WP3

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

Appendix 2.2

Final report for the project area in Slovenia

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CONTENT

1 INTRODUCTION

The main aim of the RoofOfRock project is to establish a joint platform for the sustainable use of platy limestone, its preservation and promotion, to create the relevant guidelines and to upgrade both individual and joint capacities in preserving this particularity of common natural and cultural heritage along the karstified part of the Adriatic coast. The limestone was used as a primary building material throughout the whole project area and takes one of the most important roles in creating a common human history. The specific platy limestone as the basic construction material gives the Adriatic coastline and its interior its primary character. A detailed geological investigation of the platy limestone was a basis for all other project activities.

The Geological Survey of Slovenia as the Leading Partner of the project is coordinating and managing the implementation of the project as a whole. The project partnership is established with nine other organizations from Slovenia, Italy, Croatia and Bosnia and Herzegovina. Besides, the Geological Survey of Slovenia has also coordinated geological activities of the WP3 (Platy limestone – geologic definition and its use as a mineral commodity) in the entire project area and prepared geological outputs for the project area in Slovenia.

The geological part (WP3) of the project was divided into four different activities focused mainly on the characterization and identification of the natural/physical properties of limestone along the karstified part of the Adriatic coast. In the first set of working actions all types of building limestone occurring in the project area have been studied. Limestones were classified lithostratigraphically and by their use throughout history as well as by their potential as a mineral resource. The existing relevant documents and data were reviewed with the goal of preparing a list of main types of building limestone and a list of typical quarries. After the interpretation and harmonization of the geological data, an overview geological map with a scale of 1:250,000 of spatial appearance of all types of limestone in the Kras and Matarsko Podolje area was elaborated. It has served as the basis for further studies on the occurrence of platy limestone. The general characteristics and provenance of the building stone used in the autochthonous karst architecture was studied through five selected show-case objects on the Kras. Further activities were more focused on platy limestone, a special type of building stone, most commonly used for roofing. Its geological definition is set up and its extent along the Kras area is shown on the geological map in the general scale 1:50,000. Various platy limestone horizons were identified through their major sedimentological and paleontological characteristics, stratigraphic position and age. Detailed geological mapping of selected areas as well as sedimentological and paleontological laboratory analyses were implemented. Finally, platy limestone was evaluated as a mineral commodity. According to the recognized potential and spatial appearance of all types of platy limestone previously defined on maps, we evaluated selected types of platy limestone as a mineral commodity with the final goal of identifying potential quarrying areas. Paleontological and sedimentological historical data on platy limestone and new data were evaluated from the natural heritage point of view and some geo-sites were proposed. Collected geological data were incorporated into a joint GIS-based database built in the framework of WP7.

Geologists actively cooperated with experts from adjacent project areas in Croatia (HGI-CGS) and Italy (DMG UniTS) in order to harmonize the geological data presented on the overview

map (1:250,000) and maps of platy limestone appearance. In addition, several WP3 coordination meetings were organized to coordinate the implementation of geological (WP3) activities among all four countries. They were focused especially on the harmonization of maps, the definition of procedures for selecting show-case objects, the preparation of data for the GIS database, an estimation of the quality and quantity of platy limestone and the preparation of interim reports. During the process of selection and investigation of the show-case objects we cooperated with the leaders of the WP4-cultural heritage (FB6 UP ZRS). In order to set guidelines for the sustainable exploitation of the platy limestone, geologists also collaborated with the leaders of WP5 (FB5 DMG UniTS) and WP6 (FB7 JZ PŠJ).

1.1 OVERVIEW OF THE PROJECT AREA - GEOGRAPHIC DESCRIPTION

The statistical region of Obalno-kraška located in southwestern Slovenia represents the eligible IPA programme area in Slovenia. After the first geological field-activities and an overview of the archive material it was recognized that the most important types of building limestone as well as the appearance of some platy limestone types from this area had also spread to some parts of the Notranjsko-kraška and Goriška statistical regions (Territorial derogation area). Therefore, besides the Kras area, the northernmost part of the Kras, which belongs to the Goriška region, and the Matarsko Podolje area as a part of the Notranjsko-kraška region were also included in the geological research.

Kras/Carso is located east of the Gulf of Trieste (Adriatic Sea) (Fig 1.1). It is an up to 40km long and approx. 13km wide karst plateau stretching in the Dinaric direction (northwest - southeast). Most of the Kras area belongs to Slovenia, while a smaller part, near the Adriatic coast and around Doberdob, lies in Italy. On the west and south-west studied territory it is limited by the border between Slovenia and Italy, on the north and north-east Kras borders to the Vipava valley, while towards the south-east, between Kozina and Divača, it borders the Brkini (flysch) area. The Kras area is mainly a flat karst plain with rounded hills, small hillocks, barren land, dolines, caves and abysses, all these geomorphological features being typical of karst as an integrated natural phenomenon. The average altitude of the northern part of the plateau, known as the Dolenji Kras (Lower Kras), is between 250 and 300m. The highest elevations are located in a series of hills situated along the northern and northeastern part of the plateau, with its highest peak being Trstelj (643m). In the southern part of the plateau, also known as Gornji Kras (Upper Kras), the heights range between 350 and 600m, with the highest peak being Gradišče (741m). In Kras, there is no surface water, except the River Raša on the southeastern outskirts, which is filled by spring and autumn rainfalls. Underground streams are more important, in which the water flows from different directions towards the springs of the River Timava and several smaller springs along the coast to Trieste. The largest underground river is the River Reka that disappears into the Škocjanske jame (caves) and flows as the River Timava near the town of Duino again on the surface. The territory of the plateau is today relatively densely populated, especially in the southern part, where the border town Sežana, with 6,500 inhabitants, is the economic, educational, cultural and medical centre of the region. The most important transport centre is Divača. Through it runs, the Ljubljana - Sežana - Nova Gorica railway, with a branch to Koper and Pula and the Ljubljana – Koper motorway, with a branch to Fernetiči/Fernetti. The area around Divača and Sežana is famous for its karst caves such as the Kačna jama, Divaška

jama and Vilenica caves and Lipica cave, as well as the world-famous Škocjanske jame (caves), which were added to the UNESCO World heritage list in 1986. The northern part of the Trieste-Komen plateau, known as Dolenji Kras, is more sparsely populated than the southern part. In the central part of the plateau is Komen, which is the largest town in this part of the plateau. The most famous tourist site is Štanjel, which has an ancient fortified castle complex on the Turn.

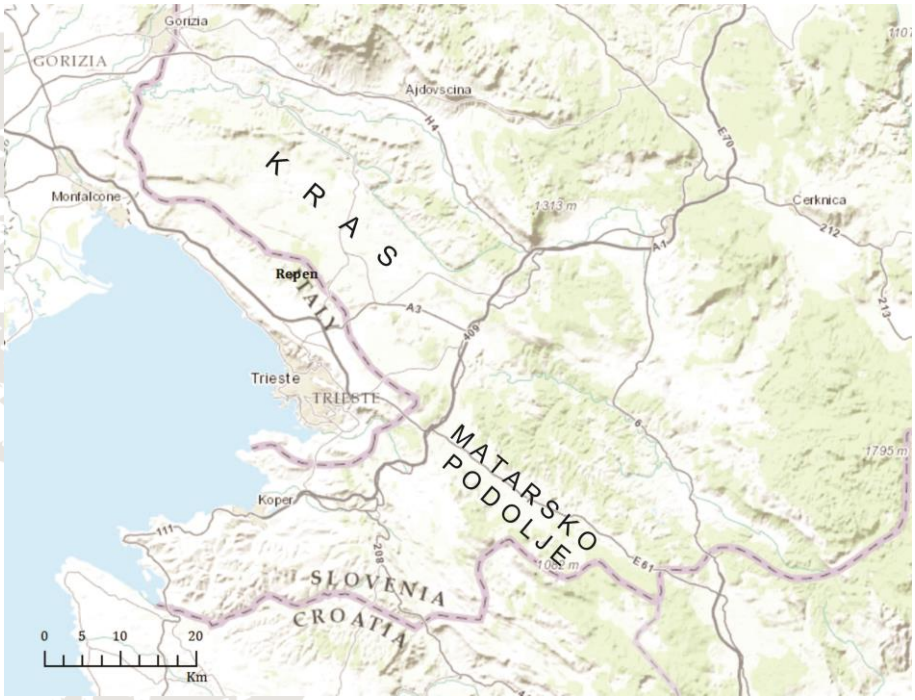


Figure 1.1 An overview map showing the position of Kras and Matarsko Podolje, the studied areas in the RoofOfRock project area in Slovenia

Matarsko Podolje is also represented by a karst plateau stretching in a northwest-southeast direction from Kozina to Starod (Fig 1.1). On the south and west the area borders the Slovenia-Croatia border and the Ćićarija area and towards the north-east it borders the Brkini (flysch) area. The area is relatively sparsely populated. All the main settlements are located along the main regional road that connects Trieste (Italy) and Rijeka (Croatia). The largest are Hrpelje, Materija, Obrov, Hrušica and Podgrad. To the north-east of the main road there are some villages on the border between the Matarsko Podolje and Brkini area, while south-west of the main road there are only three more or less abandoned villages. The average altitudes of the central part of the area are between 500 and 700m. The highest elevations are located in a series of hills situated along the southern part of the plateau, with the highest peaks Razsušica (1,083m) and Slavnik (1,028m). Also in the Matarsko Podolje there is no surface water, except the very small and local springs near the Golac and Poljane villages. The surface waters disappear at the contact between the flysch and carbonate rocks on the north-eastern side of Matarsko Podolje and flow towards the springs of the River Rižana in Istria.

Project activities, focused on the study of building limestone in general, included the entire area of Kras and Matarsko Podolje. All this area was also covered with an overview geological map in a scale of 1:250.000. On the other hand, the appearances of platy limestone were only recognized in the Kras where this material was also used as building material.

2 GEOLOGICAL OVERVIEW OF BUILDING LIMESTONE IN THE PROJECT AREA IN SLOVENIA

2.1 INTRODUCTION

The first geological activity was a general overview of building limestone along the entire project area. In Slovenia the area of the Kras and Matarsko Podolje were included, where in the past, the building stone had a significant influence on the settlement, architecture and economic development of the area. The actions were mainly focused on the identification and characterization of the most important and most widely used types of building limestone. At the same time, a cross-border harmonized overview geological map was elaborated. All the geological units shown on the map were classified according to their potential as building limestone into four categories: no potential, less potential, potential and high potential. No potential geological units are units which do not contain a significant proportion of limestone, e.g. flysch rocks. Less potential units include less-quality limestone types, not commercially but only locally used. Potential units include relatively good quality building limestone which could also be commercially used, where abandoned quarries exist. Geological units assessed as high potential include types which are/were widely commercially used in numerous quarries. On a list of the most important building limestone types and on a list of typical quarries there were mostly listed the potential and high potential limestone types.

The actions started with a review of the existing relevant documents and data from formal and informal archives located at the Geological Survey of Slovenia.

The database and the overview geological map of the Kras are based on the formal data shown on the geological map of the northern and southern part of the Trieste-Komen plateau (1:25,000) (Jurkovšek, 2008; 2010; Jurkovšek et al., 1996), while the geological map of the Matarsko Podolje is based on the related sheet of the Basic geological map 1:100,000 (Šikić et al., 1972). Besides this, all the relevant mostly unpublished data and maps gathered by the project team have also been used in the preparation of the overview map. In addition, some selected areas were geologically mapped in detail; especially in Matarsko Podolje where we did not have much archive data and the geological map had to be cross-border (SLO-CRO) harmonized. The harmonization was implemented in collaboration with an expert team from the Croatian Geological Survey.

With the aim of identifying the use of building limestone in Matarsko Podolje we implemented the mapping of houses in selected villages of this area.

2.2 GEOLOGICAL SETTING

The investigated Adriatic karst area of Slovenia (Kras and Matarsko Podolje) belongs to the Dinaric Karst located in the northeastern Adriatic region. Tectonically, the region lies in the northwestern part of the External Dinarides. These are characterized by a wide belt of folds (anticlines and synclines) and reverse faults, which strike mostly in the NW-SE (so-called Dinaric) direction. In a narrower sense, the area can be referred to as the Komen thrust, one of the many thrusts in this part of the Dinarides (Placer, 1981, 1998). Carbonate rocks in the Matarsko Podolje as well as in the Kras form an anticlinorium in the NW-SE direction. The area is dissected by numerous faults with the main direction being NW-SE. The Divača,

Tomačevica and Raša faults dominate in the Kras, while the Skadanščina fault zone dominates in Matarsko Podolje.

The Slovenian part of the project region is characterized by up to 2,000m thick Cretaceous to Paleogene (145 to 40 million years (My) before present) shallow-water carbonates of the Adriatic/Dinaric carbonate platform (*sensu* Vlahović et al., 2005). They are overlain by deep-marine Paleogene siliciclastic flysch occurring in the Vipava valley, the Brkini area and in northern Istria.

Due to the economically important occurrences of high-quality natural stones, the Kras area has been studied more often in the past. The limestones and dolomites were divided into various geological formations (Jurkovšek et al., 1996). The oldest carbonate succession belongs to the **Brje Formation** of the Berriasian to Aptian (Lower Cretaceous) age. This geological unit does not contain any important building limestone types. The Albian to Cenomanian (Upper Cretaceous) succession of biomicritic limestone and dolomites belong to the **Povir Formation**. The succession is also locally composed of thin-bedded (platy) Komen limestone. The **Repen Formation** (Fig. 2) consists of Cenomanian and Turonian mostly grained rudist bioclastic limestones, among which the high-quality natural stone of the Repen and Kopriva type also occur. The Turonian to Santonian limestone belongs to the **Sežana Formation**. Also this succession is locally composed of the platy limestone type (Komen limestone of Sežana Fm.). In the **Lipica Formation** from the Santonian to Campanian age, several types of bedded and massive limestone with prevailing bioclastic varieties are present. This geological unit contains the platy Tomaj limestone type (Jurkovšek et al., 1996) as well as the high-quality natural stone of the Lipica type. The carbonate succession is concluded by the **Kras Group** megasequence of the Maastrichtian (Upper Cretaceous) to the Paleogene age. The unit is composed of limestones of the Liburnia Formation and Trstelj Fm. and Alveolinid-nummulitid Limestone. These geological units do not contain important building limestone types.

The oldest carbonate rocks that crop out in the Matarsko Podolje are the Lower Cretaceous limestone and dolomite (Šikić et al. 1972; Jež et al., 2011). They are overlain by Albian to Cenomanian shallow-marine limestone and dolomite with intercalations of calcareous-dolomitic breccias. The Cenomanian-Turonian succession is represented by grained bioclastic limestone, while the Turonian-Santonian sequence is composed of biomicritic limestone similar to the limestone of Sežana Fm. in the Kras. The Kras group in the Matarsko Podolje is represented by a relatively thin succession of palustrine and shallow-marine foraminiferal limestone.

2.3 OVERVIEW OF BUILDING LIMESTONE TYPES AND OCCURRENCE

The Kras is one of the most interesting areas containing reserves of natural stones in Slovenia. The limestone has always played a crucial role in the cultural heritage, landscape and economy of this area. The reason for this can mainly be found in the fact that the majority of the Kras area is composed of limestone which is an important economic and architectural resource especially for the Kras region. These stones have been appreciated as a result of their sound geomechanical properties and versatility since long ago. Thus the Kras region has been associated with quarrying and manufacturing stone for over two thousand years, since the Roman period. Large numbers of quarries of different types of limestone can be found and documented; however, many of them are no longer active. Small or large quarries were once almost an unavoidable component of every village. Kras people knew

and used a number of limestones that differed in quality, colour and structure (Vesel et al., 1987; Jurkovšek et al., 2013). The extraction of limestone, which was once the most important economic activity of the local people, has been gradually decreasing in the last few decades. Excavation is active in the southern part of the plateau around the towns of Lipica, Povir, Vrhovlje and Kopriva whereas the quarrying on the northern part of Kras (Jurkovšek, 2008; 2010) has now been mostly abandoned. The excavation of technical stone in the tectonically deformed zones has also greatly decreased.

On the other hand, in the Matarsko Podolje, before the start of the project activities, active or abandoned quarries of building limestone were not known, therefore, we implemented the mapping of the use of limestone in older houses all over the Matarsko Podolje (Table 2.1). It was recorded that people used very local stone for building their houses, which was excavated very close to the villages. The data acquired during mapping of the houses helped us to classify the geological units according to their potential as building limestone. These selected units were later geologically mapped in detail and presented on the overview geological map (1.250,000) (Fig. 2.1). During the geological mapping there were evidenced some smaller abandoned limestone quarries, especially near the villages of Podgrad, Račice and Starod. The most widely used were litotypes from the Cenomanian-Turonian (ID14) unit, the Turonian-Santonian (ID15) unit and the Paleogene Foraminiferal limestone (ID 18) unit. (See the geological map). In Table 2.1 there are presented mapped houses and studied architectural elements in Matarsko Podolje and the limestone types or geological units/formations which were used to manufacture these elements.

Nr.	Village	Location	Element/part	Geological unit*/lm. type
1.	Starod	church	corner stones	15-Turonian-Santonian
2.	Starod	abandoned house near the church	window frames + wall	13-Albian-Cenomanian, 15-Turonian-Santonian, 18-Foraminiferal limestone, 19-Flysch
3.	Starod	Starod 43, three buildings	portal, walls	15-Turonian-Santonian
4.	Starod	Starod 46	portholes	15-Turonian-Santonian
5.	Starod	Starod 46-48	wall	15-Turonian-Santonian
6.	Račice	Račice 84	wall	15-Turonian-Santonian
7.	Podgrad	Podgrad 46		15-Turonian-Santonian
8.	Podgrad	Podgrad 74	abandoned house	15-Turonian-Santonian
9.	Podgrad	Podgrad 66	portals	15-Turonian-Santonian
10.	Podgrad	old church Podgrad (sv. Jakob)	walls, corner stones	15-Turonian-Santonian, partly 19-Flysch sandstone
11.	Hrušica	?	wall	limestone, 19-Flysch sandstone
12.	Hrušica	Hrušica 46, 55		15-Turonian-Santonian, individual blocks of 19-Flysch
13.	Poljane pri Podgradu	Poljane pri Podgradu 2	complex of abandoned buildings	light-grey biomicritic limestone with rudists, grey micritic limestone, grey grained limestone
14.	Poljane pri Podgradu	Poljane pri Podgradu 3	abandoned house	biomicritic limestone
15.	Poljane pri Podgradu	Poljane pri Podgradu 35	ruins of abandoned house	grey-brown limestone with peloids and algae
16.	Poljane pri Podgradu	church in Poljane	corner stones, walls, window frames	brown bioclastic limestone
17.	Golac	church in Golac	corner stones, walls	light-brown biomicritic limestone 14-Cenomanian-Turonian? grey peloid-bioclastic limestone

Nr.	Village	Location	Element/part	Geological unit*/lm. type
18.	Golac	Golac 19	2 portals, frames	grey micritic and bioclastic limestone (14-Cenomanian-Turonian?), 18-Foraminiferal limestone
19.	Golac	Golac 14	corner stones	light-brown intraclastic-foraminiferal limestone
20.	Golac	Golac 65	corner stone	light-brown biomicritic limestone
21.	Obrov	Obrov 13/41	corner stones of two houses	15-Turonian-Santonian
22.	Gradišče pri Materiji	Gradišče pri Materiji 16?	wall + window with vault	14-Cenomanian-Turonian dominates, partly 15-Turonian-Santonian
23.	Velike Loče	Velike Loče 2-3	wall	15-Turonian-Santonian, 19-Flysch
24.	Velike Loče	Velike Loče 2-3	supporting wall	19-Flysch
25.	Slivje	Slivje 28	walls	mostly 19-Flysch
26.	Slivje	church in Slivje	renovated bell tower	similar to 15-Turonian-Santonian, probably imported from Kras area
27.	Hotična	Hotična 6	abandoned house, corner stones, walls and portal	15-Turonian-Santonian dominates, partly also 18-Foraminiferal limestone and 19-Flysch, portal 14-Cenomanian-Turonian
28.	Skadanjščina	Skadanjščina 11 in 2	corner stones	brown to grey biomicritic and bioclastic limestone with calcispheres 14-Cenomanian-Turonian
29.	Bač pri Materiji	Bač pri Materiji 14/15	corner stones	limestone with calcispheres 14-Cenomanian-Turonian
30.	Brezovica	Brezovica 7a	wall	only 19-Flysch
31.	Brezovica	staircase to the church	staircase, walls	only 19-Flysch
32.	Brezovica	building near the church	wall	15-Turonian-Santonian, 14-Cenomanian-Turonian, 19-Flysch sandstone
33.	Odolina	church	walls	15-Turonian-Santonian, 14-Cenomanian-Turonian, 19-Flysch sandstone
34.	Rožice	Rožice 22	wall	14-Cenomanian-Turonian, 15-Turonian-Santonian
35.	Slope	Slope 4	wall	15-Turonian-Santonian, 19-Flysch
36.	Slope	Slope 15	wall, corner stones	mixed: 15-Turonian-Santonian, 19-Flysch
37.	Rodik	Rodik-centre of the village	fountain “štirna”	15-Turonian-Santonian
38.	Rodik	church	entrance portal	15-Turonian-Santonian
39.	Rodik	opposite the inn RACE		mixed: 15-Turonian-Santonian, 18-Foraminiferal limestone, 19-Flysch
40.	Vrhpolje	Near the house Vrhpolje 9	walls	mixed: 18-Foraminiferal limestone, 19-Flysch
41.	Nasirec	Nasirec	old walls in the village	mixed: 19-Flysch +different limestones
42.	Nasirec	church	roof	19-Flysch sandstone
43.	Nasirec	church	entrance portal	14-Cenomanian-Turonian (not local stone)
44.	Nasirec	church	plates at the ground	15-Turonian-Santonian
45.	Klanec pri Kozini	Klanec 3 in 14	walls	19-Flysch
46.	Beka	?	outbuilding-walls	19-Flysch
47.	Ocizla	Ocizla	supporting walls	19-Flysch

***For geologocal units and ID numbers see the Overview geological map (1:250.000).**

Table 2.1. Mapping of houses in the Matarsko Podolje.

