high-potential polygons. The **Vela Luka** area in the NW part of the Korčula island (surroundings of Vela Luka) is characterized by Gornji Humac PL (ID 3830) of Turonian-Santonian age. The quality of Gornji Humac PL type is very good, while a spatial limitation to potential exploitation would be its proximity to the coast and an outstanding landscape. In the central-eastern part of Korčula there are two polygon of Cenomanian Milna PL: one at **Pupnat** (3810) a few kilometers to the east of the village of Pupnat, in the vicinity of Zlo polje and Crnića dolac), and another at the village of **Žrnovo**-Podstrana (3820). The quality of these two types of Milna PL is very good. One spatial limitation is Natura2000, which covers both polygons, while the latter is also very close to a settlement, and any future exploitation could be possible only with special permission.

In the W part of the **PELJEŠAC** peninsula, in the surroundings of the village of **Lovišta**, there are a few small polygons of the high-potential Gornji Humac PL-Pelješac type (3910) of Turonian-Santonian age. The quality of this PL is very good, but most of the area of occurrence lies within 1,000 m of the sea, and only small parts can be considered for possible PL exploitation, if restrictions remain in place; the area is also entirely under Natura2000 protection.

CRO area	ID polygon / locality	Name of PL	Koefic.= % PL/100	Total surface (m^2)*	Estimated thickness (m)	Estimated volume (m^3)
Korčula	3830	Gornji Humac	0.3	9,098,420	5	13,647,630
Korčula	3810	Milna PL-Pupnat	0.4	1,112,235	5	2,224,470
Korčula	3820	Milna PL-Žrnovo	0.3	1,006,348	5	1,509,522
Pelješac	3910	Gornji Humac PL-Pelješac	0.4	363,676	5	727,352
DUBROVNIK-NERETVA COUNTY	**All**	**Cretaceous PL**	**approx. 11,500,000**			**18,000,000**

TABLE 4.6.3. General assessment on quantity of selected (high potential) PL types proposed to be considered as mineral commodity in Dubrovnik-Neretva County. *10,000 m2 = 1 ha. SHOULD BE CORRECTED FOR NATURA2000 AND 1 KM FROM THE COAST. SPECIAL RESTRICTION FOR THE ISLANDS IS NOT CONSIDERED IN THE TABLE.

4.6.4. ISTRIAN COUNTY

The main occurrence of PL in the Istrian County is within the Pula PL unit (Polygon ID_3010) of Albian age, and some minor occurrences in a few localities within the Rušnjak PL of Cenomanian age. Both were used, and are still in use for building roofs for traditional rural houses and field shelters.

The **Pula PL** has an average bed thickness from 4 to 60 cm, and can be considered as high potential after further detailed mapping. Namely, the polygon covers a very large area (more than 363 km^2), and it was impossible to define in detail local occurrences of PL within this part of the project area. Considering Natura2000 limitations, only small parts of the polygon 3010 lie within the protected zones. In existing quarries in the Pula PL unit, the limestone is exploited only for technical purposes. The limestone is used for building vertical walls of rural houses, using the same special technique that people also used for roof covering. Nowadays, the stone is used mostly for building *kažun* – small rounded field shelters, which rural people once used for keeping their tools and protecting their cattle.

In the area of Bujština (near **Oprtalj**, the northern part of the Istrian County) there are a few localities in which Rušnjak PL type appears in rather thin horizons (less than 1 m), which are intercalated within the succession of thicker beds. The horizons can only be followed for some tens of metres laterally, and none of the occurrences of Rušnjak PL from these localities is suitable for a commercial quarry. Considering the planned protection of old houses or even of the whole village as ethnological and architectural (cultural) heritage (localities ID 3021, 3022, 3023), the localities are shown in the potentiality map, in view of the possible need for PL material for reconstruction of this outstanding cultural heritage.

4.7. SUMMARY OF PLATY LIMESTONE AS A MINERAL COMMODITY AND ITS NATURAL HERITAGE

After reporting on the general occurrence of the platy limestone (PL) in the project area covered by our Croatian partners, we are focusing on PL as a mineral commodity with respect to the general spatial limitations of usage and its natural heritage. The aim of this report is to identify possible sources of the most promising types of platy limestone (high potential PL units and localities) within the investigated regions of the Adriatic karst. For this purpose, the stratigraphic position, age, major sedimentological and paleontological characteristics of various platy limestone units were studied, both in situ and during subsequent laboratory analysis. According to the recognized potential and spatial occurrence of all types of PL previously defined on maps at a general scale of 1:50,000, we evaluate selected types of platy limestone as a mineral commodity with the final goal of identifying potential quarrying areas. The quality of selected samples was assessed according to the field observations combined with the results of geomechanical laboratory analyses of flexural strength. On the selected and most promising sites, detailed sedimentological and paleontological investigations have been obtained for the purposes of proposal as natural protection (on the basis of age, paleontological and lithological characteristics, genesis, etc.)

In Zadar County (northern Dalmatia) there is a major PL occurrence within Late Paleogene succession of Promina unit commercially named “Benkovac Stone”, which is of excellent quality and rather uniformly very thin-bedded. The only restriction on use of the “Benkovac Stone” could be its yellowish colour, which differs from other (mostly Cretaceous) grayish lithotypes of PL that characterize other parts of the project area in Croatia. Thus, it would be more appropriate to use an autochthonous material if available. Considering Natura2000 limitations, all proposed high potential types in Zadar County are outside any protection category. Alongside its widespread and celebrated cultural heritage, the “Benkovac Stone” boasts prominent geo-heritage features. For our final conclusion on the potential of PL occurrences as mineral commodity, all natural and social limitations and other spatial restrictions should be integrated into the potentiality maps.

In Split-Dalmatia County (central Dalmatia) there are numerous, relatively small high potential PL polygons, most of which are on the central Dalmatian islands. In the wider TROGIR area there are two high-potential polygons: Kmečalovica area (W of Gustirna) SW of Begovići village (Jelinak PL type). On the island of ŠOLTA there are two high-potential polygons and a locality: Koludrovi doci, Kupište and Trzavica. On the island of HVAR there is a high-potential polygon of PL named Vrboska PL, located in the northeastern part of Starogradsko polje, which is already under cultural and natural protection, and can be additionally proposed as a future geo-tourism area. On the island of BRAČ there is a high-potential polygon east of Podgažul (northern slopes of Vidova gora) and Vestac locality (SW of Gornji Humac), while others are under Natura2000 protection. All the PL types are of very good to excellent quality. There are also other polygons and localities characterized by PL occurrence on the mainland and on the other islands (Veliki Drvenik, Vis). However, there are also spatial limitations for potential exploitation. Moreover, PL polygons and localities in the Split-Dalmatia County possess certain prominent geological, construction and heritage characteristics, which need to be preserved and properly presented to the public.

Realization of these opportunities ultimately lies with the local community; and it must be pointed out that economic development need not always run contrary to social concerns, as some of the PL sites and areas are far more interesting for landscape protection and geo-tourism than for the exploitation of mineral resources (e.g. Vrboska PL area on the island of Hvar and Rogač PL polygon on the island of Šolta).

In Dubrovnik-Neretva County (southern Dalmatia), there is one big polygon and two relatively small high-potential PL polygons on the island of Korčula, and a few small polygons on the Pelješac peninsula, along with a few local occurrences. On the island of KORČULA there are three high-potential polygons: Vela Luka, Pupnat and Žrnovo. All the PL types are of good quality. On the W part of the PELJEŠAC peninsula (surroundings of Lovišta village) there are a few small polygons of the high-potential Gornji Humac PL-Pelješac type (3910). One of them is characterized by artificial ridges and mounds of PL plates which are already prepared for gathering, probably as a result of major exploitation in the past. However, there are also spatial limitations for potential exploitation.

The main occurrence of PL in the **Istrian County** is within Pula PL unit (Polygon ID_3010) of Albian age, and some minor occurrences in a few Oprtalj localities within Rušnjak PL of Cenomanian age. Both were and are still in use for building roofs on traditional rural houses and field shelters.

In table 4.7. is indicated a general assessment on the PL as a mineral commodity, which is approx. 200,000,000 m^3 for three Dalmatian counties involved in the project RoofOfRock. However, current mining regulations in Croatia define special restrictions on the exploitation of mineral resources on islands in general. Istrian County is also characterized by significant PL potential, but numerical assessment is not possible without more detailed mapping of this spatially enormous yet dispersed occurrence of PL within Pula PL polygon. PL appears also in Šibenik-Knin County, which was not included in the project RoofOfRock.

RoR Dalmatia	ID polygon / locality	Name of PL	Total surface (m^2)*	Estimated volume (m^3)
ZADAR	All	"Benkovac Stone"	approx. 34,000,000	170,000,000
SPLIT-DALMATIA COUNTY	All	Cretaceous PL	approx. 7,000,000	12,000,000
DUBROVNIK-NERETVA COUNTY	All	Cretaceous PL	approx. 11,500,000	18,000,000
	All	**ALL PL TYPES**	**approx. 52,500,000**	**200,000,000**

TABLE 4.7. General assessment on quantity of selected (high potential) PL types proposed for consideration as mineral commodity in Zadar County, Split-Dalmatia County AND Dubrovnik-Neretva County. *10,000 m2 = 1 ha. SHOULD BE CORRECTED FOR NATURA2000 AND 1 KM FROM THE COAST. SPECIAL RESTRICTION FOR THE ISLANDS IS NOT CONSIDERED IN THE TABLE.

According to the results of geomechanical analyses and field (descriptive) assessment of PL quality, it can be generally estimated that the homogenous mudstones (micritic lithotypes) and laminated (microbial) mudstones are of the best quality. However, it should be noted that most of the PL samples were not lithologically homogenous, as a result of their genesis in the natural environment. Therefore, the quality of the PL within each single PL succession or within each PL quarry is not uniform. Each PL plate taken from different bed/layer can demonstrates different mechanical properties and overall quality. Due to a very heterogeneous lithology it is impossible to make a general assessment of PL quality for the entire (e.g. 5 m thick) PL sequence.

It should be noted that most of the high-potential polygons of PL are situated on the central Dalmatian islands. However, current mining regulations in Croatia define special restrictions on the exploitation of mineral resources on islands in general.

Further, we strongly support an initiative that aims to allow the restricted surface gathering of plates in areas without soil, and only for the necessary reconstruction of existing traditional houses and/or cultural (sacral) objects/structures that are located within the natural outcrops of platy limestones.

5.

SHOW-CASE OBJECTS

5.1. INTRODUCTION

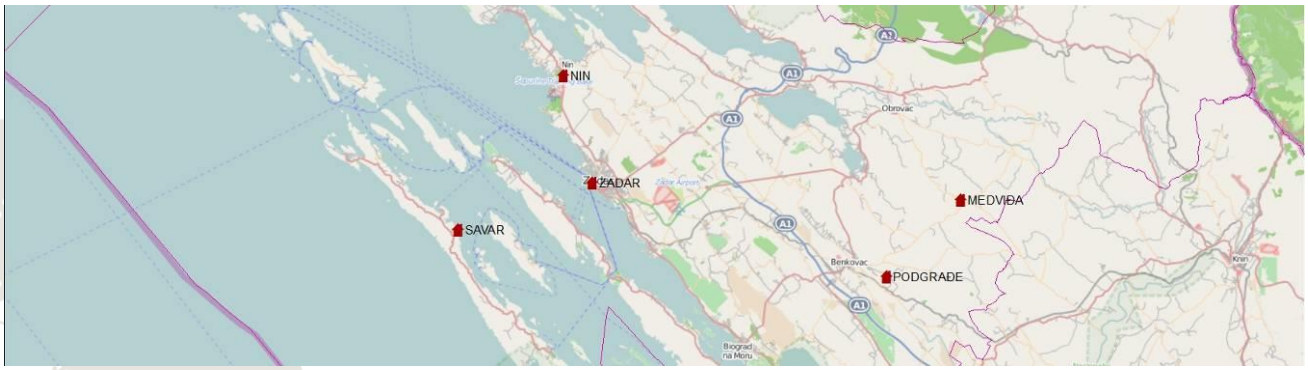
Following the first part of the RoofOfRock project on the platy limestone, we focused in the second part on the show-case objects. The main aim was to identify different types of building limestones (mostly platy limestone) used on the selected show-case objects, and to relate the used types of limestones to geological units defined in the overview geological maps 1:250,000 and/or 1:50,000. For this purpose, major sedimentological and paleontological characteristics of various building limestones used on the show-case objects were studied. According to the recognized limestone types from the building materials, the spatial occurrence of related geological (lithostratigraphical) units was defined on maps at a general scale of 1:50,000, while platy limestone materials were related to the recognized platy limestone units (included in the first part of the report on platy limestone). Furthermore, potential quarrying areas were identified. Following WP3-WP4 (geology and cultural heritage) coordination on the meetings in Trieste (February, 2014), and Split (April, 2014), along with the final conclusions of Međugorje MAoP meeting (June, 2014), we selected 11 objects for show-case in the Croatian part of the project area.
HGI external experts suggested the selection of the general areas characterized by potential show-case objects according to pre-defined spatial occurrences of platy limestone in the Adriatic karst region of Croatia, i.e. in the region of Dalmatia. In cooperation with the leading partner it was concluded that at least one building element on a proposed object should be a platy limestone. WP4 external experts agreed on the general areas, and suggested the show-cases located within the areas. The proposed objects have been discussed by the experts and WP leaders according to the photographs and field inspections during the coordination meetings in Trieste, Split and Međugorje. All the objects were investigated afterwards in cooperation with WP3 (geology) and WP4 (cultural heritage) experts. WP3 experts geologically investigated all the basic building elements on the objects, and ultimately accepted the proposed show-cases.

5.1.1. OVERVIEW OF LOCALITIES - GEOGRAPHIC DESCRIPTION

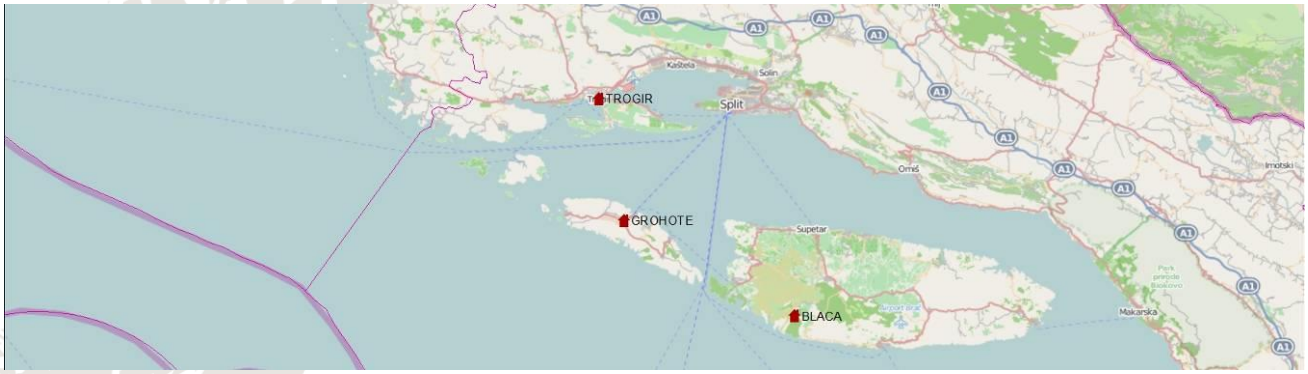
The show-case objects selected in the Croatian part of the RoofOfRock project are situated in the Dalmatian counties participating in the RoofOfRock project: 5 objects in Zadar County (ZADRA), 3 objects in Split-Dalmatia County (RERA SD), and 3 objects in Dubrovnik-Neretva (DUNEA) County (see table and maps below).

ID_locality	Location	Location (descriptive)	E (DTRS96)	N (DTRS96)
3101	**MEDVIĐA**	MEDVIĐA (Benkovac). Church of sv. Ivan Krstitelj.	442,315	4,884,934
3102	**NIN**	NIN. Church of sv. Nikola.	394,431	4,899,826
3103	**ZADAR**	ZADAR. Stone sidewalks in historical centre.	397,919	4,886,962
3104	**SAVAR**	SAVAR (Dugi otok). Church of sv. Pelegrin.	381,723	4,881,378
3105	**PODGRAĐE**	PODGRAĐE (Benkovac). “Čerina dvori”.	433,333	4,875,698
3300	**TROGIR**	TROGIR cathedral apses.	479,900	4,819,700
3400	**GROHOTE**	GROHOTE village (Šolta). “Ruića dvori”.	482,836	4,805,719
3602	**BLACA**	BLACA (Brač) monastery-museum.	502,401	4,794,768
3861	**VELA LUKA**	VELA LUKA (Korčula). “Bobana lazi”.	518,075	4,757,874
3855	**ŽRNOVO**	ŽRNOVO-Podstrana (Korčula). “Pod Veli vrh”.	549,253	4755,138
3952	**NAKOVANA**	Donja NAKOVANA village (Pelješac). "U Cvitka".	547,497	4,762,717

In **Zadar County (ZADRA)**, 2 objects are situated in the coastal mainland area (Nin and its surroundings and Zadar old town), 2 objects in the Ravni kotari area in the hinterland (Medviđa and Podgrađe villages), and 1 object is situated on the island of Dugi otok (Savar village).



In **Split-Dalmatia County (RERA SD)** 1 object is situated downtown in Trogir (Trogir cathedral apses), 1 object is on the island of Brač (Blaca), and 1 on the island of Šolta (Grohote village).



In **Dubrovnik-Neretva County (DUNEA)** 2 objects are situated on Korčula island (Vela Luka and Žrnovo-Podstrana) while 1 object is on the Pelješac peninsula (Nakovana).

5.2. METHODOLOGY OF DETAILED GEOLOGICAL INVESTIGATION

All selected show-case objects were first investigated in detail on site by at least 2 HGI experts (lithostratigraphy and paleontology experts). A set of digital photographs for every object and every building element was taken. A detailed lithological, micro- and macropaleontological investigation was performed on the building elements in situ, while collected data was discussed on location, and notes were taken on the basic characteristics of the elements. Some broken elements found in the vicinity of the objects were sampled for laboratory analyses.

The surroundings of an object were also investigated, with the aim of defining possible local occurrence of the material. Recognized lithological units were defined geologically according to existing data in the first phase of the investigation, while some specific elements were defined lithostratigraphically after additional geological mapping in the selected areas.

All the data was incorporated into the WP3 (geological aspects on PL) description sheets written for every object, according to general data and element selection shown on the description sheets from WP4 external experts. Manuscript geological maps were digitalized and prepared in a GIS environment.

Attribute tables proposed by the leading partner were first completed by WP4 (cultural heritage on PL) external experts, and then by WP3 experts, in accordance with the completed description sheets.

In the further text, results for each investigated object are organized in approximately the same order. First some general data on the object is presented, including a list of selected limestone elements. This are followed by geological data on limestone types: name of limestone, name of geological unit shown on the geological map, age of limestone, lithological and paleontological characteristics and source area of limestone. Finally, architectural elements built of the same type of limestone are numbered on photographs accompanied by a geological description below.

5.3. GEOLOGICAL DESCRIPTION SHEETS OF SHOW-CASE OBJECTS

5.3. 1. ZADAR COUNTY (ZADRA)

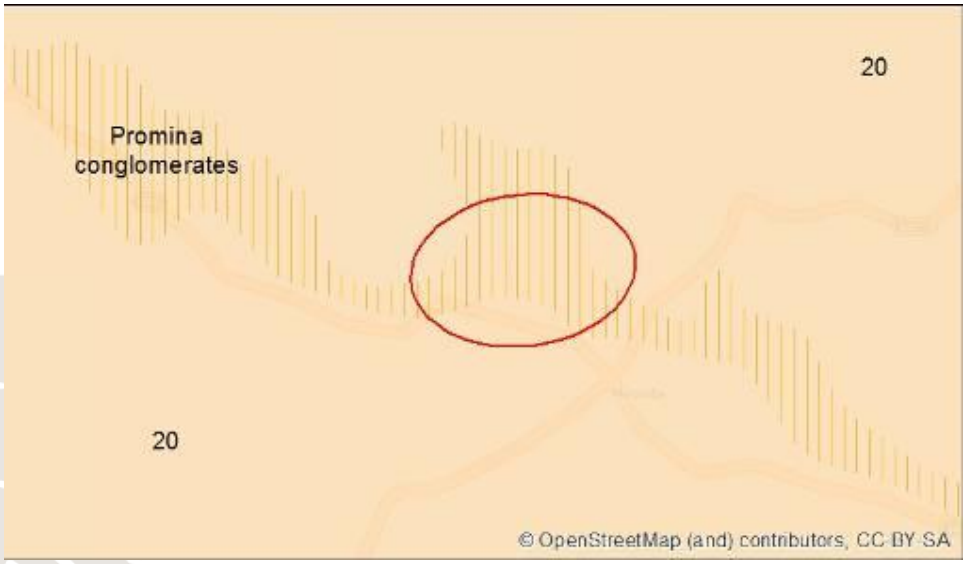
5.3.1.1. Medviđa

The church of St. John The Baptist (Crkva sv. Ivana Krstitelja) is a sacral building (cemetery church in the village of Medviđa), in occasional use and a preventive protected cultural heritage. It was built in the 13th or 14th century. The building is very picturesque because of its location at the foot of the rock, which rises above the tall tower in front of the church. The church has an elongated rectangular floor plan with a rectangular apse prominent in the area on the eastern side. It was built of plastered stone on the outside. There is no portal in the front because it is close to the stone cliff. The roof construction of the nave is made of wood, a vaulted apse is slightly broken. St. John the Baptist in Medviđa is a remarkable architectural monument, unique in Zadar County because of its position, shape, well preserved roof cover, its high tower and dual confessional use. The gabled roof is covered with large rough-cut stone slabs (Bukovica type).
Accessibility: Excellent. The main road branches off a side road leading to the church and the cemetery, with a large parking lot.

Description number	ID 3101 ZADRA
Prepared by Ladislav Fuček, Cartography: Nenad Kurtanjek, 28 .08.2014.	
Name (official and common):	Crkva Sv. Ivana Krstitelja (Church Of St. John the Baptist)
Address (location):	Local graveyard, Medviđa, Zadar County
Cadastral number, community:	1/1 i 1/3, Medviđa
Coordinates:	ϕ= 44°06'08" N λ=15°46'46" E E=442315 N=4884934
Typology:	Late medieval rural building with “Bukovica type” roof.
Investigator (geology):	Ladislav Fuček, Vlatko Brčić, Tomislav Kurečić
Date of fieldwork:	24.10.2013.
Selected limestone elements:	0 walls 1 main roof (nave ceiling) 2 extension roof (vaulted sanctuary) 3 bell tower ~~4a old wooden roof constructions~~ ~~4b new wooden roof construction~~ 5 vaulted sanctuary/apse 6 altar

Part of the object (architectural element): **0_walls, 3_bell tower, 5_vaulted sanctuary/apse, 6_altar**

Name of limestone: Promina conglomerates
Geol. unit ID (map 1:250,000): 20*, (PL ID):* 3140
Name of formation/member/geological unit: Promina / Promina conglomerates
Age: Late Paleogene
Basic lithology: Thick-bedded to massive multi-coloured polymictic carbonate conglomerates and pinkish micritic and fine grained limestones, alternating with thin-bedded (platy) fine-grained limestones (calcisiltite) and calcarenites.
Characteristics: Polymictic carbonate conglomerates with multi-coloured, very well-rounded pebbles.
Quarry/delve or source area: Possible smaller local quarries in the immediate surroundings.

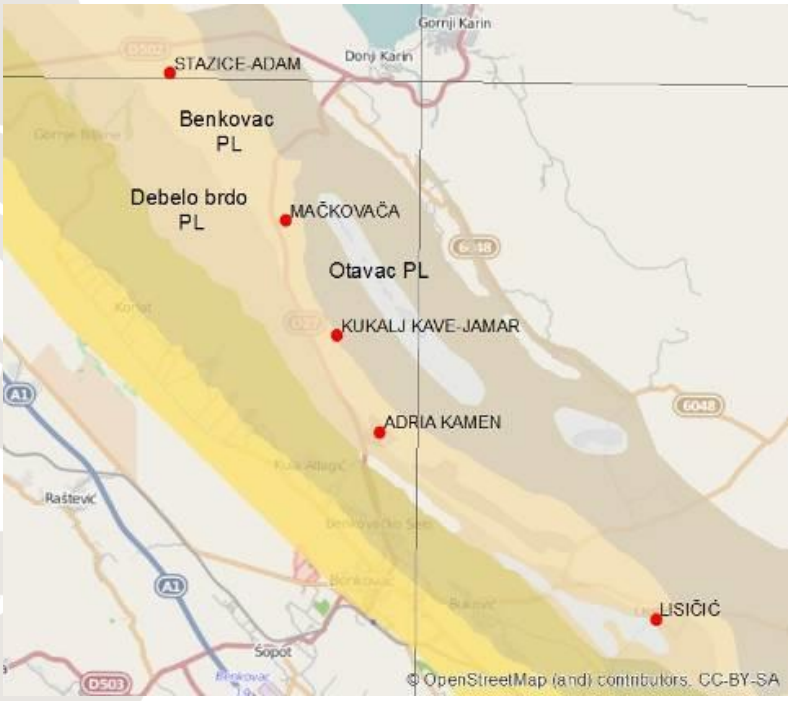


Possible source area for elements 0, 3, 5, and 6 (Promina conglomerates).

Notes: Different types of carbonate conglomerates from the immediate surrounding area were used for walls and other parts of the buildings. Today these small local quarries are abandoned and of unknown locations.

Part of the object (architectural element): **1_main roof (nave ceiling), 2_extension roof (vaulted sanctuary)**

Name of limestone: Benkovac PL
Geol. unit ID (map 1:250,000): 20a, (PL ID) 3120
Name of formation/member/geological unit: BENKOVAC / Benkovac PL
Age: Late Paleogene
Basic lithology: Thin-bedded (platy) yellowish fine-grained limestone and calcarenite in alternation.
Characteristics: Numerous trace fossils and ripple forms.
Quarry/delve or source area: The major occurrence of the Benkovac PL is in a wide area NE of Benkovac.



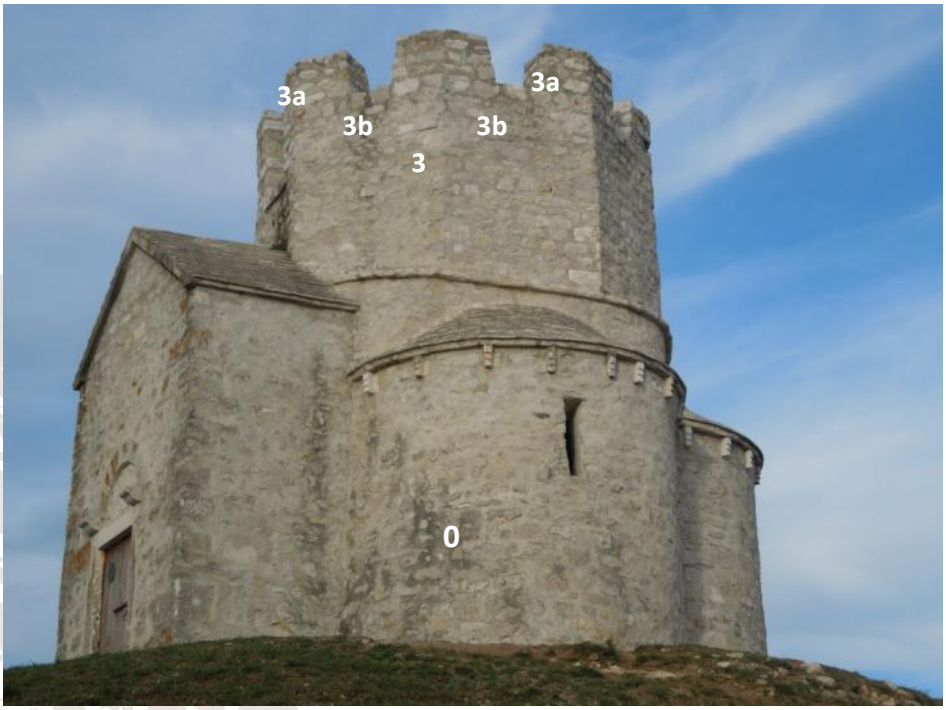
Possible source area for elements 1 and 2 (some of the quarries in Benkovac PL).