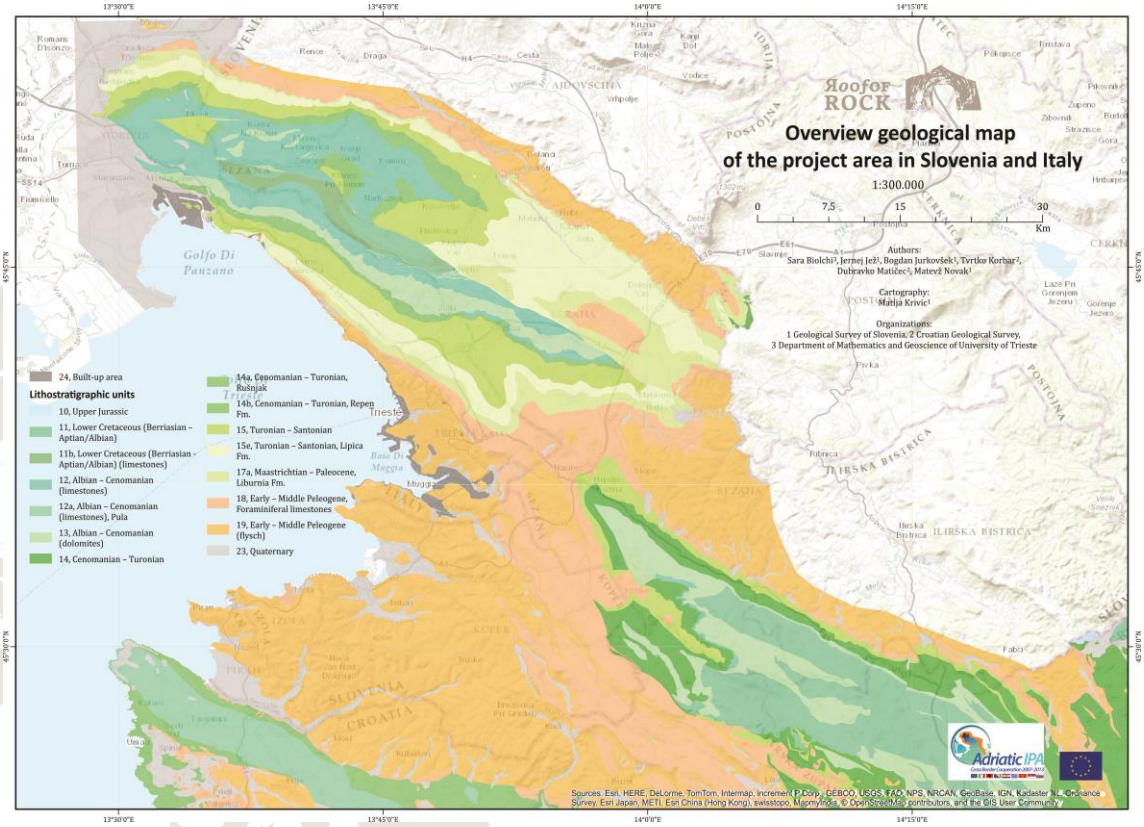


Figure 2.1 An overview geological map of the project area in Slovenia and Italy. All the presented geological units are cross-border (Slovenia-Italy and Slovenia-Croatia) harmonized.

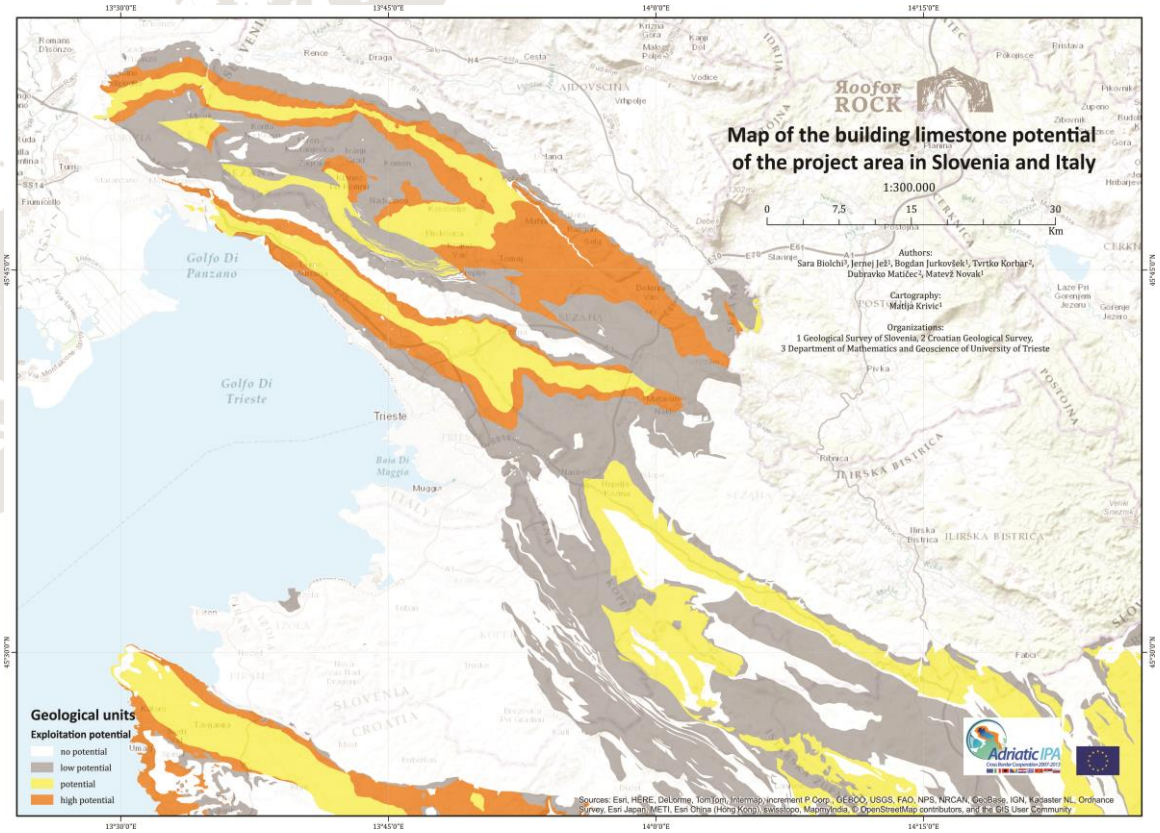


Figure 2.2. Map of the building limestone potential for the project area in Slovenia and Italy (white – no potential, grey – low potential, yellow – potential, orange – high potential).

2.3.1 BUILDING LIMESTONE IN THE KRAS AREA

The Kras region has a long history of quarrying and manufacturing of high-quality limestone therefore, this area is treated somewhat more in detail.

On the basis of a review of the existing relevant documents from the archives located at the Geological Survey of Slovenia, the documentation and geological mapping of selected localities and numerous discussions with local people and the stonecutters' list of types of building limestones and quarries in the Kras was elaborated (Table 2.2). All the listed quarries were also inserted into the GIS-based database and can be seen on the RoofOfRock project web-application.

No._ID	ID_GU 250**	No. unit	Typical quarry	Name of stone	Basic lithology	Project area	Location	Potential *
2200	155	15e	Bezovščina (Tavčar)	Lipica unito	Light brownish-grey fine-grained bioclastic limestone	Southern Kras	W of Lipica	3
2201	155	15e	Bezovščina 1	Lipica unito	Light brownish-grey fine-grained bioclastic limestone	Southern Kras	W of Lipica	3
2202	155	15e	Bezovščina 2	Lipica unito	Light brownish-grey fine-grained bioclastic limestone	Southern Kras	W of Lipica	3
2203	15	15	Brda	Bioclastic Rudist lense	Light grey bioclastic limestone with unfragmented Rudist shells	Northern Kras	NW of Hruševica	2
2204	12	12	Bristovnik	Škrbina (fiorito nero)	Black biomicritic limestone with Rudist shells, locally brecciated	Northern Kras	N of Škrbina	2
2205	155	15e	Bržina	Lipica unito	Light brownish-grey fine-grained bioclastic limestone	Southern Kras	NE of Tomaj	3
2206	155	15e	Čebarnice 1	Fiorito nero	Dark grey to black bioclastic limestone with Rudists	Southern Kras	N of Kazlje	2
2207	155	15e	Čebarnice 2	Fiorito nero	Dark grey to black bioclastic limestone with Rudists	Southern Kras	N of Kazlje	2
2208	155	15e	Čokova java	Lipica fiorito	Light to middle brownish-grey bioclastic limestone with Rudists (floatstone)	Northern Kras	NE of Lipica	3
2209	15	15	Črna java	Črna java	Black micritic limestone	Northern Kras	N of Opatje Selo	1
2210	142	14b	Debela Griža	Breccia= Debela Griža	Middle grey to brownish-grey limestone breccias in the most upper part of Repen formation	Northern Kras	E of Škrbina	3
2211	155	15e	Debelak 1	Fiorito nero	Dark grey to black bioclastic limestone with Rudists	Southern Kras	E of Kopriva	2
2212	155	15e	Debelak 2	Fiorito nero	Dark grey to black bioclastic limestone with Rudists	Southern Kras	E of Kopriva	2
2213	142	14b	Doline - Repen Fm		Light grey bioclastic limestone with Rudists (locally Rudist floatstone)	Southern Kras	SE of Vrhovlje	3
2214	142	14b	Dovce	Atypical Repen	Light grey bioclastic limestone with numerous Rudists in the upper part of Repen formation	Northern Kras	N of Mali Dol	2
2215	155	15e	Drnovc	Fiorito nero	Dark grey to black bioclastic limestone with Rudists	Southern Kras	NW of Avber	2
2216	142	14b	Gabričje 1	Tectonized limestone - cleavage platy limestone	Tectonized light grey limestone	Souhern Kras	W of Divača	3
2217	142	14b	Gabričje 2	Tectonized limestone - cleavage platy limestone	Tectonized light grey limestone	Souhern Kras	W of Divača	3
2218	155	15e	Gabrovca	Fiorito nero	Dark grey to black bioclastic limestone with Rudists	Southern Kras	S of Dobravlje	2
2219	142	14b	Gerbeva java	Repen/Kopriva (transitional type)	Light to medium grey bioclastic limestone with fragmented mollusca shells and unfragmented Rudist shells	Northern Kras	NW of Kostanjevica	2
2220	142	14b	Griža (Tavčar)	Repen	Light grey bioclastic limestone with Rudists (locally Rudist floatstone)	Southern Kras	SW of Povir	3
2221	142	14b	Ivanjske njive 1	Repen	Light grey bioclastic limestone with Rudists (locally Rudist floatstone)	Northern Kras	NW of Gorjansko	3
2222	15	15	Ivanjske njive 2	Bioclastic Rudist lense	Light grey bioclastic limestone with unfragmented Rudist shells	Northern Kras	NW of Gorjansko	2
2223	15	15	Kamna gorica	Kamna gorica (fiorito)	Middle grey limestone with radioliotids in the most upper part of Sežana formacija (it was used for	Southern Kras	NE of Dutovlje	2

No._ID	ID_GU 250**	No. unit	Typical quarry	Name of stone	Basic lithology	Project area	Location	Potential *
					construction of railway Jesenice-Trieste)			
2224	12	12	Komenska java	Coljava	Medium olive-grey brecciated limestone with Rudists and Chondrodonta and calcite	Northern Kras	S of Komen	2
2225	142	14b	Konjske Stope - Repen Fm	Repen	Light grey bioclastic limestone with Rudists (locally Rudist floatstone)	Northern Kras	NE of Kopriva	3
2226	142	14b	Kremenik	Kopriva	Light to medium grey grained limestone with fragmented mollusc shells	Northern Kras	N of Kopriva	3
2227	23	23	Linca	Calcareous sinter	Calcareous sinter	Northern Kras	S of Dolenja Brestovica	1
2228	155	15e	Lipica 1	Lipica fiorito	Light to middle brownish-grey bioclastic limestone with Rudists (floatstone)	Northern Kras	NE of Lipica	3
2229	155	15e	Lipica 2	Lipica unito	Light brownish-grey fine-grained bioclastic limestone	Southern Kras	NE of Lipica	3
2230	142	14b	Lipovci (Gabrovica)	Kopriva	Light to medium grey grained limestone with fragmented molusca shells	Southern Kras	S of Gabrovica	3
2231	23	23	Mirsce	Calcareous sinter	Calcareous sinter	Southern Kras	S of Gorjansko	1
2232	155	15e	Ogradca	Fiorito nero	Dark grey to black bioclastic limestone with Rudists	Southern Kras	SW of Dobravlje	2
2233	142	14b	Opatje Selo	Repen	Light grey bioclastic limestone with Rudists (locally Rudist floatstone)	Northern Kras	Opatje Selo	3
2234	155	15e	Plavišče 1	Fiorito nero	Dark grey to black bioclastic limestone with Rudists	Southern Kras	N of Avber	2
2235	155	15e	Plavišče 2	Fiorito nero	Dark grey to black bioclastic limestone with Rudists	Southern Kras	N of Avber	2
2236	155	15e	Podstena	Fiorito nero	Dark grey to black bioclastic limestone with Rudists	Southern Kras	NW of Avber	2
2237	142	14b	Rova	Kopriva	Light to medium grey grained limestone with fragmented molusca shells	Northern Kras	N of Kopriva	3
2238	23	23	Rusa java	Calcareous sinter	Calcareous sinter	Northern Kras	E of Škrbina	1
2239	15	15	Srebro	Srebro-fiorio nero	Black bioclastic limestone with white Rudist shells	Southern Kras	N of Dutovlje	1
2240	142	14b	Staje	Kobjeglava	Dark grey bioclastic and brecciated limestone in the most upper part of Repen formation	Northern Kras	Kobjeglava	1
2241	155	15e	Stalovci	Stalovci-fiorito	Middle to dark grey limestone with fragmented and whole Rudist shells (floatstone), the most lower part of Lipica formation	Northern Kras	NE of Temnica	2
2242	12	12	Škrbina	Škrbina (fiorito nero)	Black biomicritic limestone with Rudist shells, locally brecciated	Northern Kras	N of Škrbina	2
2243	155	15e	Špilčevka	Lipica fiorito – darker type	Middle grey bioclastic limestone with Rudists (floatstone)	Southern Kras	E of Tomaj	2
2244	12	12	Vdrjanca	Coljava	Medium olive-grey brecciated limestone with Rudists and Chondrodonta and calcite	Northern Kras	E of Coljava	2
2245	155	15e	Za debelo grižo	Fiorito and breccia	Middle grey bioclastic limestone with Rudists (floatstone) and breccia on a boundary to Liburnia formation	Northern Kras	E of Hruševica	2
2246	155	15e	Zadovček	Lipica fiorito – darker type	Middle grey bioclastic limestone with Rudists (floatstone)	Southern Kras	NW of Griže	2
2247	12	12	Berešnik		Dark grey bioclastic limestone with unfragmented Rudist shells (fiorito nero)	Kras	E of Rubije	
2248	155	15e	Beščevc		Unito type limestone with rare unfragmented Rudist shells	Kras	SE of Avber	
2249	142	14b	Bezgorice-Predole	Kopriva with Caprinids	Light grey bioclastic limestone with Caprinids	Northern Kras	S of Hruševica	
2250	12	12	Blastovca		Black bioclastic limestone with rare Rudist shells	Kras	E of Tomačevica	
2251	142	14b	Boršt		Light grey limestone with Rudists	Kras	Divača	
2252	142	14b	Bršljanovc		Light grey limestone of Repen Formation	Kras	E of Sežana	
2253	12	12	Buljenca		Dark grey to black bioclastic limestone with fragmented Rudist shells	Kras	N of Sveto	
2254	155	15e	Cencetovka		Medium grey limestone	Kras	E of Filipčje	

No._ID	ID_GU 250**	No. unit	Typical quarry	Name of stone	Basic lithology	Project area	Location	Potential *
							brdo	
2255	12	12	Doline - Povir Fm		Medium olive-grey limestone with molusca shells	Kras	S of Lipa	
2256	12	12	Draga		Dark to brownish-grey brecciated limestone with few Rudist shells	Kras	Tomačevica	
2257	155	15e	Fajti 1		Olive-grey bioclastic limestone with unfragmented and fragmented Rudist shells	Kras	NW of Kostanjevica	
2258	155	15e	Fajti 2		Medium brownish-grey bioclastic limestone with Rudists (small Radiolites)	Kras	NW of Kostanjevica	
2259	142	14b	Hrbčič 1			Kras	SE of Sežana	
2260	12	12	Hrbčič 2			Kras	E of Sežana	
2261	142	14b	Ilo		Medium olive-grey bioclastic limestone with Chondrodonta and Rudist shell fragments	Kras	NE of Tomačevica	
2262	15	15	Ilovca		Medium to light grey bioclastic limestone with fragmented Rudist shells	Kras	NW of Pliskovica	
2263	12	12	Konjske stope - Povir Fm		Black micritic limestone	Kras		1
2264	142	14b	Kopriva			Kras	N of Kopriva	2
2265	155	15e	Kosmatica		Medium gry bioclastic limestone	Kras	W of Dutovlje	
2266	142	14b	Kovačica		Medium grey fine-grained bioclastic limestone with small Rudist fragments (Kopriva unito type)	Kras	E of Škrbina	
2267	142	14b	Kovčič				E of Gorjansko	
2268	155	15e	Krnisca 1		Black bioclastic limestone with small and fragmented Rudists	Kras	E of Avber	
2269	15	15	Lenivec 1		Medium grey limestone with fragmented Rudist shells	Kras	N of Sežana	
2270	142	14b	Lenivec 2			Kras	N of Sežana	
2271	142	14b	Lisična in Vitez			Kras	SE of Vrhovelje	
2272	142	14b	Lukači		Light grey bioclastic limestone with Rudist shells	Kras	SE of Nova vas	
2273	15	15	Mandrja		Medium grey bioclastic limestone with fragmented Rudist shells	Kras	S of Sežana	
2274	12	12	Na hribu		Dark grey fine-grained bioclastic limestone with small Rudist fragments	Kras	SE of Rubije	
2275	15	15	Na rudnici		Medium grey limestone with Miliolidae	Kras	Orlek	
2276	155	15e	Na zakališču		Medium to dark grey bioclastic limestone with Rudists (fiorito type)	Kras	N of Temnica	
2277	155	15e	Oglenca 1		Merdium grey sparitic limestone with rare Rudist shells	Kras	W of Dutovlje	
2278	155	15e	Oglenca 2		Medium grey sparitic limestone with rare Rudist shells	Kras	W of Dutovlje	
2279	12	12	Ogradica		Balck bioclastic limestone with micritic matrix and rare fragmented Rudist shells	Kras	Mali Dol	
2280	12	12	Oklade 1		Medium olive-grey brecciated bioclastic limestone with Rudist shell fragments	Kras	W of Voljčji Grad	
2281	12	12	Oklade 2		Medium grey limestone with Rudists	Kras	W of Voljčji Grad	
2282			Ozidje		Calcareous sinter	Kras	S of Gorjansko	
2283	12	12	Pečina		Dark grey fine-grained bioclastic and brecciated limestone with small and medium size Rudist shell fragments	Kras	S of Komen	
2284	155	15e	Pirovnik		Dark grey bioclastic limestone with rare Rudist shells	Kras	W of Dobravlje	
2285	12	12	Pleče		Dark grey tectonized limestone with calcareous veins	Kras	S of Dolenja Brestovica	
2286	15	15	Pod žegnom		Medium grey tectonized limestone	Kras	W of Gorjansko	

No._ID	ID_GU 250**	No. unit	Typical quarry	Name of stone	Basic lithology	Project area	Location	Potential *
2287	12	12	Pobregi		Dark grey limestone with rare Rudist shells	Kras	N of Škrbina	
2288			Podlukovec		Medium grey bioclastic limestone, locally with rare Rudists	Kras	S of Lukovca	
2289	155	15e	Podsirkovca		Medium grey limestone of unito type	Kras	NW of Dutovlje	
2290	155	15e	Podvrhek		Fine-grained limestone of unito type	Kras	N of Kazlje	
2291	142	14b	Predpulj			Kras	SW of Gabrovica	
2292	155	15e	Prek dola		Medium grey bioclastic limestone with Rudists	Kras	Majcni	
2293	12	12	Prek straže		Dark grey limestone with Rudist debris and whole deformed Rudists	Kras	Divača-Gorenje	
2294	15	15	Pri čuvajnici			Kras		
2295	142/15	14b/ 15	Pri dovci		Dark grey bioclastic limestone	Kras	NW of Kobjeglava	
2296	12	12	Prjevščina		Medium olive-grey biosparitic limestone with fragmented Rudist shells	Kras	SE of Gabrovica	
2297	12	12	Prjevščina 1		Medium olive-grey biosparitic limestone with fragmented Rudist shells and Miliolidae	Kras	SE of Gabrovica	
2298	12	12	Prjevščina 2		Medium olive-grey biosparitic limestone with fragmented Rudist shells (Coljava type)	Kras	SE of Gabrovica	
2299	142	14b	Pujeva java		Light-grey bioclastic limestone with Rudist shells fragments	Kras	NW of Kostanjevica	
2300			Renški vrh		Calcareous sinter	Kras	NW of Temnica	
2301	155	15e	Repače		Medium to light grey sparitic limestone with Rudists (Radiolites) and white calcareous shells infill	Kras	NW of Dobravlje	
2302	155	15e	Rovna		Dark grey bioclastic limestone with small Rudist shell fragments	Kras	SW of Kazlje	
2303	155	15e	Rupa		Medium to dark grey limestone with Rudist shells	Kras	N of Kazlje	
2304			Smadoline		Calcareous sinter	Kras	S of Gorjansko	
2305	155	15e	Staje - Lipica Fm		Medium grey bioclastic limestone with Rudists	Kras	Majcni	
2306	12	12	Stara stršinova 1		Medium grey brecciated limestone with fragmented Rudist shells	Kras	S of Komen	
2307	12	12	Stara stršinova 2		Srednjesiv do olivnosiv bioklastični apnenec z rudisti (tip fiorito) Medium grey to olive-grey bioclastic limestone with Rudists (fiorito type)	Kras	S of Komen	
2308	15	15	Stare griže		Medium grey limestone with whole Rudists and Rudist fragments (small Caprinids)	Kras	N of Orlek	
2309	155	15e	Stari boršt		Fiorito type limestone	Kras	SW of Gradnje	
2310	12	12	Stenenca		Temnosiv sparitni apnenec Dark grey sparitic limestone	Kras	S of Klariči	
2311			Sv. Katarina		Calcareous sinter	Kras	NW of Škrbina	
2312	155	15e	Štancarji		Medium grey limestone with whole Rudist shells and its fragments	Kras	NW of Štorje	
2313	15	15	Trobčica		Dark grey bioclastic limestone with fragmented Rudist shells	Kras	N of Ponikve	
2314	155	15e	Žirska sopada		Dark grey limestone with Rudist shell fragments	Kras	NE of Dutovlje	
2315	142	14b	Zaboršt	Kopriva type	Grey bioclastic rudist limestone	Northern Kras	N of Kopriva	3
2316	17	17	Žirska sopada			Kras	N of Žiri	
2317	112	11b	Benčinovka		Medium grey brecciated limestone	Kras	S of Dolenja Brestovica	

**** ID_GU 250 = ID numbers from the geological map 1:250,000; *Potential = building limestone potential: 1- less potential, 2-potential, 3-high potential**

Table 2.1 From No._ID 2200 to 2246 there are listed widely known quarries and related limestone types, while from No._ID 2247 to 2317 are presented less known quarries (data from local stonecutters), where the name of the exploited limestone type is not identified.

In the Kras area by far the most important geological units for quarrying the architectonic – building limestone are the Repen (No. unit 14b) and the Lipica (No. unit 15e) Formations (Fig. 2.2).

The **Repen Formation** consists of three main types of limestone that pass laterally and vertically in relation to each other. The basic core of the unit is composed of bedded limestone that locally contains Komen Limestone with pelagic fossils (see Chapter 3). The upper part of the formation includes the Repen/Kopriva member with displaced and locally fractured rudist shells. This part of the formation represents the economically very promising types of natural stone. The bioclastic limestone of this member in places thins out completely, or locally the highest part of the succession contains a thick layer of dark grey limestone breccia or bioclastic onkoidal limestone (Jurkovšek et al., 1996). The Repen Formation includes an up to 30m thick horizon of the **Repen limestone type**. It is light grey, massive, biosparitic and partly recristalized limestone (mudstone to wackstone grading into rudist floatstone) (Fig. 2.3). Numerous fossils, with prevailing darker displaced rudist (radiolitid and caprinid) shells among them, give the limestone its typical appearance. The classical Repen, is of great economic importance (Vesel, 1979; Vesel at al., 1987). It was named after the Repen (Rupingrande) village in Italy.

Figure 2.3 The structure of Repen limestone type (easily visible mainly un-fragmented rudist shells)

The belt of this limestone passes from Repen (Italy) towards Sežana, Povir and Divača. In this belt there occurs a series of quarries. In the western part are the abandoned quarries of Lisično I and II, towards the east follow Vitez, Polževo I and II and the active quarry Doline (operator: Marmor Sežana) (Fig. 2.4). Also active is the Griža (Tavčar) quarry near Povir (Fig. 2.5). There are also a series of smaller abandoned delves as far as Divača (see Table 2.2 and the web GIS-application). The second important appearance of the Repen limestone is south of Gabrovica and north of Gorjansko (Jurkovšek et al., 1996). In this belt the Kopriva quarries are located. The third area of Repen stone lies between the village of Kostanjevica and the village of Opatje Selo, where several abandoned quarries also occur (Jurkovšek, 2008, 2010).

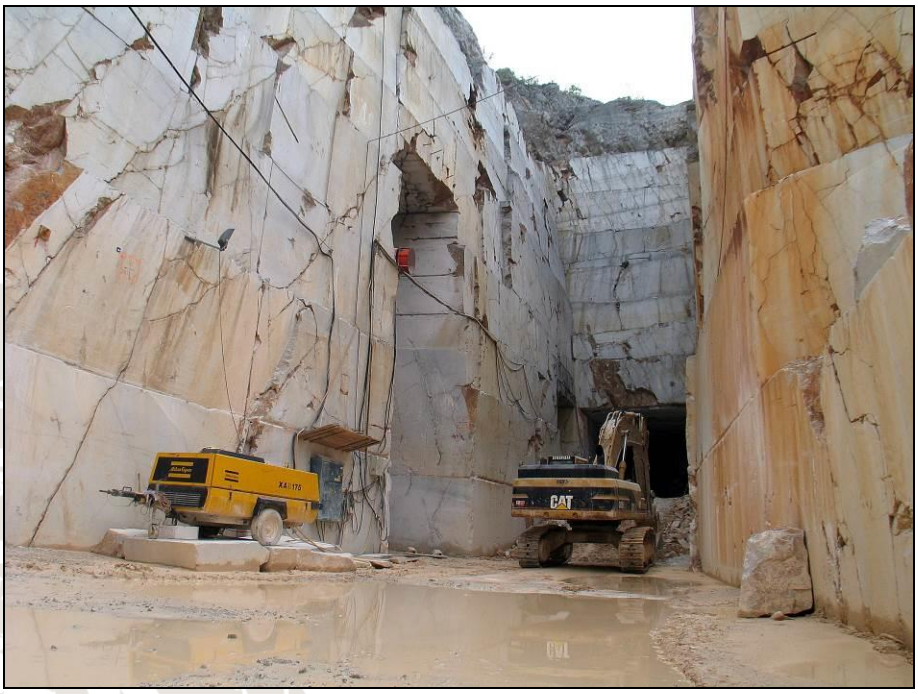


Figure 2.42 A doline quarry of the Repen type (see table 2.2; No._ID 2213)

Figure 2.5 Griža (Tavčar) quarry of Repen type near Povir (see table 2.2; No._ID 2220)

Around the village of Kopriva, in several quarries, a very solid homogeneous and massive limestone was/is excavated in the carbonate succession of the Repen Formation. It is called the **Kopriva limestone type.** The Kopriva type is a more homogeneous, massive limestone, containing crushed and rounded mollusc shells, primarily rudists (Fig. 2.6.).
As it is a very durable and high-quality natural stone, the company Marmor Sežana d.d. has just re-opened (year 2014) an abandoned quarry at Kremenik north of the village of Kopriva (Fig. 2.7).

Figure 2.6 The structure of the Kopriva limestone type (easily visible crushed and rounded mollusc shells)

Figure 2.7 Re-opening of the Kremenik quarry of the Kopriva limestone type near the village of Kopriva (see table 2.2; No._ID 2226).

In the **Lipica Formation** several types of bioclastic limestone occur. They are well-bedded or massive. They usually consist of relatively large rudist fragments, complete rudist shells, rarely rudist bouquets, clusters and parts of rudist thickets (Fig. 2.8) (Jurkovšek et al., 1996, Pleničar and Jurkovšek, 1997a, 1998, Jurkovšek, 2013). Varieties of limestones differ from each other in texture and colour. Due to the thick layering and homogeneous structure, this limestone represents the most economically interesting part of the carbonate rocks in the Kras.

Figure 2.8 Well-bedded rudist limestone from the Lipica Formation near Divača (Kras, Slovenia)

Lipica stone is a general name for natural stone from the Lipica Formation. From the bioclastic limestone sequence two characteristic limestone types are exploited. The first type is the uniform stone - **Lipica unito** which is light olive grey, homogeneous, compact, fine to coarse-grained limestone (Fig. 2.9). Fossils or their fragments are only several millimetres in size. The second type of Lipica stone is the rosy stone (fiorito) – **Lipica fiorito** which is predominantly a light grey, fine-grained, somewhat porous limestone that contains numerous fossil remains, especially rudist valves, of various sizes (Fig. 2.10).
In addition, one of the most beautiful varieties is the dark grey to black rudist limestone called **Lipica fiorito nero type**. It is composed of a dark micritic matrix and mainly un-fragmented rudists (Fig. 2.11). This and similar types were excavated northwest of the village of Kazlje, in a series of abandoned quarries in the area of Nadraša north of the village of Avber and north of the village of Temnica (see table 2.2 and the web GIS-application).

Figure 2.9 The homogeneous structure of Lipica unito limestone type (fine-grained bioclastic limestone)

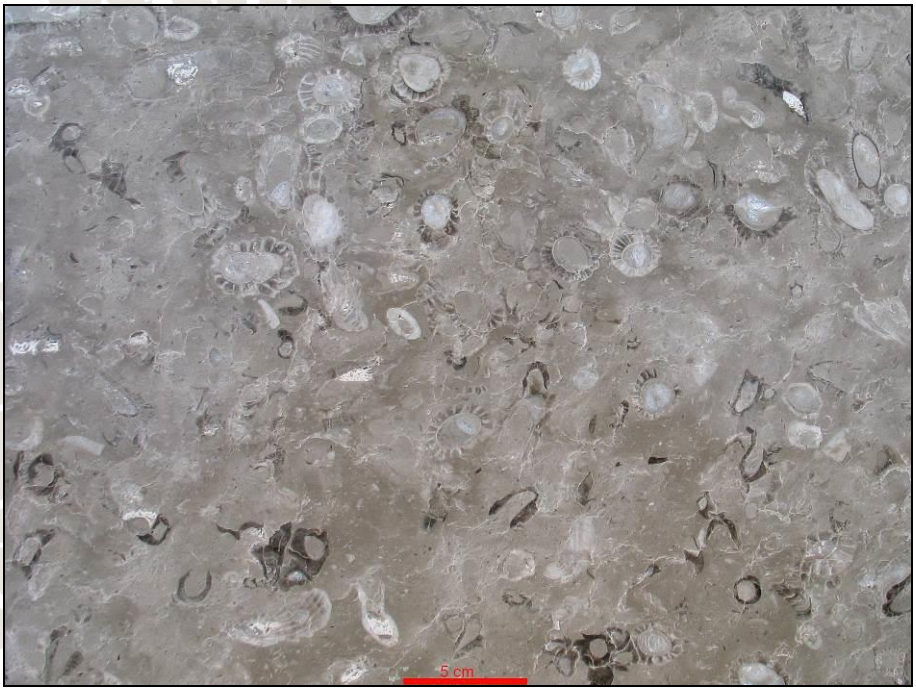


Figure 2.10 The Lipica fiorito limestone type (easily visible mainly un-fragmented rudist shells)

Figure 2.11 The Lipica fiorito nero type limestone

All abandoned quarries of architectonic-building stone in Lipica Formation are associated with the abundant occurrances of rudist shells (rudist bioherms and biostromes). These fossils give the rock a specific appearance and character.
Today the production of Lipica stone is limited to two types only (Lipica unito and Lipica fiorito) that are extracted in the quarries Lipica I and Lipica II (Fig. 2.12.).
Smaller abandoned quarries in the Lipica Formation with different types of building limestone are located all over the Kras area. They have various local names (see table 2.2 and web GIS-application).

Figure 2.12 The Lipica 1 quarry of Lipica limestone types near Lipica village (see table 2.2; No._ID 2228).

The above-presented quarries of Repen and Lipica stone are just localities where this limestone has been the most widely economically exploited. In addition, as can be seen from the list of quarries and limestone types (table 2.2) the same types of limestone were in the past widely exploited at many other locations all over the Kras area. Practically each village had its own quarry. The stone was mainly used for local use – building houses. In addition, some limestone types (e.g. Coljava, Kopriva with Caprinids, see table 2.2) were due to their interesting and colourful structure also used as decorative stone.
It can be concluded that the reserves of good quality architectonic-building limestone in Kras are almost unlimited, but for exploiting, great care is needed due to the sensitive karst natural environment. Nevertheless, the Kras stone and stone-cutting activity presents a part

of the Kras culture and identity. New possibilities are perhaps offered for expanding the relatively poor offer of Kras by the revival of smaller abandoned quarries, especially in the darker limestones of the Lipica Formation.

3 SHOW-CASE OBJECTS – PROVENANCE OF THE BUILDING STONE

3.1 INTRODUCTION and METHODOLOGY

The second geological project activity was focused on the identification of the provenance of the building stone used in typical autochthonous karst architecture. In Slovenia this action was implemented through the study of the use of limestone on five (5) selected show-case objects in the Kras.
The show-case objects were selected in close cooperation with WP4 (cultural heritage) contractors. For this purpose, joint (Wp3-Wp4 experts) field visits were organized. In collaboration with Wp4 experts we also developed and set a common field-description sheet, which was used for the investigation of all 26 selected show-case objects over the entire project area.
The architectural elements on the selected show-case object were geologically investigated in detail with the focus on the major in-situ sedimentological and micro- and macro-paleontological characteristics of the various building limestones used. These properties later assisted in finding the source areas of the stones used. A set of digital photographs for every building and every architectural element was taken.
The recognized lithological units were defined geologically according to data from the first (building limestone) and the third (platy limestone) RoofOfRock project activities (see Chapters 2 and 4). Some geological data were verified during the geological mapping of the selected areas.
The provenance of the types of limestone used was evidenced on the geological maps. All the geological data on the investigated show-case buildings were entered into the attribute tables set by the GIS (Wp7) experts.

3.2 OVERVIEW OF LOCALITIES - GEOGRAPHICAL DESCRIPTION

The five show-case buildings selected in the Slovenian part of the RoofOfRock project are situated in the Kras. Two of them are typical karst houses or farm houses and three of them are churches. Four objects are located in the southern part of Kras, while St. Elijah church is located in the village of Kopriva in the central part of the plateau. One house is situated in Divača and one farm house in the village of Gorenje pri Divači. One church is located on Gura hill above Povir village and one in the village of Šmarje pri Sežani (see table 3.1; Fig. 3.1).

ID_building	Location	Location (descriptive)	lat (wgs84)	lon (wgs84)
2001	GORENJE PRI DIVAČI	Home “pri Blaževih”	45,692859	13,948930
2002	POVIR (GURA)	Church “Marijinega vnebovzetja”	45,698297	13,918369
2003	ŠMARJE PRI SEŽANI	Church “Marije vnebovzete”	45,721967	13,866784
2004	KOPRIVA	St. Elija church	45,781364	13,834564
2005	DIVAČA	Home “Škrateljnova domačija”	45,684115	13,971021

Table 3. Locations of five (5) selected show-case buildings

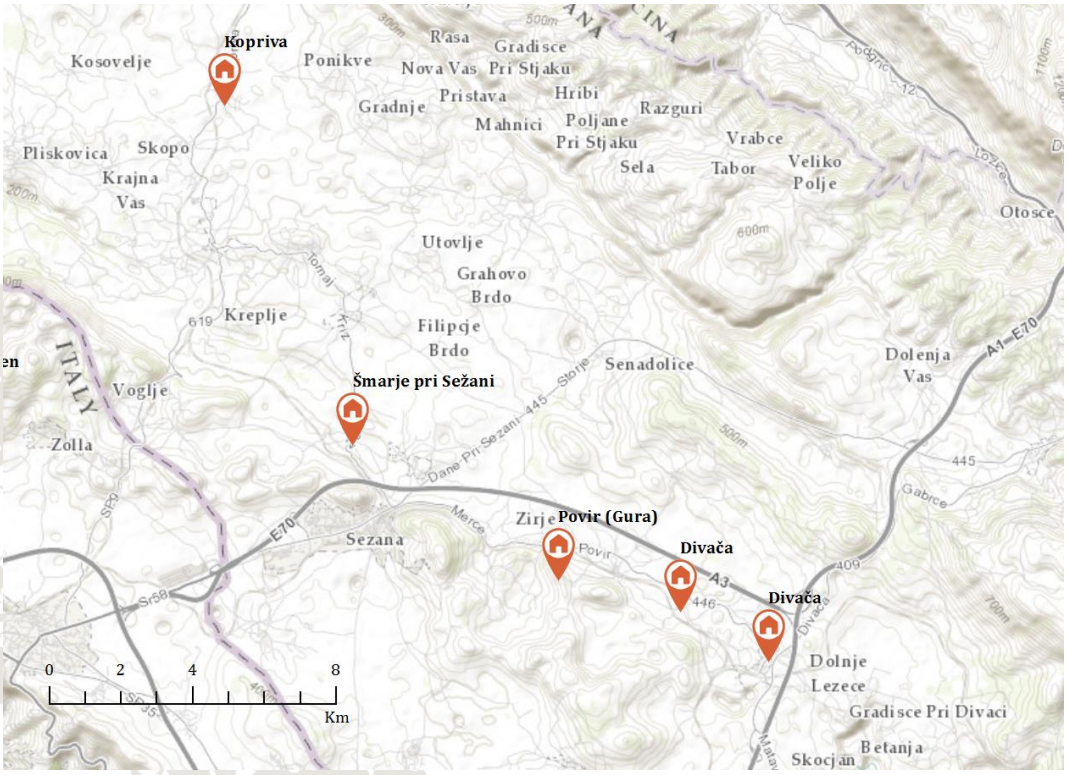


Figure 3.1 Locations of five (5) selected show-case objects in the Kras, Slovenia

3.3 USE AND GEOLOGY OF BUILDING STONE IN SELECTED SHOW-CASE BUILDINGS

3.3.1 GORENJE PRI DIVAČI – PR'BLAŽEVIH HOMESTEAD

The Blaževi homestead is located in the village square in central Gorenje pri Divači. The house is registered in the Registry of Immovable Cultural Heritage under the name of Gorenje pri Divači - House Gorenje 14, and under heritage unique reference number (EŠD) 7338. It consists of a preserved old hut called a *zidanica,* with an added kitchen, a *spahnjenica*.

The corners of the rectangular two-storey building are fortified with oblong corner blocks. The *spahnjenica* that was added to the southern façade has an unusual, four-sixths floor plan and a tall chimney that reaches above the ridge of the pitched roof. To the right of the *spahnjenica* is the entrance to the house, and on the other side is a masonry oven extending from its side wall.

The slopes of the slate roof of both the house and the *spahnjenica* are a steep 45 degrees, with both roofs exquisitely designed and well made. The roof slope facing the street features three slits or smoke vents, and under the drip edge is a console-mounted stone gutter for rainwater that ends with a stone valley; rainwater runs into a well with a cut-stone rim.

The building complex as a whole, with its special stone elements, is an exceptional architectural and masonry achievement. While its date of origin remains unknown, the dates on some of the neighbouring village buildings and on the former stone cross that once stood on the square next to the homestead suggest that it was built towards the end of the 17th century, or no later than the very early 18th century.

The accessibility of the house is excellent. The house is located near the main road.

Figure 3.2 Pr'Blaževih homestead, view from the south

List of studied limestone elements	
1	walls
2	main roof
3	extension roof
4	oven roof
5	eave (gutter) corbels
6	eaves (gutters)
7	corner stones
8	window frame
9	window frame (kitchen):
10	doorpost
11	yard wall
12	cistern scarp
13	cistern rim
14	trough
15	stone vessel

Part of the building (element): 1-walls

Name of limestone: limestone from the Povir Formation, Repen limestone

Geol. unit ID (map 1:250,000): 12, 142

Name of the geological unit: Albian-Cenomanian limestone (Povir Fm.), Repen Formation

Age: Albian-Cenomanian, Cenomanian-Turonian

Basic lithology:
Repen limestone: light grey bioclastic limestone with rudists
Povir limestone: dark micritic and biomicritic limestone, locally dolomite

Characteristics: In the blocks of Repen limestone rudist (radiolitid and requienid) shells are locally well-expressed

Quarry or source area:
Povir Fm. - around the village of Gorenje pri Divači, possible quarry: Prek Straže
Repen Fm. - south of Gorenje village, possible quarries: Boršt, Gabričje 1, Gabričje 2 and Griža (Tavčar) quarry (see web GIS-application)

Parts of the building (elements): 2-main roof, 3-extended kitchen roof, 6-eave (gutter) corbels, 6-eaves (gutters), 12-cistern scarp

Name of limestone: Fractured Repen limestone

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: light grey thick-bedded to massive bioclastic limestone with displaced, locally broken and rounded rudist shells

Characteristics: Fractured limestone = tectonically related discontinuities enable to excavate 3 to 7cm thick plates from the originally massive or thick-bedded limestone

Quarry or source area: Repenska Fm. south and west of the village of Gorenje pri Divači, possible quarries: Gabričje 1, Gabričje 2 and Griža (Tavčar) quarry

Part of the building (element): 4-oven roof

Name of limestone: Fractured Repen limestone, limestone of Povir Formation

Geol. unit ID (map 1:250,000): 142, 12

Name of the geological unit: Repen Formation, Albian-Cenomanian limestones (Povir Fm.)

Age: Cenomanian-Turonian, Albian-Cenomanian

Basic lithology:
Fractured Repen limestone: light grey thick-bedded to massive bioclastic limestone with rudist shells
Limestone from the Povir Formation: dark grey micritic limestone (only a few plates)

Characteristics:
Limestone of the Povir Fm.: within a succession of bedded micritic limestone, thin beds (up to 10cm) occur locally. A few of them were used for roofing in this case. The local occurrence of this type of limestone is not shown on the map of platy limestone (1:50,000) as polygons
Fractured Repen limestone: Fractured = tectonically related discontinuities enable the excavation of 3 to 7cm thick plates from the originally massive or thick-bedded limestone

Quarry or source area:
Repenska Fm. - south and west of the village of Gorenje pri Divači, possible quarries: Gabričje 1, Gabričje 2 and Griža (Tavčar) quarry
Povirska Fm. - south and west of the village of Gorenje pri Divači

Parts of the building (elements): 7-corner stones, 8-window frame, 10-doorpost, 13-cistern rim, 14-trough, 15-stone vessel

Name of limestone: Repen limestone

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: light grey to light brown coarse-grained thick-bedded to massive bioclastic limestone with rudist shells

Characteristics: Rudist (radiolitid and requienid) shells are locally parallel orientated (laminated structure)

Quarry or source area: Repenska Fm. south and west of the village of Gorenje pri Divači, possible quarries: Griža (Tavčar) and Boršt

Part of the building (element): 9-window frame (kitchen)

Name of limestone: Lipica unito

Geol. unit ID (map 1:250,000): 155

Name of the geological unit: Lipica Formation

Age: Santonian-Campanian

Basic lithology: light brownish-grey bedded fine-grained bioclastic limestone

Characteristics: fine-grained bioclastic debris

Quarry or source area: Most probable Lipica Fm. south and west of Divača, possible quarries: Lipica 1 or Lipica 2

3.3.2 DIVAČA – ŠKRATELJNOVI HOMESTEAD

The Škrateljnovi homestead is situated in central Divača and is registered in the Registry of Immovable Cultural Heritage under the name of Divača – Homestead Kraška 26, and under heritage unique reference number (EŠD) 94. The two-storey house with a long southern and a short eastern wing is situated directly on the main road that runs through the village. On the north-eastern side, the interior courtyard that showcases a stone-rimmed well borders on the long outbuilding of the former stable with a hayloft and added pigsty. On the south-western side of the courtyard there is a long, single-storey building that once housed a barn and a wine cellar.
The house grew in stages and acquired several additions over the centuries. Its architecture boasts picturesque, dynamic façades and a *gank* (wooden balcony) with an exterior staircase. In the corner between both wings there is a kitchen extension, a *spahnjenica*, with a stand-alone chimney projecting over the roof ridges of the house. The southern side of the kitchen showcases a masonry oven. The whole complex is covered with steep slate roofs, except for the overhang above the *gank*, which is covered with barrel tiles that also cover the former outbuildings.
There are no dates inscribed on the Škrateljnovi homestead. Alterations and extensions that gave it the form it had retained up until the most recent renovation likely took place between the beginning of the 1830s up to the early 1920s.