Notes: It is possible that the primary material for roofing was of various platy lithotypes within the sequence of the Promina unit (calcsiltites and calcarenites in alternation with thick-bedded to massive multi-coloured polimictic carbonate conglomerates).

5.3.1.2. Nin

The church of St. Nicholas (Crkva sv. Nikole) is a sacral building, in occasional use, owned by "Muzej ninskih starina" (Nin). This is a central Pre-Romanesque church with an irregular circular ground plan. The church was built on a prehistoric tumulus in a field between Nin and Zaton (Prahulje). It has a trefoil ground plan with a vaulted conch. The centre of the building is vaulted with a dome. It is an early Romanesque building from the early 12th century. The walls of the buildings were built from roughly shaped limestone and originally covered with plaster.

Description number	ID 3102 ZADRA
Prepared by Ladislav Fuček, Cartography: Nenad Kurtanjek, 28.08.2014.	
Name (official and common):	Crkva Sv. Nikole, Nin (Church of St. Nicholas, Nin)
Address (location):	Prahulje, near the town Nin, Zadar County
Cadastral number, community:	3277/8, Zaton-Nin, Nin
Coordinates:	ϕ= 44°13'51" N λ=15°10'42" E E=394431 N=4899826
Typology:	Central early-Romanesque church with irregular circular ground plan.
Investigator (geology):	Fuček Ladislav, Korbar Tvrtko
Date of fieldwork:	22.05.2014.
Selected limestone elements:	0 walls 1 main dome: 2 extension roof 3 battlement/crenulation 3a merlons 3b crenels 4 cross-ribbed vault 5a original Romanesque corbels/console 5b new corbel restoration at the end of the 20th century 6 cornice 7 door frame 8 pilaster 9 transom restoration at the end of the 20th century 10 door corbels 11 doorpost



Part of the object (architectural element): **0_walls, 3_battlement/crenelation, 3a_merlons, 3b_crenels**

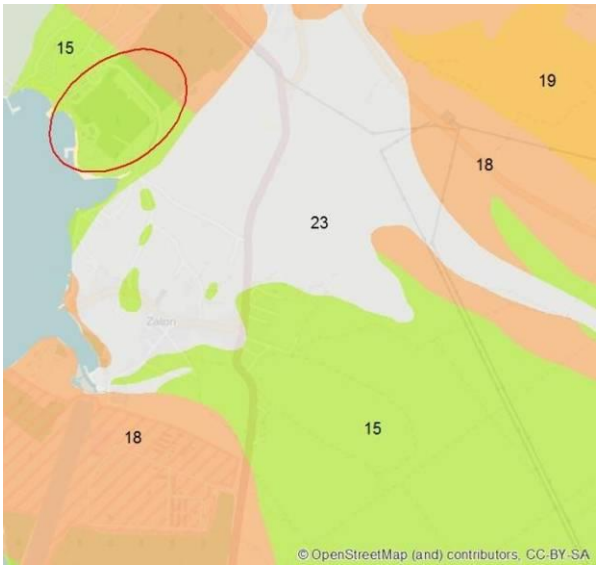
Name of limestone: Turonian – Santonian limestone, Foraminiferal limestones, sandstones (Flysch)
Geol. unit ID (map 1:250,000): 15, 18, 19
Name of formation/member/geological unit: Turonian – Santonian, Foraminiferal limestones, Flysch
Age: Turonian – Santonian, Early – Middle Paleogene, Middle - Late Paleogene
Basic lithology: Turonian – Santonian: skeletal micritic to peloidal limestones with rudists, Foraminiferal limestones: skeletal brownish limestones with large foraminiferas, Flysch: alteration of marl and calcareous sandstone
Characteristics: In the Turonian – Santonian limestone rudist shells locally occur within these recrystallized limestones, while large foraminifera commonly occur in the Foraminiferal limestones.

Block of recrystallized Turonian-Santonian limestone

Block of Paleogene Foraminiferal limestone

Blocks of sandstones (Flysch)

Quarry/delve or source area: possible quarries: Rupe (tourist resort “Zaton”)

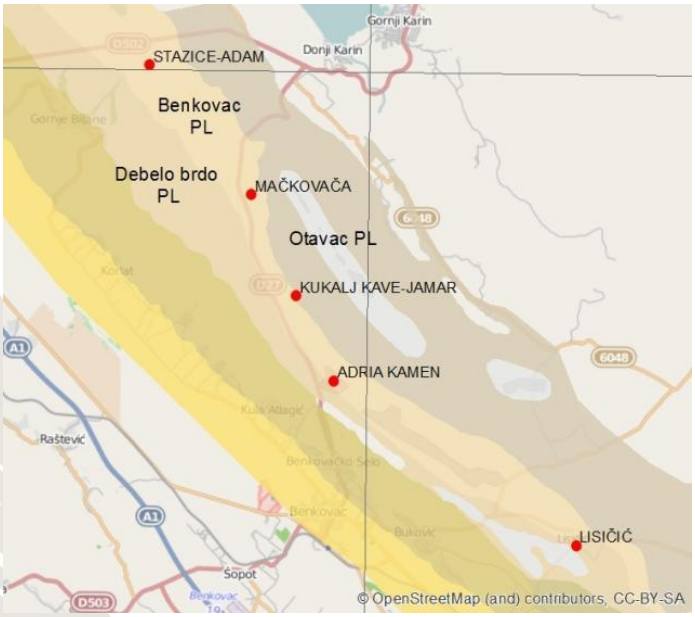


Possible source area for elements 0, 3, 3a and 3b (local stone).

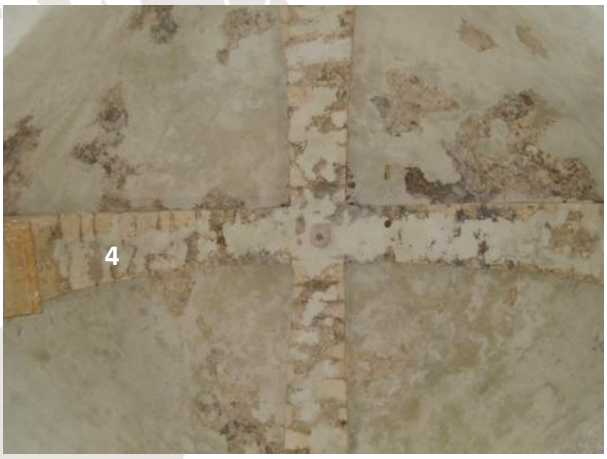
Notes: Different types of limestone and calcareous sandstone from nearby geological units/formations were used for the walls.

Part of the object (architectural element): **1*_main dome, 2_extension roof, 6_cornice**
Name of limestone: Benkovac PL
Geol. unit ID (map 1:250,000): 20a, (PL ID) 3120
Name of formation/member/geological unit: BENKOVAC / Benkovac PL
Age: Late Paleogene - Oligocene
Basic lithology: Thin-bedded (platy) yellowish fine-grained limestone and calcarenite in alteration
Characteristics: Numerous trace fossils and ripple forms
Quarry/delve or source area: Benkovac PL in a wide area NE of Benkovac.

*not visible from the ground (tower roof).



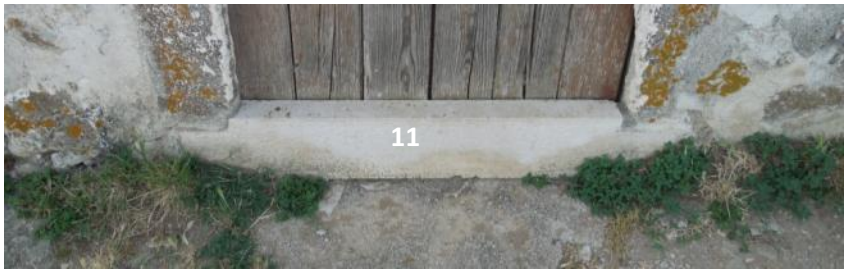
Possible source area for elements 1, 2 and 6 (some of the quarries in Benkovac PL).



Part of the object (architectural element): **4_cross-ribbed vault, 5a_original Romanesque corbels/console, 7_door frame 8_pilaster, 10_door corbels**

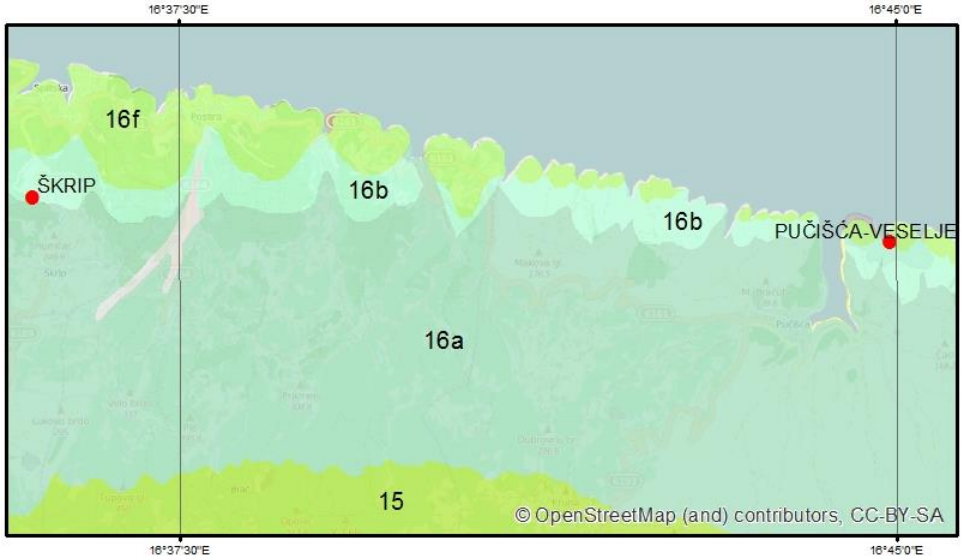
Name of limestone: Borišina-Ovča
Geol. unit ID (map 1:250,000): 15, (*PL ID*): 3150
Name of formation/member/geological unit: Turonian – Santonian / Borišina-Ovča
Age: Turonian - Santonian
Basic lithology: Turonian – Santonian (Borišina-Ovča member): thick-bedded to massive greyish-white fine to coarse grained bioclastic limestone with rudist fragments
Characteristics: limestone with numerous fragments of rudist shells
Quarry/delve or source area: abandoned Borišina and Ovča quarries, ID: 26 (Dugi otok island)

Possible source area for elements 4, 5a, 7, 8 and 10 (Borišina-Ovča mb).



Part of the object (architectural element): **5b_new corbel restoration at the end of the 20th century, 9_transom restoration at the end of the 20th century, 11_doorpost**

Name of limestone: different limestone types of Pučišća Formation
Geol. unit ID (map 1:250,000): 16b
Name of formation/member/geological unit: Pučišća Fm.
Age: Campanian
Basic lithology: Thick-bedded to massive greyish-white fine to coarse grained bioclastic limestone with rudist fragments
Characteristics: The Pučišća is characterized by yellowish light-grey unito type (grainy limestone) or fiorito type (shelly bioclastic limestones).
Quarry/delve or source area: Pučišća Fm. From the northern-central coastal part of Brač island (possible quarries Škrip ID 53, and Pučišća ID 49).



Possible source area for elements 5b, 9 and 11 (Pučišća Fm from Brač island).

5.3.1.3. Zadar

Throughout its history, the streets and squares of Zadar were covered with stone slabs several times, from ancient Roman times through the Middle Ages up until today. But most of the pavement today is from the time of the Austro-Hungarian administration (the late 19th century). Stones from the island of Lavdara were used. This reddish limestone was chosen because of its strength and resistance to pedestrian traffic. Stone slabs were 5 to 15 cm thick. Originally, the plates were laid out in dry layers of red clayish soil. Today 2-3 cm thin plates are laid in concrete.
Accessibility: Excellent. This stone sidewalks surrounding Zadar's old town are used for walking, and are a few minutes away from official parking and the main harbour.

Description number	ID 3103 ZADRA
Prepared by Ladislav Fuček, Cartography: Nenad Kurtanjek, 28.08.2014.	
Name (official and common):	Stone sidewalks in Zadar old town
Address (location):	Zadar, Zadar County
Cadastral number, community:	10777; 10769; 9934; 9854; 10772
Coordinates:	ϕ= 44°06'51" N λ=15°13'40" E E=397919 N=4886962
Typology:	Public sidewalks and pavements
Investigator (geology):	Ladislav Fuček, Korbar Tvrtko
Date of fieldwork:	24.05.2014.
Selected limestone elements:	1 street plates 2 street plates 3 street plates 4 street plates 5 street plates 6 street plates 7 street plates

Part of the object (architectural element): **1_ street plates, 2_ street plates, 3_ street plates, 4_ street plates, 5_ street plates**

Name of limestone: Limestone of Milna Formation (Lavdara type)
Geol. unit ID (map 1:250,000): 14 (geological unit on map 1:250,000: Cenomanian-Turonian limestone)
Name of formation/member/geological unit: Cenomanian-Turonian
Age: Cenomanian
Basic lithology: Cenomanian-Turonian (Milna Fm.): Mostly well-bedded micritic to grainy skeletal limestones with rudist and chondrodont bivalves, in places dolomites.
Characteristics: Different lithotypes in stone slabs from Lavdara island:

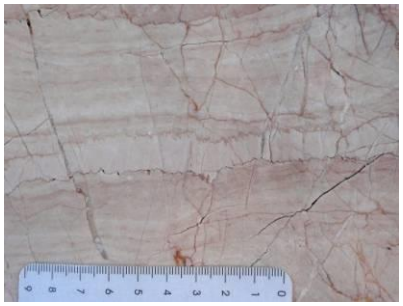
1) Reddish to brownish micritic limestone
2) Reddish to brownish laminated limestone
3) Reddish to brownish laminated limestone with light grey to white chondrodonta fragments
4) Reddish to brownish fine to coarse-grained bioturbated limestone with stylolites
5) Reddish to brownish limestone with light grey to white Cenomanian radiolitid rudist fragments.

Thick-bedded rudist floatstone.

Thick-bedded floatstone with chondrodont bivalves.

Reddish breccias with irregular stylolites.

Alternation of thick-bedded rudist limestones, oncoidal-peloidal-skeletal wackestones-packestones-grainstones and reddish stromatolites.

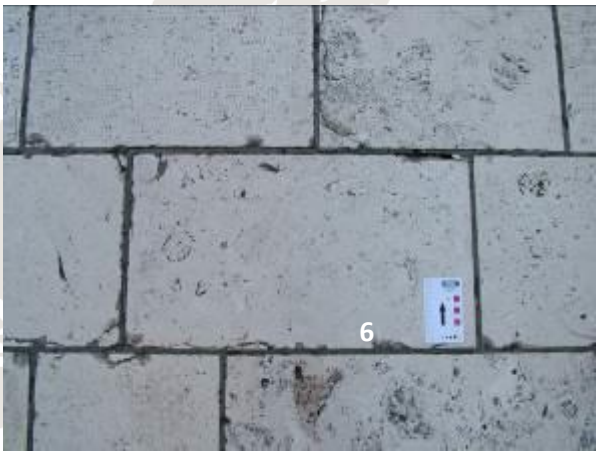


Reddish stromatolites with stylolites.

Abandoned quarries on the southwestern coast of Lavdara island.

Possible source area for elements 1, 2, 3, 4 and 5 (Milna Fm on Lavdara island, quarry ID 74).

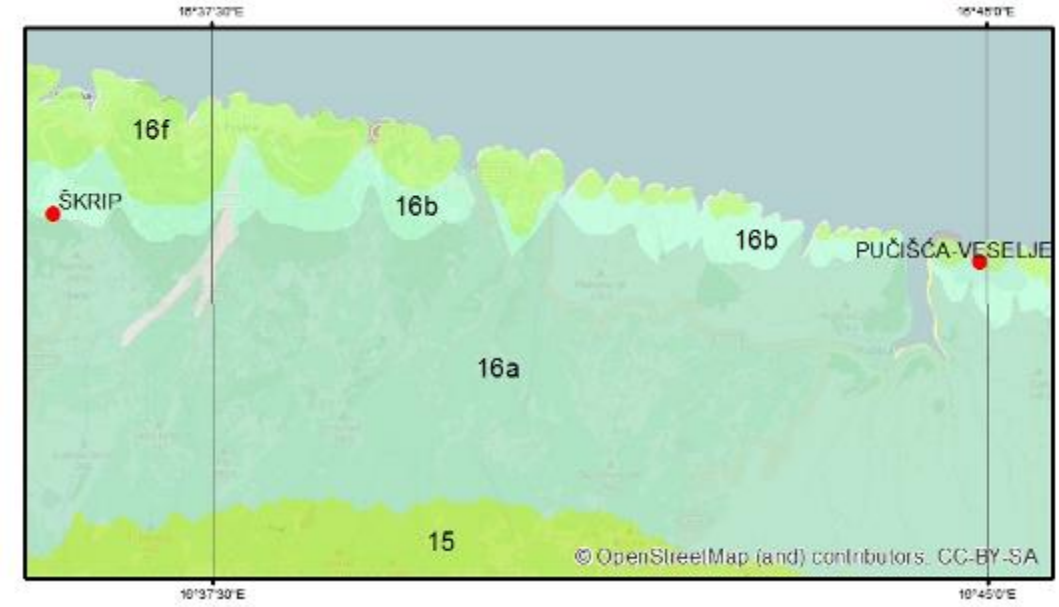
Quarry/delve or source area: Milna Fm. on southwestern coastal part of Lavdara island (quarry ID 74).
Notes: Complete SW coast of Lavdara island is an abandoned quarrying area.



Part of the object (architectural element): **6_street plates**
Name of limestone: Pučišća fiorito
Geol. unit ID (map 1:250,000): 16b
Name of formation/member/geological unit: Pučišća Fm.
Age: Santonian-Campanian
Basic lithology: Thick-bedded to massive yellowish to greyish-white fine to coarse grained bioclastic limestone with rudist fragments.
Characteristics: Grayish-white bioclastic limestone with typical Middle Campanian rudists (e.g. *Pironaea* sp.)
Quarry/delve or source area: Pučišća Fm on northern-central coastal part of Brač island (possible quarries Škrip and Pučišća).

***Part of the object (architectural element):* 7_street plates**

Name of limestone: Dol (Sivac)
Geol. unit ID (map 1:250,000): 16a
Name of formation/member/geological unit: Dol Fm.
Age: Santonian-Campanian
Basic lithology: Thick-bedded partly dolomitized, biomicrite with bioturbations and bituminous patches and intercalations of thick-bedded to massive, partly dolomitized greyish fine-grained bioclastic limestone and carbonate breccias.
Characteristics: Brownish micritic limestone with bioturbations and bituminous veins and patches.
Quarry/delve or source area: Dol Fm. on northern-central coastal part of Brač island (possible quarries: Pučišća).



Possible source area for element 7 (Pučišća Fm from Brač island).

Notes: These plates are probably more recent replacements.

5.3.1.4. Savar

The church of St. Peregrine (Crkva sv. Pelegrina) is a pre-Romanesque sacral building of the central type from the IX. century and is a protected cultural heritage. The church is built on a small island connected to the mound on the Island of Dugi otok. This is the most valuable early medieval monument in the Zadar archipelago. The church consists of a nave and a sanctuary. Once there was a small sacristy to the sanctuary, which was demolished in 1958. The square sanctuary is domed, and represents the core of the church. It was actually originally a small Romanesque church, to which were later attached a nave and a sacristy. The church was extended in the 15th century, when it was built on a rectangular vessel. In 1747, a small bell tower was built above the entrance to the church and a sacristy was added. According to tradition, some elements of the church were built by stonemasons of nearby quarries, which are the most famous medieval quarries of Zadar. The dome of the first church (which is now a sacristy) is covered with stone slabs.
Accessibility: Excellent. The church is located at the end of the main road, and served by a bus-friendly parking.

Description number	ID 3104 ZADRA
Prepared by Ladislav Fuček, Cartography: Nenad Kurtanjek, 28.08.2014.	
Name (official and common):	Crkva sv. Pelegrina, Savar (Church of St. Peregrine, Savar)
Address (location):	Savar, Dugi otok, Zadarska županija
Cadastral number, community:	20; 745, Savar
Coordinates:	ϕ= 44°03'46" N λ=15°01'25" E E=381723 N=4881378
Typology:	Pre-Romanesque church of the central type from IX. century.
Investigator (geology):	Fuček Ladislav, Korbar Tvrtko
Date of fieldwork:	19.05.2014.
Selected limestone elements:	0 walls 1 stone roof (vaulted sanctuary) ~~2 main tile roof (nave ceiling)~~ 3 bell tower 4 vaulted sanctuary/dome 5 transom 6 doorpost 7 door frame 8 openings (ponare) 9 window frame 10 replacement window frame

Part of the object (architectural element): **0_walls, 1_stone roof (vaulted sanctuary), 3_bell tower**
Name of limestone: Milna
Geol. unit ID (map 1:250,000): 13
Name of formation/member/geological unit: Albian-Cenomanian dolomites
Age: Albian – Cenomanian
Basic lithology: Predominantly crystalline dolomites and limestones, with intercalations of micritic to grainy limestones.
Characteristics: In the Cenomanian limestones (Milna) rudist and chondrodont shells locally occur. Platy limestones are thin-bedded greyish micritic to grainy limestones and stromatolites.
Quarry/delve or source area: Only local use around the Savar village. Platy limestone possibly from local occurrence (ID 3125) near the Savar village.

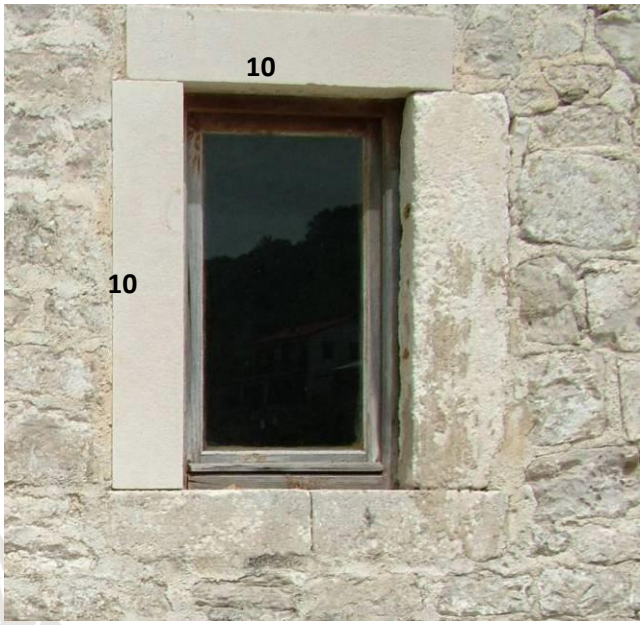
Possible source area for elements 0, 1 and 3 (local limestone).

Notes: Different types of limestones and dolomites from nearby geological units (Milna) were used for walls.

Part of the object (architectural element): **5_transom, 6_doorpost, 7_door frame, 8_openings (ponare), 9_window frame**

Name of limestone: Borišina-Ovča
Geol. unit ID (map 1:250,000): 15, (*PL ID):* 3150
Name of formation/member/geological unit: Turonian – Santonian (Borišina-Ovča member)
Age: Turonian - Santonian
Basic lithology: Turonian – Santonian (Borišina-Ovča member): thick-bedded to massive greyish-white fine to coarse grained bioclastic limestone with rudist fragments
Characteristics: limestone with numerous fragments of rudist bivalves shells
Quarry/delve or source area: possibly one of abandoned quarries: Borišina (ID 26) and/or Ovča quarry (Dugi otok island)

Possible source area for elements 5, 6, 7, 8 and 9 (Borišina-Ovča mb).



Part of the object (architectural element): **10_replacement window frame**

Name of limestone: Pučišća unito

Geol. unit ID (map 1:250,000): 16b

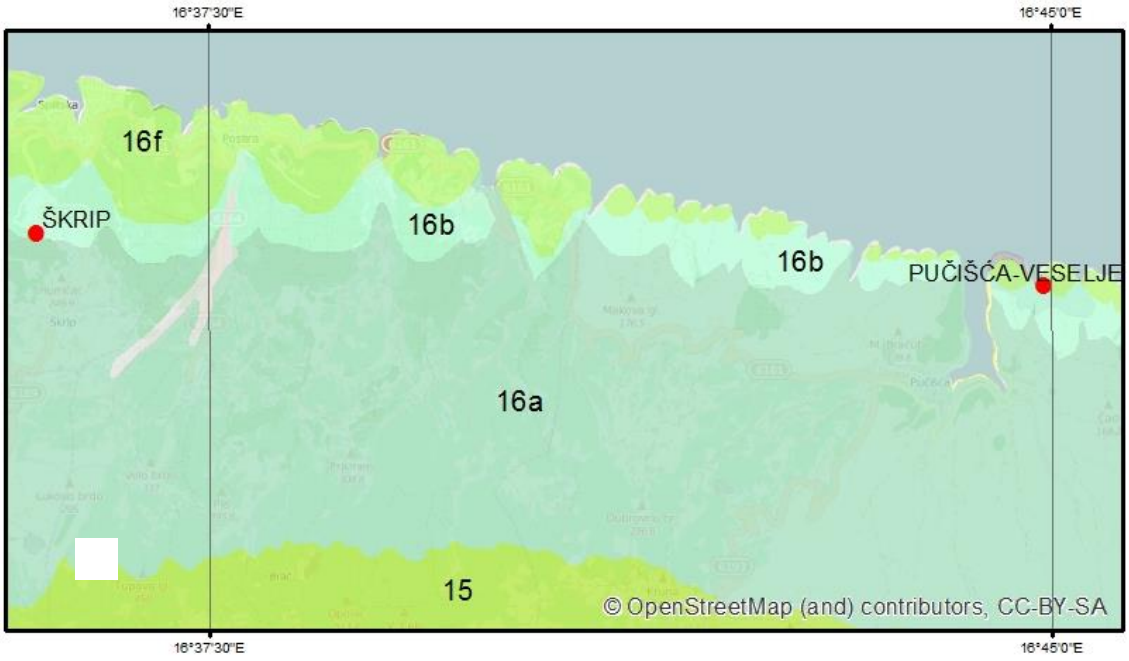
Name of formation/member/geological unit: Pučišća Fm.

Age: Campanian

Basic lithology: Thick-bedded to massive greyish-white fine to coarse grained bioclastic limestone with rudist fragments

Characteristics (lithological, paleontological, …): The Pučišća is characterized by yellowish light-grey unito type (grainy limestone) or fiorito type (shelly bioclastic limestones).

Quarry/delve or source area: Pučišća Fm. on northern-central coastal part of Brač island (possible quarries Škrip ID 53, and Pučišća ID 54).



Possible source area for element 10 (Pučišća Fm from Brač island).

5.3.1.5. Podgrađe

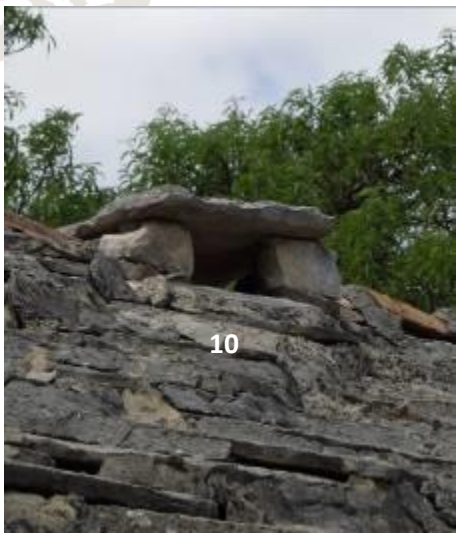
"Čerina dvori" is a complex of private family houses in the village of Podgrađe, near the town of Benkovac. The complex of family houses represents a typical example of traditional architecture of the Dalmatian Zagora, of the *bukovica* type. The complex of houses is grouped around a central walled courtyard and consists of three residential houses, *vatrenica*, and two barns for livestock. In the front yard, on a raised area, is a paved threshing floor. All the houses were built from extruded or roughly shaped stone. They are covered with stone plates 1 to 5 cm thick. The corners of buildings, window frames and door posts were built of regularly chiselled blocks of stone. The walls of the buildings are minimally perforated. The modest decoration, except for window frames, makes a series of niche-holes in the upper triangular zone. They represent an ornament and a pigeon loft. On the roof of the "crna kužina"/"vatrenica" is a primitive chimney, a ventilation shaft called a "badža". The highest northern house with an inner courtyard is associated with massive stone stairs. The courtyard and threshing front yard, called a "gumno", are also tiled. Stone plates are used in niches, benches, holes for pigeons and a chimney-opening.
Accessibility: Excellent. The complex of family house is located right along the main road, with bus-friendly parking.

Description number	ID 3105 ZADRA
Prepared by Ladislav Fuček, Cartography: Nenad Kurtanjek, 28.08.2014.	
Name (official and common):	Home "Čerina dvori"
Address (location):	Podgrađe (near Benkovac), Zadar County
Cadastral number, community:	801/1; 801/2; 835/2; 40/1; 40/2; 40/3; 40/5; Podgrađe, Lisičić, Benkovac
Coordinates:	ϕ= 44°01'05" N λ=15°40'06" E E=433333 N=4875698
Typology:	Complex of traditional stone houses - "dvori"; bukovica-type
Investigator (geology):	Fuček Ladislav, Korbar Tvrtko
Date of fieldwork:	23.05.2014.
Selected limestone elements:	0 walls 1 roofs 2 courtyard pavement 3 corner stones 4 window frames 5 "klupica" bench 6 "golubinjaci"-niches in the wall for pigeons 7 "gumno"- threshing front yard 8 courtyard wall ~~9 rustic wooden roof construction~~ 10 "badža"- rustic chimney


1
1
1
1
1


2

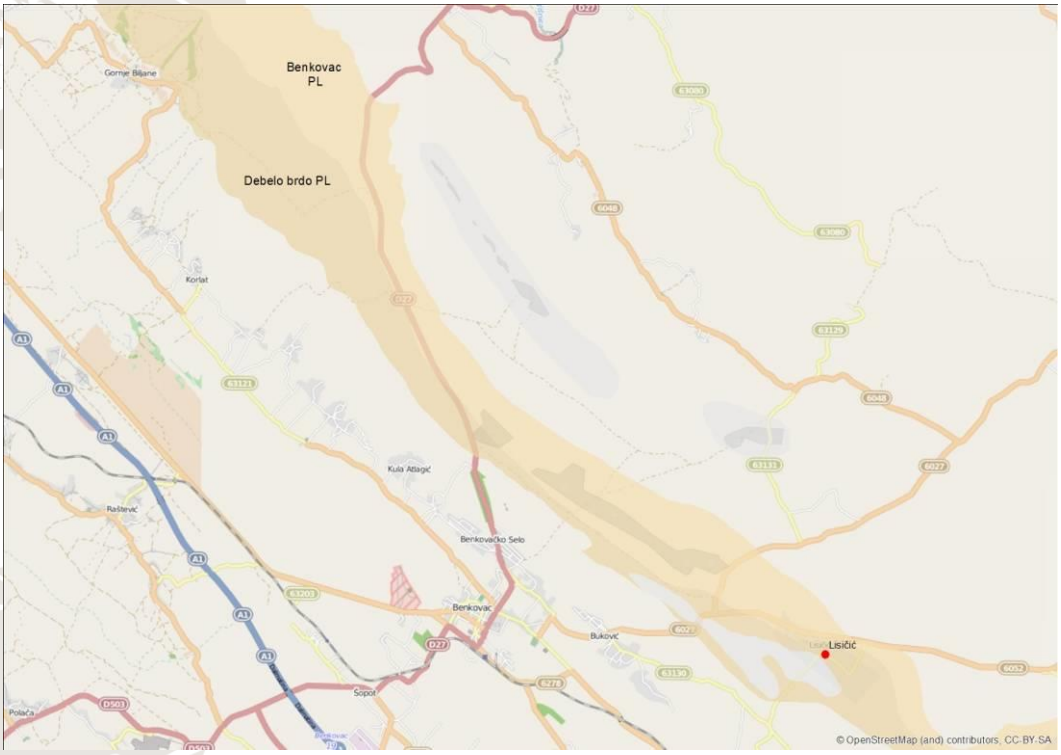

6
5


10


7

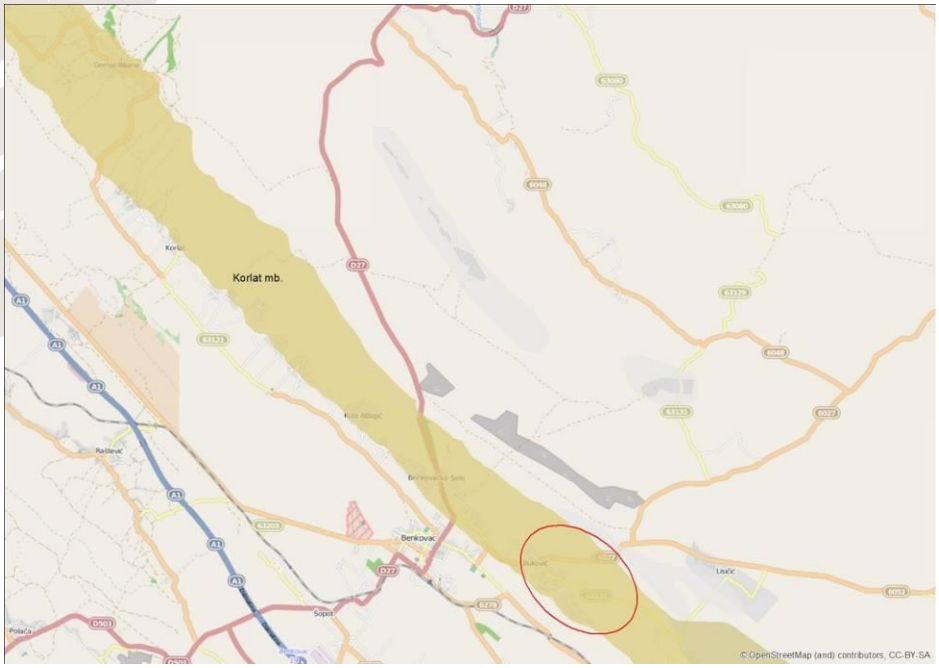
Part of the object (architectural element): **1_roofs, 2 courtyard pavement, 5_"klupica" bench, 6_"golubinjaci"-niches in the wall for the pigeons, 7_"*gumno*"- threshing front yard, 10_"badža"-rustic chimney**

Name of limestone: Benkovac PL
Geol. unit ID (map 1:250,000): 20a, (PL ID) 3120
Name of formation/member/geological unit: BENKOVAC / Benkovac PL
Age: Late Paleogene
Basic lithology: Thin-bedded (platy) yellowish to grayish fine-grained limestone and calcarenite in alteration
Characteristics: Numerous trace fossils and ripple forms
Quarry/delve or source area: The major occurrence of the Benkovac PL is in a wide area NE of Benkovac, possible quarries: Lisičić quarry (ID 3111).



Possible source area for element 1, 2, 5, 6 and 10 (Benkovac PL from Lisičić quarry).

Part of the object (architectural element): **0_walls, 3_corner stones, 4_window frames, 8_courtyard wall**
Name of limestone: Korlat (marlstone and sandstone, Upper part of Flysch)
Geol. unit ID (map 1:250,000): 19*, (PL ID):* 3160 (Korlat member)
Name of formation/member/geological unit: Flysch
Age: Early-Middle Paleogene
Basic lithology: Predominantly alternation of marlstone and calcareous sandstone, sporadically carbonate breccia.
Characteristics: Thick-bedded calcareous sandstone and calcareous breccia-conglomerates with marlstone and fine-grained calcareous sandstone in alteration (upper part of Flysch succession, only in this area).
Quarry/delve or source area: Possible quarries in the wider area of Podgrađe village.



Possible source area for element 0, 3, 4 and 8 (Korlat mb - Upper part of Flysch).

5.3.2. SPLIT-DALMATIA COUNTY (RERA SD)

5.3.2.1. Trogir

Trogir's cathedral of St. Lawrence (Croatian: Katedrala sv. Lovre) is a major sacral building situated in the centre of Trogir. The cathedral is a Roman Catholic triple-naved basilica constructed in Romanesque-Gothic style. Since its construction started in the 12th century and lasted several centuries, it illustrates all the styles that succeeded one another in Dalmatia. It serves now as the most imposing monument in the town of Trogir, which is under protection by UNESCO as a World Heritage Site. Only the cathedral apses are described as a show-case within the RoofOfRock project.

Accessibility: Excellent. The cathedral is located between the main road in the old town of Trogir and the pedestrian centre, both used by public traffic, a few minutes from official parking and the local harbour.

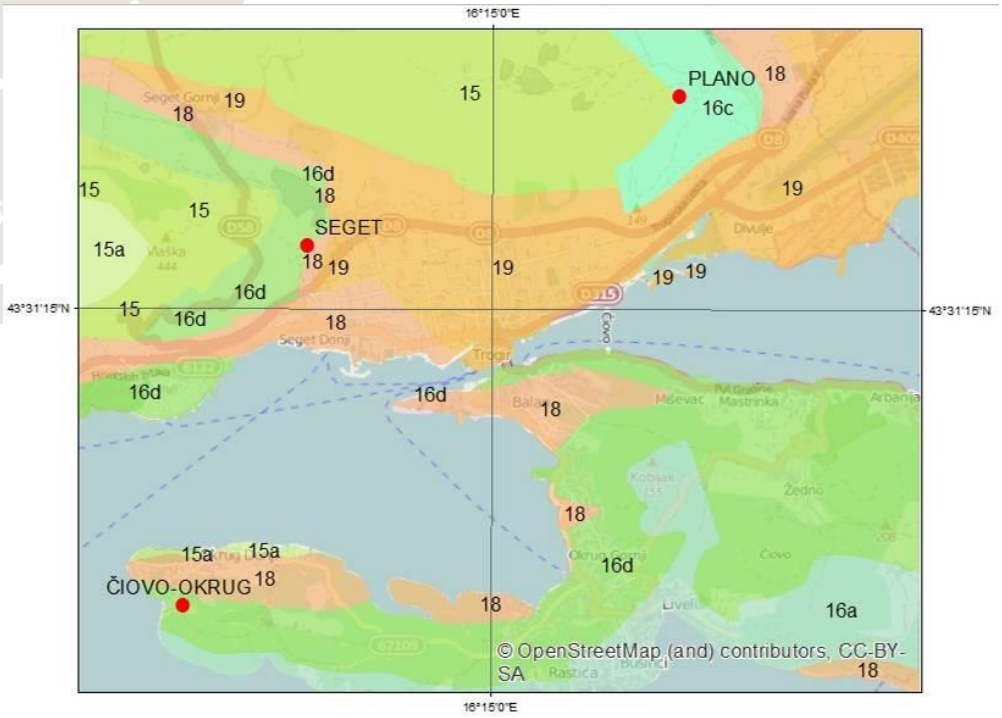
Description number	ID 3300 RERA SD
Prepared by Tvrtko Korbar, Cartography: Nenad Kurtanjek, 29.09.2014.	
Name (official and common):	Trogir cathedral apses
Address (location):	Trogir, Croatia
Cadastral number, community:	3798, 3799, 3800, 3801, 3802 K.O. Trogir
Coordinates:	E=479904 , N=4819708
Typology:	Major cathedral
Investigator (geology):	Tvrtko Korbar
Date of fieldwork:	04.04.2014
Selected limestone elements:	1 walls 2 main roof 5 eaves 47 cornice eaves

Part of the object (architectural element): **1_walls, 5 eaves, 47 cornice eaves (non-platy elements)**

Name of limestone: Pučišća and Seget (Plano)
Geol. unit ID (map 1:250,000): 16b (16c) and 16d
Name of formation/member/geological unit: Pučišća Fm. (Plano Fm.) and Seget Fm.
Age: Campanian
Basic lithology: Pučišća (16b): thick-bedded to massive yellowish- to grayish-white fine to coarse grained bioclastic limestone with rudist fragments; Seget (16d): thick-bedded to massive grayish-white, and porous fine-grained recrystallized bioclastic limestone.
Characteristics: The Pučišća (and Plano Fm.) is characterized by yellowish- to grayish-white *unito* type (grainy limestone) or *fiorito* type (shelly bioclastic, the most common macrofossils are radiolitid rudist shells, e.g. brownish *Biradiolites* sp., while in places huge brown hippuritid rudist shells occur, e.g. *Vaccinites archiaci*, see photos below).

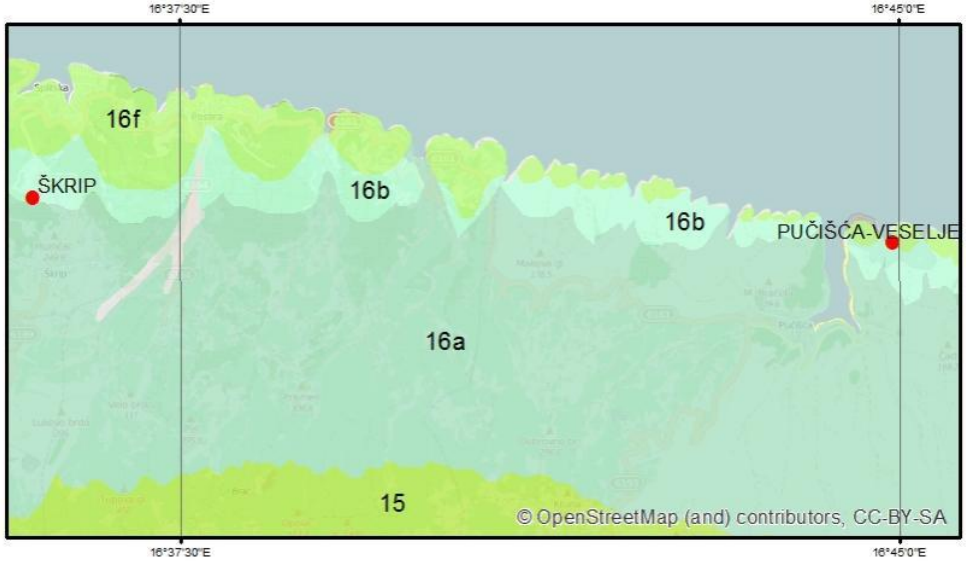
The Seget Fm. is characterized by light-grey recrystallized *unito* type (see photos below).

Quarry/delve or source area:
Seget Fm.(unit 16d) in Trogir area: possible quarries Seget (ID 60) and Čiovo-Okrug (ID 61).
Alternatively: Plano Fm. (unit 16c) NE of Trogir: possible quarry Plano (ID 59).



Possible source area for element 1, 5 and 47 (some of historical local quarries – red dots).

Pučišća Fm. /unit 16b) on the northern-central coastal part of Brač island: possible quarry Škrip (ID 53).



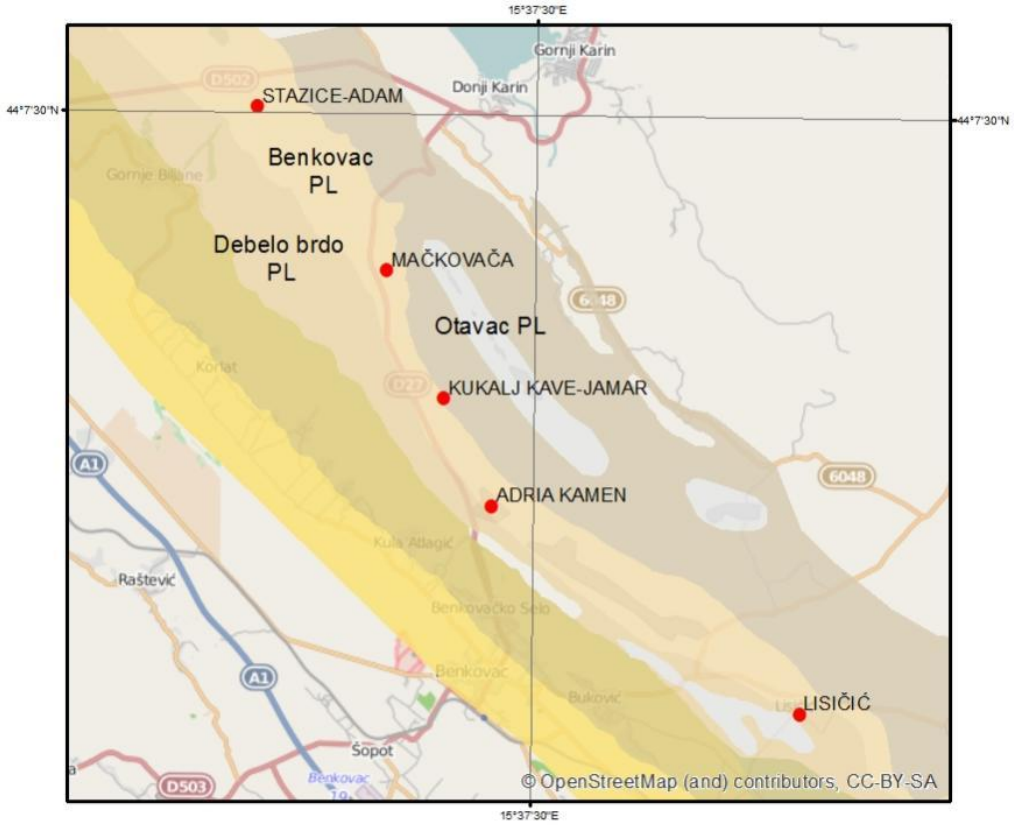
Possible source area for element 1, 5 and 47 (Škrip quarry, Pučišća Fm from Brač island).

Notes: different limestone types of Pučišća and Seget (Plano as possible recent replacements) formations were used for these basic elements. Mostly fine-grained *unito* lithotypes of Pučišća Fm. (along with some possible recent replacements by Plano Fm.) were used for sculpting.

Part of the object (architectural element): **2_main roof**

Name of limestone: Benkovac PL
Geol. unit ID (map 1:250,000): 20a, (*PL ID*) 3120
Name of formation/member/geological unit: BENKOVAC / Benkovac PL
Age: Late Peleogene
Basic lithology: Predominantly thin-bedded (platy) yellowish fine-grained limestone to clayey limestone
Characteristics: Laminated alternation of calcarenite, calcisiltite and calcilutite, commonly with ichnofossils on bedding (plate) surface.

Quarry/delve or source area: Benkovac area (Zadar County), possible quarries: some of the quarries in central part of Benkovac PL unit.



Possible source area for element 2 (some of the quarries in Benkovac PL).

Notes: Benkovac PL probably replaced an ancient roof.

5.3.2.2. Grohote

A group of rural houses "Ruića dvori" is situated in the village of Grohote (the island of Šolta) and is a protected cultural-historical site. The residential complex consists of several houses that are connected through common courtyards mainly used for processing agricultural products. The courtyard contains a stone mill for pressing grapes and olives and a lime storage facility (vapnenica za gašenje vapna). The ground floor is used as a tavern (konoba), while the living area is placed on the first floor which is accessed by an external stone staircase. Its picturesque occurrence was used many times as the setting for the filming of authentic Dalmatian scenes (HTV archives). A major part of the object is owned and governed by the Municipality of Šolta.
Accessibility: Very good. The object is located in the eastern part of the village of Grohote, within walking distance of the official parking lot in the village centre.

Description number	ID 3400 RERA S.D.
Prepared by Tvrtko Korbar, Cartography: Nenad Kurtanjek, 29.09.2014.	
Name (official and common):	o. Šolta, Grohote, Ruića dvori
Address (location):	Ruića dvori 9, Grohote (Šolta), Croatia
Cadastral number, community:	1313 i 1308 K.O. Grohote
Coordinates:	Y=4805719, X=482836
Typology:	Residential complex
Investigator (geology):	Tvrtko Korbar, Ladislav Fuček
Date of fieldwork:	10.04.2014
Selected limestone elements:	1 walls 2 main roof 4 eaves 6 corner stones 7 window frame 9 doorpost 11 stairs 12 outside pavement 18 stone bordure 19 vault 37 window consoles 38 stair enclose consoles 39 wall cover 40 openings (ponare) 41 grapes stone mill 42 olive stone mill 43 lime storage (vapnenica) 44 bench 45 chimney 46 stone game (trilja)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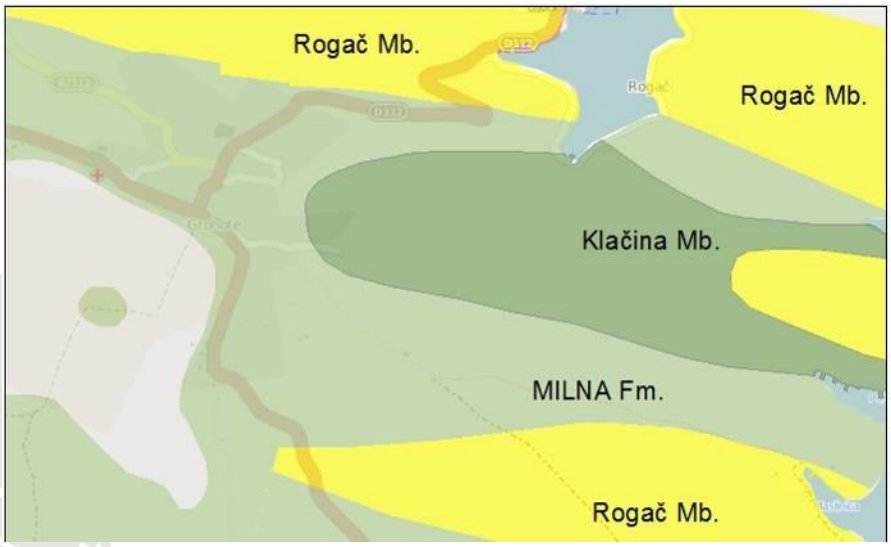
Part of the object (architectural element): **1_walls, 6_corner stones, 11_stairs, 19_vault, 38_stair enclose consoles, 40_openings (ponare), 41_grapes stone mill, 42_olive stone mill, 43_lime storage (vapnenica), 44_bench, 45_chimney, 46_stone game (trilja)**

Name of limestone: Milna/Klačina
Geol. unit ID (map 1:250,000): 14 (central part of Šolta island), (*PL ID*): 3450
Name of formation/member/geological unit: Milna Fm./Klačina Mb.
Age: Cenomanian
Basic lithology: Mostly well-bedded (thick- to medium-bedded) horizontally-laminated brownish-grey skeletal (grainy) limestone to peloidal (micritic) limestones.
Characteristics: Horizontally laminated skeletal limestones contain microgastropods (see photos below),

and micritic limestones, which in places contain brown requieniid-rudist shells (see photos below).

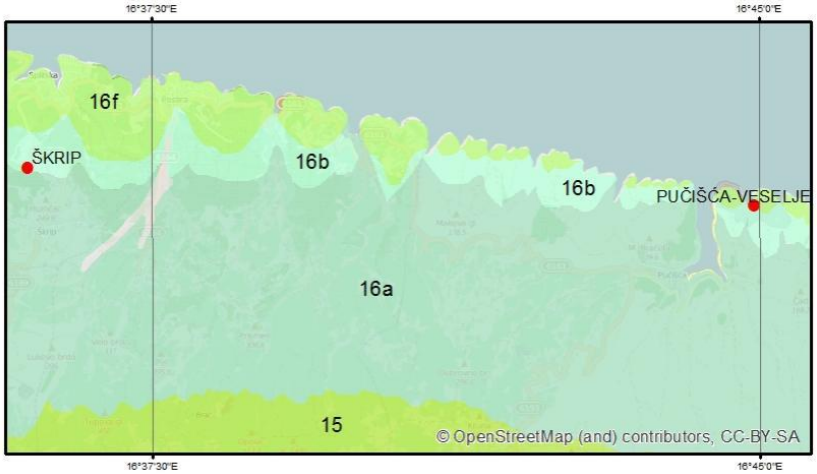
Quarry/delve or source area: Local material of various Milna Fm. limestone lithotypes (mostly Klačina Mb.), outcropping in Grohote area. It could possibly be a case of strictly local excavation of the blocks.



Possible source area for non-standardised massive elements (local limestone from Klačina Mb.).

Notes: All locally used elements are characterized by rugged surfaces, since they were produced using simple hand tools. All types of limestone from the unit were used for these elements.

Part of the object (architectural element): **7_window frame, 9_doorpost, 37_window consoles**
Name of limestone: Pučišća.
Geol. unit ID (map 1:250,000): 16b
Name of formation/member/geological unit: Pučišća Fm.
Age: Campanian
Basic lithology: Pučišća: thick-bedded to massive yellowish- to grayish-white fine to coarse grained bioclastic limestone with rudist fragments.
Characteristics: The commonly used lithotype of Pučišća Fm. for standardized construction elements is characterized by yellowish to light-grey *unito* grainy limestone.
Quarry/delve or source area: Pučišća Fm. (unit 16b) on northern-central coastal part of Brač island (possible quarries: Škrip ID 53 and Pučišća ID 54). See map.



Possible source area for elements 7, 9 and 37 (Pučišća Fm from Brač island).

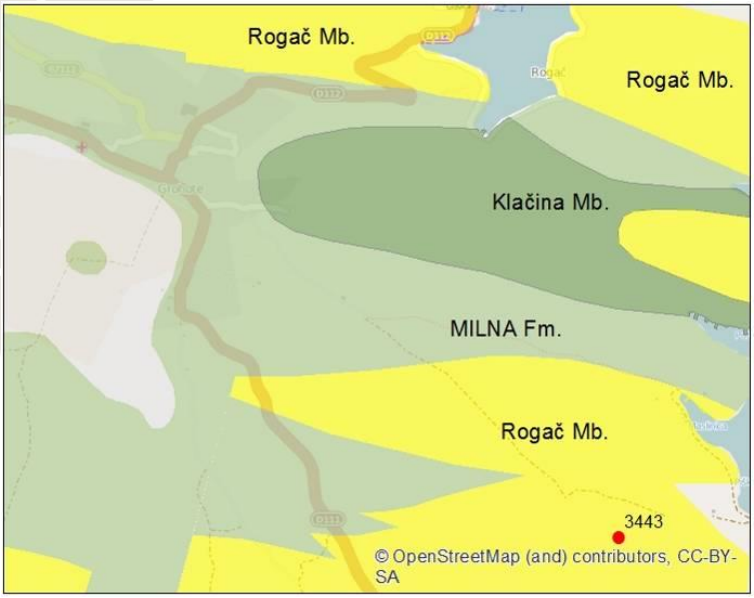
Notes: These standardized elements are characterized by smooth surfaces, since they were produced on machines in a professional manufacturing process.