Accessibility is excellent. The house is located near the main road (Fig. 3.3).

Figure 3.3 Škrateljnova homestead, view from the south

List of studied limestone elements	
1	main roof (South) W part
2	main roof (South) E part
3	main roof (East)
4	small roof along stairs
5	extended kitchen roof
6	neighbour's house roof
7a	small/lower window frame (SE wall)
7b	roof above smaller window (SE wall)
7c	lower window frame (SE wall - without roof)
7d	new window frames (SE wall)

7e	small/upper window frame (SE wall - to balcony)
7f	window frame (SW wall - above stairs)
7g	window frame (NW wall - near kitchen)
9	former eave (gutter) corbels
10	middle balcony column
11	balcony fence shelf
12	cistern
13a	lower entrance doorpost
13b	upper entrance doorpost
14a	balcony floor
14b	yard floor
15	base of *Ita Rina* statue
16	stairs

Parts of the building (elements): 1-main roof (South) W part, 2-main roof (South) E part, 3-main roof (East), 4-small roof along stairs, 5-extended kitchen roof

Name of limestone: Fractured Repen limestone, Sežana Formation limestone (2%)

Geol. unit ID (map 1:250,000): 142, 15

Name of the geological unit: Repen Formation, Turonian-Santonian (Sežana Fm.)

Age: Cenomanian-Turonian, Turonian-Santonian

Basic lithology:
Fractured Repen limestone: fine-grained rudist bioclastic limestone
Sežana Fm. limestone: platy pelmicritic limestone

Characteristics: Fractured limestone = tectonically related discontinuities enable excavation of 3 to 7cm thick plates from originally massive or thick-bedded limestone. It consists of fragmented angular rudist shells

Quarry or source area:
Fractured Repen limestone: Gabričje quarry
Sežana Fm. limestone: Turonian-Santonian unit (Sežana Fm.) near Divača village

Part of the building (element): 6-neighbour's house roof

Name of limestone: Platy Komen limestone

Geol. unit ID (map 1:250,000): 12

Name of the geological unit: Albian-Cenomanian limestones (Povir Fm.)

Age: Albian-Cenomanian

Basic lithology: dark-grey platy pelmicritic limestone

Characteristics: lamination (stylolites) is well-expressed

Quarry or source area: Povir Formation

Parts of the building (elements): 7-small/lower window frame (SE wall), 22-base of Ita Rina statue

Name of limestone: Lipica fiorito

Geol. unit ID (map 1:250,000): 155

Name of the geological unit: Lipica Formation

Age: Santonian-Campanian

Basic lithology: coarse-grained bioclastic limestone with some unfragmented rudist shells and other macrofossils

Characteristics: in the limestone were evidenced fossils: *Katzeria herzegovinaensis, Gorianovicia sp., Bournonia, Medeella, Biradiolites,* Stromatoporidae

Quarry or source area: Lipica Formation, Lipica 1 quarry

Parts of the building (elements): 8-roof above smaller window (SE wall), 9-lower window frame (SE wall), 10-new window frames (SE wall), 11-small/upper window frame (SE wall - to balcony), 12-window frame (SW wall - above stairs), 13-window frame (NW wall - near kitchen), 18-lower entrance doorpost, 19-upper entrance doorpost

Name of limestone: Kopriva limestone

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: light-grey bioclastic limestone

Characteristics: locally rudists *Toucasia* occur

Quarry or source area: Repen Formation, Griža (Tavčar) quarry

Parts of the building (elements): 14-former eave (gutter) corbel, 16-balcony fence shelf

Name of limestone: Fractured Repen limestone

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: light-grey bioclastic limestone with radiolitid laminae

Characteristics: parallel rudist laminae, Fractured limestone = tectonically related discontinuities enable the excavation of 3 to 7cm thick plates from originally massive or thick-bedded limestone

Quarry or source area: Repen Formation, possible quarries: Gabričje1 , Gabričje 2, Griža (Tavčar)

Parts of the building (elements): 15-middle balcony column, 17-cistern

Name of limestone: Repen limestone

Geol. unit ID (map 1:250,000): 142

Name of geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: light-grey bioclastic limestone with radiolitid laminae

Characteristics: rudists Toucasia (Requiendae)

Quarry or source area: Repen Formation, possible quarries: Gabričje 1, Gabričje 2, Griža (Tavčar)

Part of the building (element): 20-balcony floor

Name of limestone: Kopriva limestone, Sežana Formation limestone

Geol. unit ID (map 1:250,000): 142, 15

Name of the geological unit: Repen Formation, Turonian-Santonian (Sežana Fm.)

Age: Cenomanian-Turonian, Turonian-Santonian

Basic lithology:
Kopriva limestone: light-grey fine-grained bioclastic limestone, rudist debris
Sežana Fm. limestone: grey pelbiomicritic limestone without macrofossils

Characteristics: /

Quarry or source area:
Repen Formation, possible quarry: Griža (Tavčar)
Sežana Formation near Divača village

Part of the building (element): 21-yard floor

Name of limestone: Lipica unito, Lipica fiorito

Geol. unit ID (map 1:250,000): 155

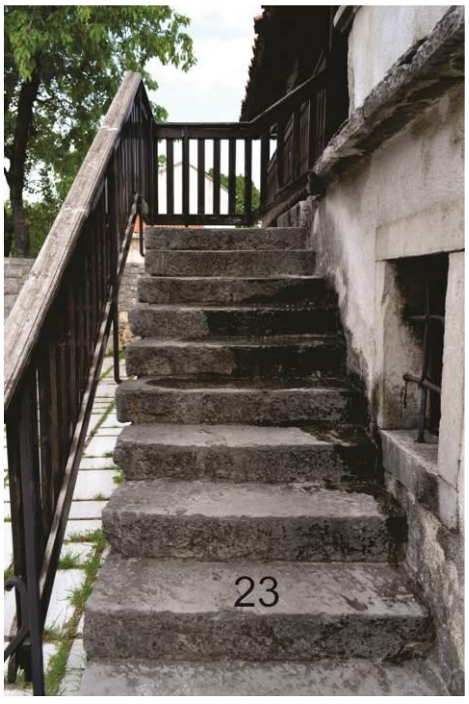
Name of the geological unit: Lipica Formation

Age: Santonian-Campanian

Basic lithology: grey fine-grained bioclastic limestone (Lipica unito), bioclastic limestone with rudist shells (Lipca fiorito)

Characteristics: newly paved floor

Quarry or source area: Lipica Formation, possible quarries: Lipica 1 and Lipica 2



Part of the building (element): 23-stairs

Name of limestone: Fractured Repen limestone, Sežana Fm. limestone (one stair)

Geol. unit ID (map 1:250,000): 142, 15

Name of the geological unit: Repen Formation, Turonian-Santonian (Sežana Fm.)

Age: Cenomanian-Turonian, Turonian-Santonian

Basic lithology:
Fractured Repen limestone: grey bioclastic coarse-grained rudist limestone
Sežana Fm. limestone: pelbiomicritic limestone

Characteristics: Fractured limestone = tectonically related discontinuities enable the excavation of 3 to 7cm thick plates from the originally massive or thick-bedded limestone, parallel oriented radiolitid (rudists) shells

Quarry or source area:
Repen Formation, possible quarries: Griža (Tavčar), Gabričje 1, Gabričje 2
Sežana Formation near Divača village

3.3.3 POVIR (GURA) – THE CHURCH OF THE ASSUMPTION OF THE BLESSED VIRGIN

The succursal church of the Assumption of the Blessed Virgin is situated on Gura Hill above the villages of Povir and Plešivica. It is registered in the Registry of Immovable Cultural Heritage under the name of Plešivica pri Sežani - Cerkev Marijinega Vnebovzetja, and under heritage unique reference number (EŠD) 3944. Its floor plan features a trilaterally closed presbytery, a rectangular nave and a belfry, correctly oriented along an east-west axis. The church is covered by a uniform, steep slate roof, and the belfry features a bell-shaped, angular slate roof. This is the only church in the Slovenian Littoral that is entirely, including the belfry, covered with slate.
It was rebuilt by master mason Jernej Kraševec from Postojna between 1642 and 1647, when he added an narthex (which is no longer there) to the façade. The construction of the belfry began in 1816 in its place, which is evidenced by the dedicatory inscription: B(EATAE) M(ARIAE) V(IRGINI) 1816. It was completed in 1863 by master mason Miha Blažko from Lokavec in the Vipava Valley, who had this year engraved on the front embrasures of the belfry. The stones for the belfry were cut by the stonemason Jožef Vrabec from Kopriva.

The church is located on the top of Gura hill and is accessible only on foot.

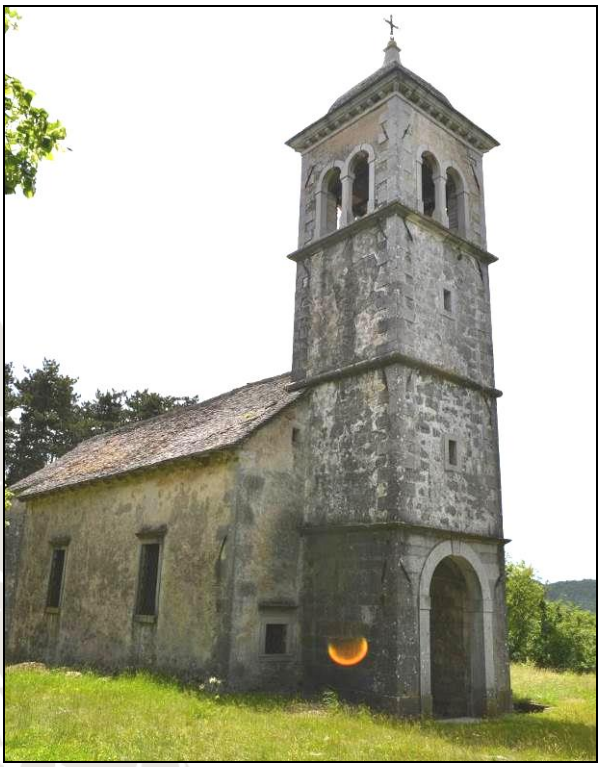


Figure 3.4 Church on Gura hill near Povir village, view from the north

List of studied limestone elements	
1	walls
2	bell tower roof
3	church main roof
4	bell tower corner stones
5	church corner stones
6	window frames (two near central entrance-door)
7	window frames (three on the church South wall)
8	flared portion
9	flared portion corbels
10	bell tower vault
11	main door doorpost
12	final stone
13	church foundation

Parts of the building (elements): 1-walls, 13-church foundation

Name of limestone: Povir Formation limestone, Povir Formation dolomite, limestone with Chondrodonta

Geol. unit ID (map 1:250,000): 12, 13

Name of the geological unit: Albian-Cenomanian limestones (Povir Fm.), Albian-Cenomanian dolomites (Povir Fm.)

Age: Albian – Cenomanian

Basic lithology: dark-grey to grey pelbiomicritic limestone with Chondrodonta bivalve shells, dark greyish-brown chrystalline dolomite

Characteristics: very often Chondrodonta shells, locally parallel oriented

Quarry or source area: nearby Albian-Cenomanian limestones and dolomites (Povir Fm.). Limestone with Chondrodonta cropping-out around the church suggests very local use of stone for building the walls and foundation.

Parts of the building (elements): 2-bell tower roof, 8-flared portion

Name of limestone: Fractured Repen limestone

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: grey grained bioclastic limestone

Characteristics: Fractured limestone = tectonically related discontinuities enable the excavation of 3 to 7cm thick plates from originally massive or thick-bedded limestone

Quarry or source area: Griža (Tavčar) quarry

Part of the building (element): 3-church main roof

Name of limestone: Fractured Repen limestone (~70%), platy limestone of Povir Formation (~30%)

Geol. unit ID (map 1:250,000): 142, 12

Name of the geological unit: Repen Formation, Albian-Cenomanian limestones (Povir Fm.)

Age: Cenomanian-Turonian, Albian-Cenomanian

Basic lithology:
Repen limestone: grey grained bioclastic limestone
Platy limestone of PF: dark colored platy pelmicritic laminated limestone

Characteristics: Platy limestone of Povir Fm. is of poor quality, it is disintegrating into slabs along the laminated structure

Quarry or source area:
Repen limestone: Griža (Tavčar) quarry
Platy limestone of PF: local appearances on the southern slopes of Strmca hill (PL locality ID_2112)

Parts of the building (elements): 4-bell tower corner stones, 5-church corner stones, 9-flared portion corbels, 10-bell tower vault, 11-main door doorpost

Name of limestone: Repen limestone

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: light-grey fine-grained biomicrite-biosparite bioclastic limestone with rare rudist shells

Characteristics: locally parallel oriented radiolitid shells

Quarry or source area: Repen Formation, Griža (Tavčar) quarry

Part of the building (element): 6-window frames (two windows near the main entrance)

Name of limestone: Repen limestone, Fractured Repen limestone

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: light-grey bioclastic limestone

Characteristics: /

Quarry or source area: Repen Formation, Griža (Tavčar) quarry

Parts of the building (elements): 7-window frames (three on the church south wall), 12-final stone

Name of limestone: Repen limestone, bioclastic rudist lenses

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: typical fine-coarse grained Repen bioclastic limestone with parallel orientated rudist shells, rudist limestone (biostroma)

Characteristics: fiorito type – uppermost part of the Repen Formation or the lowermost part of the Sežana Formation (bioclastic rudist lenses)

Quarry or source area: Repen Formation, Griža (Tavčar) quarry

3.3.4 ŠMARJE PRI SEŽANI – THE CHURCH OF OUR LADY OF THE ASSUMPTION

The Church of Our Lady of the Assumption in Šmarje pri Sežani is situated in the southern part of the village along the Sežana – Tomaj road. It is registered in the Registry of Immovable Cultural Heritage under the name of Šmarje pri Sežani - Cerkev Matere božje vnebovzete, and under heritage unique reference number (EŠD) 746, while the granary is registered under the name of Šmarje pri Sežani - Komunska kašča and under unique reference number (EŠD) 7355. The space that surrounds the church and was once the site of a cemetery is enclosed by a low stone wall covered with thick plates. On the south-facing side, just next to the wall, there is the so-called communal granary (Ribčeva kašča), which is roughly as old as the church; and together with the walls they form one of the most picturesque architectural complexes covered with stone roof tiles in the Littoral region (Primorska). This harmonious architecture, built from stone from its foundations to the roof ridge, grew entirely out of the Karst soil.
The church is correctly oriented: in the floor plan, from east to west, the trilaterally closed presbytery precedes the rectangular nave, which is followed by the narthex. A sacristy was added to the presbytery on the north-facing side and a tall bell gable rises from the façade of the church nave. The church has two Gothic portals concluding in a pointed arch. The year 1502, carved in Roman Numerals, and a stonemason's inscription on the main portal testify to the church being built in the late Gothic period.
During the 17th, 18th and 19th centuries the church was lifted and given new equipment and additions. In 1668, master mason and stonemason Anže Rojina from Brezovica in the Brkini Hills built a two-storey cut-stone bell gable, and in the 18th century Baroque period the church acquired its stone interior: the main altar and side altars with the choir dated 1779, and the narthex. The sacristy was added in 1823.

Accessibility is excellent. The house is located near the main road (Fig. 3.5.).

Figure 3.5 Church in Šmarje pri Sežani, view from the south

List of studied limestone elements	
1	walls
2	bell tower walls
3	main roof
4	SE roof
5	external entrance roof
6	entrance shed roof
7	corner stones
8	former entrance doorpost
9	external entrance doorpost
10	window frames
11	main doorpost
12	vestry entrance doorpost
13	entrance shed corbels
14	final stone
15	former entrance shed and brackets
16	vestry roof
17	outside floor

Parts of the object (elements): 1-walls, 2-bell tower walls, 7-corner stones, 8-former entrance doorpost, 9-external entrance doorpost, 10-window frames, 11-main doorpost, 13-entrance shed corbels, 14-final stone, 15-former shed entrance and brackets

Name of limestone: Repen limestone

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: grey coarse-grained bioclastic rudist limestone

Characteristics: /

Quarry or source area: Repen Formation, possible quarries: Lisična, Vitez, Doline

Parts of the building (elements): 3-main roof, 4-SE roof, 5-external entrance roof, 6-entrance shed roof, 16-vestry roof

Name of limestone: Komen limestone

Geol. unit ID (map 1:250,000): 12

Name of the geological unit: Albian-Cenomanian limestones (Povir Formation)

Age: Albian-Cenomanian

Basic lithology: dark coloured platy biomicritic limestone, 2-5cm thick beds

Characteristics: /

Quarry or source area: Albian-Cenomanian limestones (Povir Formation) near Šmarje village

Part of the building (element): 8b-vestry entrance doorpost

Name of limestone: Repen limestone – fiorito type

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: grey coarse grained bioclastic rudist (radiolitid) limestone

Characteristics: limestone consists of unfragmented (flower like) rudist shells

Quarry or source area: Repen Formation, possible quarries: Lisična, Vitez, Doline

Part of the building (element): 17-entrance shed floor

Name of limestone: Kopriva limestone

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: grey fine-grained locally laminated bioclastic limestone

Characteristics: typical fine-grained Kopriva limestone

Quarry or source area: Repen Formation, possible quarries: Lisična, Vitez, Doline

3.3.5 KOPRIVA – SAINT ELIJAH PARISH CHURCH

The parish church of St. Elijah is situated on the southeastern edge of the village and is correctly oriented from east to west. The church is registered in the Registry of Immovable Cultural Heritage under the name of Kopriva – Cerkev sv. Elije and under the unique heritage reference number (EŠD) 3780. Its floor plan has a trilaterally closed presbytery, rectangular nave and a belfry, while the sacristy was added on the south-facing side. Built from the local limestone, all of the church's corners were fortified with cut corner blocks. The presbytery has a steep slate roof, but other roofs are gently sloping and covered with barrel tiles (*korci*). Construction of the church that was built and consecrated in 1823 began in 1802. It incorporated the portal from the former Church of St. Elijah at Brje pri Koprivi, dated 1647, and the main altar, which was built in Gorizia in 1751. In 1824 the ground floor of the belfry was added to the façade and completed between 1852 and 1853 by master mason Miha Blažko from Lokavec in the Vipava Valley. At the same time, two side altars dedicated to St. Ursula and St. Stephen were built. Most likely in 1875 the local stonemason Anton Lavrenčič - Oštirac built the altar of Our Lady of Lourdes and placed it at the left wall of the church nave. This altar and other cut-stone building elements are made of different limestones excavated from quarries in the immediate vicinity of Kopriva and Brje.

Accessibility is excellent. The house is located near the main road in the centre of the settlement.

Figure 3.6 Church in Kopriva, view from the west.

List of studied limestone elements	
1	walls - general
2	roof
3	corner stones
4	final stone (bell tower)
5	bell tower vault
6	bell tower columns
7	main entrance doorpost
8	vestry entrance doorpost
9	former entrance doorpost
10	entrance floor (under the bell tower)
11	entrance threshold
12	window frames (2) on the entrance wall
13	window frames (4) on the side walls
14	vestry window frames (2)
15	Mary altar (nave) stairs (2)
16	Mary altar (nave) main part
17	upper part of the Mary altar (nave)
18	edge of the Mary statue
19	Mary altar outer columns (2)
20	Mary altar inner columns (2)
21	balustrade
22	choir pillars
23	stoup
24	upper and lower part of the choir pillars
25	water stone (stoup)
26	ciborium
27	left side-altar stairs
28	church floor
29	vestry floor
30	St. Elijah altar stairs (2)

Part of the building (element): 0-walls, general

Name of limestone: Pliskovica pelagic limestone, Kopriva limestone, limestone of Sežana Formation, oncoid limestone of Sežana Formation

Geol. unit ID (map 1:250,000): 15, 142

Name of the geological unit: Turonian-Santonian (Sežana Fm.), Repen Formation

Age: Turonian-Santonian, Cenomanian-Turonian

Basic lithology:
Pliskovica pelagic limestone: micritic limestone with calcispheres and pitonelas
Sežana limestone: biopelmicritic limestone with rare rudists
Oncoid limestone of Sežana Formation: light-grey thick-bedded biomicritic limestone with large oncoids
Kopriva limestone: fine-grained bioclastic rudist limestone

Characteristics: used at least four types of limestone from geological units nearby Kopriva village

Quarry or source area:
Sežana Formation (near Brje pri Koprivi), Sežana Fm. in general
Repen Formation north of Kopriva village, Rova quarry

Parts of the building (elements): 2-roof, 29-vestry floor

Name of limestone: Komen limestone

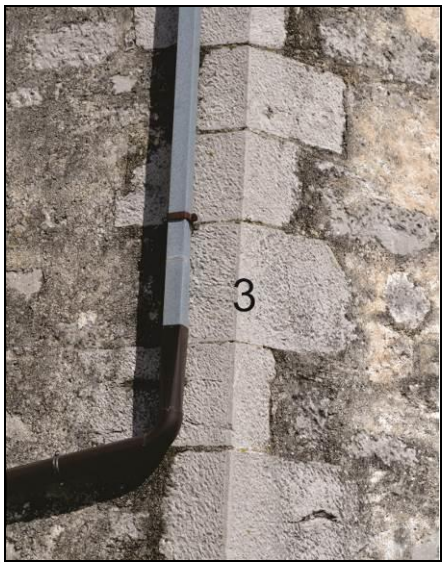
Geol. unit ID (map 1:250,000): 12

Name of the geological unit: Turonian-Santonian (Sežana Formation)

Age: Turonian-Santonian

Basic lithology: dark coloured laminated biomicritic and stromatolitic platy limestone

Characteristics: relatively poor quality (see report: Analysis of platy limestone chemical and mechanical properties)
Quarry or source area: Occurrences of Komen platy limestone (SW an S of Kopriva), possible quarries: Kosovelje and Kopriva (PL localities ID: 2110, 2111).