Part of the object (architectural element): **2 main roof, 4 eaves, 12 outside pavement, 18 stone bordure, 39 wall cover (all marked on the photograph above)**

Name of limestone: Rogač.
Geol. unit ID (map 1:250,000): 14 (*PL ID*) 3440
Name of formation/member/geological unit: Milna Fm./Rogač Mb.
Age: Cenomanian
Basic lithology: Thin-bedded (platy) fine grained grayish skeletal packstones and cyanobacterial laminites.
Characteristics: In places soft-sediment (plastic) folding.

A typical Rogač PL limestone plates 30x20x2 cm

Quarry/delve or source area: Rogač Mb. (PL ID 3440) in central part of the island of Šolta (Grohote area), probably Trzavica quarry (ID 3443).



Possible source area for platy elements (local quarry in Rogač Mb.).

Notes: There are also other platy limestone quarries on the island of Šolta, but traditionally inhabitants usually used the material that was most easily accessible (nearby).

5.3.2.3. Blaca

The Blaca hermitic monastery is today a museum situated in a distant location on the SE part of the island of Brač. The hermit monks built the first objects of the complex in the 16th century. Today the complex is governed by Centar za kulturu Brač and is a protected cultural heritage.
Accessibility: Walking! The monastery can be accessed only by a 30-minute walk downhill from the parking lot at the end of a long (some kilometres) macadam road, branching from a local asphalt road to Vidova gora (southern branch of the main road Supetar-Gornji Humac) in Nerežišća municipality. Some tourist agencies also offer a visit to the monastery by boat to Blaca cove, followed by a 45-minute walk uphill.

Description number	ID 3602 RERA S.D.
Prepared by Tvrtko Korbar, Cartography: Nenad Kurtanjek, 29.08.2014.	
Name (official and common):	Blaca hermitic monastery, “Pustinja Blaca”
Address (location):	Nerežišća bb, Brač, Croatia
Cadastral number, community:	*34, Nerežišća
Coordinates:	Y=4794800, X=502400
Typology:	monastery (museum) complex
Investigator (geology):	Tvrtko Korbar, Ladislav Fuček
Date of fieldwork:	15.05.2014
Selected limestone elements:	1 walls 2 main roof 5 eaves 7 window frame 9 doorpost 12 outside pavement 41 stone grape mill 48 bee farm/plates for bee houses

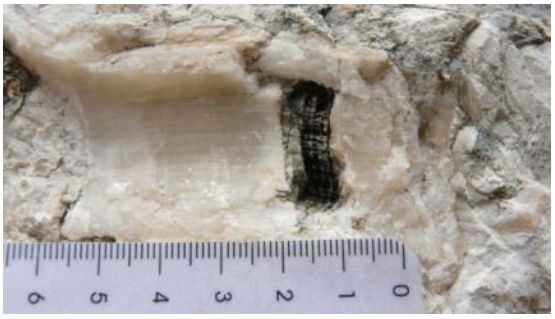
Part of the object (architectural element): **1_walls**

Part of the object (architectural element): **41_ stone grape mill:**

Part of the object (architectural element): **12_outside pavement**

Name of limestone: Gornji Humac
Geol. unit ID (map 1:250,000): 15 (SW part of Brač)
Name of formation/member/geological unit: Turonian - Santonian (Gornji Humac Fm.)
Age: Turonian - Santonian
Basic lithology: Mostly well-bedded skeletal micritic to peloidal limestones with rudist bivalves.
Characteristics: The Gornji Humac (unit 15 on Brač) is characterized here by alternation of brownish-grey skeletal, micritic to grainy, in places laminated limestone,

and bioclastic limestones, which almost exclusively contain radiolitid rudist shells.



Quarry/delve or source area: Limestone of Gornji Humac Formation was most probably excavated on the site of the house in question.

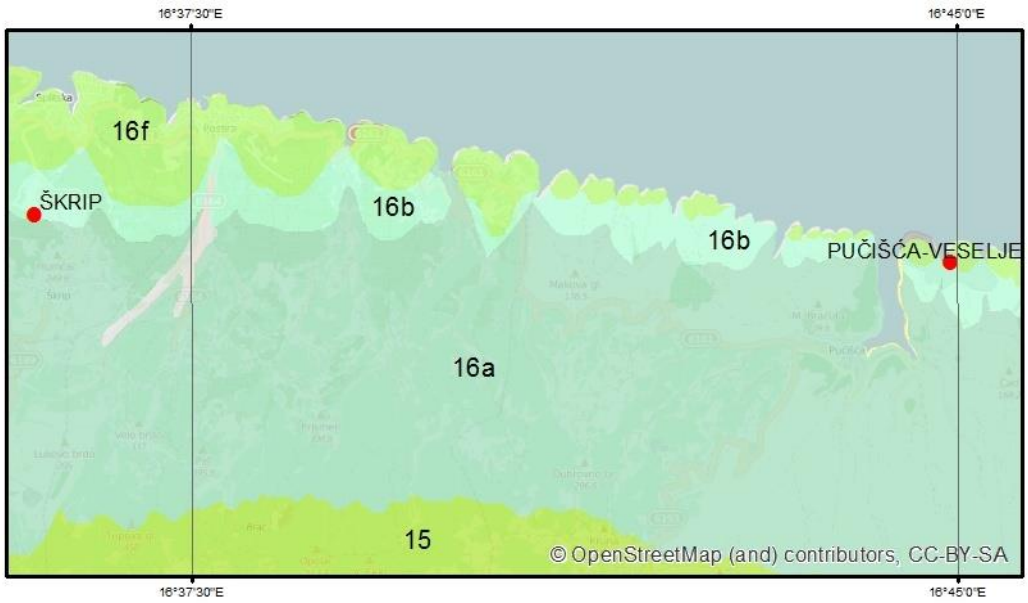
Possible source area for elements 1, 41 and 12 (local limestone of Gornji Humac Fm).

Notes: In the basement and the background of the complex, there are natural outcrops of subhorizontal thick-bedded and medium-bedded limestones. The constructors used bedding discontinuities and a nearly perpendicular joint system to excavate and use building blocks for basic elements (walls, streets, frames...), even as a base for *in situ* construction of some facilities within the original rock (e.g. basement for grape/olive pressure system). All autochthonously excavated building elements are characterized by a coarse-finish produced by hand tools. All types of limestone from the Gornji Humac formation were used for the basic elements.

***Part of the object (architectural element):* 7_window frames**

Part of the object (architectural element): **9_doorpost**

Name of limestone: Pučišća
Geol. unit ID (map 1:250,000): 16b
Name of formation/member/geological unit: Pučišća Fm.
Age: Campanian
Basic lithology: Pučišća: thick-bedded to massive yellowish- to grayish-white fine to coarse grained bioclastic limestone with rudist fragments.
Characteristics: The elements are characterized by finer-grained *unito* limestone with rare rudist bioclasts (fragments).
Quarry/delve or source area: Pučišća Fm. (unit 16b) on northern-central coastal part of Brač island (possible quarries: Škrip and Pučišća-Veselje). See map below.



Possible source area for elements 7 and 9 (Pučišća Fm from Brač island).

Notes: standardized elements are probably delivered by a professional stone cutter, and could also be replacements.

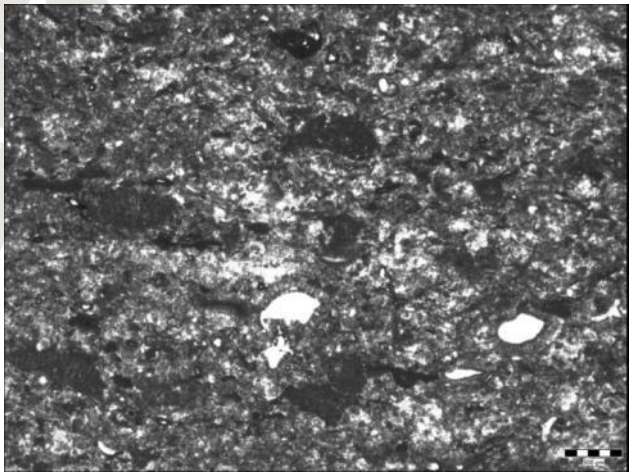
Part of the object (architectural element): **2_roofs, 5 eaves**

Part of the object (architectural element): **48_bee farm / plates for bee houses**

Name of limestone: Gornji Humac PL and Gračišće PL
Geol. unit ID (map 1:250,000): 15 (*PL ID*) 3630 and 3620
Name of formation/member/geological unit: Gornji Humac Formation/ Gornji Humac PL and Gračišće PL
Age: Turonian - Santonian

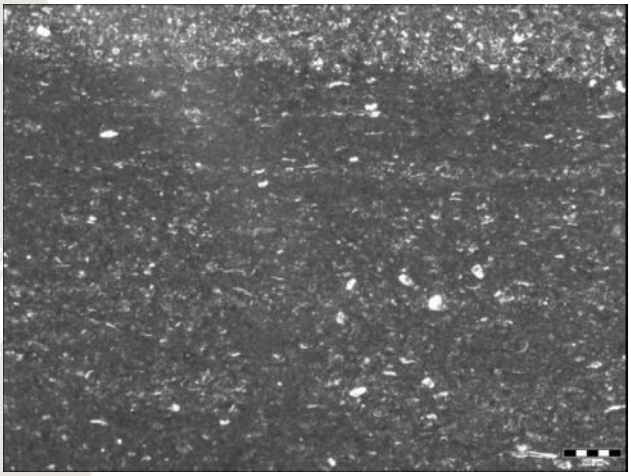
Basic lithology: Mostly well-bedded and platy skeletal micritic to peloidal limestones with rudist bivalves. Micritic limestones with rare calcispheres appear in places.
Characteristics: Gornji Humac PL is characterized by skeletal limestone and >30% of the unit thickness is platy limestone, while Gračišće PL is mostly micritic and <30% is platy limestone, although all basic lithologies alternate within both units. Thus, various lithotypes were used for the construction of roofs, and it is not possible to assign the plates to one of these two units.

A typical plate of laminated skeletal limestone 30x20x2 cm.


Microphotograph of the typical plate, skeletal peloidal limestone with *Thaumatoporella* and *Decastronema*. Scale bar 500 µm.

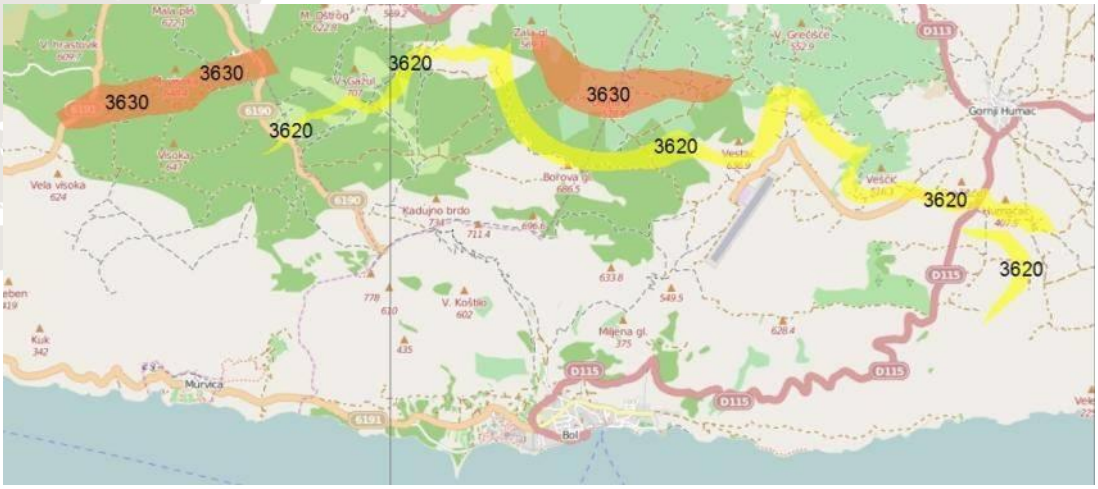
Huge and regularly thick plates of indistinctly laminated micritic limestone with calcispheres, mostly originally used for construction of the bee houses can be found in places within the Gornji Humac PL and Gračišće PL.

A huge limestone plate 90x50x3 cm.



Microphotograph of the huge limestone plate, micritic limestone with rare calcisphere. Scale bar 500 µm.

Quarry/delve or source area: PL (PL ID 3620) in central part of the island of Brač.



Possible source area for elements 2, 5 and 48 (PL units 3620 and 3630 from Brač island).

Notes: It is also possible that some plates originate from some other small local occurrence of PL from the Gornji Humac Fm. (from the Blaca surroundings). The majority of the plates for bee houses are of concrete (replacements?), but all bee houses are devastated.

5.3.3. DUBROVNIK-NERETVA COUNTY (DUNEA)

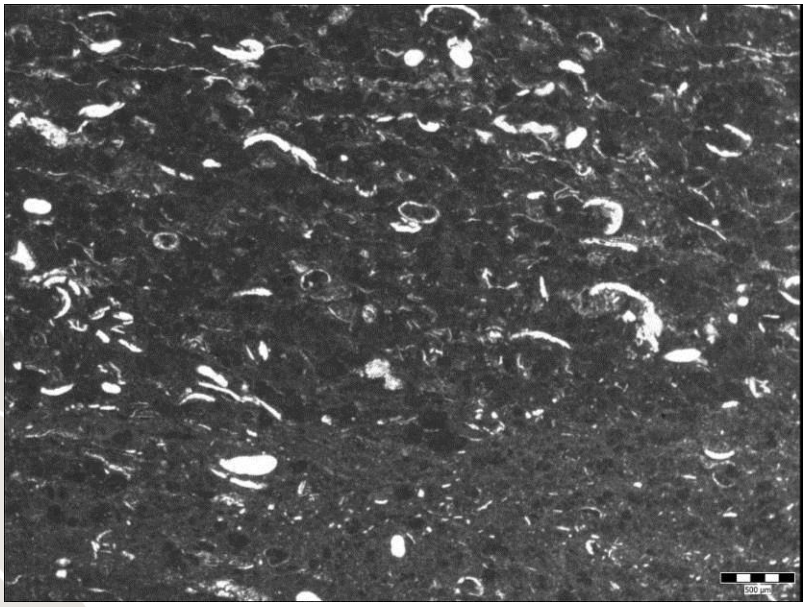
5.3.3.1. Vela Luka

Here an arbored walk by the cemetery of St. Roko (Aleja kod groblja sv. Roko). A typical dry stone wall stable with a rectangular floor plan and inner concrete divider wall for keeping a donkey. By the side wall is a smaller annex (demolished), and in front of the house there are two small eaves, and a vaulted water cistern. The object is one of 20 almost identical dwellings that were surely built after 1880, because they are not in the Austrian Empire cadastral map. There is an unconfirmed story, that the houses serving the agricultural use of the local community were built between the two World Wars, as a reaction by the local residents to have a new road to the cemetery. The main gable roof, eaves roofs, doorpost and terrace around the water cistern were built of platy limestone. The main object is in good shape, but two smaller eaves roofs need reconstruction of the plates.
Accessibility: Excellent. Very close to the main road to the cemetery of St. Roko (Vela Luka).

Description number	ID 3861 DUNEA
Prepared by Damir Palenik, Cartography: Nenad Kurtanjek, 28.08.2014.	
Name (official and common):	VELA LUKA - Štala/stable
Address (location):	Aleja kod Groblja / Arbored walk by the cemetery of St. Roko
Cadastral number, community:	1769/1, Vela Luka
Coordinates:	E= 518075, N= 4757874
Typology:	Single cell house with added smaller one (demolished)
Investigator (geology):	Korbar Tvrtko, Fuček Ladislav
Date of fieldwork:	16.4.2014
Selected limestone elements:	0 walls 1 main roof 2 eaves roofs 3 corner stones 4 doorpost (wooden and platy limestone) 5 window frame ~~6a lintel (wooden)~~ ~~7 divider wall - of concrete~~ 8 outside pavement 9 yard wall 10 cistern

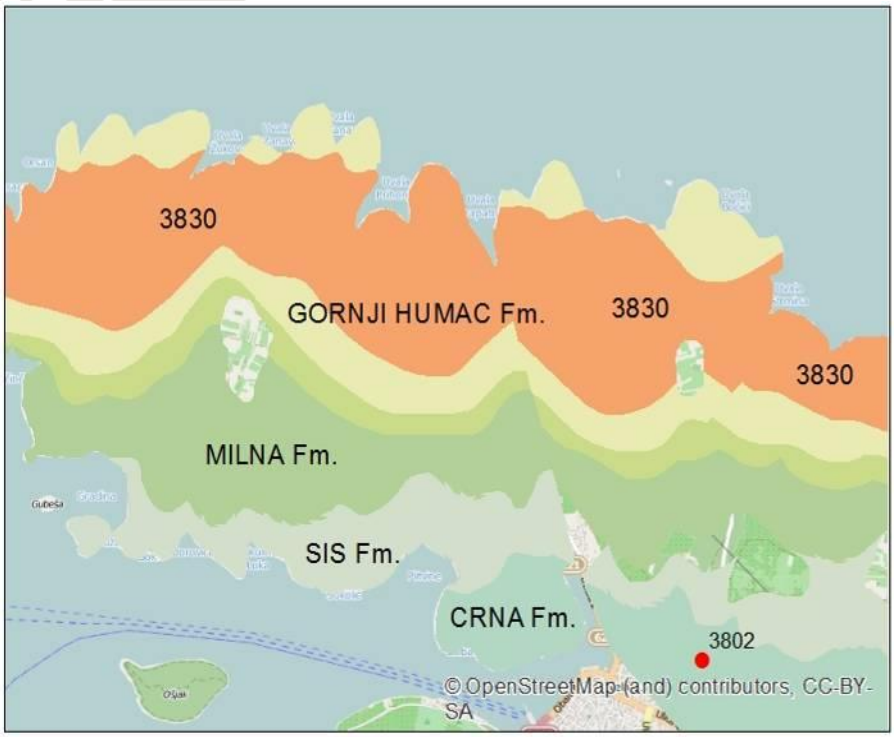
Part of the object (architectural element): **1_main roof, 2_eaves roofs**

Name of limestone: Crna PL and Gornji Humac-PL-Vela Luka
Geol. unit ID (map 1:250,000): 13 and 15, (*PL ID*): 3840 (Crna Fm.) and 3830 (Gornji Humac-PL-Vela Luka)
Name of formation/member/geological unit: Crna Fm. and Gornji Humac Fm.
Age: Albian-Cenomanian (Crna Fm.), Turonian-Santonian (Gornji Humac Fm.)
Basic lithology: Albian-Cenomanian (Crna Fm): predominantly crystalline dolomites and limestones, with intercalations of micritic to grainy limestones, rarely platy limestone intercalations; Gornji Humac: Mostly well-bedded skeletal micritic to peloidal limestones with rudist bivalves. In places micritic limestones with calcispheres. Localy thick-bedded to massive recrystallized fine to coarse-grained intraclastic-bioclastic grainy limestones.
Characteristics: Crna Fm. - limestone: mostly platy to thin-bedded bioclastic wackestone with ostracods and benthic foraminifera, rare bivalves.
Gornji Humac-PL-Vela Luka limestone – lithological characteristics: Alteration of medium and thin-bedded (platy) limestones. Platy limestones (> 30%) are mainly represented by laminites which show microbial influence on the sedimentation. Gornji Humac-PL-Vela Luka limestone – paleontological characteristics: contain Turonian-Santonian microfossils association (mostly benthic foraminifera, algae - aeolisacus and thaumatoporellas) and macrofossils (rudists).



Microphotograph of the plate of Crna Fm.: carbonate micrite sediment made of tiny rounded micrite particles with sparse tiny fossils fragments (mostly ostracods and bivalves). Scale bar 500 µm.

Quarry/delve or source area: Vela Luka area (on Korčula Island). Local occurrence of platy limestone (ID 3802) of Crna Fm in the vicinity of the object belonging to the unit. Gornji Humac-PL-Vela Luka: In the northern part of the island of Korčula there is a major zone of the unit (unit 3830).



Possible source area for elements 1 and 2 (local PL from unit 3830 and locality 3802).

Notes: the main and eaves roofs are covered with both types of limestone from Vela Luka area (Crna Fm. and Gornji Humac-PL-Vela Luka).

Part of the object (architectural element): **0_walls, 3_corner stones, 4_doorpost, 5_window frame, 8_outside pavement, 9_yard wall, and 10_cistern**

Name of limestone: Crna
Geol. unit ID (map 1:250,000): 13
Age: Albian-Cenomanian

Basic lithology: predominantly crystalline dolomites and limestones with intercalations of micritic to grainy limestones.
Characteristics: mostly medium to thick-bedded mudstones and skeletal wackestone with ostracods and benthic foraminifera, rare bivalves.
Quarry/delve or source area: Vela Luka area (on Korčula Island). Near and around the object there are outcrops of Crna Fm. See map above.
Notes: walls, corner stones and window frame of the object are built of different limestone types of Crna Fm. from the vicinity, and strictly local material.

5.3.3.2. Žrnovo

Agriculture housing – single cell houses (kućice). Partially buried in the terrain, a set of three houses built in traditional coastal style are connected together, forming a small courtyard which is enclosed by a boundary wall. A few meters from the objects there is a small quarry inside the lot, leading only one – through the common courtyard of these three houses. In the cadastral map of 1836 (revision 1880) the objects are not visible, although near the lot there is a significant widening of the road, probably indicating that the quarry was exploited at the time. The main roofs, courtyard tiling and terrace over the water cistern were built with platy limestone and all of these elements are well preserved, except the roof ridge, which needs fixing.
Accessibility: Excellent. Parking at the main road crossing, 100 m from the object.

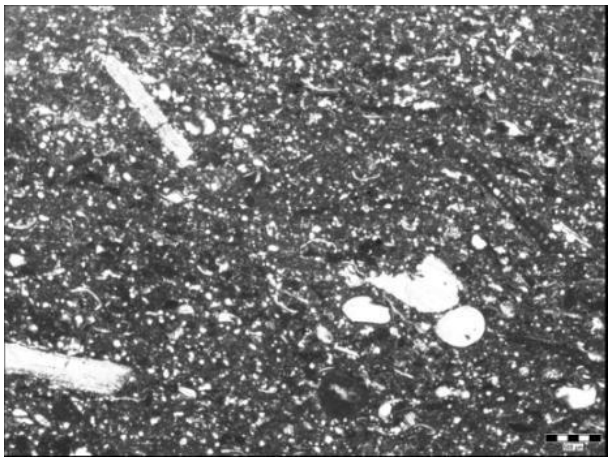
Description number	ID 3855 DUNEA
Prepared by Damir Palenik, Cartography: Nenad Kurtanjek, 28.08. 2014.	
Name (official and common):	ŽRNOVO - kućice
Address (location):	Pod Veli vrh
Cadastral number, community:	6159/2 , Postrana / Žrnovo - Korčula
Coordinates:	E= 549253 , N= 4755138
Typology:	Single cell houses
Investigator (geology)*:*	Tvrtko Korbar
Date of fieldwork:	30.11.2013
Selected limestone elements:	0 walls 1 main roof 2 corner stones 3 gutter 4 roof ridge covered with slate eaves 5 window frame 6 doorpost 7 threshold 8 relieving opening 9 scarp of cistern 10 rim of cistern 11 yard wall

Part of the object (architectural element): **0 walls, 1 main roof, 2 corner stones, 3 gutter, 4 roof ridge covered with slates eaves, 5 window frame, 6 doorpost, 7 threshold, 8 relieving opening, 9 scarp of cistern, 10 rim of cistern, 11 yard wall – ALL ELEMENTS**

Name of limestone: Milna limestone (Žrnovo type)
Geol. unit ID (map 1:250,000): 14, (*PL ID*): 3820
Name of formation/member/geological unit: Milna Fm./Milna-PL-Žrnovo
Age: Cenomanian
Basic lithology: Milna-PL-Žrnovo is composed of alternation of medium- to thin-bedded, platy and thick bedded bioclastic limestones with rudists. Platy limestones (about 20% of the unit) are mainly composed of skeletal wackestones and packstones.

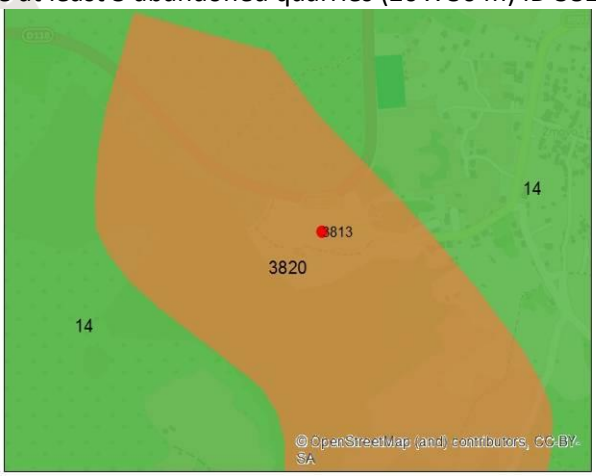
One of small Žrnovo-Podstrana quarries of platy and thick-bedded limestone of Cenomanian age.

Characteristics: The Milna-PL-Žrnovo limestones (on Korčula Island) contain the Cenomanian fossils association, mostly benthic foraminifera and other marine microfossils as well as macrofossils of rudist bivalves.



Microphotograph of the bioclastic wackestone-packstone, which include foraminifer *Pastrikella* sp. Scale bar 500 µm.

Quarry/delve or source area: ŽRNOVO-POSTRANA area on Korčula Island (unit 3820), possible quarries: in close vicinity to this object are at least 3 abandoned quarries (20 X 30 m) ID 3813.



All the elements are from the local quarries.

One of smaller Žrnovo-Podstrana quarries of thick-bedded limestone of Cenomanian age and the show-case house behind.

Notes: All elements (parts of the object) of these rural houses are built from different types limestone of Milna-PL-Žrnovo units (Milna Fm.). All platy, thin- and thick-bedded limestone for construction are from nearby, from abandoned quarries very near these rural houses. See photo above.

5.3.3.3. Nakovana

Residential houses with auxiliary objects – two storey houses with a detached kitchen (konoba), bread oven (krušna peć), threshing floor and stone mill. Square ground plan, built of processed limestone blocks and finished in lime mortar, inner plastering, door and window lintels, eaves, windows with iron fittings. There are indications that the area around this village was inhabited 8000 years ago, but the first mention of the place (Nacovalda) was recorded in 1335. Two villages, Upper and Lower Nakovana, belonged to the space Trstenice, administrative units of the Dubrovnik Republic since the 14th century, when previous settlements formed in two present-day villages in the Middle Ages. The whole area of the Nakovana plateau saw continuous life from Neolithic times until W.W. II., due to people moving to the coastal area and to emigration. The village can be seen on the cadastral map from 1836 (revision 1880), including a drawing of the buildings. Specific pottery remains and fragments were found in nearby Neolithic caves and were designated Nakovana culture. Platy limestone is mainly used for building roof surfaces, residential and kitchen houses, chimneys, pavement, scarp of water cistern, eaves, tables and benches. Although the structure of most objects is well preserved, several of them need new roofs or a complete roof reconstruction, while some of the objects simply need rearrangement of the limestone plates.
Accessibility: Very good. Very near the main road between Viganj and Lovište (Pelješac peninsula), with a big parking lot.

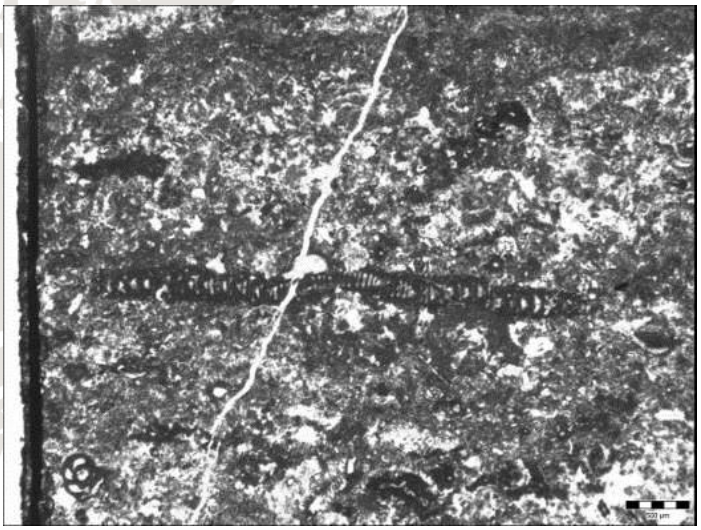
Description number	ID 3952 DUNEA
Prepared by Nenad Oštrić, Cartography: Nenad Kurtanjek, 28 .08.2014.	
Name (official and common):	Donja NAKOVANA / "U Cvitka"
Address (location):	Nakovanj bb
Cadastral number, community:	49.2 / 49.3 /49.4 / 49.5 /, Orebić
Coordinates:	E= 547497, N= 4762717
Typology:	Two storey houses with dislocated kitchen (konoba), bread oven (krušna peć), threshing floor and stone mill
Investigator (geology)*:*	Oštrić Nenad, Fuček Ladislav
Date of fieldwork:	7.05.2014
Selected limestone elements:	0 walls: 1 main roof 2 eaves: 3 window frame 4 doorpost 5 corner stone 6 stairs 7 courtyard pavement 8a rim of cistern 8b scarp of cistern 9 stone mill 10 consoles 11 threshing floor

***Part of the object (architectural element)*: 0_walls, 5_corner stone, 6_stairs, 11_threshing floor, 7_courtyard pavement**

Name of limestone: Milna limestone.
Geol. unit ID (map 1:250,000): 14
Name of formation/member/geological unit: Cenomanian – Turonian (Milna Fm.)
Age: Cenomanian
Basic lithology: Well-bedded micritic to grainy limestones with rudists and chondrodonts, only in places they are thick-bedded to massive.
Characteristics: Well-bedded micritic to grainy and skeletal limestones with rudists.
Quarry/delve or source area: Milna Fm. limestone lithotypes (unit 14), outcropping in Donja Nakovana village area. Strictly local excavation of the blocks is also possible. See map below.

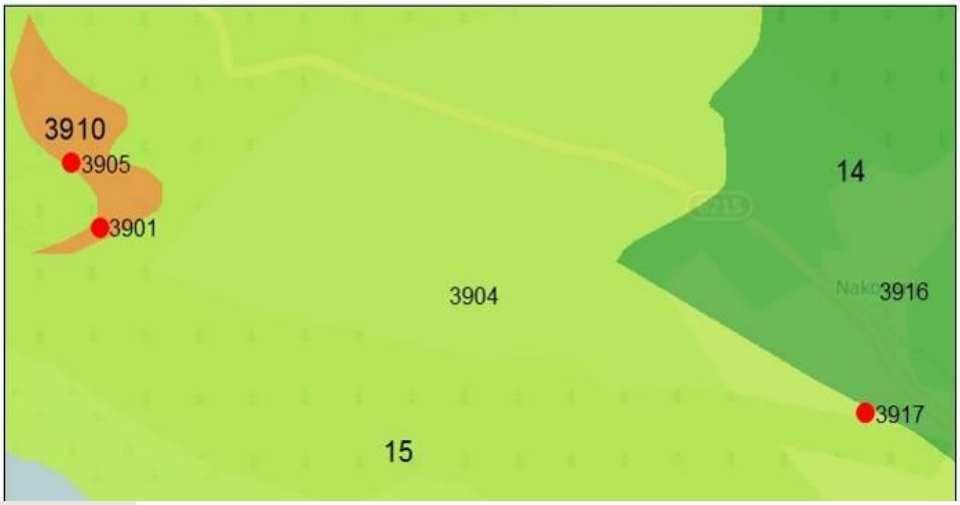
***Part of the object (architectural element)*: 1_main roof, 2_eaves, 8a_rim of cistern, 8b_scarp of cistern**

Name of limestone: Milna PL – Pelješac / Gornji Humac PL - Pelješac
Geol. unit ID (map 1:250,000): 14 , (*PL ID*): 3917 and 3910
Name of formation/member/geological unit: Cenomanian (Milna Fm.) / Turonian – Santonian (Gornji Humac PL)
Age: Cenomanian / Turonian - Santonian
Basic lithology: In Milna PL – Pelješac there is an alternation of thin-bedded, platy and laminated micritic to grainy limestones which are partly recrystallized and in places they contain reddish cyanobacterial laminas. Gornji Humac PL - Pelješac unit is composed of thin-bedded micritic to grainy limestones.
Characteristics: Thin-bedded, platy and laminated micritic to grainy limestones in places contain calcispheres, thaumatoporellas and aeolisacus as well as lithosomes of rudists.



3916_S1. *Pastrikella balcanica* from Milna PL – Pelješac in fine-grained peloidal packstone. Scale bar 500 µm.

Quarry/delve or source area: In the area of DONJA NAKOVANA village there is local occurrence of Milna PL – Pelješac in an abandoned quarry (ID 3917). The closest and biggest outcrops of Gornji Humac PL – Pelješac (ID 3910) appear near LOVIŠTA, a few kilometers to the west (ID 3901). See map below.

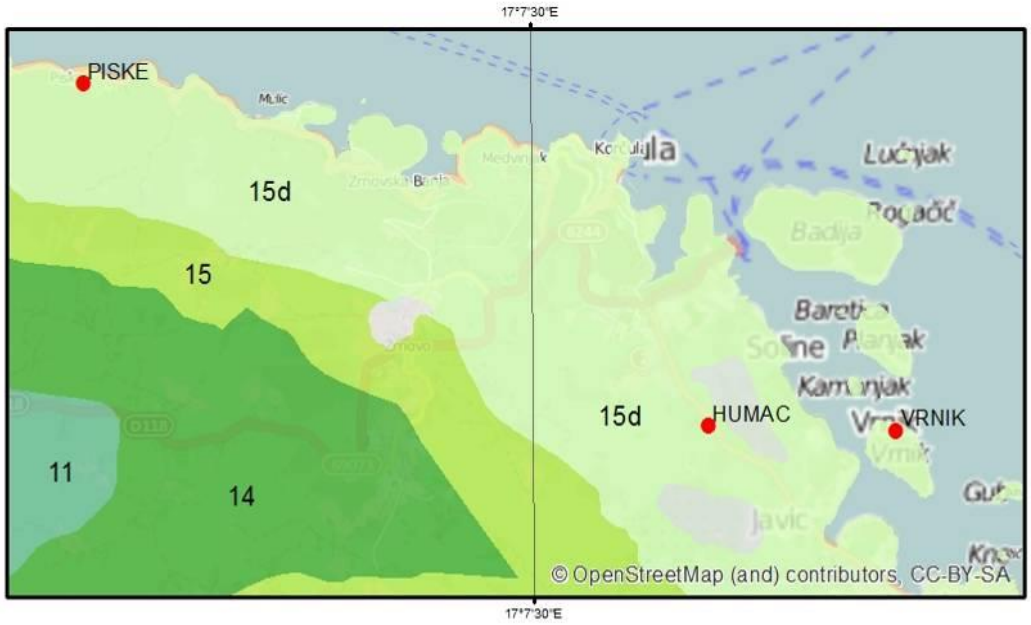


Possible source area for elements 1, 2, 8a and 8b (local PL from unit 3910 and locality 3917).

Notes: roofs are covered with the both types of platy limestone, Milna PL – Pelješac and Gornji Humac PL – Pelješac.

***Part of the object (architectural element)*: 3_window frame, 4_doorpost, 9_stonemill, 10_consoles**

Name of limestone: Korčula limestone
Geol. unit ID (map 1:250,000): 15d
Name of formation/member/geological unit: Korčula
Age: Turonian - Santonian
Basic lithology: Thick-bedded to massive light-grey to brownish bioclastic limestones with rudist fragments.
Quarry/delve or source area: Korčula limestone (unit 15d) and possible quarries Piske (ID250: 69), Humac (ID250: 70) or Vrnik (ID250: 71). See map.



Possible source area for elements 3, 4, 9 and 10 (some of the quarries around the town of Korčula).

Notes: The architectural elements that are mentioned above (3, 4, 9 and 10) were carved from the blocks of limestones from quarries on the nearby island of Korčula. The standardized elements were probably produced by a professional stone cutter.

5.4. SUMMARY FOR SHOW-CASE OBJECTS

5.4.1. Zadar County (ZADRA)

In Zadar County (ZADRA), 2 objects are situated in the coastal mainland area (Nin surroundings and Zadar old town), 2 objects in Ravni kotari area in the hinterland (Medviđa and Podgrađe villages), and 1 object is situated on the island of Dugi otok (Savar village). The church of St. John The Baptist (Crkva sv. Ivana Krstitelja) is a sacral building (the cemetery church in the village of Medviđa). The church of St. Nicholas (Crkva sv. Nikole) is a sacral building, in occasional use, and owned by "Muzej ninskih starina" (Nin). The streets and squares of downtown Zadar have been covered with stone slabs several times throughout history. The church of St. Peregrine (Crkva sv. Pelegrina) on Dugi otok is a pre-Romanesque sacral building of the central type from the 9th century and is protected cultural heritage. Home "Čerina dvori" is a complex of private family houses in the village of Podgrađe village near the town of Benkovac. Accessibility to all objects is very good via asphalt roads, either by car or bus, with spacious parking.

Platy limestone elements used on roofs of the mainland objects mostly originate from Benkovac PL, which is a major regional source for platy limestone commonly used as both an original and replacement material. The objects located in the outcropping area of Benkovac PL are built from the platy limestone from strictly local sources, small abandoned quarries or material gathered in the fields. Platy elements on the roof of Savar (Dugi otok) originate from a local source (local occurrence of platy limestone of Cenomanian age). Some of the street signs in Zadar, especially those protected as historical sites, originate from the Cenomanian of Lavdara island, and are characterized by their large size and original bedding surfaces.

Building blocks for walls and other non-standardized elements on all 4 rural objects are mostly strictly local, from the place itself or within the vicinity of the objects. These are various Upper Cretaceous and Paleogene units outcropping in the areas.

Manufactured elements characterized by standardized dimensions mostly originate from one of the major historical quarries in massive grainy limestone characterizing some geological units. The most probable quarries in the area of Zadar county are those located in the central part of the island of Dugi otok (Borišina-Ovča), characterized by the occurrence of massive and grainy material which is suitable for the formation of bigger elements and for sculptures. All original manufactured elements are characterized by coarse-finishing produced by hand tools. However, some more recent replacements come largely from the major quarries on the island of Brač (Pučišća unit). The replacements are characterized by fine-finishing produced by machines. Besides, all historical (the oldest) blocks used for Zadar's downtown streets originate from Lavdara island (brownish to reddish limestone of Cenomanian age), which is obviously recognized as a major place of excavation of these semi-manufactured elements (using of natural bed thickness) owing to the accessibility to these coastal outcrops of subhorizontal medium- to thick-bedded and sporadically platy limestones by boat. However, most of the present day replacements on the streets in Zadar also originate from major but distant historical quarries located on the island of Brač (Pučišća and Dol formations from quarries located in Pučišća and Škrip).

5.4.2. Split-Dalmatia County (RERA SD)

In Split-Dalmatia County 1 object is situated in the centre of the coastal (mainland) town of Trogir (Trogir cathedral), 1 object on the island of Brač (Blaca monastery), and 1 object on the island of Šolta (Grohote village), in the wider Split region. The Trogir cathedral is a major sacral building

situated in the centre of the historical town of Trogir, which is under protection of UNESCO. A group of residential houses with auxiliary objects "Ruića dvori" is situated in the village of Grohote village on the island of Šolta. The Blaca hermitic monastery today is a museum situated in a remote location on the SE part of the island of Brač.

Platy limestone used on the Trogir cathedral apses roofs has probably replaced with Benkovac PL. There is a question of possible local origin of the original plates, seeing as there is a lot of platy limestone material outcropping in the wider Trogir area (see chapter PLATY LIMESTONE).

Platy limestone used for roofs in Blaca monastery originates from platy horizons appearing within broadly distributed Gornji Humac PL and Gračišće unit, characterized mostly by medium- to thick-bedded limestones. Major occurrence of these units is between Fantovi doci and Gornji Humac villages, while the later is characterized by PL quarries that were active until 2012.

Platy limestone used in "Ruića dvori" originates from a local source, i.e. from the Rogač member of the Milna formation outcropping in the central part of the island of Šolta.

Building block for the walls and other non-standardized elements on the residential houses "Ruića dvori" in Grohote are strictly local, from the place itself or nearby the object, belonging to the Klačina member of the Milna formation.

Building blocks found in the Blaca hermitic monastery represent an exceptional geological example of the use of a local source of limestone for building of such a major architectural complex. In the basement and the background of the complex, there are natural outcrops of subhorizontal beds of Turonian-Santonian limestones (Gornji Humac Fm). The constructors used bedding discontinuities and a nearly perpendicular joint system to excavate and use building blocks for basic elements (walls, streets, frames...). Furthermore, they used natural limestone beds for the construction of some unique *in-situ* facilities (basement for olive/grape pressure system). All autochthonously excavated building elements are characterized by a coarse-finish produced by hand tools. All types of limestone from the Turonian-Santonian limestones (Gornji Humac Fm) were used for the basic elements.

Manufactured elements including *building blocks* for the Trogir cathedral apses are of local and regional origin, keeping in mind the fact that there are at least two major and historical quarries (Seget and Čiovo-Okrug) in the massive grayish-white grainy limestone of the Seget formation outcropping in the Trogir region. However, many blocks also originate from the Pučišća Formation and some from the major and historical quarries located on Brač island (Pučišća and Škrip). The Pučišća is characterized by a lithology (thick-bedded to massive yellowish- to grayish-white fine to coarse-grained bioclastic limestone with rudist white and brown fragments) similar to the Plano Formation outcropping exclusively NE of Trogir, but there is no data on historical quarries in the area. The same but finer-grained material was used for the sculpting of the Trogir cathedral's original sculptures, which are characterized by coarse-finishing produced by hand tools, while some of the restorations are characterized by fine finishing produced by machine.

Manufactured elements characterized by standardized dimensions (e.g. window frames and door posts) used in Blaca and Grohote originate also from some of the major quarries in the massive grainy limestone of the Pučišća formation, possibly from quarries located in Pučišća and Škrip on the island of Brač. Considering the location of Blaca, it is also possible that some of the manufactured elements originate from similar material outcroppings in the village of Nerežišće (Dračevica quarry).

5.4.3. Dubrovnik-Neretva County (DUNEA)

Two objects in the Dubrovnik-Neretva County are situated on Korčula island (Vela Luka and

Žrnovo-Podstrana), while 1 object is on the Pelješac peninsula (Nakovana). On the island of Korčula, the typical dry stone stable wall is located in Vela Luka in an arbored walk by the cemetery of St. Roko (Aleja kod groblja sv. Roko), while in Žrnovo-Podstrana there is an agricultural housing complex of single cell houses (kućice). In Donja Nakovana (Pelješac), we described the geology of residential houses with auxiliary objects – two storey houses with a detached kitchen (konoba), bread oven (krušna peć), threshing floor and stone mill.

Platy limestone elements used on the roofs in Vela Luka largely originate from a local occurrence of Crna PL in the vicinity of the object and from the Gornji Humac-PL unit, characterized by mostly platy to thin-bedded bioclastic wackestone with ostracods and benthic foraminifera, and an outcropping in a huge area north of Vela Luka. The plates from Nakovana also mostly originate from an abandoned quarry in Milna PL found in the vicinity of the object, and are characterized by alternation of thin-bedded, platy and laminated micritic to grainy limestones that are partly recrystallized, and in some places contain reddish cyanobacterial laminas. Other plates originate from a major outcropping area of Gornji Humac PL on the westernmost part of the Pelješac peninsula (Lovišta).

Building blocks for all three objects originate from the place or the vicinity of the objects, thus belonging either to Crna Fm. (Vela Luka) of Albian- Cenomanian age or Milna Fm. (Žrnovo and Nakovana), of Cenomanian age.

Manufactured elements characterized by standardized dimensions (e.g. window frames and door posts) used in Nakovana originate from Korčula limestone (thick-bedded to massive light-grey to brownish bioclastic limestones with rudist fragments), exploited from some of the major quarries on the NE part of the neighbouring island of Korčula – Piske, Humac or Vrnik. However, those used in Žrnovo object are from the site itself, considering the fact that the object was built within the outcropping area of Milna PL Žrnovo-Podstrana. At least three small abandoned quarries are found within the vicinity of the object, and are characterized by the alternation of platy and thick-bedded bioclastic Cenomanian limestones. The architectural elements used on both objects were carved from thick-bedded bioclastic limestones by skilled professional masons or “stone-artists”, since there are small stone cutters that are still active in the area of Žrnovo and Korčula.

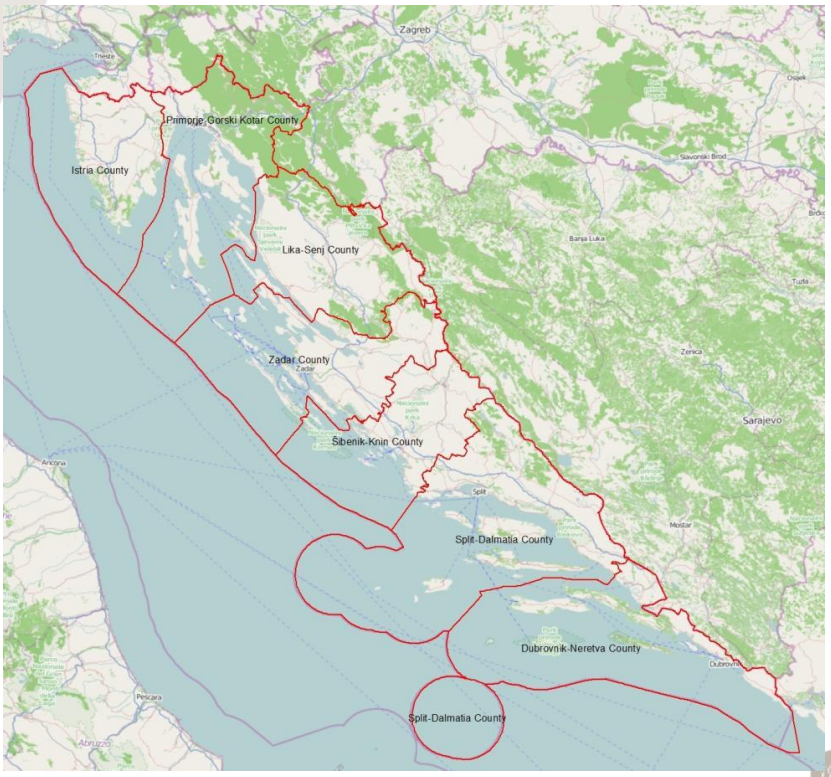
6. EXTENDED SUMMARY, CONCLUSIONS, GUIDELINES AND RECOMMENDATIONS

6.1. INTRODUCTION

Hrvatski geološki institut – The Croatian Geological Survey (HGI-CGS) has contracts with all four Croatian RoofOfRock project partners: IDA (Istria County), ZADRA (Zadar County), RERA SD (Split-Dalmatia County), and DUNEA (Dubrovnik-Neretva County), to work on the project as an external expert and to prepare the project outputs. The contract requirements comprise all geological aspects of the RoofOfRock project, defined and supervised by the leading partner – Geological Survey of Slovenia (GeoZS). The research has been organized through project work packages (WP): WP3, partially WP4, WP5 and WP7. HGI-CGS has been working in close collaboration with the project partners and other external experts in the process of determining a common definition of platy limestone as well as in the collection of data for the database and geological maps.

Following an overview of building limestone in the Croatian part of the project area (Chapter 2), we focused on the main goal of the RoofOfRock project – platy limestone (PL). The aim was to identify possible different types of PL within the investigated regions of the Adriatic karst. To this end, major sedimentological and paleontological characteristics, stratigraphic position and the age of various PL horizons were studied. After an extensive geological survey done by HGI-CGS teams, PL general characteristics and spatial occurrences, together with an assessment of the value of the projects are shown on the maps at a general scale of 1:50,000 (Chapter 3); more detailed descriptions of the PL occurrences that could be evaluated as possible mineral commodity, including any natural/environmental protection and other spatial restrictions in place, are summarized in Chapter 4. Show-case objects are described in Chapter 5. An extended summary, conclusions, guidelines and recommendations are gathered together in Chapter 6.

The Croatian part of the RoofOfRock project comprises Croatian counties situated along the north-eastern coastal region of the Adriatic Sea. A general overview on building limestone was prepared for the entire region, while detailed investigations of PL focused only on selected areas of Istria (IDA), Zadar (ZADRA), Split-Dalmatia (RERA SD), and Dubrovnik-Neretva (DUNEA) counties.



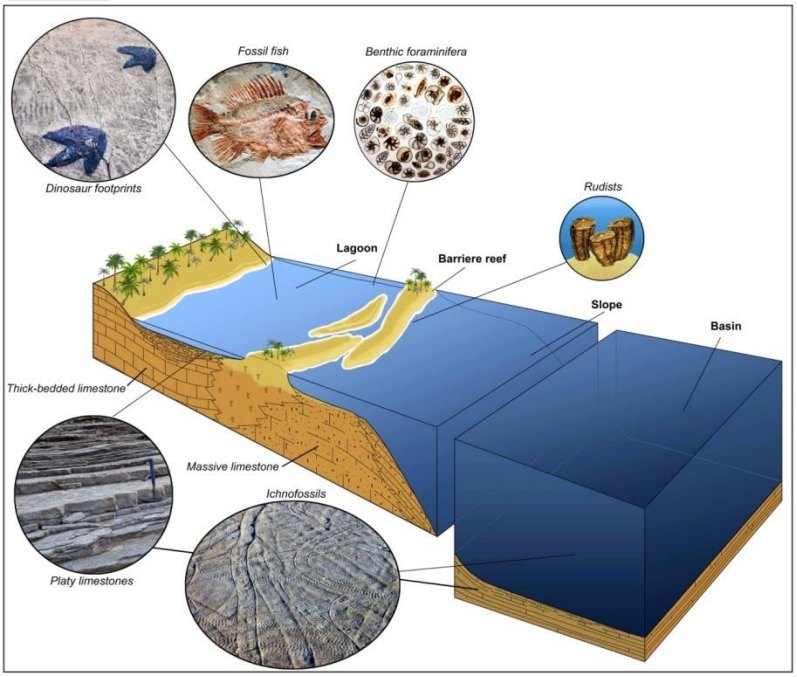
Overview geographical map showing the Adriatic region and Croatian counties within the RoofOfRock project area.

6.2. DEFINITION OF (PLATY) LIMESTONE AND OVERVIEW ON BUILDING LIMESTONE

According to some of the most widely-cited geological classifications (TREFETHEN, 1950) limestone is a carbonate sedimentary rock that is characterized by more than 90% of calcium carbonate ($CaCO_3$), while platy limestone is a very thin- bedded limestone that is characterized by a bed thickness of 1-10 cm (cf. McKEE & WEIR, 1953; CAMPBELL, 1967; combined in KORBAR et al., 2012). According to such a classification scheme, we further consider laminated rock (<1 cm in thickness), thin-bedded (10-30 cm), medium thick-bedded (30-60 cm), thick-bedded (60-120 cm), very thick-bedded (>120 cm), and massive sedimentary rocks.

The north-eastern Adriatic coastal area belongs to the Dinaric Karst region, an area known the world over for its typical karstic geomorphological features developed within tectonically deformed and eroded carbonate sedimentary rocks (mostly limestone and dolomite), deposited within a broad Adriatic/Dinaric carbonate platform. The majority of the carbonates cropping out in the region were deposited during the Mesozoic era, some 200 to 66 million years (My) ago, from the Late Triassic to the end of the Cretaceous (VLAHOVIĆ et al., 2005 and references therein). The entire region was a part of the Adria, a northern promontory of the African continent, which was located during the Mesozoic approximately 2000 kilometres to the south, within a (sub)tropical climate belt. Younger carbonate and siliciclastic rocks were deposited later, at the beginning of the Cenozoic period (66 My ago), when Adria collided with Europe. Uplifted rocks were eroded and material began to accumulate over the carbonate platform deposits, within the so-called foreland basins (KORBAR, 2009, and references therein).

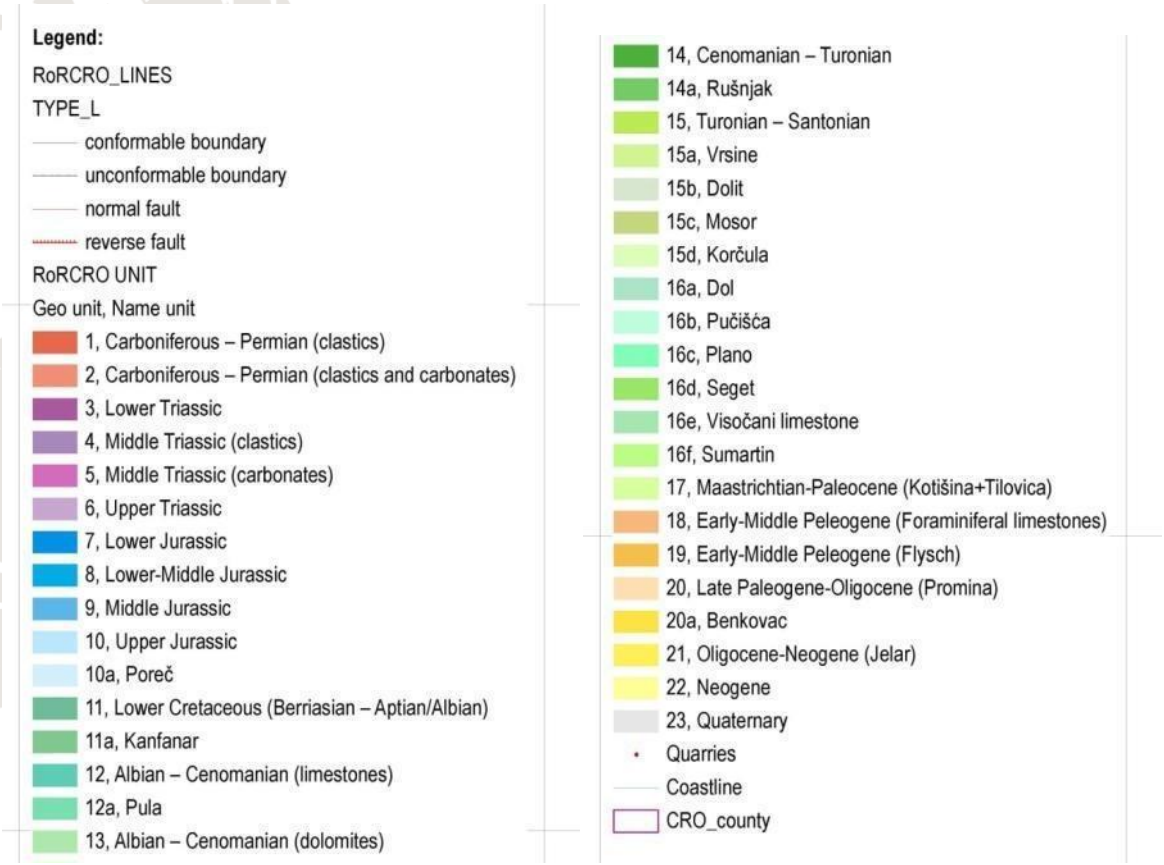
During the Cretaceous, a shallow water area spread over the Adriatic/Dinaric carbonate platform, and was encompassed by intervening deep marine basins within the Tethys Ocean (the present day Mediterranean), a situation similar to the present day Bahamas. A variety of depositional environments can be found within such an area, in which various limestone lithotypes (DUNHAM, 1962) were deposited. Later during the Cenozoic, carbonates were deposited during short time intervals only.