Part of the building (element): 3-corner stones

Name of limestone: Kopriva limestone, Onkoid limestone

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: fine-grained light grey bioclastic limestone

Characteristics: /

Quarry or source area:
Kopriva limestone: Repen Formation, Rova quarry
Onkoid limestone: Repen Formation

Parts of the object (elements): 4-final stone (bell tower), 5-bell tower vault, 6-bell tower columns, 8-vestry entrance doorpost, 10-entrance floor (under the bell tower), 12-window frames on entering wall, 13-window frames on side walls, 14-vestry window frames, 17-upper part of Mary altar (nave), 20-Mary altar inner columns, 21-balustrade, 24-upper and lower part of choir pillars, 25-water stone (vestry), 28-church floor, 30-St. Elijah altar stairs

Name of limestone: Kopriva limestone

Geol. unit ID (map 1:250,000): Repen Formation

Name of the geological unit: 142

Age: Cenomanian-Turonian

Basic lithology: light-grey bioclastic limestone with rudist debris

Characteristics: high-quality Kopriva limestone was used for many outer and inner church elements

Quarry or source area: Repen Formation (N of Kopriva), Rova quarry (maybe also other quarries in Repen Fm. N of Kopriva)

Part of the object (element): 7-main entrance doorpost

Name of limestone: Kopriva limestone (right), Repen limestone (left)

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology:
Kopriva limestone - grey fine-grained bioclastic limestone
Repen limestone - light-grey coarse-grained rudist limestone

Characteristics: Repen limestone – parallel rudist laminae

Quarry or source area:
Repen limestone - Repen Formation, Konjske stope quarry

Kopriva limestone - Repen Formation, Rova quarry

Part of the object (element): 9-former entrance doorpost

Name of limestone: Repen limestone

Geol. unit ID (map 1:250,000): 142

Name of geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: light-grey bioclastic limestone

Characteristics: parallel rudist shells

Quarry or source area: Repen Formation, Konjske stope quarry

Parts of the building (elements): 11-entrance threshold, 18-edge of Mary statue, 19-Mary altar outer columns

Name of limestone: Lipica fiorito nero

Geol. unit ID (map 1:250,000): 155

Name of the geological unit: Lipica Formation

Age: Santonian-Campanian

Basic lithology: Radiolitid biostroma, dark grey-black rudist limestone

Characteristics: radiolitid shells in their life position (bouquets)

Quarry or source area: Lipica Formation, Čebranice I. and II. quarries

Part of the object (element): 15-Mary altar (nave) stairs

Name of limestone: Repen limestone with Caprinids

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: bioclastic rudist breccia

Characteristics: very characteristic Caprinids (*Caprinidae*) up to 10cm in diameter

Quarry or source area: Repen Formation, Predole (Bezgorice) quarry

Part of the building (element): 16-Mary altar (nave) main part

Name of limestone: Lipica fiorito

Geol. unit ID (map 1:250,000): 155

Name of geological unit: Lipica Formation

Age: Santonian-Campanian

Basic lithology: grey bioclastic rudist limestone

Characteristics: rudists Vaccinites, Stromatoporoidea, rudists Radiolitids

Quarry or source area: Lipica Formation, Lipica I. quarry

Parts of the object (elements): 22-choir pillars, 26-ciborium

Name of limestone: Kopriva limestone with Caprinids

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: light-grey bioclastic rudist limestone with Caprinids

Characteristics: Kopriva limestone with up to 30cm (10cm in diameter) large Caprinids

Quarry or source area: Repen Formation, Predole (Bezgorice) quarry

Part of the object (elements): 12b-stoup

Name of limestone: Kopriva limestone with gastropods Acteonelidae

Geol. unit ID (map 1:250,000): 142

Name of the geological unit: Repen Formation

Age: Cenomanian-Turonian

Basic lithology: dark-grey bioclastic limestone with gastropods

Characteristics: very characteristic limestone with gastropods

Quarry or source area: Repen Formation, Rova quarry

Part of the building (element): 16-left side-altar stairs

Name of limestone: Kopriva limestone with Caprinids (lower stair), Sežana Formation limestone (upper stair)

Geol. unit ID (map 1:250,000): 142, 15

Name of geological unit: Repen Formation, Turonian-Santonian (Sežana Formation)

Age: Cenomanian-Turonian, Turonian-Santonian

Basic lithology:
Kopriva limestone with Caprinids - bioclastic rudist breccia (lower stair)
Sežana Fm. limestone - dark-grey bioclastic rudist limestone (upper stair)

Characteristics: *rudists:* Radiolitidae, Hippurites

Quarry or source area:
Repen Formation, Predole (Bezgorice) quarry
Sežana Formation?

3.4 SUMMARY - GEOLOGY AND PROVENANCE OF THE BUILDING STONE USED IN THE SELECTED SHOW-CASE BUILDINGS

3.4.1 ŠMARJE PRI DIVAČI – PR'BLAŽEVIH HOMESTEAD

A farm house Pr'Blaževih in the village of Gorenje pri Divači is built of material from the close vicinity of the village. The main roof of the house as well as an extended kitchen roof is covered with plates of fractured Repen limestone. It originated from the Repen Formation, most probably from the Gabričje quarries (Figs. 3.7, 3.8, 3.9) located south of the Gorenje and Povir villages. From the same type of limestone there are also made eaves (gutters) and their corbels. Other architectural elements such as corner stones, window frames, doorposts, a cistern and stone vessels are made of classical Repen limestone. It was also excavated in the nearby quarries (Boršt or Griža) south of Gorenje village (Fig. 3.7). For building the house walls, limestone from the Povir Formation and Repen limestone were used. Limestone from the Povir formation could be excavated in the Prek Straže quarry south-east of Gorenje (Fig. 3.7.).

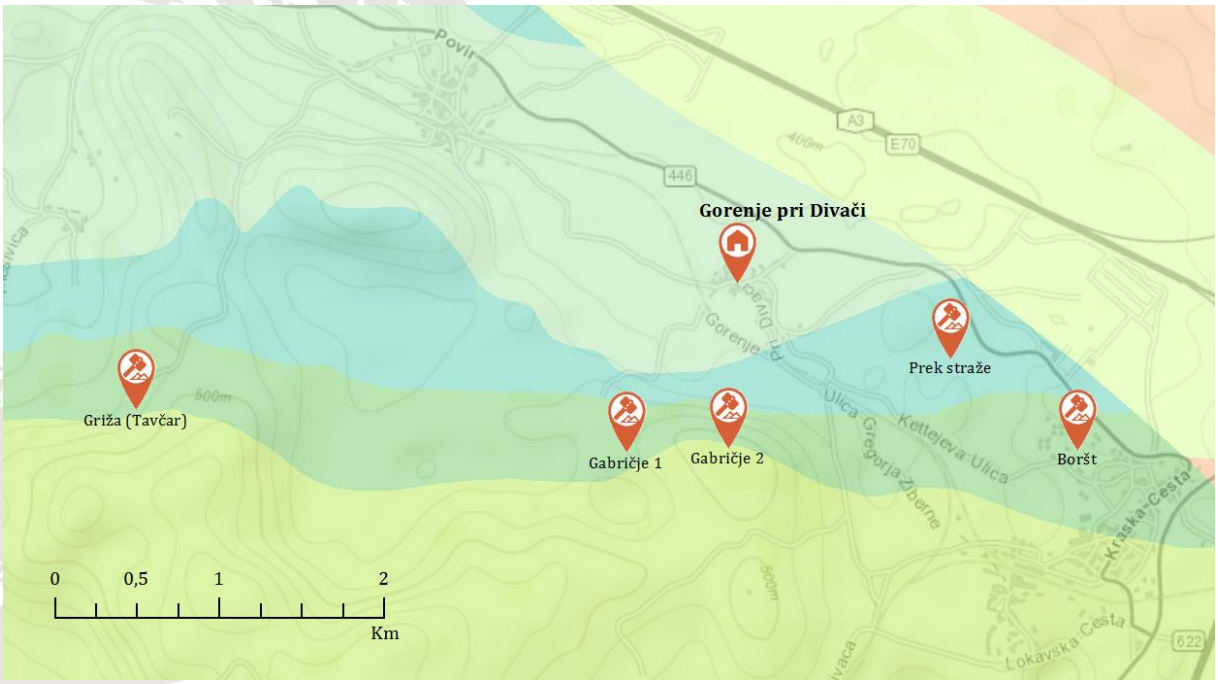


Figure 3.7 Map of surroundings of Gorenje pri Divači village and possible quarries for the limestone types used in the Pr'Blaževih homestead. Griža (Tavčar), Gabričje and Boršt quarries within the Repen Formation and the Prek Straže quarry in the Albian-Cenomanian (Povir) unit.

Figure 3.8 A small abandoned quarry at Gabričje, west of Divača where fractured limestone was excavated.

Figure 3.9 A detail from the Gabričje quarry; tectonically related fractures enabled the excavation of limestone plates.

3.4.2 DIVAČA – ŠKRATELJNOVA HOMESTEAD

The main roof, the extended kitchen roof and a small roof above the stairs of the Škrateljnova homestead are mainly covered with plates of fractured Repen limestone. It was excavated in a quarry from the Repen Formation, probably in the Gabričje quarries (Figs. 3.7, 3.8, 3.9) west of Divača. The entrance staircase, the balcony fence shelf and eave (gutter) corble are also made of plates of the same type of limestone. The window frames, balcony floor and entrance doorposts are mainly built of Kopriva limestone of Repen Formation. The

classical Repen limestone which is used in the middle balcony column and cistern belongs to the same formation. Both types, the Kopriva and Repen, could be excavated in Griža (Tavčar) quarry (Fig. 3.7, 3.10). One stair of the outside staircase and a few plates on the balcony floor are of the Limestone of Sežana Fm. This unit is exposed in the surroundings of Divača.
The new outside architectural elements such as the yard floor and the pedestal of the statue of *Ita Rina* are made of Lipica unito and Lipica fiorito limestone types. They belong to the Lipica Formation and could be excavated in the Lipica 1 or Lipica 2 quarries.

Figure 3.10 Fractured Repen limestone in the Griža (Tavčar) quarry near Povir. The dense system of parallel vertical tectonic fissures enable the excavation of thin limestone plates. They were widely used for roofing in the nearby villages of Divača, Gorenje and Povir.

3.4.3 POVIR (GURA) – THE CHURCH OF THE ASSUMPTION OF THE BLESSED VIRGIN

The church on Gura hill (509m a.s.l) is situated on the limestone and dolomite of the Povir Formation. These rocks were mainly used for building the church foundations and walls. The church main roof is partly (approx. 70%) covered with the fractured Repen limestone and partly (~ 30%) by plates of platy limestone from the Povir formation. Both stone types are very local. The fractured Repen limestone was most probably excavated in the Repen Formation near the Griža (Tavčar) quarry (Figs. 3.10 and 3.11), while the platy limestone from the Povir formation originated in the Albian-Cenomanian (Povir) unit. Possible source areas were found on the southern slopes of Strmca hill (Figs. 3.11 and 3.12). The quality of the fractured Repen limestone plates is very good, while the Povir Fm. limestone is laminated and therefore not so resistant to external atmospheric conditions (Fig. 3.13).
Other building elements such as corner stones, window frames, the bell tower vault and doorpost are made of classical Repen limestone. This was excavated in the nearby Griža (Tavčar) quarry south of Gura hill (Fig. 3.11).

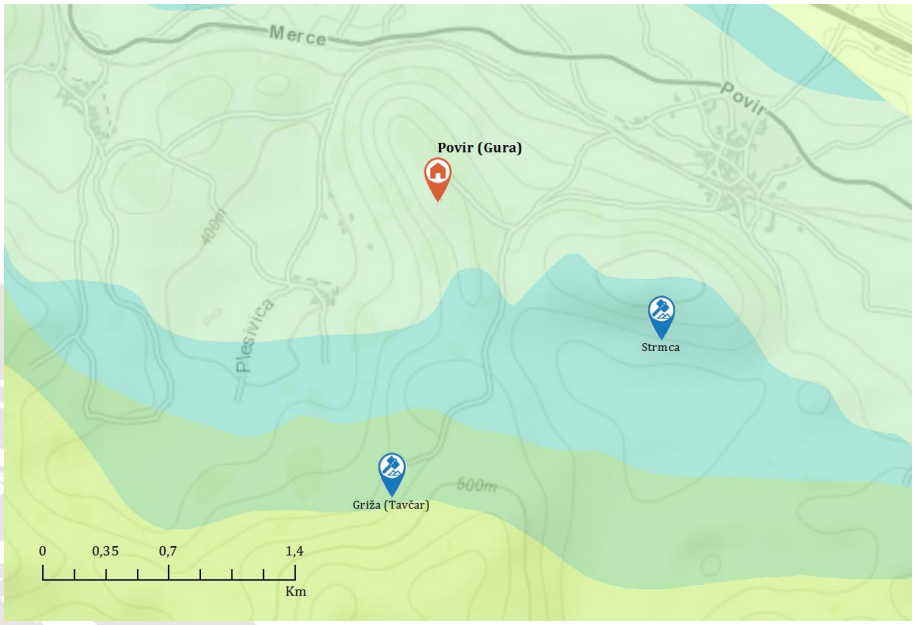


Figure 3.11 The location of the church on Gura (W of Povir village) and two possible quarries (blue) for the limestone plates used on the church main roof: Griža (Tavčar) and Strmca.

Figure 3.12 Outcrops of platy limestone from the Povir Formation along the road in the Strmca locality (PL locality ID 2112). The locality could be a possible source area for a part of the limestone plates on the roof of Gura church.

Figure 3.13 A detail from the roof of the church on Gura hill. The platy limestone of Povir Fm. (dark fields) is disintegrating due to its lower-quality. Fractured Repen limestone (~ 70% of the roof) is more resistant to external atmospheric conditions.

3.4.4 ŠMARJE PRI SEŽANI – THE CHURCH OF OUR LADY OF THE ASSUMPTION

The main roof, entrance shed roof and vestry roof of the church in Šmarje pri Sežani are covered with Komen limestone plates originated from Albian-Cenomanian limestones (Povir Formation), which are exposed on a wider area of Šmarje village.
Other elements such as corner stones, all doorposts, window frames, bell tower walls and entrance shed corbels are made of Repen limestone belonging to the Repen Formation. Stone could be excavated in the Lisična and Vitez and Doline quarries (Fig. 3.14). From these localities the Kopriva type of limestone used for paving the floor in front of the church's main entrance could also have originated.

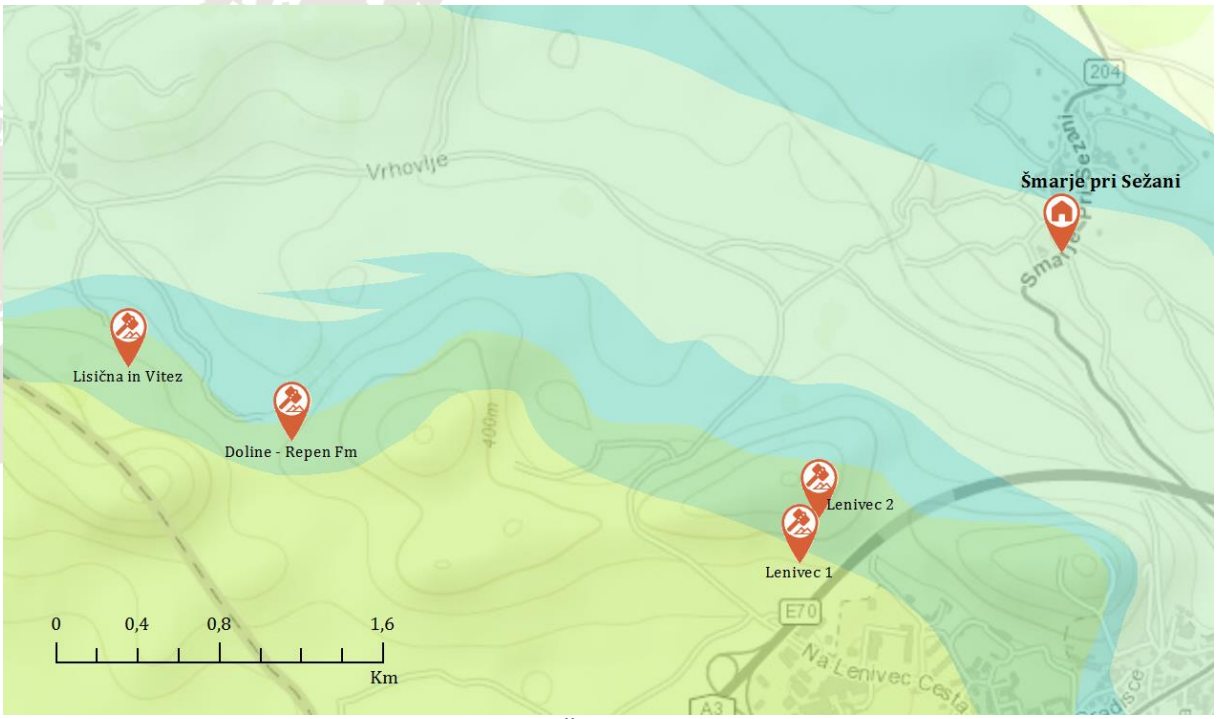


Figure 3.14 Map of the surroundings of Sežana and Šmarje village and possible quarries for the limestones used in studied church. Stone could be excavated in the Lisična and Vitez and Doline quarries.

3.4.5 KOPRIVA – SAINT ELIJAH PARISH CHURCH

The geographical position of the St. Elijah church in Kopriva enabled the use of very varied types of building stone from almost all the geological formations. The Kopriva village is located on the area of contact of four important formations (Povir, Repen, Sežana and Lipica) contributing important types of natural stones (e.g. Kopriva, Lipica fiorito, Lipica fiorito nero).

The southern part of the church roof is covered with Komen platy limestone plates belonging to the Sežana Formation. The limestone plates were excavated in the wider area between the Kopriva, Skopo and Kosovelje villages. Two smaller abandoned quarries, Kopriva and Kosovelje (PL localities ID: 2110 and 2111), were evidenced west of the village of Kopriva (Figs. 3.15 and 3.16).

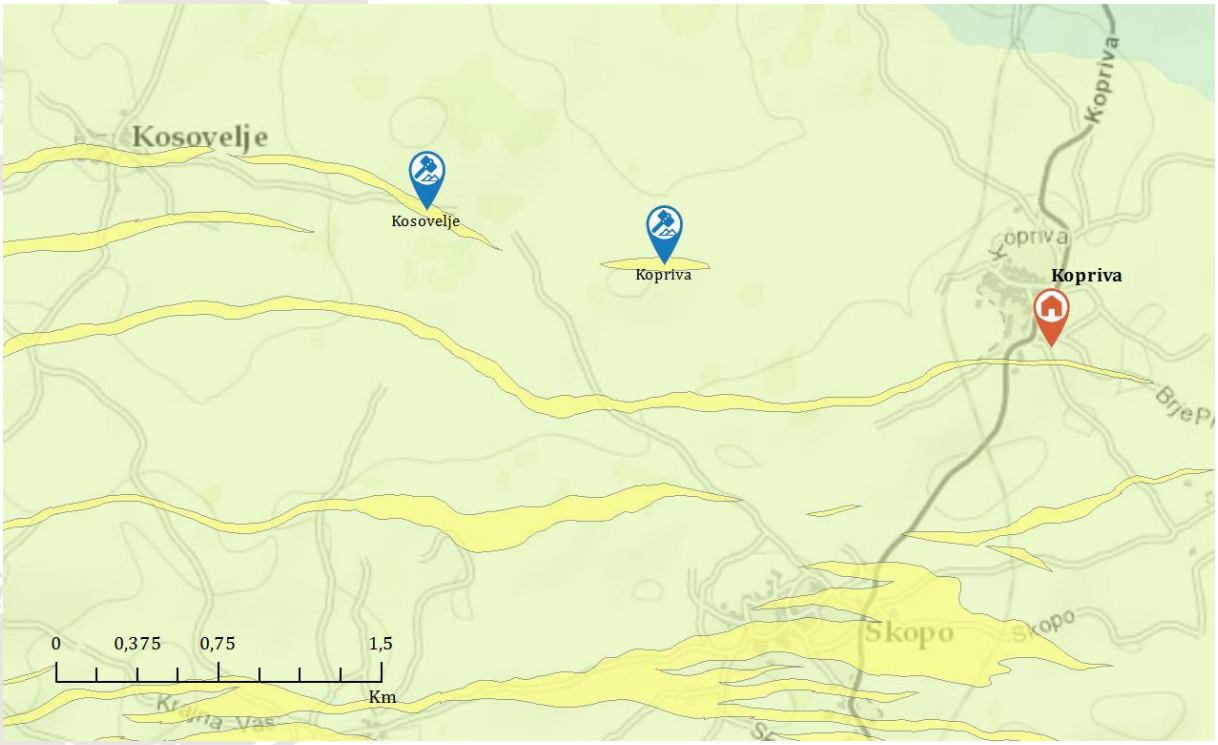


Figure 3.15 Location of the church in Kopriva, occurrences of Komen platy limestone between the villages of Skopo, Kosovelje and Kopriva (yellow) and two possible quarries (blue) for the limestone plates used on the church main roof: Kosovelje and Kopriva.

Figure 3.16 The abandoned quarry of Komen platy limestone from the Sežana Formation west of Kopriva village.

Kopriva and Repen limestone types were widely used in the other architectural elements of the church. Both types originated from the Repen Formation which extends in the wider area north of Kopriva village (Fig. 3.17). They were excavated in the quarries of Rova (Fig. 3.18), Kremenik and Predole. The corner stones, the lower part of the bell tower, the entrance floor, vestry entrance doorpost, window frames and the right part of the main entrance doorpost are built of Kopriva limestone, while for the left part of the main entrance doorpost and the former side doorpost Repen limestone was used. The entrance threshold is of a special (fiorito) type of dark stone containing rudist fragments. It originates in the Lipica Formation.

Very characteristic and decorative types of local limestone were also used in making the interior sacral elements of the church. Choir pillars, the ciborium and some altar stairs are made of Kopriva limestone with huge rudist shells (Caprinids), while the stoup is of Kopriva limestone with gastropods Acteonelidae. Parts of the Mary altar are made of Lipica fiorito stone from the Lipica 1 quarry and the Lipica fiorito nero type that can be found in the Lipica Formation near Kazlje.