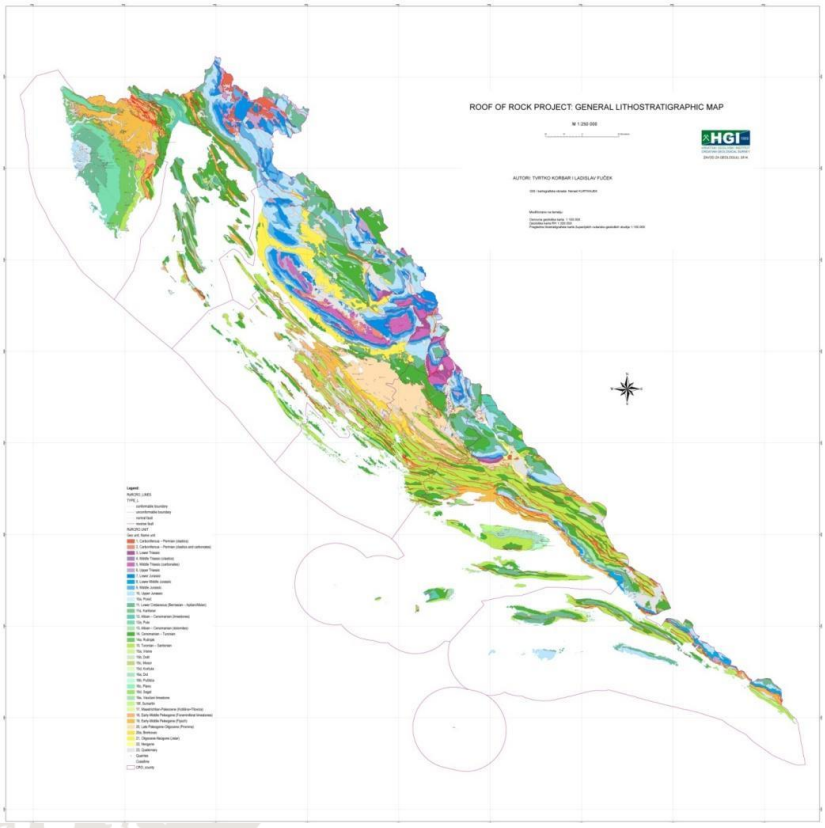
Schematic block-diagram of depositional environments of thin-bedded (platy), thick-bedded and massive limestones within a shallow-water carbonate platform (including lagoon), platform margin (barrier reef), adjacent slopes and a deep marine basin.

The database and the overview map of the Adriatic region of Croatia at scale 1:250,000 are based on the formal data shown on related sheets of the Basic geological map 1:100,000 (CROATIAN GEOLOGICAL SURVEY, 1951-1978), compiled in the geological overview map of Croatia at scale 1:300,000 (CROATIAN GEOLOGICAL SURVEY, 2009). Some data has been extracted from a professional book on Croatian Mineral Deposits (MARKOVIĆ, 2002). A huge amount of unpublished data has also been collected, mostly from informal materials gathered by the HGI-CGS team members, and from unpublished but formal mining-geological studies in the region (JELASKA et al., 2006, MIKO et al., 2008, 2013). For the final overview on the data, we used several official documents of the Government of the Republic of Croatia (see http//: pages at the end of the REFERENCE LIST).

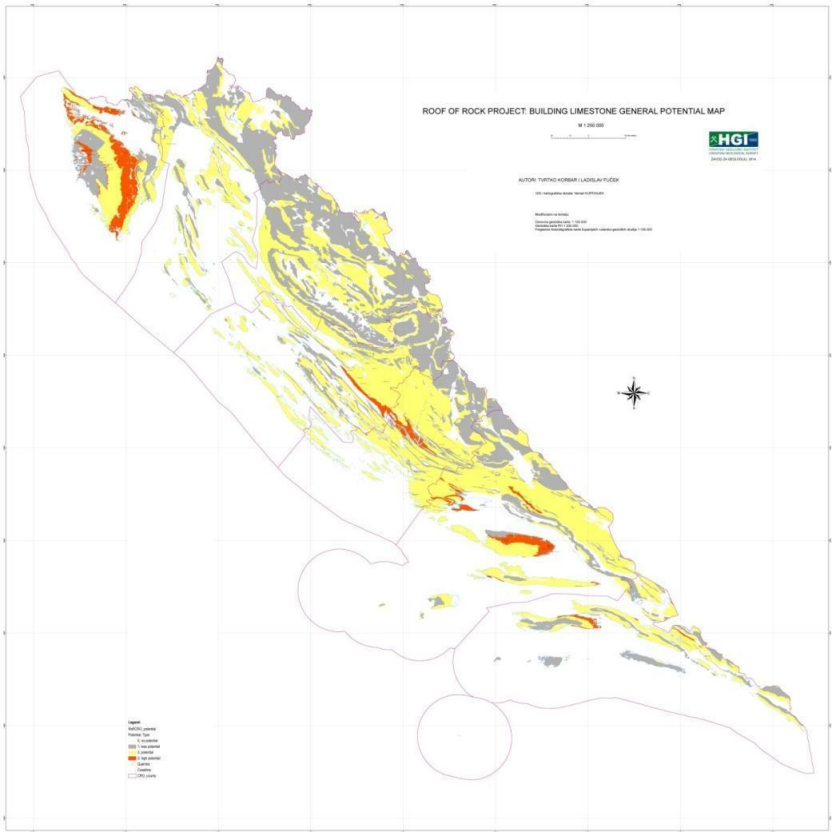
According to their potential as building limestones, geological units are classified into three categories: **low potential, potential and high potential.** low potential types include lower-quality limestone used only locally, not commercially. Potential types include relatively quality building limestones that could also be commercially used, where abandoned quarries exist. High potential types include types that are/were widely commercially used in a number of active quarries, and their occurrence is usually presented on more detailed lithostratigraphic maps. More than 40 of the most important types of building limestones in the project area are selected in the list (Appendix 1), along with 74 typical quarries of the building limestones (Appendix 2).



Overview of major geological units of the Croatian part of the RoofOfRock project area shown on the geological overview map.



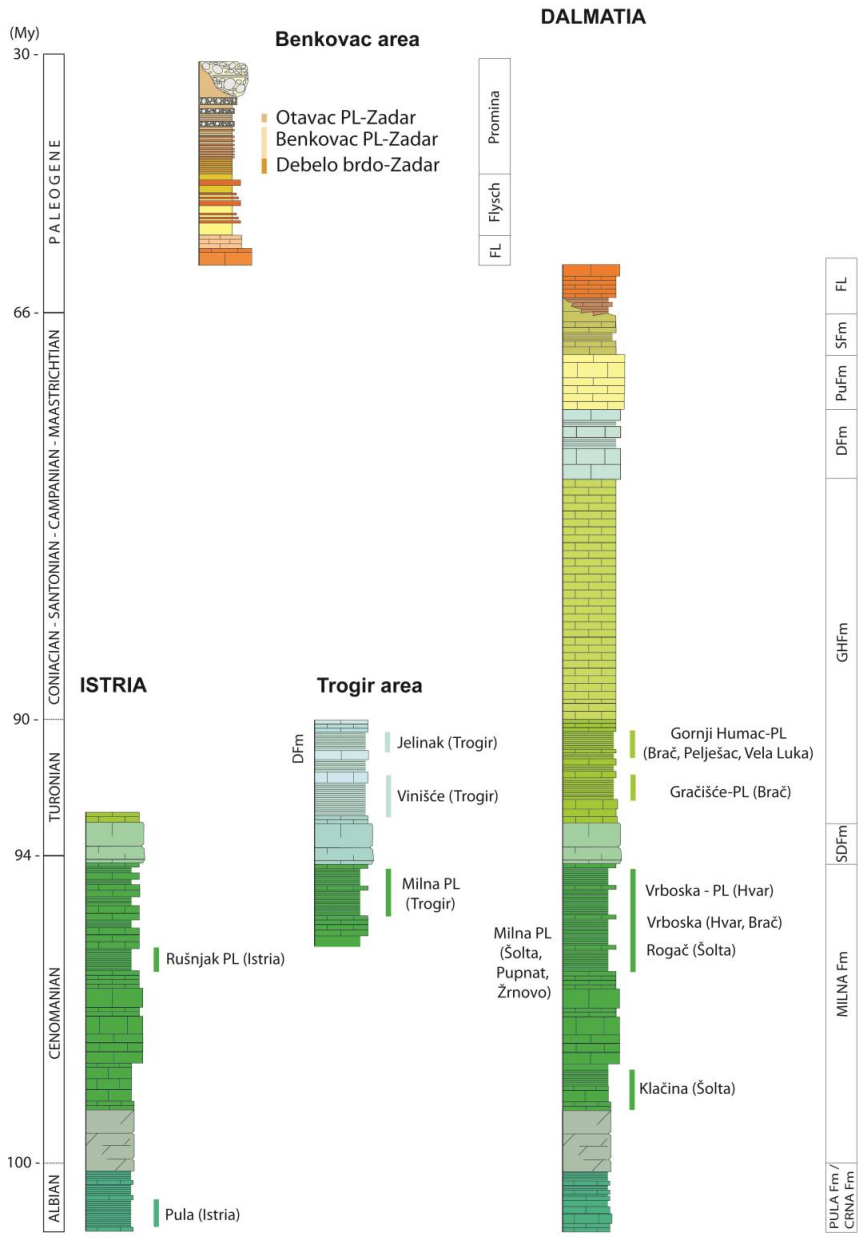
Overview geological map of the Croatian part of the RoofOfRock project area, as the basis for an overview on building limestone potential.



Overview map of building limestone potential in general of the Croatian part of the RoofOfRock project area (grey – low potential, yellow – potential, orange – high potential).

6.3. GEOLOGICAL RESEARCH ON PLATY LIMESTONE

The sequences of PL belong to various geological (lithostratigraphical) units, or represent separate units themselves. In the Croatian part of the project area, platy limestones (PL) appear within sequences that could be up to some tens of meters thick.



Schematic correlation of sedimentary successions which include major PL occurrence in the Adriatic karst region of Croatia (the upper part of a "layer-cake" of sedimentary rocks some km thick). Cretaceous carbonate units in the lower part (Albian to Maastrichtian in age, green: shallow-water limestone, blue: deeper-water limestones, grey: dolomites). Paleogene carbonate and siliciclastic units in the uppermost part (orange to brown: shallow- to deep-water units). Appearances of platy limestone are marked by closely spaced lines, while the units shown on the detailed maps as polygons are represented by vertical bars and names (not in scale). My-million years (age of the rocks), PL-platy limestone, Fm-Formation=sedimentary units: SD-Sveti Duh, GH-Gornji Humac, D-Dol, Pu-Pučišća, S-Sumartin, FL-Foraminiferal Limestones.

It must be noted that most of the PL sequences are only a few meters thick, in some places less than a meter. According to a general approach agreed on at the coordination meetings, and during the more detailed fieldwork on PL (lithostratigraphic mapping in scale 1:50,000), we recognized three categories of PL potentiality, defined primarily according to the main criterion – a percentage of PL within the

lithostratigraphic unit thickness. Namely, every stratigraphic unit defined spatially during lithostratigraphic mapping is characterized by a substantial thickness of the sedimentary succession (on average up to some tens of meters). Every sedimentary succession is a stack of sedimentary strata (beds) of various thickness (one centimetre up to a few meters). In most of the cases only a certain portion of the succession is characterized by platy occurrence (beds 1-10 cm in thickness). This means that PL appears only in a restricted part of the unit at the surface (outcrops), although some units can be completely characterized by PL occurrence (100 %). However, the superficial spatial occurrence of PL depends significantly on the relation of the geological (bed dip angles) and morphological (flat or steep relief) features: the more concordant these two geometrical issues are, the broader the occurrence of a PL unit on the surface. This criterion was used as secondary for characterization of the PL in the three categories:

1. LOW POTENTIAL (<10% of PL, not shown on the maps),
2. POTENTIAL (10-30% of PL, **yellow** colour on the maps),
3. HIGH POTENTIAL (>30% of PL, **orange** colour on the maps).

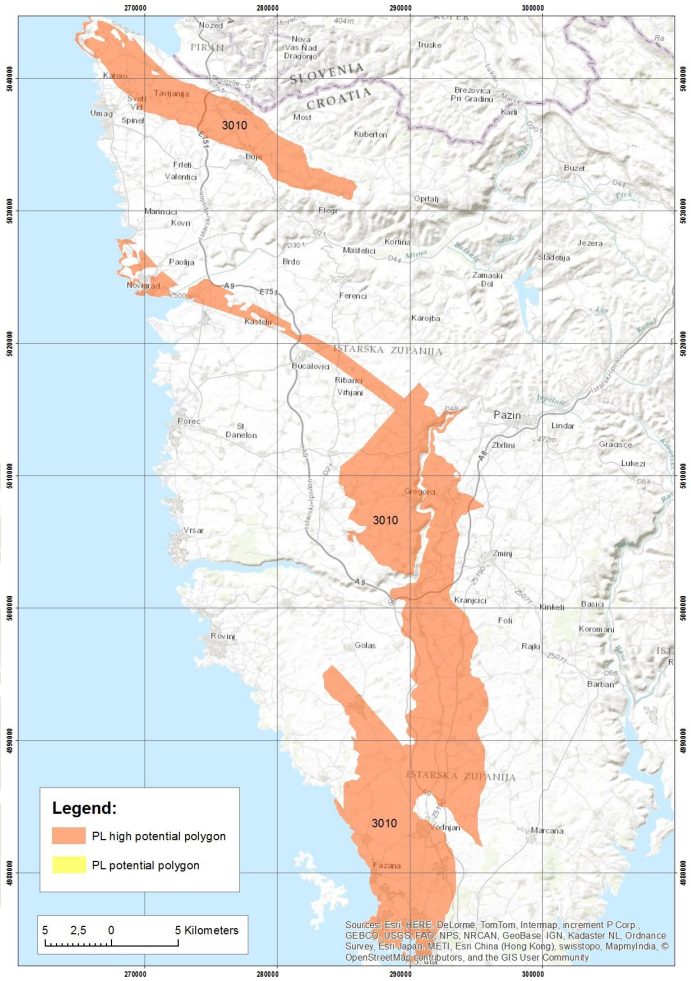
For purposes of the project, the potential and high potential units (Appendix 3) are spatially defined and shown on the topographic maps (OpenStreetMap). It should be noted that these PL units cover more than 500 km^2 of the Croatian project territory. The less potential units are not shown on the maps, owing to a significant number of restricted and dispersed local occurrences of such thin (mostly <1m thick) intercalations, within mostly thickly-bedded geological units outcropping in a large project region in Croatia. Almost all limestone units shown on the 250K general map can be considered low potential PL units, especially units: 7, 10, 12, 12a,13, 14, 15, 16a, 16f, 18, and 20a.

In this summary, only an overview table and maps of potential and high-potential PL polygons in Istria, Zadar, Split-Dalmatia and Dubrovnik-Neretva counties are shown.

No	area	ID polygon	Name of PL	Age	Area of occurrence (descriptive)	PL potential
1	Istra	3010	Pula PL-Istria	Albian	between Pula and Savudria (Istria)	high-potential !
2	Zadar	3110	Debelo brdo-Zadar	Late Eocene	Between Islam Grčki - Smilčići villages and Debelo brdo to Mejanica hill.	potential
3	Zadar	3120	Benkovac PL-Zadar	Late Eocene-Lower Oligocene	NW-SE trending belt located between Smilčići village and Mejanica hill and extends for more than 5 km SE.	high-potential
4	Zadar	3130	Otavac PL-Zadar	Late Eocene-Lower Oligocene	Two larger areas: northeastern slopes of Kukalj hill and southwest of Pliskovo village.	high-potential
5	Trogir	3310	Milna PL-Trogir	Cenomanian	Between Svinca and Gustirna (W of Trogir).	high-potential
6	Trogir	3320	Vinišće-Trogir	Turonian	East of Vinišće (SW of Trogir) and northern part of Veli Drvenik island.	potential
7	Trogir	3330	Jelinak-Trogir	Turonian-Santonian	Between Bristivica and Blizna at Jelinak Mt. hinterland (NW of Trogir).	high-potential
8	Šolta	3410	Klačina PL-Šolta	Cenomanian	Koludrovi doci. Between Stomorska and Gornje Selo (Šolta).	high-potential
9	Šolta	3420	Klačina PL-Šolta	Cenomanian	In Stomorska village and Nečujam cove (Šolta).	potential
10	Šolta	3440	Rogač-Šolta	Cenomanian	Central part of Šolta island.	potential
11	Šolta	3430	Milna PL-Šolta	Cenomanian	Kupište. W of Gornje Selo (Šolta)	high-potential
12	Hvar	3510	Vrboska-Hvar	Cenomanian	between Vrboska and Stari Grad	potential
13	Hvar	3520	Vrboska PL-Hvar	Cenomanian	northern part of Starogradsko polje, between Vrboska and Stari Grad	high-potential
14	Brač	3610	Vrboska-Brač	Cenomanian	Westernmost part of the island of Brač.	potential
15	Brač	3620	Gračišće-PL-Brač	Turonian	Central-southern part of the island of Brač.	potential
16	Brač	3630	Gornji Humac-PL-Brač	Turonian	Central-southern part of the island of Brač.	high-potential
17	Korčula	3810	Milna-PL-Pupnat	Cenomanian	In the eastern part of the island of Korčula (east of the Pupnat village).	high-potential
18	Korčula	3820	Milna-PL-Žrnovo	Cenomanian	In the eastern part of the Island of Korčula; (Žrnovo-(Postrana).	high-potential
19	Korčula	3830	Gornji Humac-PL-Vela Luka	Turonian - Santonian	In the NW part of the island of Korčula; from Prigradica to the eastern tip of the island.	high-potential
20	Pelješac	3910	Gornji Humac PL - Pelješac	Turonian-Santonian	Westernmost part of the Pelješac peninsula (around Lovište).	high-potential
21	Pelješac	3920	Gornji Humac PL - Pelješac	Turonian-Santonian	Westernmost part of the Pelješac peninsula (around Lovište).	potential

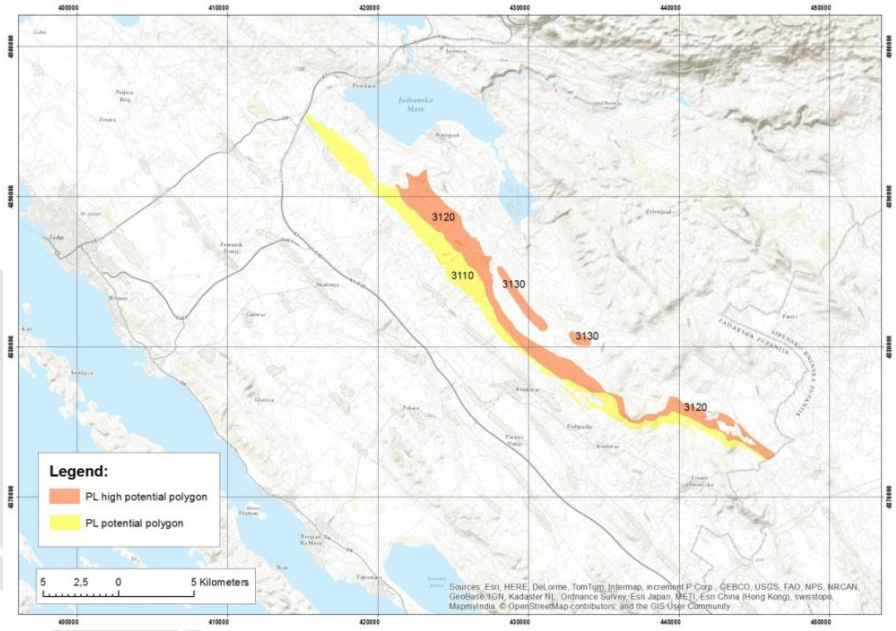
Table of potential and high-potential PL polygons in Istria, Zadar, Split-Dalmatia and Dubrovnik-Neretva counties (Croatia).

In the **Istrian County** there is a major occurrence of PL within Pula PL unit of Albian age, along with a few high-potential localities in Oprtalj area.



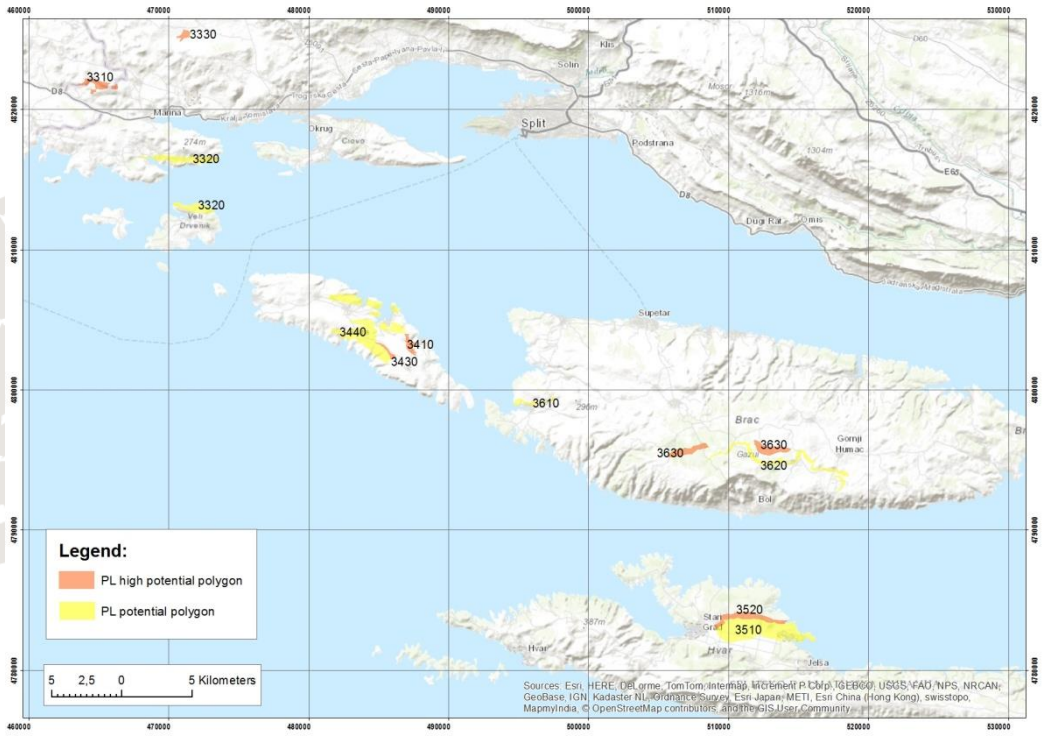
Overview map of platy limestone occurrence in the investigated area of Istrian county.

In the **Zadar county (northern Dalmatia)** there is a major PL occurrence of the so called “Benkovac Stone”, in upper Paleogene Promina unit, which is mapped in detail within the project RoofOfRock.



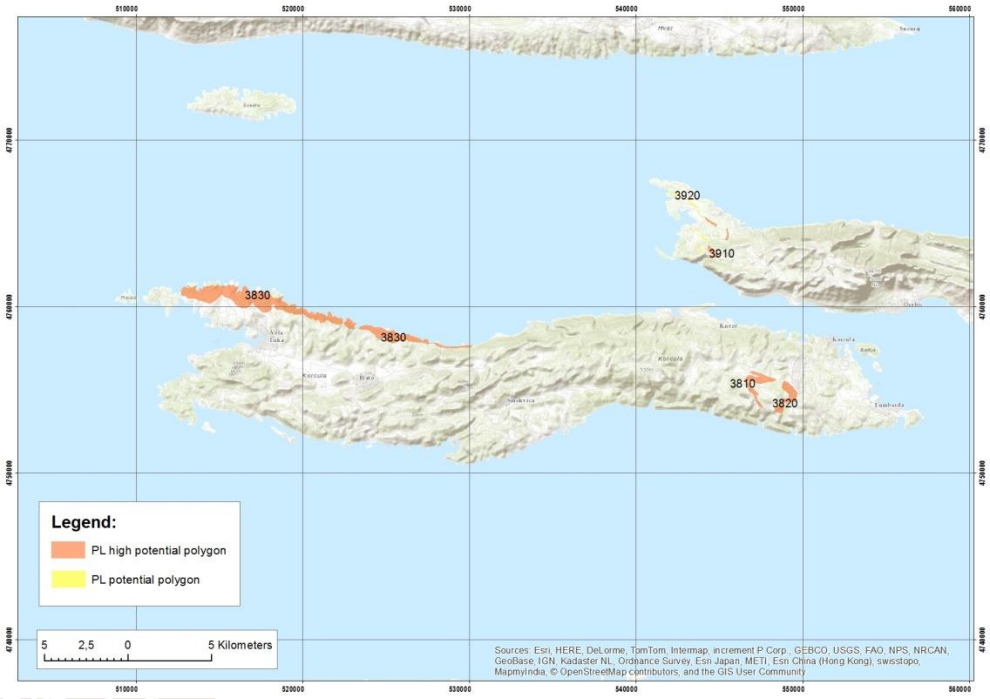
Overview map of platy limestone occurrence in the investigated area of Zadar county (northern Dalmatia).

In the **Split-Dalmatia county (central Dalmatia**), in the Trogir area and on the islands of Šolta, Brač, and Hvar, many Cretaceous lithostratigraphic units characterized by platy limestone are recognized and mapped: Klačina (Šolta), Milna PL (Trogir, Šolta), Rogač (Šolta), Vrboska PL (Hvar), Gračišće PL and Gornji Humac PL (Brač), Vinišće (Vinišće and Veliki Drvenik), and Jelinak (Trogir).



Overview map of platy limestone occurrence in the investigated area of Split-Dalmatia county (central Dalmatia).

In the **Dubrovnik-Neretva county (southern Dalmatia),** on the island of Korčula and on Pelješac peninsula, two main Cretaceous lithostratigraphic units characterized by platy limestone are recognized and mapped: Milna PL (Pupnat and Žrnovo on Korčula) and Gornji Humac PL (Vela Luka on Korčula and Lovišta on Pelješac).



Overview map of platy limestone occurrence in the investigated area of Dubrovnik-Neretva county (southern Dalmatia).

6.4. PLATY LIMESTONE AS A MINERAL COMMODITY AND ITS NATURAL HERITAGE

After reporting on the general occurrence of PL in the project area covered by our Croatian partners, PL has been evaluated as a mineral commodity with respect to general spatial limitations on use and its natural heritage. For this purpose only high-potential units and localities have been selected.

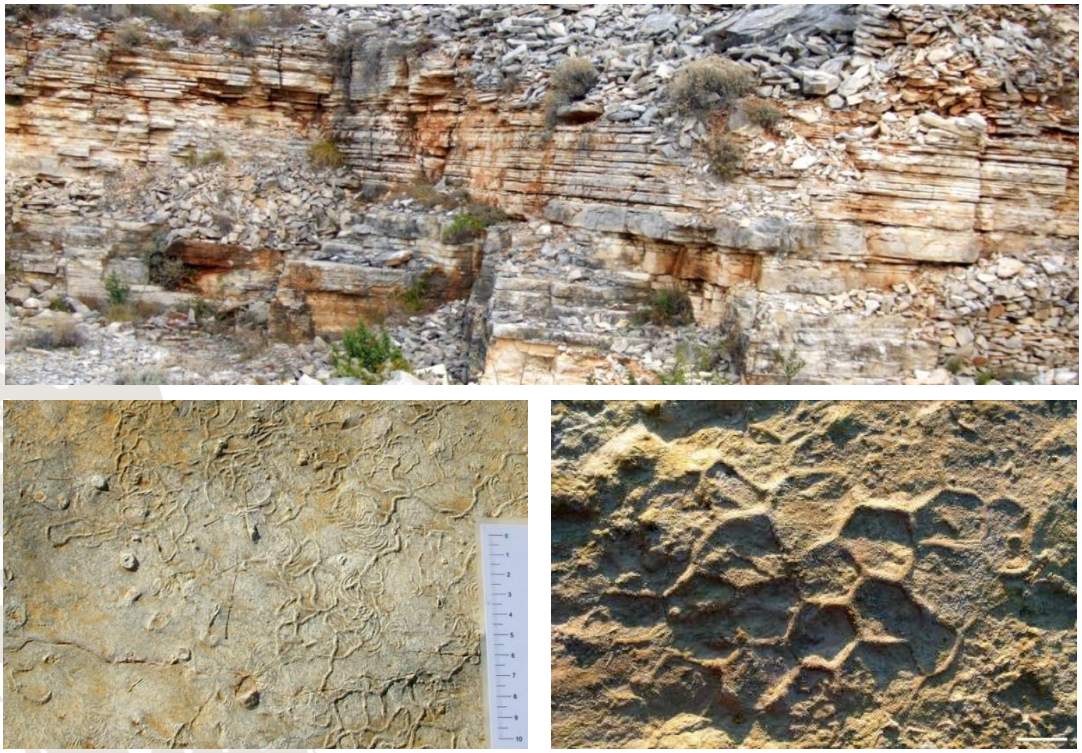
The main occurrence of PL in the **Istrian County** is within the generally high-potential Pula PL unit of Albian age, and some minor occurrences in a few localities near Oprtalj, within Rušnjak PL of Cenomanian age. Pula PL is only of general high-potential due to the very thin PL horizons that are sparsely distributed within the units. For this reason more detailed research within this unit is needed. Both PL types were exploited from many delves, and used for building roofs on traditional rural houses and field shelters.

Pula PL and Rušnjak PL delves and use of PL on *kažuns* and in an old village (Laganisi).

In the **Zadar County (northern Dalmatia)** there is a major PL occurrence within Late Paleogene succession of the Promina unit that goes by the commercial name of "Benkovac Stone". The stone is characterized by a PL succession up to some tens of meters thick (up to 100 % of PL) that is rather uniformly very thin-bedded. The stone is still commercially exploited and widely used in Croatia. Debelo brdo and Benkovac PL units are of excellent quality, since the PL is mostly densely packed micrite and fine-grained calcarenite.

Benkovac Stone PL quarries and use.

The only restriction on the usage of the "Benkovac Stone" could be its yellowish colour, which differs from other (mostly Cretaceous) grayish lithotypes of PL that characterize other parts of the project area in Croatia. All proposed high potential types in the Zadar County are outside any Natura2000 protection category. Alongside its celebrated cultural heritage "Benkovac Stone" maintains prominent geo-heritage features that could be protected within the proposed geo-locality Vlačina.



Vlačina geo-locality and the ichnofossils from Benkovac stone PL.

In **Split-Dalmatia County (central Dalmatia)**, there are numerous, relatively small high potential PL polygons, most of them on the central Dalmatian islands. In the wider TROGIR area there are two high-potential polygons: Kmečalovica area (W of Gustirna) and SW of Begovići village (Jelinak). On the island of ŠOLTA there are two high-potential polygons and one locality: Koludrovi doci, Kupište and Trzavica. On the island of HVAR there is a high-potential polygon of PL named Vrboska PL, located in the northeastern part of Starogradsko polje, which is already under cultural and natural protection, and can be additionally proposed as a future geo-touristic area. On the island of BRAČ there is a high-potential polygon east of Podgažul (northern slopes of Vidova gora) and Vestac locality (SW of Gornji Humac), while others are under Natura2000 protection.

"Vestac" quarry of Gračišće PL type and Gornji Humac PL type on Fantovi doci (the island of Brač).

All the PL types are of very good to excellent quality. There are also other polygons and localities characterized by PL occurrence on the mainland and on the other islands (Veliki Drvenik, Vis). However, there are also spatial limitations for potential exploitation under Natura2000 and island-specific restrictions. Many PL polygons and localities in the Split-Dalmatia County maintain prominent geological characteristics, which need to be properly presented to the public in future. It must be pointed out that economic development need not always run contrary to social concerns, as some of the PL sites and areas are far more interesting for landscape protection and geo-tourism than for exploitation of mineral resources (e.g. Vrboska PL area on the island of Hvar and Rogač PL polygon on the island of Šolta).

"Fish facies" of central Dalmatia: Stara Straža fish fossil (Grohote, Šolta), and soft-sediment deformations in PL (Vrboska, Hvar).

In **Dubrovnik-Neretva County (southern Dalmatia)**, there is one big polygon and two relatively small high-potential PL polygons on the island of Korčula, and a few small polygons on the Pelješac peninsula, along with a few local occurrences. On the island of KORČULA there are three high-potential polygons: Vela Luka, Pupnat and Žrnovo. All the PL types are of good quality. On the W part of the PELJEŠAC peninsula (surroundings of Lovišta village) there are a few small polygons of the high-potential Gornji Humac PL-Pelješac type. One of them is characterized by artificial ridges and mounds of PL plates that are already prepared for use, probably as a result of major exploitation in the past.


Outcrop of Gornji Humac PL at Lovišta on the Pelješac peninsula.

Keeping in mind certain general spatial limitations of potential exploitation related to Natura2000, proximity to the coast and settlements, and their respective positions on the islands, we can recommend an area of Vela Luka in particular as an outstanding landscape developed within the major PL occurrence of Gornji Humac PL.



Outstanding platy limestone landscape on the island of Korčula – polygon of Gornji Humac PL, north of Vela Luka.

The table below shows a general evaluation of quantities of PL as a mineral commodity, which is approx. 200,000,000 m^3 for three Dalmatian counties involved in the project RoofOfRock. However, current mining regulations in Croatia lay down special restrictions for exploitation of mineral resources on the islands in general. Istrian County is also characterized by a significant PL potential, but numerical assessment is not possible without more detail mapping of huge spatial yet widely dispersed occurrences of PL within the Pula PL polygon.

RoR CRO area	ID polygon / locality	Name of PL	Total surface (m^2)*	Estimated volume (m^3)
ZADAR	All	"Benkovac Stone"	approx. 34,00,000	170,000,000
SPLIT-DALMATIA COUNTY	All	Cretaceous PL	approx. 7,000,000	12,000,000
DUBROVNIK-NERETVA COUNTY	All	Cretaceous PL	approx. 11,500,000	18,000,000
	All	**ALL PL TYPES**	**approx. 52,500,000**	**200,000,000**

Table of general evaluation of quantity of selected (high potential) PL types proposed to be considered as mineral commodity in Zadar County, Split-Dalmatia County and Dubrovnik-Neretva County. *10,000 m2 = 1 ha.
Table should be corrected for Natura2000 and 1 km from the coast, and 500m from settlements. Special restrictions for the islands are not considered in the table.

Following extensive field research, samples of selected PL types were analysed within the project RoofOfRock for the purposes of determining a more precise petrological definition of PL, interpretation of its origin, and evaluation of quality with reference to the field assessments and the results of geomechanical analyses (flexural strength measured in IDA-METRIS laboratory):

ID_SAMPLE	FLEXURAL STRENGTH (MPa)	PL unit ID/locality and name (lithology)	FLEXURAL STRENGTH (descript.)	FIELD QUALITY ASSESS.	NOTES
3107_S4	19.21	3110 Debelo brdo – Benkovac (M)	excellent	excellent	outcrop
3109_S3	9.57	3120 Benkovac PL- Benkovac (M-P)	good	excellent	outcrop
3303_S1	17.02	3320 Vinišće (M-Bi)	excellent	very good	outcrop+use
3308_S1	6.69	3310 Milna-PL (G-R biokl.)	good	good	outcrop
3308_S2	13.45	3310 Milna-PL (Bi)	very good	very good	outcrop
3313_S1	8.31	Prapratnica (P kalc. Lam.)	good	bad	outcrop
3314_S1	6.70	3330 Jelinak (P kalc.)	good	good	outcrop
3444_S1	3.89	3440 Rogač (W)	bad	very good	outcrop+use
3444_S2	15.21	3440 Rogač (Bi)	excellent	very good	outcrop+use
3431_S1	3.04	3430 Milna PL (Bi)	bad	very good	outcrop
3502_S1	9.53	Milna - M. Stiniva (M)	good	very good	outcrop

3504_S1	9.72	3520 Vrboska PL (Bi)	good	excellent	outcrop
3505_S1	7.10	3520 Vrboska PL (Bi)	good	excellent	outcrop
3506_S1	8.46	3520 Vrboska PL	good	excellent	outcrop
3607_S1	4.56	3620 Gračišće-PL (Bi)	bad	excellent	outcrop
3608_S1	15.80	3620 Gračišće-PL (Bi)	excellent	excellent	outcrop
3609_S1	8.46	3620 Gračišće-PL (Bi)	good	excellent	outcrop
3612_S1	7.20	3630 Gornji Humac-PL (P)	good	good	outcrop
3612_S2	9.47	3630 Gornji Humac-PL (P)	good	good	outcrop
3612_S3	6.51	3630 Gornji Humac-PL (P)	good	good	outcrop
3702_S1	2.25	Gornji Humac PL - Vis (P)	bad	very good	outcrop
3807_S1	15.85	Milna-PL (Vela Luka. M/W/P)	excellent	good	outcrop
3813_S1	9.21	3820 Milna-PL (Žrnovo. P)	good	good	outcrop+use
3813_S3	7.68	3820 Milna-PL (Žrnovo. P)	good	good	outcrop+use
3905_S1	8.79	3910 Gornji Humac PL (P/M)	good	very good	outcrop+use
3917_S1	8.31	Milna PL - Nakovana (Bi)	good	very good	outcrop
3918_S1	10.62	Milna PL – Nakovana (M)	very good	very good	use
descriptive categories for flexural strength	**1-5 bad**	In red are samples from the same outcrop or similar lithology with significantly different results on flexural strength!	**QUALITY ASSESMENT FROM BOTH METHODS (in scale of grey)**		**bad**
	5-10 good				**good**
	10-15 very good				**very good**
	15-20 excellent				**excellent**

Table showing comparison of the flexural strength and a field assessment to the PL quality of the selected PL types.

Bi-laminated mudstone, M-mudstone, W-mudstone + fine grains, P-fine grains, G-grains, R-coarse grains.

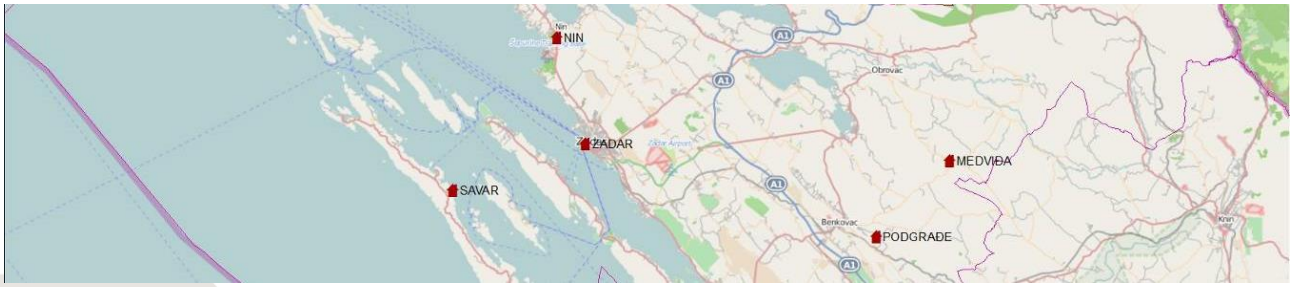
6.5. SHOW-CASE OBJECTS – PROVENANCE OF BUILDING LIMESTONE

In cooperation with partners leading WP3 (geology) and WP4 (cultural heritage), and with WP4 experts for our Croatian partners, 11 show-case objects were selected in Croatia (see table below).

ID_locality	Location	Location (descriptive)	E (DTRS96)	N (DTRS96)
3101	**MEDVIĐA**	MEDVIĐA (Benkovac). Church of sv. Ivan Krstitelj.	442315	4884934
3102	**NIN**	NIN. Church of sv. Nikola.	394431	4899826
3103	**ZADAR**	ZADAR. Stone sidewalks in historical centre.	397919	4886962
3104	**SAVAR**	SAVAR (Dugi otok). Church of sv. Pelegrin	381723	4881378
3105	**PODGRAĐE**	PODGRAĐE (Benkovac). "Čerina dvori".	433333	4875698
3300	**TROGIR**	TROGIR cathedral apses.	479900	4819700
3400	**GROHOTE**	GROHOTE village (Šolta). "Ruića dvori".	482836	4805719
3602	**BLACA**	BLACA (Brač) monastery-museum.	502401	4794768
3861	**VELA LUKA**	VELA LUKA (Korčula). "Bobana lazi".	518075	4757874
3855	**ŽRNOVO**	ŽRNOVO-Podstrana (Korčula). "Pod Veli vrh".	549253	4755138
3952	**NAKOVANA**	Donja NAKOVANA village (Pelješac). "U Cvitka"	547497	4762717

Table of show-case objects in Croatia

In **Zadar County** (ZADRA), 2 objects are situated in the coastal mainland area (Nin surroundings and Zadar old town), 2 in the Ravni kotari area in the hinterland (Medviđa and Podgrađe villages), and 1 is situated on the island of Dugi otok (Savar village).



Overview map of show-case objects in Zadar County.

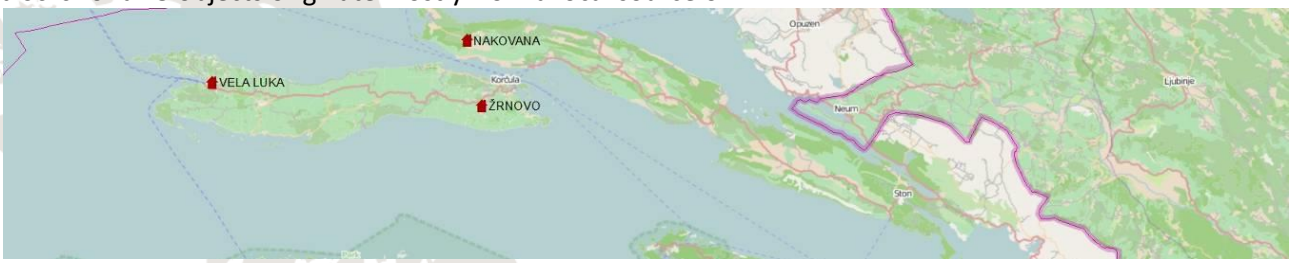
Platy limestone elements used on roofs of the mainland objects mostly originate from Benkovac PL, which is a major regional source for platy limestone, and commonly used as both an original and replacement material. Platy elements on the roof of Savar (Dugi otok) originate from a minor local source. Some of the street signs in Zadar, especially those protected as historical sites, originate from the Cenomanian Milna formation on the island of Lavdara. However, these blocky "plates" have been produced by cutting. Yet, some rare PL horizons on Lavdara are characterized by particularly large plates.
Building blocks for walls and other non-standardized elements on all four rural objects are mostly strictly local, from the place itself or within the vicinity of the objects.
Manufactured elements characterized by standardized dimensions mostly originate from the major and historical quarries of massive grainy limestone outcroppings in Dalmatia. The most probable quarries in the area of the Zadar county are those located in the central part of the island of Dugi otok (Borišina-Ovča). However, more recent replacements are commonly from the major quarries on the island of Brač (Pučišća unit). All original manufactured elements are characterized by coarse finishing produced by hand tools, while the replacements are characterized by fine finishing produced on machinery. All historical (the oldest) blocks used for Zadar's downtown streets originate from Lavdara island (brownish to reddish limestone), which is clearly recognized as a major source for the simple excavation of these semi-manufactured elements owing to the subhorizontal bedding and accessibility to these coastal outcrops by sea. However, most of the replacements in the streets of Zadar originate also from major historical quarries located on Brač island (Pučišća and Dol formations from quarries located in Pučišća and Škrip).
In **Split-Dalmatia County** 1 object is situated in the centre of the coastal (mainland) town of Trogir (Trogir cathedral), 1 object is on the island of Brač (Blaca monastery), and 1 object on the island of Šolta (Grohote village), in the wider Split region.

Overview map of show-case objects in Split-Dalmatia County.

Platy limestone used for the Trogir cathedral apses roofs has probably been replaced with Benkovac PL. There is a question as to the possible local origin of the original plates, since there is a lot of platy limestone material outcropping in the wider Trogir area. *PL* used for roofs in Blaca monastery and in the "Ruića dvori" development originates from local PL units recognized in this study.
Building block for walls and other non-standardized elements of residential houses "Ruića dvori" in Grohote are strictly local, from the place or close vicinity of the object. *Building blocks* found in the Blaca hermitic monastery represent an exceptional geological example of the use of a local source of limestone for the building of such a major architectural complex. In the basement and the background of the complex, there are natural outcrops of subhorizontal limestone beds (Gornji Humac Fm). The constructors used bedding discontinuities and a nearly perpendicular joint system to excavate and uses building blocks for basic

elements (walls, streets, frames etc.). Furthermore, they used natural limestone beds for the construction of some unique *in-situ* facilities (basement for olive/grape pressure system).
Manufactured elements including *building blocks* for the Trogir cathedral apses are of local and regional origin, considering the fact that there are at least two major and historical quarries (Seget and Čiovo-Okrug) in the massive grayish-white grainy limestone of the Seget Formation outcropping in the Trogir region. However, many blocks and sculptures also originate from some of the major and historical quarries located on the island of Brač (Pučišća and Škrip). *Manufactured elements* characterized by standardized dimensions (e.g. window frames and door posts) used in Blaca and Grohote also originate from some of the major quarries in massive grainy limestone of the Pučišća formation, possibly from quarries located in Pučišća and Škrip on Brač. Considering the location of Blaca, it is also possible that some of the manufactured elements originate from a similar material outcropping in the village of Nerežišće (Dračevica quarry).

In the **Dubrovnik-Neretva County** 2 objects are situated on the Korčula island (Vela Luka and Žrnovo-Podstrana), while 1 object is on the Pelješac peninsula (Nakovana). *Platy limestone* elements and *Building blocks* for all 3 objects originate mostly from a local source of PL.



Overview map of show-case objects in Dubrovnik-Neretva County.

Manufactured elements characterized by standardized dimensions (e.g. window frames and door posts) used in Nakovana originate from Korčula limestone, while the elements used for the Žrnovo object originate from the strictly local PL quarries. They were carved from the intercalated thick-bedded bioclastic limestones by skilled professional stonemasons or “stone-artists”. Today there are still small stone-cutters active in the area of Žrnovo and Korčula.

6.6. CONCLUSIONS, GUIDELINES AND RECOMMENDATIONS

Within the framework of the service contracts with all four Croatian RoofOfRock project partners, all of the planned outputs have been prepared:

- General geological map in scale 1:250,000, with special attention paid to major types of building limestone in the Croatian part of the RoofOfRock project area, and identification of potential resource areas of building limestone (typical quarries);
- Maps of provenance of building limestone used in 11 selected objects;
- Detailed geological maps in scale 1:50,000 (lithostratigraphic/formational but simplified in reports for public use), of spatial occurrences of platy limestone over certain parts of the Adriatic karst in Croatia, with written reports on exact geologic definitions for platy limestone;
- Maps of regions where platy limestone as potential mineral resource occurs, including an evaluation of its potential as a mineral commodity;
- Harmonized geological dataset for the building of the joint database made available in the GIS environment.

PLATY LIMESTONE OCCURRENCE(Chapter 3).

The Croatian part represents the largest part of the whole RoofOfRock project area. The PL units are

irregularly distributed within the carbonate succession and are of different ages (mostly late Cretaceous and late Paleogene), as a consequence of deposition in sedimentary environments that have constantly been changing through geological time and space. The most important PL units shown in this report are up to a few tens of meters thick. However, in many places PL horizons are less than a meter thick, while spatial occurrence of PL depends significantly on the relation of the geological (bed dip angles) and morphological (slope angles) features.

Considering such a sparse distribution of the PL within the Adriatic coastal area of Croatia (including counties that were not involved in the project RoofOfRock), any further research in greater detail will certainly result in many new findings of PL on the surface. Such findings should be evaluated according to the same criteria established in this study.

PLATY LIMESTONE AS A MINERAL COMMODITY AND ITS NATURAL HERITAGE (Chapter 4).

According to the results of geomechanical analyses and field (descriptive) assessment of the quality of PL, it can generally be estimated that the homogenous, very fine-grained limestones (mudstone or micritic lithotypes) and horizontally laminated (microbial) muddy limestones represent the best quality limestones. However, it should be noted that most of the PL outcrops and even single beds are not lithologically homogenous, as a result of its genesis in the natural environment. Generally, it can be concluded that some of the most widely used materials (e.g. “Benkovac stone”, Rogač PL from Šolta, Gračišće PL from Brač, Vrboska PL from Hvar and some localities of Milna PL in general) represent the best quality stones.

It should be noted that according to the Mining Act and related regulations in Croatia the procedure for legal exploitation of the natural stone, including platy limestone, is complex. There are special restrictions on any mining activities on most of the islands in Croatia, which are also characterized by extensive PL occurrence. Thus, the realization of any commercial exploitation of PL ultimately depends on the current and future national mining regulations.

However, in the Croatian part of the project area (Istria and Dalmatia) PL was traditionally exploited extensively for local use, and there are many examples of good practice of PL gathering and use. People used the stone plates without significant impact on the natural environment, collecting it by traditional “stone-gathering” (*branje kamena*) means. Considering that most of the PL units usually have very restricted and dispersed spatial occurrence, a traditional gathering of the plates using only simple hand tools (non-motorized) should be possible, but only in areas that are not covered by soil.

Traditional gathering of the PL in a field.

Therefore, we strongly support an initiative that aims to allow restricted gathering of the plates (stone-gathering) from field surfaces for the necessary reconstruction of existing traditional houses or cultural (sacral) objects that are located within the natural outcrops of platy limestones. In other words, traditional local use is recommended to the relevant decision-makers, since there are many suitable localities (see Chapter 3 of the final report), but only for restricted and controlled exploitation.

Similarly, some of the PL sites and areas are far more interesting for landscape protection and for development of geo-tourism than for commercial exploitation of mineral resources.

SHOW-CASE OBJECTS (Chapter 5)

The building limestone used on selected show-case rural objects has followed a typical rule using local source materials wherever possible. Building limestone materials used in more complex urban show-case objects representing major historical heritage were mostly derived from a few major quarries in the Adriatic coastal region of Dalmatia, which were capable of supplying huge quantities of the building material and were situated as close as possible to the coast for access by sea. Possible future reconstructions of historical objects should be based on geological evaluation of similar materials from active quarries.

Furthermore, some of the major quarries and related stone production facilities were traditionally also able to produce standardized limestone building elements necessary for the construction of some crucial architectural elements, even in traditional rural architecture (e.g. standardized window frames and door posts). These elements were used all over Dalmatia. There are many stonemasonries in the region today that are (still) able to produce such elements.

Platy limestone used in show-case objects mostly originates from the local sources situated in the vicinity of the objects. However, there is a general trend of using the yellowish Benkovac platy limestone in more recent replacements on some objects, since there are no other legal quarries of the local greyish PL in the project region. Thus, we generally recommend legalization of simple traditional “stone-gathering”, but only for local reconstructions that should be controlled by a local government authority.

Zagreb, 29.04.2015

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Appendix 1. List of the geological units shown at 1:250,000 of the project region of Croatia.