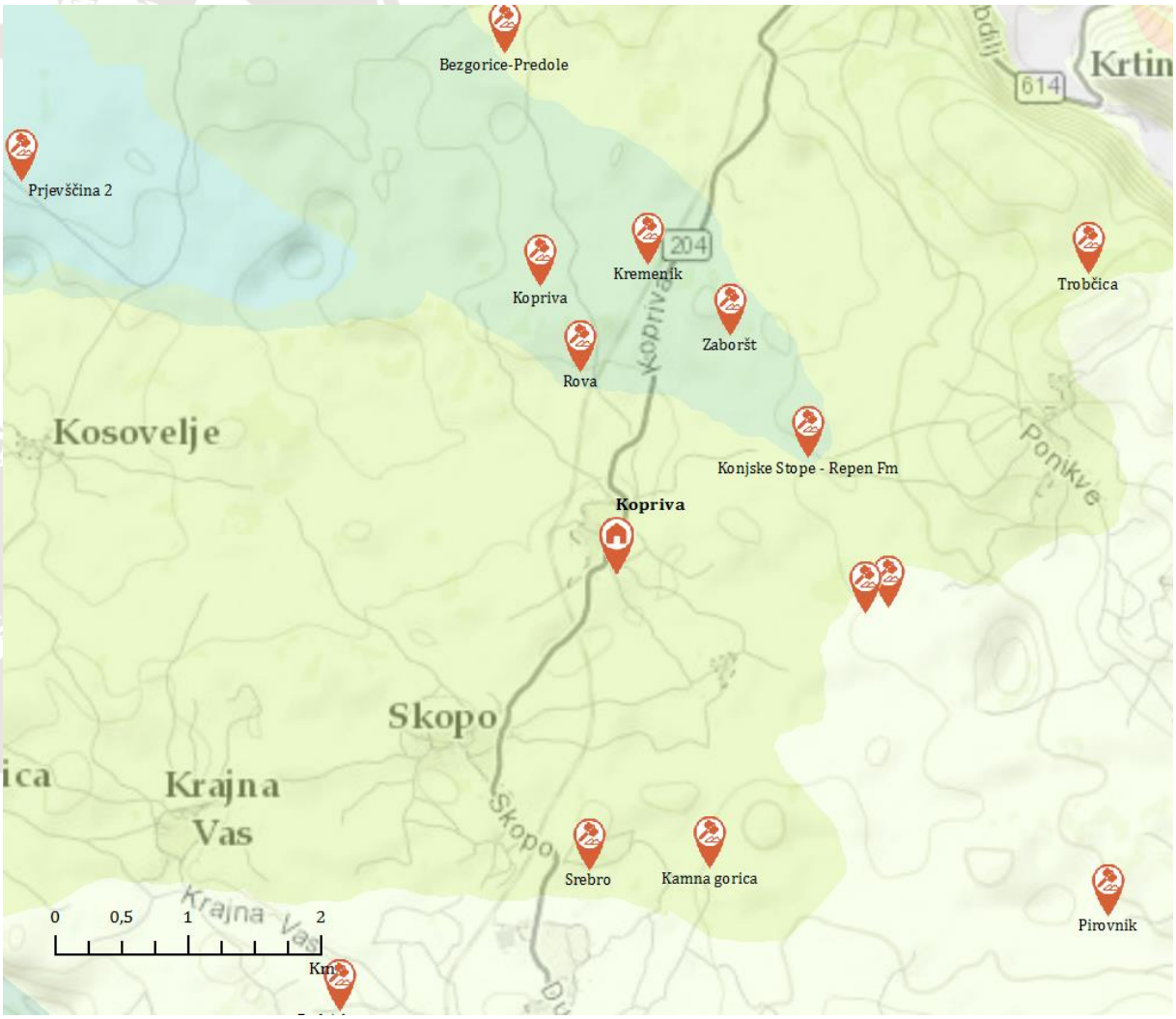


Figure 3.17 The Kopriva village (centre) is located on the area of contact of four important geological formations from the Kras: Povir, Repen, Sežana and Lipica. Important quarries of natural stone are marked in orange.

Figure 3.18 Abandoned delves at the Rova locality north of Kopriva where quality Repen limestone was excavated.

3.5 CONCLUSIONS

The architectural elements of the five selected show-case objects in the Kras area were geologically investigated in detail with the aim of identifying the main characteristics of the various building limestones used and to find their source areas. Two typical karst houses are located in Divača and Gorenje pri Divači villages; one church is situated on the Gura hill above Povir, while another two churches are in the villages of Šmarje pri Sežani and Kopriva.

The roofs of the studied houses in Divača and Gorenje and the church on Gura are mainly covered with limestone plates of fractured Repen limestone. The stone originates from the Repen Formation extending in a narrow belt from Divača to Sežana. In this area three important abandoned quarries were evidenced at the Gabričje and Griža (Tavčar) localities. These are potential source areas for the relatively high-quality limestone plates. On the roofs of these (3) objects only a few plates of platy limestone types from Sežana or the Povir Formations were found. They were excavated in the close vicinity of the objects. On the other hand, the limestone plates used on the roofs of churches in Šmarje and Kopriva originate from “real” Komen platy limestone successions (see Chapter 4). On the church in Šmarje Komen limestone from Povir Fm. was used for the roofing. It is exposed over a wider area of Šmarje village. The church roof in Kopriva is covered with plates of Komen platy limestone from the Sežana Formation, which is exposed over a wider area between Kopriva, Skopo and the Kosovelje villages. West of Kopriva two smaller abandoned quarries of this limestone type were found.
In all five objects, other external building elements were mainly made of Repen and Kopriva limestone types. Only some elements of Lipica unito or Lipica fiorito types originate from the Lipica Formation. Repen and Kopriva types are one of the highest quality natural stones in the Kras and due to their excellent quality very suitable for external use. In the southern part of the Kras Repen and Kopriva types were excavated in Griža (Tavčar) and Boršt quarries. Around Sežana these types can be found in the Lisična, Vitez and Doline quarries as well as in some smaller abandoned quarries (e.g. Lenivec 2, Bršljanovc). In the area of the village of Kopriva the Repen Formation is exposed in the north of the village. The Rova, Kremenik,

Zaboršt and Predole quarries are known there, where the Repen and Kopriva limestone can be found.

Finally, the building limestone in the selected show-case objects mostly originates from local sources, situated in the vicinity of the objects. This is typical for both the platy limestone elements as well as other external architectural elements. The walls of the studied objects were mainly built of material from the immediate surroundings of the objects, while more important (manufactured) elements of larger dimensions (e.g. corner stones, window frame, door posts) originate from the nearby quarries of quality natural stone.

4 PLATY LIMESTONE

4.1 OBJECTIVES and METHODOLOGY

The main geological activity of the RoofOfRock project was focused on platy limestone as a special type of building stone, most commonly used for roofing. The action started with a comprehensive analysis of the existing archived literature and maps as a base for the preparation of the fieldwork and geological mapping of selected areas on the Kras. Various platy limestone horizons were identified through their major sedimentological and paleontological characteristics, stratigraphic position and age. In addition, some sedimentological and paleontological laboratory analyses were implemented. Geological activities were also directed by the findings of Wp4 (cultural heritage) related with the use of platy limestone. During the data acquisition, the quality and quantity of single types of platy limestone were observed and some the most representative samples were collected for laboratory analyses.

The organization of the geological data on platy limestone for the GIS-based database has been agreed and coordinated on several Wp3 coordination meetings.

The output of this action is a geological definition of platy limestone as well as the spatial occurrence of platy limestone along the project area in Slovenia shown on the geological map in a general scale of 1:50,000.

4.2 GEOLOGICAL DEFINITION OF PLATY LIMESTONE

4.2.1 DEPOSITIONAL ENVIRONMENTS

The limestone and dolomite that are mostly used to build the project area in Slovenia and Italy have been deposited during the Cretaceous, some 140 to 65 million years (My) ago. Carbonate rocks of this area as well as those exposed along the eastern Adriatic coastal area towards the south, from Istria to Dalmatia and Herzegovina, were deposited within a broad marine shallow-water area called the Adriatic/Dinaric carbonate platform (Vlahović et al., 2005). The carbonate depositional environments on the platform were very similar to the conditions on present-day Bahamas. Due to the diverse topography on the former carbonate platform, a variety of depositional environments existed on it and various limestone lithotypes were deposited.

At the bottom of up to a few metres' deep shallow and warm tropical sea, carbonate mud, peloids (micritic grains) and carbonate skeletal sands (grainy sediment) have been deposited. Skeletal grains are the most commonly represented by micro and macroscopic benthic organisms and their debris (e.g. mollusc shells, foraminifera, calcispheres). Beside the uniform shallow marine areas, lowlands (islands) and intraplatform depressions/deeper lagoons on the platform also occurred (Fig. 4.1). In these specific environments thin-bedded or platy limestones have usually been deposited. It was characteristic also for the Kras area where platy limestones were deposited in spatially limited intraplatform basins and/or deeper lagoons in the vicinity of the exposed areas (low land islands) (Palci et al., 2008; Jurkovšek, 2008; 2010; Cavin et al., 2000; Jurkovšek & Kolar-Jurkovšek, 2007; Summesberger

et al., 1999). A relatively small amount of benthic fauna, occurrences of pyrite pigment and organic matter indicate occasional anoxic and dysoxic conditions on the bottom. The thin-bedded lagoonal limestone is rich in macrofossils, especially in fossil land plants, fishes and vertebretes (Fig. 4.1).

Various depositional processes as well as later processes of diagenesis (maturation and lithification of previous soft sediments) enabled the formation of bedded/layered rock textures. According to the classifications (e.g. Boggs, 1995) carbonate sedimentary rocks can be generally divided into laminated rocks (<1cm in thickness), thin-bedded (10-30cm), bedded (30-60cm), thick-bedded (60-120cm), very thick-bedded (>120cm), and massive rocks. Platy rock is considered to be very thin-bedded (up to 10cm) rock. Therefore, **platy limestone is very thin- bedded limestone that is characterized by a bed thickness from 1 to 10cm.**

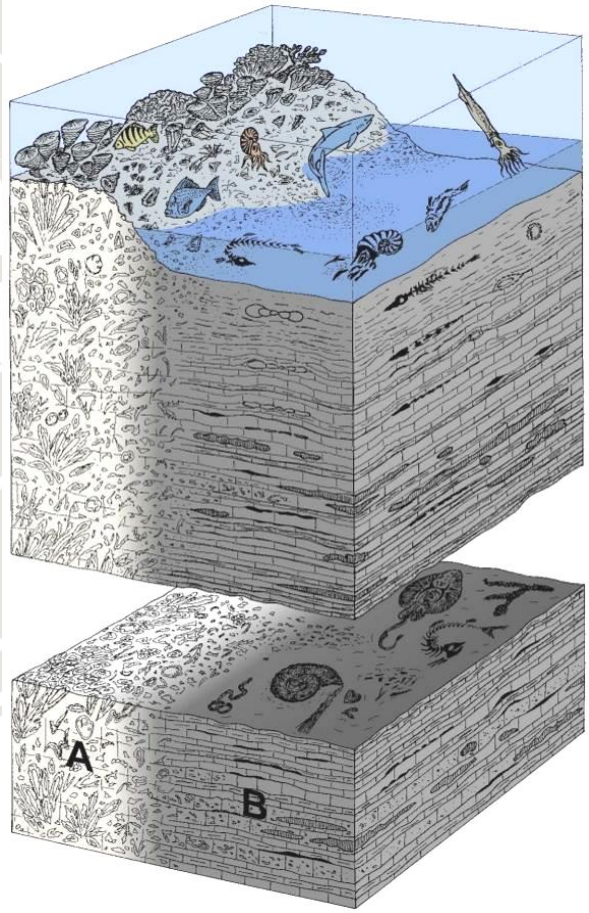


Figure 4.1 A simplified view of the carbonate platform depositional environments and fossilization (A – a predominantly shallow marine environment with rudists, B – an intraplatform basin (deeper lagoon) depositional environment of platy limestone). Prepared by Bogdan Jurkovšek.

4.2.2 DEFINITION FOR THE PROJECT AREA IN SLOVENIA

According to the general characteristics of the studied platy limestone lithotypes in the Kras in Slovenia we set up the following definition of platy limestone:

According to its lithological characteristics it is a very thin-bedded limestone. Bedding is very well-expressed by clear discontinuities. The thickness of the individual beds ranges from

1cm to 10cm, on average from 2 to 5cm. It can be laminated and/or stromatolitic, commonly dark-coloured and bituminous (contains disseminated organic matter and pyritic pigment in the form of framboids). Generally it is a fine-grained biomicrite mudstone and wackestone, while Tomaj limestone also contains grained biocalcarenite (grain size above 2mm) to calcisiltite (carbonate mud) textural types. It commonly contains chert, which appears in the form of noddules and thin lenses.

According to its paleontological characteristics platy limestone is very important. It usually contains reptiles (mainly marine), fish, ammonites, planktonic stemless crinoids, macroflora, planktonic and benthic forams and different mollusc and echinoderm fragments.

Genetically different types of platy limestone are associated with various sedimentary environments from more or less closed deeper lagoons to intraplatform basins. Lagoonal and intraplatform basin environments were predominantly low-energy. Sporadically, in the marginal parts of the lagoons there were also higher-energy storm events. On steeply aligned slopes of intraplatform basins, slides and slumps of sediments have occurred. Depositional settings were connected with differentiations of topography of the carbonate platform by tectonic events or deposition was controlled by eustatic sea-level changes and consequently with oceanographic events.

According to age and stratigraphic position platy limestone in the Kras belongs to carbonate successions from the upper parts of the Lower Cretaceous (Albian) to the Upper Cretaceous (Campanian). Locally, sporadic occurrences of platy limestone in the Upper Cretaceous (Maastrichtian) to the Paleocene sequence also occur.

Platy limestone occurs as thin (few metres to up to 40m) uniform but laterally discontinuous sedimentary bodies (lenses, horizon) within other bedded to thick-bedded carbonates or locally as very thin (< 1m) horizons in alternation with other bedded limestone. The most important platy limestone types were evidenced in Povir, Sežana and Lipica Formations.

According to its use, platy limestone is most probably the oldest building material in the Kras area. The limestone plates were used for building dry-walls, roofing and paving.

4.3 MAIN TYPES OF PLATY LIMESTONE (PL) AND THEIR OCCURRENCE IN THE PROJECT AREA IN SLOVENIA

After a review of the existing geological maps, detailed lithological and stratigraphical analyses and field work in the Kras four main types of platy limestone (PL) were evidenced: Komen limestone from the Povir Formation, Komen Limestone with pelagic microfossils from the Repen Fm., Komen limestone of Sežana Formation and Tomaj limestone from the Lipica Formation. They can be distinguished after their litholocical and paleontological characteristics, stratigraphic position, spatial occurrences and their age (Fig. 4.2.). Three of them are subtypes of Komen limestone that occur at different stratigraphic levels and belong to different geological formations, ranging from the Albian to the Campanian (Fig. 4.2).

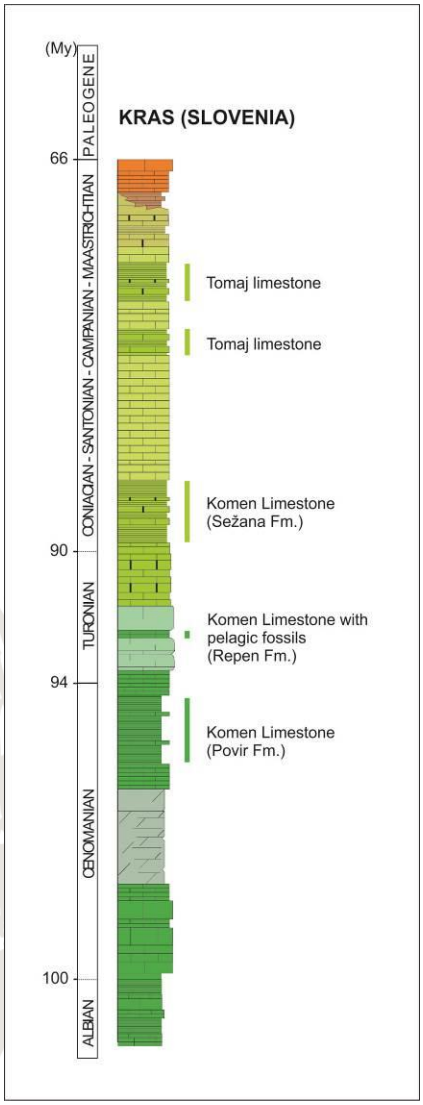


Figure 4.2 A schematic lithostratigraphic column showing the occurrences of four main platy limestone (PL) types in the Kras (Slovenia).

4.3.1 KOMEN LIMESTONE FROM THE POVIR FORMATION

Komen platy limestone of Povir Fm. is exposed in the wider area of the villages of Komen, Gabrovica, Tomačevica, Volčji Grad, Mali Dol, Sveto and Škrbina (Fig. 4.3). There it covers approx. a 10km long and 5km wide area. In this area we also evidenced at least seven abandoned quarries of this type of PL (see the project web GIS application).

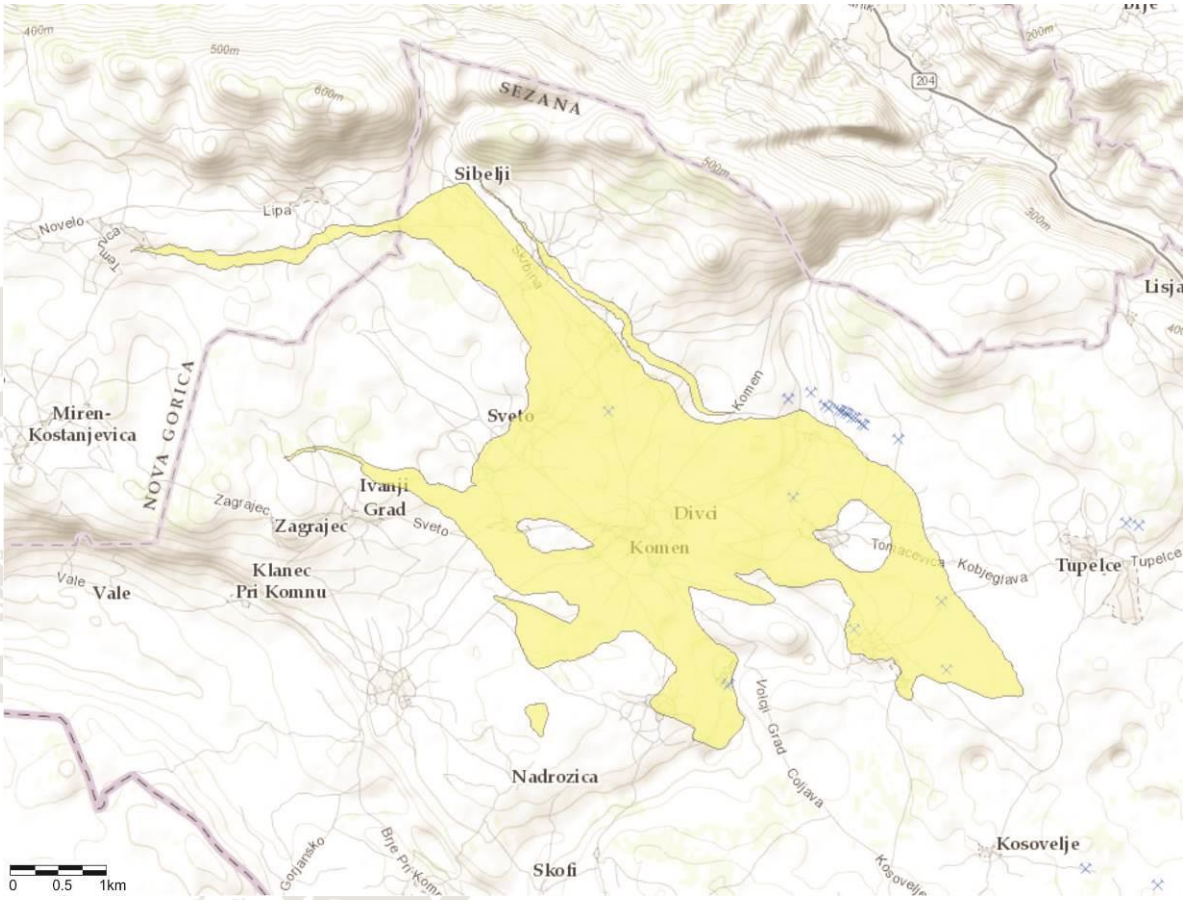


Figure 4.3 Occurrence of Komen PL type in the wider area of Komen, Kras, Slovenia

For the entire sequence of the Komen Limestone from the Povir Formation alternation of a) "flat pebble" breccia, b) well stratified and platy limestone and c) stromatolitic limestone is characteristic (Figs. 4.4, 4.6 and 4.7). Limestones are bedded to very thin-bedded (platy) (Fig. 4.4.). All litotypes contain chert nodules and lenses (Fig. 4.5). The entire carbonate sequence is up to 100m thick, while individual horizons of PL reach thicknesses of up to 20m.

Figure 4.4 An outcrop of well-bedded Komen PL from the Povir Fm. with chert near Škrbina village (Kras, Slovenia)

Figure 4.5 Chert lenses within Komen limestone plates near Gabrovica village (Kras, Slovenia)

Figure 4.6 An outcrop of Komen PL from the Povir Fm. at Mrtvaški hrib locality (Kras, Slovenia)

Figure 4.7 Parallel and hummocky (upper part) laminated Komen PL from the Povir Fm. at Mrtvaški hrib locality (Kras, Slovenia)

Lithologically, alternations of mudstones, cyanobacterial laminites, and rare fine-grained skeletal packstones are characteristic (Figs. 4.8 and 4.9). The microfacies are changing at the level of the lamina.

Facies' changes are the result of slight changes in the depositional environment. As a general sedimentation model an intraplatform basin was proposed (Palci et al., 2008). The bottom water in the basin was occasionally disoxic to anoxic.

Among the macrofossils, vertebrates, primarily fish and reptiles, are the most important. Remnants of conifers represent land plants. The microfossil association consists of *Broeckina (Pastrikella) balcanica*, *Merlingina cretacea* and *Trochospira avnimelechi*. In some places pelagic debris, sponge spicules and calcispheres are abundant.

According to the foraminifer association and stratigraphic position of Komen limestone within the entire carbonate succession of the Povir Formation this platy limestone type is from the Cenomanian (~ 100 – 94 My) age.