No.	ID geol. unit	Name of unit	Basic lithology	Typical area	Project Area (Counties*)	build. llmst. pot.*
1	1	Carboniferous-Permian (clastics)	Coarse to fine grained predominantly siliciclastic rocks, localy evaporites	Gorski Kotar, Knin-Sinj area	PG, LS, ŠK, SD	0
2	2	Carboniferous-Permian (clastics and carbonates)	Siliciclastic series with sporadic intercalations and lenses of limestone in lower part, and mostly dolomites with clastic intercalations in the uppermost part.	Velebit Mt and its hinterland	LS	1
3	3	Lower Triassic	Predominantly clastic rocks, siliciclastic lower part and impure carbonate clastic upper part, thin limestone layers, sporadically dolomite in the uppermost part.	Gorski Kotar, Lika and Dalmatinska Zagora mainland	PG, LS, Z, ŠK, SD	1
4	4	Middle Triassic (clastics)	Medium- to fine-grained clastic and pyroclastic rocks, in places thin bedded limestone and chert, rare effusives, also evaporitic-clastic-carbonate complex.	Velebit Mt hinterland, N of Knin mainland, Vis island	LS, Z, ŠK, SD	0
5	5	Middle Triassic (carbonates)	Predominantly massive to thick-bedded often recrystallized limestone and crystalline dolomite.	Velebit Mt, Lika and Dalmatinska Zagora mainland	LS, Z, ŠK, SD	1
6	6	Upper Triassic	Massive to thick-bedded micritic and crystalline dolomite with sporadically clastic rocks in the basal part.	All the karstified project area	PG, LS, Z, ŠK, SD, DN	0
7	7	Lower Jurassic	Well-bedded mostly micritic limestone and crystalline dolomite in the lower part, thick- to thin-bedded dark-grey bioclastic limestone with lithiotid bivalves and gastropods in the middle part and bioturbated thin-bedded limestone in the upper part.	Mountainous part of the karstified project area	PG, LS, Z, ŠK, SD, DN	2
8	8	Lower-Middle Jurassic	Thick-bedded to massive grayish recrystallized grainy limestones, limestone microbreccia and crystalline dolomites with lithiotid bivalves, gastropods, thin-bedded intervals in lower part and thick-bedded mostly grainy and fenestral in upper part.	Mountain and coastal Makarska-Ploče-Dubrovnik area	SD, DN	2
9	9	Middle Jurassic	Thick-bedded limestone, mainly mudstone, with intercalations of crystalline dolomite.	Hinterland karstified project area and western Istra	PG, LS, Z, ŠK, SD, DN, I	1
10	10	Upper Jurassic	Diverse types of micritic and grainy limestone, often bioclastic, laterally and vertically interchanged, sporadically crystalline dolomite. In some hinterland areas thin-bedded and platy limestone with chert are present.	All the karstified project area	PG, LS, Z, ŠK, SD, DN, I	1
11	10a	Poreč	Thick-bedded mostly white micritic limestone with stylolites and black pebble breccia in lower part, well-bedded dolomites with chert in upper part.	Poreč - Rovinj	I	3
12	11	Lower Cretaceous (Berriasian – Aptian/Albian)	Thick-bedded mostly micritic limestone in lower part, well-bedded skeletal, micritic and grainy limestone with emersion breccia, orbitolinid and oncoid- limestone in the middle part and well-bedded limestone in upper part. Dolomites in places.	All the karstified project area	PG, LS, Z, ŠK, SD, DN, I	1
13	11a	Kanfanar	Thick-bedded to massive yellowish mostly micritic and grainy limestone with baccinella-oncoids and orbitolinid foraminiferas. In upper part emersion breccia are present.	Istra	I, PG	3
14	12	Albian – Cenomanian (limestones)	Predominantly well-bedded micritic to grainy and skeletal limestones with benthic foraminifera and algae, sporadically crystalline dolomites.	All the karstified project area	PG, LS, Z, ŠK, SD, DN, I	1
15	12a	Pula	Thin-bedded to platy grayish-white micritic to grainy limestones with sporadically crystalline dolomites and quartz-sandstone in the upper part.	Istra	I	2
16	13	Albian – Cenomanian (dolomites)	Predominantly crystalline dolomites and limestones, with intercalations of micritic to grainy limestones.	All the karstified project area	PG, LS, Z, ŠK, SD, DN,I	0
17	14	Cenomanian – Turonian	Mostly well-bedded micritic to grainy skeletal limestones with rudist and chondrodont bivalves, In places dolomites. In upper part micritic limestones with calcispheres or thick-bedded to massive intraclastic-bioclastic grainy limestones.	All the karstified project area	PG, LS, Z, ŠK, SD, DN, I	2

18	14a	Rušnjak	Thick-bedded to massive grayish to white bioclastic grainy limestone with rudist fragments. In lower part thin-bedded to platy limestone with stromatolites and massive limestone with calcispheres in upper part.	Istra	I	3
19	15	Turonian – Santonian	Mostly well-bedded skeletal micritic to peloidal limestones with rudist bivalves. In places micritic limestones with calcispheres Localy thick-bedded to massive recrystallized fine to coarse-grained intraclastic-bioclastic grainy limestones.	All the karstified project area	PG, LS, Z, ŠK, SD, DN,I	2
20	15a	Vrsine	Thick-bedded to massive recrystallized coarse-grained bioclastic/intraclastic limestone containing rudist bivalves.	Trogir hinterland	SD	3
21	15b	Dolit	Thick-bedded brownish to grayish micritic limestone.	Mosor Mt. hinterland	SD	3
22	15c	Mosor	Thick-bedded to massive coarse-grained bioclastic-intraclastic limestone and limestone breccia.	Mosor Mt. hinterland	SD	3
23	15d	Korčula	Thick-bedded to massive light-grey to brownish bioclastic limestones with rudist fragments.	Korčula	DN	3
24	16a	Dol	Thick-bedded partly dolomitized, biomicrite with bioturbations and bituminous patches and intercalations of thick-bedded to massive, partly dolomitized grayish fine-grained bioclastic limestone and carbonate breccias.	Brač, Hvar, Čiovo, Pelješac region	SD, DN	3
25	16b	Pučišća	Thick-bedded to massive yellowish- to grayish-white fine to coarse grained bioclastic limestone with rudist fragments. In upper part well-bedded micritic to peloidal-skeletal limestones with rudist bivalves and brown to dark-grey bioclastic limestones.	Brač, Hvar	SD	3
26	16c	Plano	Thick-bedded to massive grayish-white bioclastic limestone with rudist white and brown fragments.	Trogir hinterland	SD	3
27	16d	Seget	Thick-bedded to massive grayish-white and porous fine-grained recrystallized bioclastic limestone.	Trogir hinterland	SD	3
28	16e	Visočani	Thick-bedded to massive light-grey to white recrystallized bioclastic limestones with rudist fragments.	Pelješac and hinterland	DN	3
29	16f	Sumartin	Well-bedded crystalline dolomites and recrystallized limestone with rudist lithosomes and micritic to skeletal limestones in uppermost part.	Brač, Hvar, Pelješac	SD, DN	1
30	17	Maastrichtian-Paleocene (Kotišina+Tilovica)	Thick bedded to massive mostly tectonized light-grey crystalline limestones and limestone breccia with rare thin intercalation of biomicritic limestones.	Split-Makarska southern mountains slopes (Mosor, Biokovo)	SD	1
31	18	Early-Middle Peleogene (Foraminiferal limestones)	Predominantly thick-bedded to massive skeletal brownish limestones with large foraminiferal tests. In places massive yellowish skeletal-bioclastic foraminiferal limestone, and massive unsorted polimictic carbonate breccias.	All the karstified project area	PG, LS, Z, ŠK, SD, DN, I	1
32	19	Early-Middle Peleogene (Flysch)	Predominantly alternation of marl and calcareous sandstone, sporadically carbonate breccia.	All the karstified project area	PG, LS, Z, ŠK, SD, DN, I	0
33	20	Late Paleogene-Oligocene (Promina)	Thick-bedded multi-coloured polimictic carbonate conglomerates and pinkish micritic and fine grained limestones, alternating with thin-bedded (platy) fine-grained limestones (calcisiltite), clayey limestone and calcarenites, rarely limestone breccias.	Ravni Kotari mainland, Šibenik hinterland, Sinj	Z, ŠK, SD	2
34	20a	Benkovac	Predominantly thin-bedded (platy) yellowish fine-grained limestone to clayey limestone and alternation with calcarenite, calcisiltite and calcilutite.	Benkovac, Konjevrate	Z, ŠK	3
35	21	Oligocene-Neogene (Jelar)	Thick-bedded to massive pinkish, reddish and dark grayish carbonate polimictic clast-supported and well cemented carbonate breccia.	Krk island, Velebit Mt. and hinterland, eastern Lika and other smaller occurrences	PG, LS, Z, ŠK, SD, DN	2
36	22	Neogene	Diverse lacustrine, porous and soft carbonates and siliciclastics with coal intercalations.	Pag island, Sinj, Petrovo polje	Z, ŠK, SD	0
37	23	Quaternary	Lacustrine, alluvial and colluvial clastic sediments,	All the karstified	PG, LS, Z, ŠK,	0

			Terra Rossa, aeolian sands and loess.	project area	SD, DN, I	

* LEGEND

I-Istrian
PG-Primorsko-goranska
LS-Lika-Senj
Z-Zadar
ŠK-Šibenik-Knin
SD-Split-Dalmatia
DN-Dubrovnik-Neretva

3 - high potential
2 - potential
1 – low potential
0 - no potential

Appendix 2. List of typical quarries of building limestones in the project region of Croatia.

No.	ID geol. unit	Name of stone	Basic lithology	Typical quarries	County* (local)	E (HTRS96)	N (HTRS96)	build. llmst. pot.*
1	10a	Kirmenjak	Thick-bedded greyish limestone with stylolites	KIRMENJAK-SJEVER	I (Kirmenjak)	279299	5010554	3
2	10a	Kirmenjak	Thick-bedded greyish limestone with stylolites	KIRMENJAK-JUG	I (Kirmenjak)	279648	5008295	3
3	10a	Kirmenjak	Thick-bedded greyish limestone with stylolites	VALKARIN	I (Valkarin)	276733	5010522	3
4	11a	Kanfanar	Thick-bedded greyish to yellowish micritic and grainy oncoid-limestone	KANFANAR-SJEVER	I (Kanfanar)	288196	5003144	3
5	11a	Kanfanar	Thick-bedded greyish to yellowish micritic and grainy oncoid-limestone	KANFANAR-JUG	I (Kanfanar)	289458	5000156	3
6	11a	Kanfanar	Thick-bedded greyish to yellowish micritic and grainy oncoid-limestone	KANFANAR-DVIGRAD	I (Kanfanar-Dvigrad)	288631	5001225	3
7	11a	Kanfanar	Thick-bedded greyish to yellowish micritic and grainy oncoid-limestone	BALE	I (Bale)	285541	4991141	3
8	11a	Kanfanar	Thick-bedded greyish to yellowish micritic and grainy oncoid-limestone	SELINA 4	I (Selina)	286799	5004467	3
9	11a	Kanfanar	Thick-bedded greyish to yellowish micritic and grainy oncoid-limestone	TRI JEZERCA	I (Sv. Lovreč)	285222	5006532	3
10	12a	Žminj	Thin-bedded to platy greyish micritic to grainy limestone.	ŽMINJ	I (Žminj)	295358	5005027	2
11	14a	Bazgalji	Thin-bedded to platy greyish micritic limestone with stromatolites.	BAZGALJI	I (Bazgalji)	299075	5009337	3
12	14a	Marušići	Thick-bedded to massive greyish-white bioclastic grainy limestone.	MARUŠIĆI	I (Marušići)	282873	5033697	3
13	14a	Lucija	Thick-bedded light-grey to brownish bituminous limestone with rudist fragments.	LUCIJA I	I (Oprtalj-Zrenj)	292368	5031791	3
14	14a	Lucija	Thick-bedded light-grey to brownish bituminous limestone with rudist fragments.	LUCIJA II	I (Oprtalj-Zrenj)	292077	5032620	3
15	14a	Marčana	Thick-bedded to massive light-grey to brownish recrystallized bioclastic limestone with rudist fragments.	MARČANA	I (Marčana)	300560	4979857	3
16	14a	Marčana	Thick-bedded to massive light-grey to brownish recrystallized	PRODOL	I (Prodol)	300330	4986815	3

			bioclastic limestone with rudist fragments.					
17	14a	Vinkuran	Thick-bedded to massive light-grey to white fine to coarse grained limestone with rudist fragments.	VINKURAN	I (Vinkuran)	291270	4970009	3
18	15	Valtura	Thick-bedded light-grey to white fine to coarse grained bioclastic limestone with brownish rudist fragments.	VALTURA	I (Valtura)	300135	4975445	2
19	18	Istranka	Thick-bedded greyish to brownish skeletal limestone with large foraminiferas.	ISTRANKA	I (Lupoglav)	311872	5027392	1
20	7	Negrofiorit	Thick-bedded to massive black-greyish bioclastic limestone with white fragments of lithiotid bivalves and gastropods.	MALI ALAN	Z (Mali Alan)	431697	4905739	3
21	7	Negrofiorit	Thick-bedded greyish-black bioclastic limestone with white fragments of lithiotid bivalves.	ŽUTA LOKVA	LS (Žuta Lokva)	386375	4982254	3
22	7	Negrofiorit	Thick-bedded greyish-black bioclastic limestone with white fragments of lithiotid bivalves.	CVITUŠA	LS (Lovinac)	435084	4916847	3
23	7	Negrofiorit	Thick-bedded greyish-black bioclastic limestone with white fragments of lithiotid bivalves.	DEBELO BRDO	LS (Gospić)	404738	4933832	3
24	12	Goli	Thick-bedded to massive greyish-white bioclastic limestone with rudist fragments.	GOLI	PG (Goli)	366064	4968784	2
25	12	Opatija	Thick-bedded to massive greyish-white bioclastic limestone with rudist fragments.	MOŠČENIĆKA DRAGA	PG (Moščenićka Draga)	322362	5014148	2
26	15	Borišina - Ovča	Thick-bedded to massive greyish-white bioclastic limestone with rudist fragments.	BORIŠINA	Z (Dugi otok)	381879	4877728	3
27	15	Mažova Gora	Thick-bedded greyish-white bioclastic limestone with rudist fragments.	MAŽOVA GORA	PG (Lošinj)	328911	4954590	2
28	20	Marići	Thick-bedded to massive pinkish to greyish polimictic carbonate conglomerates.	MARIĆI	Z (Marići)	433802	4892850	3
29	20	Linjača	Thin-bedded (platy) fine-grained limestones (calcarenites) alternating with thick-bedded polimictic carbonate conglomerates and breccias.	KRUŠEVO II	Z (Obrovac)	439484	4885799	3
30	20a	Benkovac	Thin-bedded (platy) yellowish fine-grained limestone to clayey limestone and alternation with calcarenite, calcisiltite and calcilutite.	KUKALJ KAVE-JAMAR	Z (Benkovačko Selo)	428299	4882451	3
31	20a	Benkovac	Thin-bedded (platy) yellowish fine-grained limestone to clayey limestone and alternation with calcarenite, calcisiltite and calcilutite.	ADRIA-KAMEN	Z (Benkovačko Selo)	429163	4880497	3
32	20a	Benkovac	Thin-bedded (platy) yellowish fine-grained limestone to clayey limestone and alternation with calcarenite, calcisiltite and calcilutite.	STAZICE-ADAM	Z (Benkovačko Selo)	424904	4887769	3
33	20a	Benkovac	Thin-bedded (platy) yellowish fine-grained limestone to clayey limestone and alternation with calcarenite, calcisiltite and calcilutite.	MAČKOVAČA	Z (Benkovačko Selo)	427261	4884786	3
34	21	Jelar breccia	Thick-bedded to massive pinkish polimictic carbonate breccia.	DONJA SUVAJA	Z (D. Suvaja)	468298	4919080	3
35	21	Romanovac Tulovac	Thick-bedded to massive reddish and dark greyish carbonate breccia.	ROMANOVAC	Z (Tulove grede)	431419	4902763	3
36	7	Negris fiorito	Medium to thick-bedded dark-grey skeletal lithiotid limestones.	VELIĆ	SD (Trilj)	523350	4831420	3
37	11	Brestovci	Thick-bedded greyish to yellowish	BRESTOVCI	ŠK	496250	4872100	3

			micrite limestone.		(Civljane)			
38	14	Žitnić-micrite	Thick-bedded to massive brownish-grey micritic limestone with thin calcite joints and tiny dolomite crystals.	ŽITNIĆ	ŠK (Drniš)	471749	4855880	3
39	15	Bogomolje	Thick-bedded to massive recrystallized greyish-white fine to coarse-grained bioclastic limestone.	BURINA PAZUHA	SD (Hvar)	543309	4775338	3
40	15	Zečevo	Massive porous greyish-white bioclastic limestone with rudist bioclasts.	PELEŠ-BUCAVAC	ŠK (Primošten)	455241	4824850	3
41	15	Krtolin-fiorito	Thick-bedded to massive recrystallized greyish-white bioclastic limestone with rudist white and brown fragments and rare intercalations of micritic limestone.	KRTOLIN	ŠK (Šibenik)	458960	4844943	3
42	15	Krtolin-fiorito	Thick-bedded to massive recrystallized bioclastic limestone with rudist white and brown fragments, rare intercalations of micritic limestone.	KRŠINE	ŠK (Šibenik)	457209	4841136	3
43	15a	Perlato, Perlatino	Thick-bedded to massive recrystallized coarse-grained bioclastic/intraclastic limestone.	VRSINE	SD (Trogir)	472867	4822081	3
44	15b	Dolit	Thick-bedded brownish to greyish micritic limestone.	DOLIT-SLAVE	SD (Mosor)	516671	4821078	3
45	15c	Mosor	Thick-bedded to massive coarse-grained bioclastic-intraclastic limestone and limestone breccia.	MOSORSKI DOLAC	SD (Mosor)	514542	4819533	3
46	15c	Mosor fantazija	Massive coarse-grained bioclastic-intraclastic limestone (fiorito).	PUTIŠIĆ	SD (Mosor)	517460	4817690	3
47	16a	Sivac	Thick-bedded partly dolomitized, biomicrite with bioturbations and bituminous patches.	NOVO SELO	SD (Brač)	527601	4796852	3
48	16a	Sivac	Thick-bedded partly dolomitized, biomicrite with bioturbations and bituminous patches.	SELCA-ZEČEVO	SD (Brač)	528174	4797367	3
49	16a	Sivac	Thick-bedded partly dolomitized, biomicrite with bioturbations and bituminous patches.	PUČIŠĆA-VESELJE	SD (Brač)	520181	4802069	3
50	16a	Sivac	Thick-bedded partly dolomitized, biomicrite and fine-grained bioclastic limestone (unito) .	DONJI HUMAC	SD (Brač)	504019	4800607	3
51	16a	Dračevica	Thick-bedded to massive dolomitized greyish fine-grained bioclastic limestone (unito).	DRAGONJIK	SD (Brač)	504362	4799600	3
52	16b	Brač "marbles"	Thick-bedded to massive greyish-white fine to coarse grained bioclastic limestone with rudist white and brown fragments (unito and fiorito).	POVLJA	SD (Brač)	527432	4799905	3
53	16b	Brač "marbles"	Thick-bedded to massive greyish-white fine to coarse grained bioclastic limestone with rudist white and brown fragments (unito and fiorito).	ŠKRIP	SD (Brač)	508070	4802700	3
54	16b	Brač "marbles"	Thick-bedded to massive greyish-white fine to coarse grained bioclastic limestone with rudist white and brown fragments (unito and fiorito).	PUČIŠĆA-PUNTA	SD (Brač)	519629	4802179	3
55	16b	Brač "marbles"	Thick-bedded to massive greyish-white fine to coarse grained bioclastic limestone with rudist white and brown fragments (unito and fiorito).	SELCA-HUM	SD (Brač)	525430	4795300	3
56	16b	Rasotica	Thick-bedded brown to dark-grey coloured bioclastic floatstone (fiorito).	SELCA-ŽAGANJ DOLAC	SD (Brač)	529128	4793929	3
57	16b	Brač "marbles"	Thick-bedded to massive greyish fine to coarse-grained bioclastic limestone (unito).	KRIŽNA LUKA	SD (Hvar)	495622	4780660	3

58	16b	Brač "marbles"	Thick-bedded to massive greyish fine to coarse-grained bioclastic limestone (unito).	POKONJI DOL	SD (Hvar)	496543	4780480	3
59	16c	Plano	Thick-bedded to massive greyish-white bioclastic limestone with rudist white and brown fragments (fiorito).	PLANO	SD (Trogir)	481753	4822341	3
60	16d	Seget	Thick-bedded to massive greyish-white and porous fine-grained bioclastic limestone (unito).	SEGET	SD (Trogir)	477874	4820791	3
61	16d	Seget	Thick-bedded to massive greyish-white and porous fine-grained bioclastic limestone (unito).	ČIOVO-OKRUG	SD (Trogir)	476575	4817043	3
62	18	Oklad	Massive unsorted polimictic carbonate breccias.	SELCA-NOVO SELO	SD (Brač)	528158	4796145	3
63	18	Primaroso	Massive yellowish skeletal-bioclastic foraminiferal limestone.	SEDRAMIĆ	ŠK (Drniš)	473439	4849338	3
64	20	Multikolor	Thick-bedded to massive multi-coloured polimictic carbonate conglomerates. (alternating with pinky micrite to fine-grained limestones).	NEORIĆ	SD (Sinj)	500240	4836705	3
65	20	Alkasin	Thick-bedded to massive pinky micrite to fine-grained limestone (alternating with multi-coloured polimictic carbonate conglomerates).	RADOŠIĆ	SD (Sinj)	507237	4840536	3
66	20	Rozalit	Thick-bedded multi-coloured polimictic carbonate conglomerates alternating with pinky micritic and fine grained limestones.	PAKOVO SELO	ŠK (Drniš)	469285	4851872	3
67	20	Alkasin-Multicolor	Thick-bedded to massive multi-coloured polimictic carbonate conglomerates alternating with pinky micritic and fine grained limestones.	ČVRLJEVO	ŠK (Unešić)	484085	4841145	3
68	8	Ivan Dol	Thick-bedded light grey grainy limestone.	IVAN DOL	DN (Osojnik)	627720	4731600	2
69	15d	Korčula	Thick-bedded to massive light-grey bioclastic limestones with rudist fragments.	PISKE	DN (Koromačin, Korčula)	546560	4758800	3
70	15d	Korčula	Thick-bedded to massive light-grey bioclastic limestones with rudist fragments.	HUMAC	DN (Lumbarda, Korčula)	552750	4755550	3
71	15d	Korčula	Thick-bedded to massive light-grey bioclastic limestones with rudist fragments.	VRNIK	DN (Lumbarda, Korčula)	554600	4755500	3
72	16a	Sivac	Thick-bedded biomicrite and fine-grained bioclastic limestone.	MIRONJA II	DN (Mravnica)	610000	4743000	2
73	16e	Visočani	Thick-bedded to massive light-grey to white recrystallized bioclastic limestones with rudist fragments.	VISOČANI	DN (Visočani)	606000	4746600	3
74	14	Lavdara	Mostly well-bedded micritic to grainy skeletal limestones with rudist and chondrodont bivalves.	LAVDARA	Z (Lavdara)	395385	4867532	2

Appendix 3. List of the platy limestone geological units (polygons) shown on 1:50,000 map of selected areas in Croatia.

No	CRO area	ID polygon	Name of platy limestone type	Basic lithology	Age	Area of occurrence (descriptive)	Platy lmst. pot.*
1	Istra	3010	Pula PL-Istria	Alternation of medium to thin-bedded (platy) limestones. Lateral occurrence of platy limestones is rather changeable. Somewhere they dominates with > 70%, and somewhere <30%. Both are composed of rather thin Alternation (2-30 cm) of mudstones, packstones and grainstones. On some localities they are bituminous.	Albian	Between Pula and Savudria (Istria)	3
2	Zadar	3110	Debelo brdo-Zadar	Medium to thin-bedded (platy) light brownish to yellowish fine-grained limestone to clayey limestone and rarely calcarenite and calcisiltite in alternation.	Late Eocene	Between Islam Grčki - Smilčići villages and Debelo brdo to Mejanica hill.	2
3	Zadar	3120	Benkovac PL-Zadar	Thin-bedded (platy) yellowish to light brownish fine-grained limestone to clayey limestone and alternation with calcarenite, calcisiltite and calcilutite.	Late Eocene-Lower Oligocene	NW-SE trending belt located between Smilčići village and Mejanica hill and extends for more than 5 km toward SE.	3
4	Zadar	3130	Otavac PL-Zadar	Thin-bedded (platy) fine-grained calcisiltites, clayey limestones and calcarenites, within the general succession of thick-bedded polimictic carbonate conglomerates.	Late Eocene-Lower Oligocene	Two larger areas: northeastern slopes of Kukalj hill and southwest of Pliskovo village.	3
5	Trogir	3310	Milna PL-Trogir	Mostly well-bedded micritic to grainy skeletal limestones. Platy ones (>30%) are mainly composed of laminated stromatolitic limestones.	Cenomanian	Between Svinca and Gustirna (W of Trogir)	3
6	Trogir	3320	Vinišće-Trogir	Medium to thin-bedded, platy and laminated limestones. Platy (<30%) is mainly composed of benthic and planktonic microfossil wackestones and packstones while laminated are mudstones and wackestones with rare reddish microbial laminas.	Turonian	East of Vinišće (SW of Trogir) and northern part of Veli Drvenik island	2
7	Trogir	3330	Jelinak-Trogir	Alternation of medium to thin-bedded, platy and laminated limestones. Platy ones (>30%) are mainly composed of calcispheres wackestones and packstones with rare reddish cyanobacterial laminas.	Turonian-Santonian	Between Bristivica and Blizna at Jelinak Mt. hinterland (NW of Trogir)	3
8	Šolta	3410	Klačina PL-Šolta	Mostly well-bedded micritic to grainy skeletal limestones. Platy ones (>30%) are mainly composed of laminated stromatolitic limestones.	Cenomanian	Koludrovi doci. Between Stomorska and Gornje Selo (Šolta)	3
9	Šolta	3420	Klačina PL-Šolta	Mostly well-bedded micritic to grainy skeletal limestones and dolomites. Platy ones (>30%) are mainly composed of laminated stromatolitic limestones.	Cenomanian	In Stomorska village and Nečujam cove (Šolta)	2
10	Šolta	3440	Rogač-Šolta	Alternation of medium to thin-bedded, platy and laminated limestones. Platy ones (<30%) are mainly composed of fine grained peloidal packestones and calcispheres wackestones with cyanobacterial laminites.	Cenomanian	Central part of Šolta island.	2
11	Šolta	3430	Milna PL-Šolta	Alternation of medium to thin-bedded, platy and laminated limestones. Platy ones (>30%) are mainly composed of skeletal wackestones and packstones while laminated ones are madstones and wackestones with rare reddish cyanobacterial laminas.	Cenomanian	KUPIŠTE. W of Gornje Selo (Šolta)	3

12	Hvar	3510	Vrboska-Hvar	Alternation of medium to thin-bedded, platy and laminated limestones. Platy ones (<30%) are mainly composed of partly recrystallized wackestones and packstones while laminated ones are madstones and wackestones with reddish cyanobacterial laminas.	Cenomanian	Between Vrboska and Stari Grad	2
13	Hvar	3520	Vrboska PL-Hvar	Alternation of medium to thin-bedded, platy and laminated limestones. Platy ones (>30%) are mainly composed of partly recrystallized wackestones and packstones while laminated ones are madstones and wackestones with reddish cyanobacterial laminas.	Cenomanian	Northern part of Starogradsko polje, between Vrboska and Stari Grad	3
14	Brač	3610	Vrboska-Brač	Medium to thin-bedded, platy and laminated limestones. Recrystallized wackestones and packstones and madstones with reddish cyanobacterial laminas. Rare intercalations of grainy, bioclastic and intraclastic limestone.	Cenomanian	Westernmost part of the island of Brač	2
15	Brač	3620	Gračišće-PL-Brač	Thick to thin-bedded limestones. Mostly wackestones and packstones, onkolite floatstone and madstones. Rare beds with rudist bivalves.	Turonian	Central-southern part of the island of Brač	2
16	Brač	3630	Gornji Humac-PL-Brač	Alternation of medium to thin-bedded, platy limestone mainly composed of fine-grained skeletal wackestones and packstones.	Turonian	Central-southern part of the island of Brač	3
17	Korčula	3810	Milna-PL-Pupnat	Alternation of medium to thin-bedded, platy mostly micritic limestones. Platy (30%) are mainly composed of skeletal wackestones; laminated ones are madstones and wackestones with rare cyanobacterial laminas.	Cenomanian	In the eastern part of the island of Korčula (east of the Pupnat village)	3
18	Korčula	3820	Milna-PL-Žrnovo	Alternation of medium to thin-bedded, platy and thick bedded bioclastic limestones. Platy ones (30%) are mainly composed of skeletal wackestones and packstones.	Cenomanian	In the eastern part of the Island of Korčula; (Žrnovo-(Postrana)	3
19	Korčula	3830	Gornji Humac-PL-Vela Luka	Alternation of medium and thin-bedded (platy) limestones. Platy limestones (> 30%) are mainly represented by laminites which show microbial influence on the sedimentation.	Turonian - Santonian	In the NW part of the island of Korčula; from Prigradica. to eastern tip of the island.	3
20	Pelješac	3910	Gornji Humac PL - Pelješac	Peloidal packstones with thaumatoporellas and aeolisacus. Mostly well-bedded skeletal micritic to peloidal limestones with lithosomes of rudists. In places micritic limestones with calcispheres. Localy thick-bedded to massive.	Turonian-Santonian	Westernmost part of the Pelješac peninsula (around Lovište).	3
21	Pelješac	3920	Gornji Humac PL - Pelješac	Peloidal packstones with thaumatoporellas and aeolisacus. Mostly well-bedded skeletal micritic to peloidal limestones with lithosomes of rudists. In places micritic limestones with calcispheres. Localy thick-bedded to massive.	Turonian-Santonian	Westernmost part of the Pelješac peninsula (around Lovište).	2

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