Figure 4.8 Laminated/stromatolitic Komen PL from the Povir Fm. at the Gabrovica locality (Kras, Slovenia)

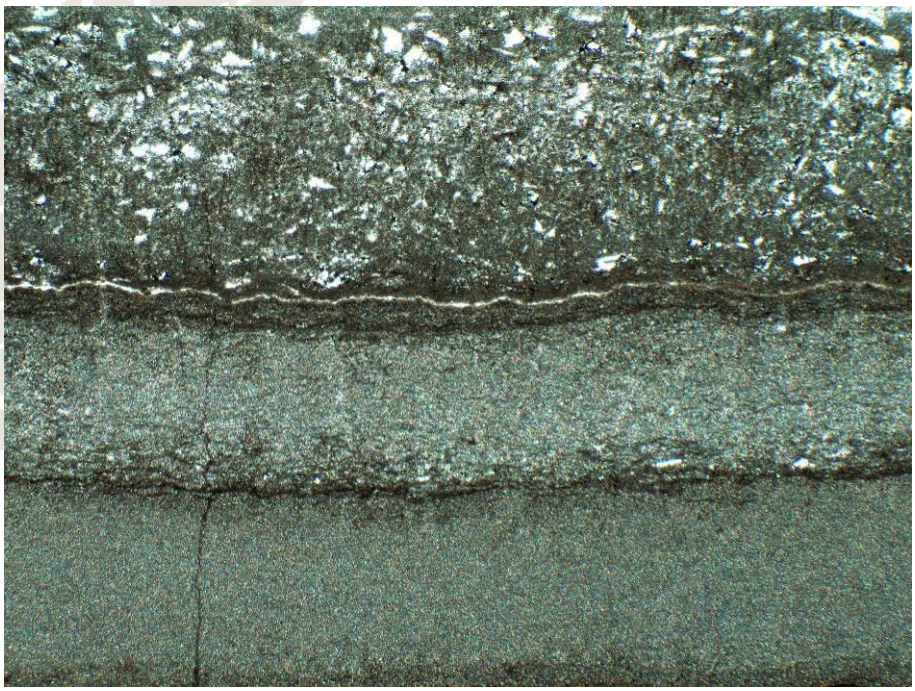


Figure 4.9 A microphotograph of laminated mudstone of Komen PL from the Povir Fm. Microfacies is represented by the very fine microcrystalline and micrite laminae of stromatolite origin. The long edge of the photograph is approx. 5mm.

4.3.2 KOMEN LIMESTONE WITH PELAGIC MICROFOSSILS

Komen limestone with pelagic microfossils is exposed in relatively narrow (up to 200m wide) belts in the area between Kobjeglava, Tomačevica, Mali Dol and Škrbina and north of Ivanji Grad (Fig. 4.10). Numerous small abandoned delves are known from the area north-east of Mali Dol.

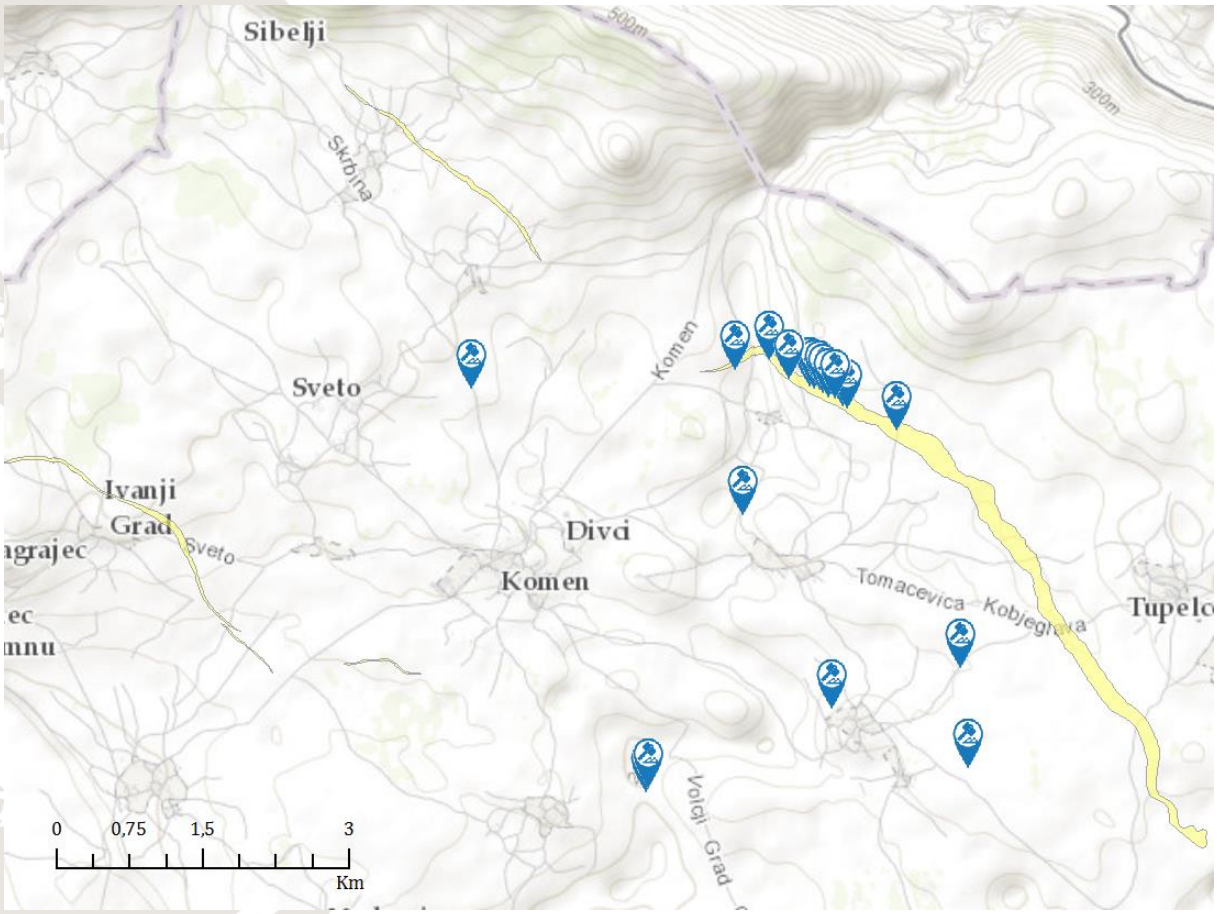


Figure 4.10 The occurrence of Komen limestone with pelagic microfossils in narrow belts (yellow) near Mali Dol, Škrbina and Ivanji Grad (Kras, Slovenia)

Komen limestone with pelagic microfossils is represented by a three to four metre thick package of dark grey, very thin-bedded (platy) and laminated limestone (Fig. 4.11). The PL carbonate sequence occurs in the central part of the Repen Formation. The transition from the lighter grey, massive, mainly micritic limestone from the Repen Fm. to platy limestone can be sharp or gradual. In some places, the lower part of the PL succession starts with fine-grained breccia containing light grey clasts of calcisphere limestone.

Some authors (Jurkovšek et al., 1996; Jurkovšek, 2010) relate the deposition of this dark grey, platy laminated bituminous limestone with transgression under conditions of the upwelling of organic rich bottom water from the basin to the shallower marginal parts of the carbonate platform. This may have happened during the so-called second Ocean anoxic Event (OAE-2).

Among macrofossils, mainly fish and rare ammonoids occur, while among microfossils, planktonic foraminifera of the genera *Dicarinella* and *Whiteinella* are common, as well as numerous calcispheres and pithonellas (Fig. 4.12). Autochthonous benthic organisms in these beds are not presented.

According to the stratigraphic position of these platy limestone horizons they are of the Cenomanian-Turonian (~ 95 – 92 My) age.

Figure 4.11 An outcrop of platy Komen limestone with pelagic microfossils near Mali Dol village (Kras, Slovenia)

Figure 4.12 A microphotograph of laminated Komen limestone with pelagic microfossils and thin bituminous intercalation. The small rounded skeletal grains are calcispheres. The long edge of the photograph is approx. 5mm.

4.3.3 KOMEN LIMESTONE FROM THE SEŽANA FORMATION

The Komen limestone from the Sežana Formation is exposed in narrow belts between Kopriva, Skopo, Pliskovica and Kosovelje villages and between Ponikve and Hruševica village (Fig. 4.13.). Some smaller abandoned delves were evidenced between Kopriva and Kosovelje village.

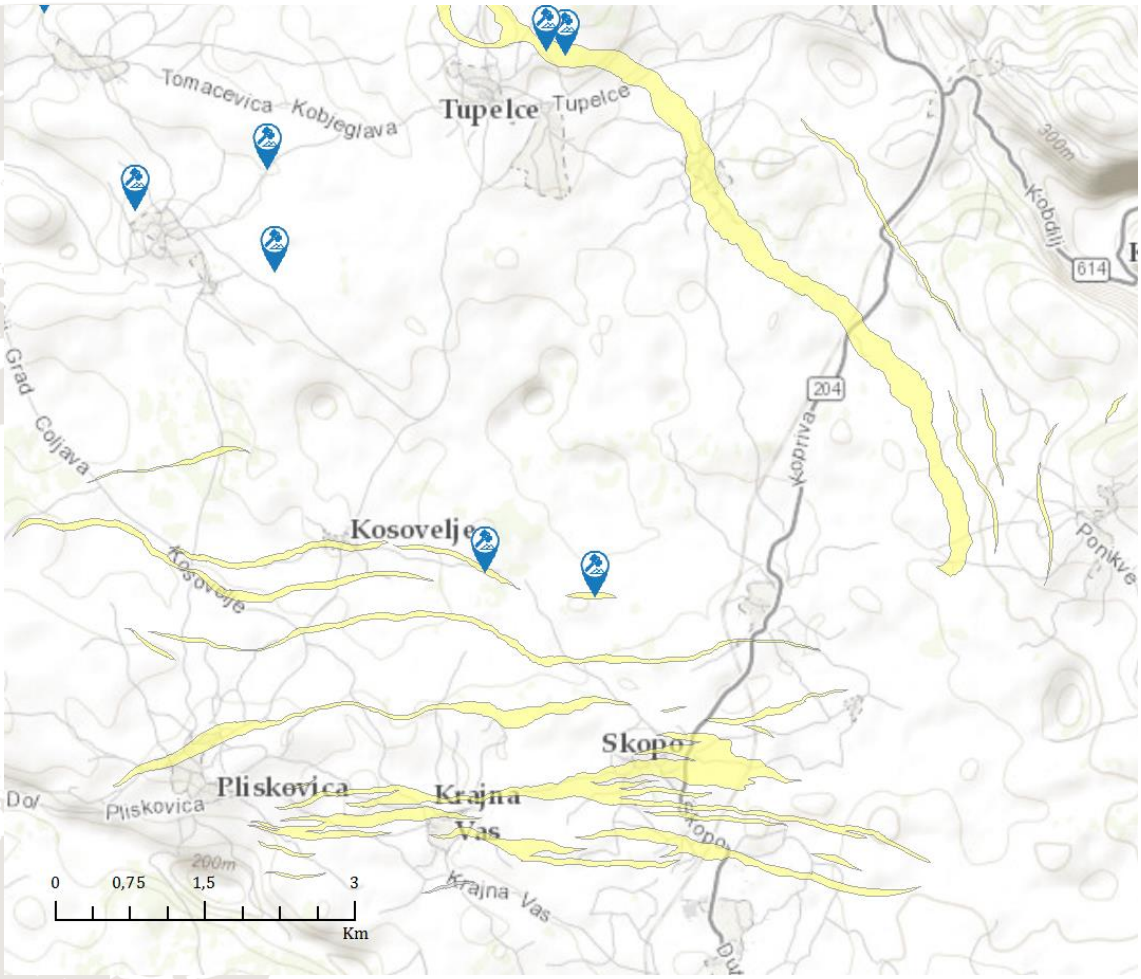


Figure 4.13 An occurrence of Komen limestone from the Sežana Fm. in narrow belts between Kopriva, Skopo, Pliskovica and Kosovelje villages and between Ponikve and Hruševica village (Kras, Slovenia)

Komen PL with chert occurs in different stratigraphic levels of the Sežana Formation. The thickness of the Komen PL sequences within the bedded limestone from the Sežana Formation varies from very thin to maximum 40m thick packages. On average they do not exceed 10m. Basic lithological characteristics are very similar to the Komen Limestone in the Povir Formation. In texture it is mostly mudstone to bioclastic wackestone. Limestone beds contain nodules and thinner lenses of chert, in which the original structure of the primary rock is partly preserved. In certain levels Komen limestone is laminated or stromatolitic.

Microfossil benthic association is rare and insignificant. In places pelagic debris and poorly preserved planktonic foraminifera occur. Macrofossils are represented mainly by fish(Jurkovšek et al., 1996; Cavin et al., 2000) and land plant fossils (gymnosperms).

The absence of abundant benthic fauna suggests a deeper lagoonal environment with occasional anoxic and disoxic conditions on the sea floor, as indicated by the pyrite pigment and organic matter.

According to the foraminiferal assemblages found in the surrounding limestone from the Sežana Fm. this type of PL is from the Turonian-Santonian (92 – 83 My) age.

Figure 4.14 An outcrop of laminated platy Komen limestone from the Sežana Fm. in Skopo village (Kras, Slovenia)

Figure 4.15 An outcrop of platy Komen limestone from the Sežana Fm. near Kopriva village (Kras, Slovenia)

Figure 4.16 A detail of platy Komen limestone from the Sežana Fm. near Kopriva village (Kras, Slovenia)

Figure 4.17 A microphotograph of laminated mudstone of Komen limestone from the Sežana Fm. The long edge of the photograph is approx. 5mm.

4.3.4 TOMAJ LIMESTONE

Tomaj platy limestone is exposed in a wider area of Dutovlje, Tomaj, Križ, Dobravlje, Avber and Kazlje. Some thin horizons are also exposed north of the Raša fault, north-west of Dolenja vas (Fig. 4.18). An abandoned quarry was evidenced near Kazlje village.

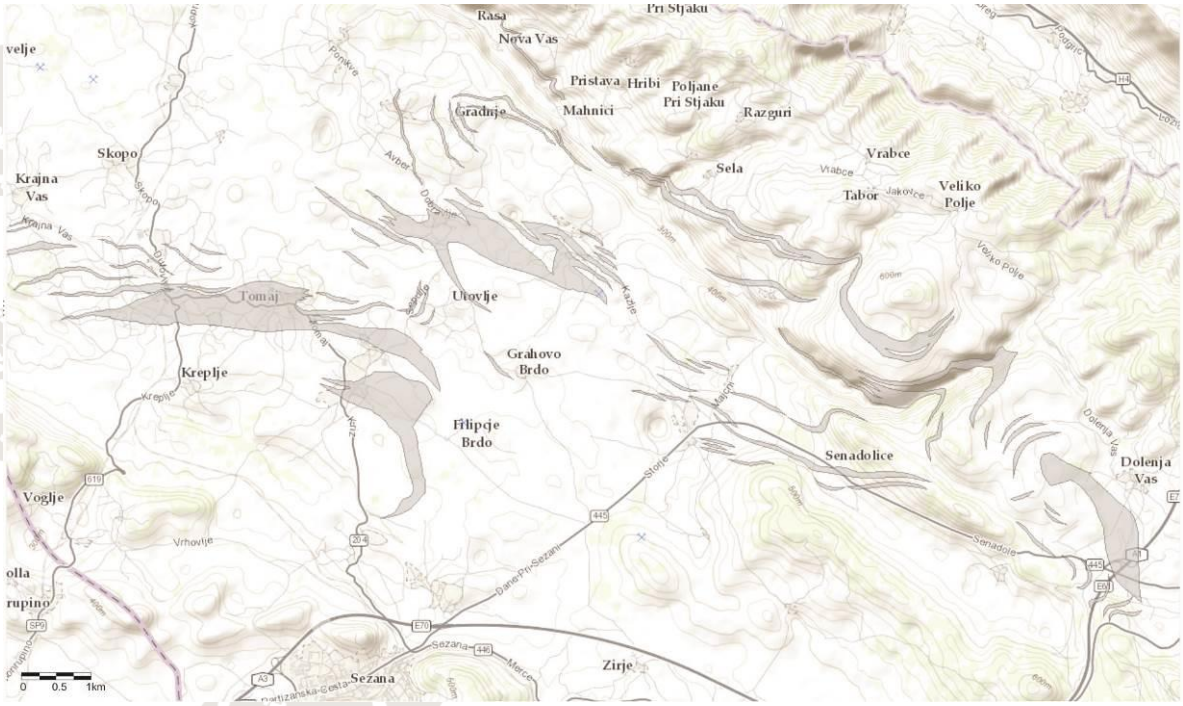


Figure 4.18 An occurrence of Tomaj limestone (in grey) in the wider area of Tomaj, Dobravlje, Kazlje and Dolenja vas villages (Kras, Slovenia)

Tomaj limestone is represented by bituminous, thin-bedded (platy) (Fig. 4.20.) and laminated limestone of a dark grey to black colour. Mudstone to wackestone textural types prevail. Sequences of platy limestone appear within the bedded limestone of the Lipica formation in the form of thin and discontinuous lenses. They are from a few metres up to 40m thick, in average no thicker than 10m. Locally, brecciated limestone or graded fine to coarse-grained (calcarenite to calcisiltite) bioclastic lithofacies also occur (Fig. 4.22). They usually build thicker (5 to 50cm) beds. The chert in the Tomaj Limestone occurs in the form of nodules and thin lenses (Fig. 4.21) that were formed during the late diagenesis, as it is evidenced by the structure of the original rock.

The most common fossils within the Tomaj limestone are fossil land plants, fish and other vertebrates and pelagic microorganisms. Pelagic organisms were brought into a depositional environment from open-marine environments. Benthic organisms are very rare. Among fossil macroflora, conifers dominate.
Imprints of the soft parts of the ammonoids, ammonoids with aptychi in the body chambers and the mass mortality of fish were most probably the result of occasional mixing of the stratified water in the lagoon. Deeper lagoonal environment of deposition is shown by the absence of primary benthos, graded bioclastic limestones and textures of slumping (Cavin et al., 2000; Jurkovšek & Kolar-Jurkovšek, 2007). The connection of depositional environments to the open sea is evidenced by the presence of pelagic microfossils and ammonoids with

aptychi. The redox conditions at the sea floor are indicated by the dispersed organic matter and the pyrite pigment in the form of framboids, and the absence of bioturbations.

Fossil assemblages in the surrounding Lipica Formation limestones suggest the Santonian-Campanian (85 – 70 My) age of the Tomaj limestone.

Figure 4.20 An outcrop of Tomaj limestone near Kazlje village (Kras, Slovenia)

Figure 4.21 Tomaj limestone with chert.

Figure 4.22 A microphotograph of laminated Tomaj limestone. Facies is represented by the thin lamina of skeletal wackestone to packstone and the microcrystalline lamina. The long edge of the photograph is approx. 4mm.

4.4 FRACTURED "QUASI PLATY" LIMESTONE FROM THE REPEN AND LIPICA FORMATIONS

A review of the use of limestone plates as architectural building material also revealed that especially in the southern part of the Kras a special type of limestone plates were used for roofing. According to the set geological definitions (see above, Chapter 4.2.2) this type of limestone could not be classified as genuine platy limestone as its platy appearance is not related to its genesis (processes of deposition and diagenesis) but is of tectonic origin. Dense systems of parallel tectonic fissures/fractures enabled people to excavate thin, 3- 10cm thick, limestone plates (Figs. 4.23 and 4.24). These were widely used as building material as they originate from previously homogeneous and high-quality grained limestone, which is very resistant to external climatic conditions.

During the field-work we identified that such types of limestone plates were excavated in limestone sequences from the Repen and Lipica Formation. Rudist bioclastic limestone plates of Repen Fm. were used for roofing in the wider area of Divača, Gorenje and Povir villages. They were excavated in Repen Fm. which is exposed in a narrow belt between Divača and Sežana. In this area, abandoned quarries of this stone were recorded at the Gabričje and Griža (Tavčar) locality. On the other hand, limestone plates from the Lipica Formation were used for roofing in the area of Filipčje Brdo and Križ village. They were excavated from thick bedded bioclastic limestone (unito) from the Lipica Formation. One quarry was found near Filipčje Brdo village.

Figure 4.23 Fractured Repen limestone in Griža (Tavčar) quarry near Povir. The dense system of parallel vertical tectonic fissures enable excavating thin limestone plates.

Figure 4.24 A detail from the Gabričje quarry; tectinically related fractures enabled to excavate limestone plates.

Due to the relatively complex and unexplained origin as well as its unknown spatial occurrence we decided to acquire expertise on this subject to resolve the open issues in detail. It was implemented by a group of experts from the department of Geology, Faculty of Natural Sciences and Engineering at the University in Ljubljana. The expertise can be found at this.

With respect to the genesis the expertise suggests naming the limestone **fractured limestone**. Therefore, in further text we will use names: **fractured Repen limestone** for limestone plates from the Repen Fm. and **fractured Lipica limestone** for limestone plates from the Lipica Fm.

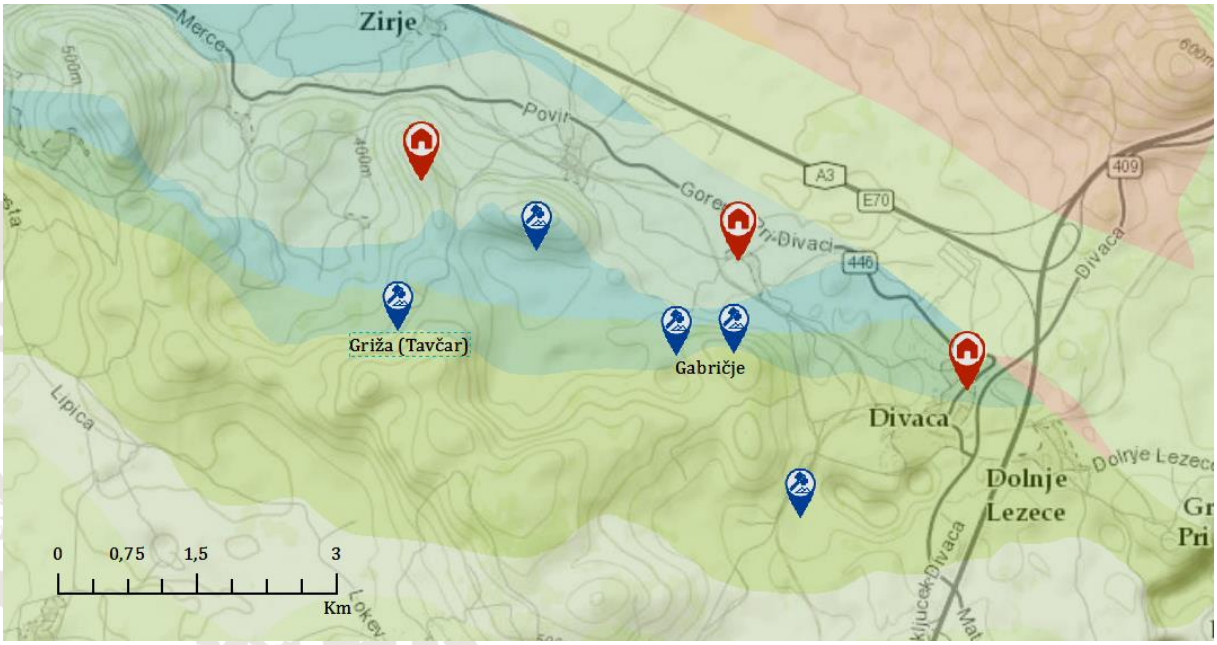


Figure 4.25 Exposure of the Repen Formation (dark green) in a narrow belt between Divača and Sežana. Marked are also the abandoned quarries of fractured Repen limestone at the Gabričje and Griža (Tavčar) localities.

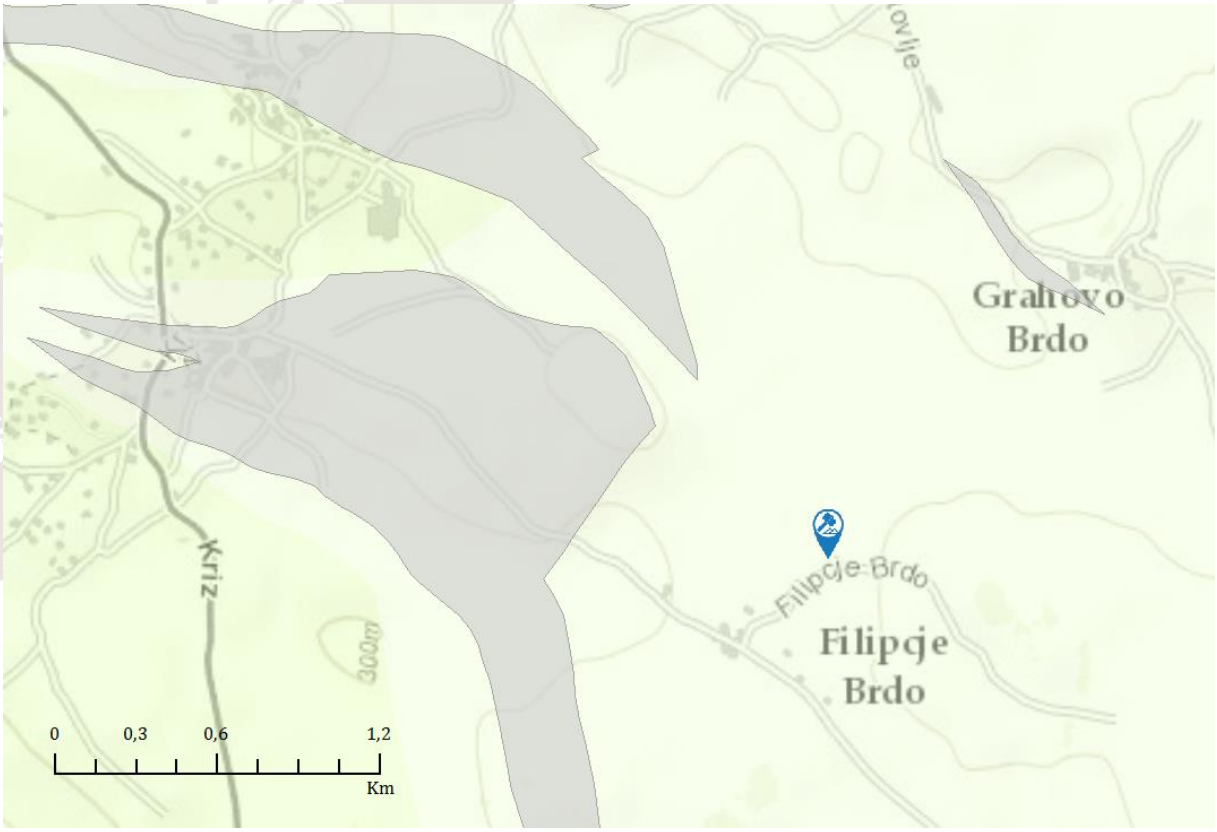


Figure 4.26 Location of the quarry of the fractured Lipica limestone northeast of Filipčje Brdo village.

4.5 THIN-BEDDED (PLATY) LIMESTONE OUTSIDE THE KRAS AREA

As mentioned in the geographic description, the statistical region of Obalno-kraška as an eligible project area and the Notranjsko-kraška and Goriška statistical regions as a territorial derogation area, were included in the detailed geological research of platy limestone. However, some other locations outside of this area with potential occurrences of thin-bedded to platy limestone have been noticed during an overview of archival materials. Thus, relatively good quality genuine platy limestone from the Cretaceous age was reported from the wider area of the Banjšice high karst plateau, near the villages of Kal nad Kanalom, Tolminski Lom and Kanalski Lom. On the other hand, in the upper part of the Vipava valley partly used limestone slabs from Mt. Nanos were used for roofing. Also recorded were some abandoned quarries of fractured massive bioclastic limestone on the southwestern edge of the Nanos plateau.

In the regions where flysch rocks are exposed (e.g. Vipava valley, Brkini area, Istria) sandstone slabs were partly used for roofing. Since this rock type is not typical for Adriatic karstified areas and is not classified as limestone it is not included in the detailed investigation.

5 PLATY LIMESTONE AS A MINERAL COMMODITY AND NATURAL HERITAGE

The final action within WP3 was the evaluation of platy limestone as a mineral commodity as natural heritage. According to the recognized spatial appearance and the potential of all types of platy limestone previously defined on the maps, we assessed selected types of platy limestone as a mineral commodity with the final goal to identify potential quarrying areas. Paleontological and sedimentological historical data on platy limestone and new data were evaluated from the natural heritage point of view and some geo-sites were proposed.

As presented above, every sedimentary succession is composed of sedimentary strata (beds) of various thicknesses (from a centimetre up to a few metres). In most cases just a certain portion of the succession is characterized by its platy appearance (beds 1-10cm in thickness). This means that platy limestone mostly appears only in a restricted part of the unit at the surface (outcrops), although some units can be completely characterized by platy limestone (100%). In addition, the superficial spatial appearance of platy limestone very much depends on the relation of the geological (bed dip) and the morphological (flat or steep relief) features. In the areas where the dip of the limestone beds is gentle and the surface is relatively flat, platy limestone can be exposed over wide areas.

According to the common approach agreed among the contractors of WP3 actions (geologists) identified platy limestone types along the entire project area were classified in three categories: **1 - low potential** (grey colour on the map), **2- potential** (yellow colour on the map) and **3 - high potential** (orange colour on the map). In the Kras area the main criteria for the divisions were:

a) thicknesses of individual platy limestone horizons within the entire geological unit succession (percentage of platy limestone)
b) spatial occurrence of platy limestone
c) field expert geological evaluation of quality
d) known use of platy limestone as a building material on buildings

Spatial occurrences and thicknesses of sequences for four main platy limestone types from the Kras were presented in chapter 4, while an evaluation of the quality and their use as a building material are presented below.

5.1 GEOLOGICAL ASSESSMENT AS A MINERAL COMMODITY

5.1.1 KOMEN LIMESTONE FROM THE POVIR FORMATION

In the wider area of the villages Komen, Gabrovica, Tomačevica, Volčji Grad, Mali Dol, Sveto and Škrbina Komen, platy limestone from the Povir Fm. from the Cenomanian age, occurs. It covers an approx. 10km long and 5km wide area. In this area at least seven abandoned quarries and some smaller illegal active delves of this PL type were recorded (Figs. 5.1 and 5.2).

The entire sequence of bedded limestone from the Povir Formation is composed of different lithotypes. It is up to 100m thick; while individual horizons of platy limestone reach thickness up to 20m. Beds usually dip 10 to 20 degrees towards the SW.
Limestone is characterized by the alternation of mudstones, cyanobacterial laminites, and rare fine-grained skeletal packstones. The microfacies are changing at the level of the lamina.

Due to the layer of soil, the shape and dimensions of the limestone plates could not be assessed in natural outcrops. In active delves it was noticed that the plates are of irregular shape, usually 20 x 30cm (Figs. 5.1 and 5.2), or larger, up to 30 x 40cm. Plate thickness varies from 2 to 7cm.

Figure 5.1 A small quarry of Komen platy limestone from the Povir Fm. near Gabrovica village (archive photo, taken by: B. Jurkovšek)

Figure 5.2 A small delve of Komen platy limestone from the Povir Fm. (archive photo, taken by: B. Jurkovšek).

Figure 5.3 Limestone slabs of Komen platy limestone from the Povir Fm. ready for use.

The plates are used for the roofs of traditional Kras houses in the surrounding villages, for field-shelters (Fig. 5.4) and dry-walls. Today's use is known especially from Gabrovica (Fig. 5.5). In addition, the use of Komen limestone plates from Povir Fm. is also evidenced in some other locations in the Kras (e.g. churches in Šmarje (Fig. 5.6) or on Gura hill), where most probably a very local source of limestone plates was used. Such local occurrences (e.g. Strmca locality south of Povir; PL_locality ID: 2112) are not shown on the map as polygons due to their very limited spatial extent.

Figure 5.4 Field-shelter partly built of Komen platy limestone from the Povir Fm. near Volčji Grad village.

Figure 5.5 A recently renovated house in Gabrovica, roofed with Komen platy limestone from the Povir Fm. from the close vicinity of the village.

Figure 5.6 The church in Šmarje pri Sežani roofed by Komen limestone from the Povir Fm.

The quality of Komen platy limestone from the Povir Fm. is estimated as relatively good. Good physical properties of this PL type are suggested also by laboratory analyses implemented on a sample taken from Gabrovica locality (see report: Analysis of platy limestone chemical and mechanical properties). Locally, the laminations that can appear in some horizons (Fig. 5.7) predispose the formation of very thin slabs. On the map of platy limestone spatial occurrence this type of PL is presented as potential (yellow colour, see web GIS application).

Although the regions are under restriction for mining activity and there is a complex procedure for the legal exploitation of the natural stone, geologists recommend an exception in permitting procedures for the surrounding area of Komen. This can be the limited use of Komen limestone from abandoned quarries.
According to the spatial extent of the Komen platy limestone, relatively good quality and predominantly subhorizontal beds as possible exploitation areas are the proposed micro-locations of Gabrovica and Mrtvaški hrib. The area is proposed only for a limited exploitation for the renovation of traditional houses under control of (at least local) the authorities and under strict monitoring of any fossil findings.
It must be noted that even in the proposed sites it is not possible to obtain large quantities of high-quality limestone slabs. Compared to some other project areas (e.g. Middle Dalmatia) in the Kras area limestone plates could not be simply gathered on the surface without impacting the sensitive natural environment due to the soil cover. An appropriate amount of limestone plates can only be gathered by removing the soil over a large area.

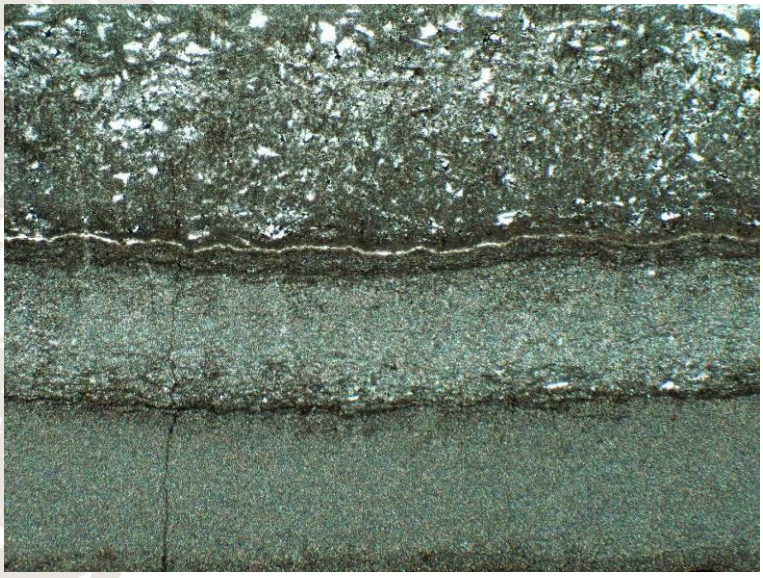


Figure 5.7 Laminated microstructure of Komen PL from the Povir Fm. typically reduces the quality of the limestone slabs.

5.1.2 KOMEN LIMESTONE WITH PELAGIC MICROFOSSILS

Komen limestone with pelagic microfossils is exposed in narrow belts between Kobjeglava, Tomačevica, Mali Dol and Škrbina and north of Ivanji Grad in the northern part of the Kras.

The three to four metre thick sequence is composed of dark grey, very thin-bedded (platy) and laminated limestone. The limestone usually contains numerous calcispheres. It is characterized for the central part of the thick-bedded and massive limestone succession from the Repen Formation. The platy limestone succession is from the Cenomanian-Turonian (~ 95 – 92 My) age.
Between Kobjeglava and Tomačevica thin beds dip 5 to 10 degrees toward the E.

The use of this type of PL as building material is not known from this region. However, numerous small abandoned delves are known from the area north-east of Mali Dol (Fig. 5.8) suggesting the occasional use of this type in the past.

Figure 5.8 Many of the small abandoned delves of Komen limestone with pelagic microfossils (blue) north of Mali Dol village (Kras, Slovenia)

Due to the relatively thin platy limestone horizons (max. 4m) the quantity of this PL type is limited. According to the abandoned quarries in the surroundings of Mali Dol indicating a historical use of platy limestone which is presented on the map as a potential type (yellow).

5.1.3 KOMEN LIMESTONE FROM THE SEŽANA FORMATION

The youngest, Turonian-Santonian (92 – 83 My), Komen limestone type is exposed on the surface between the villages of Kopriva, Skopo, Pliskovica and Kosovelje (area approx. 6 x 3km) and between Ponikve and Hruševica villages (an approx. 5km long area).
Komen PL sequences occur within the bedded to thin-bedded limestone from the Sežana Formation. The thickness of the platy horizons varies from a few metres to a maximum 40m, on average they do not exceed 10m.
They are characterized by an alternation of dark-grey to black fine-grained peloidal to skeletal laminated or stromatolitic limestone, in places with intercalations of chert lenses. Mudstone to wackestone textural types prevail.
In the area of Skopo, Pliskovica and Kosovelje, beds dip 10 to 20 degrees toward the S.

Some smaller abandoned delves were recorded between Kopriva and Kosovelje (Fig. 5.9.). The plates are of an irregularly quadrangular shape, from 10 x 20cm, to 25 x 30cm in size.

Figure 5.9 An abandoned quarry of Komen platy limestone from the Sežana Formation west of Kopriva village.

The plates were used mostly for roofing, paving and dry-walls in Kopriva (Fig. 5.10.) and its surroundings.

The quality of Komen platy limestone of Sežana Fm. is estimated as medium. The lamination that commonly appears (Fig. 5.11) may predispose the disintegration of the plates into thinner slabs. On the map, Komen PL of Sežana Fm. is presented as a potential platy limestone type (see web GIS application) but due to the relatively thin and spatially dispersed PL horizons and the limited quality we do not propose a possible exploitation site in this area.

Figure 5.10 The church in Kopriva roofed by Komen limestone from the Sežana Fm.

Figure 5.11 Laminated microstructure of Komen PL from the Sežana Fm. usually enable the disintegration of the rock into thinner slabs.

5.1.4 TOMAJ LIMESTONE

Dark grey to black bituminous very thin-bedded and laminated Tomaj limestone occurs in the wider area of Dutovlje, Tomaj, Križ, Dobravlje, Avber and Kazlje, while some thin horizons are also exposed north-west of Dolenja vas (the overall area with natural surface outcrops approximates 12 x 7km). From a few metres up to 40m, on average up to 10m, thick platy limestone sequences occur within other bedded to thick-bedded skeletal limestone of Lipica Formation. The succession is from the Santonian-Campanian (85 – 70 My) age.
West of the Tomačevica fault (west of Dobravlje village), beds of Tomaj limestone dip 15 to 20 degrees toward the SW, while east of Tomačevica the fault beds dip on average 10 to 20 degrees toward the NE.

Abandoned quarries were recorded near Kazlje village, the biggest one at the Zaleškovje locality (PL locality ID: 2019).
Due to the layer of soil, the shape and size of the limestone plates could not be assessed in the natural outcrops. Plates used for roofing were usually from 15 x 20cm to 30 x 35cm in size and 2 to 5cm thick (Fig. 5.12).

Figure 5.12 Plates of Tomaj limestone ready for roofing (archive photo, B. Jurkovšek).

Plates of Tomaj limestone were used for roofing traditional Kras houses (Fig. 5.13) and sacral objects (Fig. 5.14) in the wider area of Dobravlje, Kazlje, Dutovlje, Tomaj and Križ. According to the relatively wide spatial extent of the PL horizons, limestone plates were most probably also used for simple field-shelters and dry-walls. Active delves of this limestone type are not known.

Due to the lamination which reduces the resistance of the plates, the quality of Tomaj limestone is estimated as low. On the map (see web GIS application) this type of PL is presented as low potential (grey colour).

Figure 5.13 Rural house in Kazlje roofed using Tomaj limestone (archive photo, B. Jurkovšek).

Figure 5.14 The church in Križ was originally roofed using Tomaj limestone (archive photo, B. Jurkovšek).

5.1.5 FRACTURED "QUASI PLATY" LIMESTONE FROM THE REPEN AND LIPICA FORMATIONS

As a mineral commodity it was evaluated as well as the fractured limestone, although according to geological definitions it could not be classified as genuine platy limestone (see chapter 4). This type was widely used as architectural building material especially in the southern part of the Kras. As limestone plates originate from previously homogeneous and high-quality bioclastic limestone of Repen and Lipica Formations they are of high-quality and are resistant to external climatic conditions.

Fractured Repen limestone was used for roofing over a wider area of Divača, Gorenje (Fig. 5.15.) and Povir villages. Plates were excavated from the Repen Fm. which is exposed in a narrow belt between Divača and Sežana. In this area, abandoned quarries were recorded at Gabričje (Fig. 5.16) and Griža (Tavčar) localities. Fractured Lipica limestone was used for roofing in the area of Filipčje Brdo and Križ village (Fig. 5.17). Limestone plates were excavated from thick bedded bioclastic limestone from the Lipica Formation. An area of several smaller abandoned and occasionally active illegal delves were found north-east of Filipčje Brdo (Fig. 5.18.).

Figure 5.15 The use of fractured Repen limestone for roofing in Gorenje pri Divači (southern Kras, Slovenia)

Figure 5.16 A small abandoned quarry at Gabričje, west of Divača where fractured limestone from the Repen Fm. was excavated.

Figure 5.17 Renovation of the roof on the church in Križ village. Originally it was roofed using Tomaj limestone, which was partly replaced by the fractured limestone from the Lipica Fm. (archive photo, B. Jurkovšek).

Figure 5.18 Abandoned and active delves north-east of Filipčje Brdo village where fractured Lipica limestone is being excavated.

In the past, limestone plates of Repen limestone were excavated using hand tools. People had followed the zones in the Repen limestone where the rock was densely fractured by systems of fissures. The efficiency of such excavation and the quantity of the acquired material was relatively low. The size of the plates used for roofing varies a lot (Fig. 5.15). The largest plates can be up to 40 x 80cm in size. The thickness of the fractured limestone plates may present the biggest problem for use as building material, especially for roofing. It is highly dependent on the distribution of tectonic fractures in its nature. Appropriate plates with a uniform thickness along the entire plate are difficult to find, since the fractures are not ideally parallel in the outcrops.

Fractured Repen limestone could be currently found in legal Griža (Tavčar) quarry near Povir in the uppermost part of the limestone succession. In close vicinity to the active quarry, small abandoned delves were also recorded. The Griža quarry may be a possibility for the

exploitation of smaller quantities of this type of limestone plates for the renovation of houses. They can be acquired with modern equipment from bigger limestone blocks.

5.2 GEOMECHANICAL PROPERTIES OF PLATY LIMESTONE TYPES

With the aim of verifying and correlating a descriptive geological field-assessment of the PL quality with the analyzed numerical values of PL strength, some selected representative samples of platy limestone were collected and sent to METRIS (Materials Research Centre) laboratory in Pula owned by the project partner IDA. The flexural strength and compressive strength were analyzed on four samples from the Kras area (Table 5.1). Mechanical tests were implemented using the universal 250kN testing machine Messphysik Beta 250. The operators were Davor Mandić MSc in mechanical engineering and Tea Zubin MSc. Table 5.2 presents the analyzed flexural strength and compressive strength values for the PL samples from the Kras (see report: Analysis of platy limestone chemical and mechanical properties).
In addition, in the field, on natural PL outcrops, there were also implemented N-type sclerometer tests. The general data from the N-type sclerometer tests implemented in the Kras and the analyzed rock strength and density are presented in Table 5.3.

PL_locality_ID	ID_Sample	Sampler	Date	Sample field name	PL type and geological unit
2003	2003_2	Jurkovšek B.	March 2014	Gabrovica	Komen PL of Povir Fm.
2007	2007_2	Jurkovšek B.	March 2014	MH - Mrtvaški hrib	Komen PL of Povir Fm.
2019	2019_2	Jurkovšek B.	March 2014	Kazlje	Tomaj PL of Lipica Fm.
2103	2103_2	Jež J.	April 2014	Griza	Fractured limestone of Repen Fm.

Table 5.1 General data from PL samples from the Kras sent to the METRIS laboratory– Materials Research Centre in Pula, Croatia

PL_locality_ID	ID_Sample	Sample field name	Field quality assessment	Flexural Strength – σf M (MPa)	Compressive Strength - Rn (MPa)
2003	2003_2	Gabrovica	Relatively good	**19.89**	**83.98**
2007	2007_2	MH - Mrtvaški hrib	Low quality	**3.156**	**39.77**
2019	2019_2	Kazlje	Low quality	**-**	**83.61**
2103	2103_2	Griza	Relatively good	**8.281**	**70.95**

Table 5.2 The measured flexural strength and compressive strength values for the PL samples from the Kras.

PL_locality_ID	Location	Operator	Date	PL type and geological unit	AverageRn values*	Rock strength σc [MPa]	Density [kN/m3]	Density [kg/m3]
2019	Kazlje	Devoto, Biolchi, Jež, Jurkovšek	12.6.2014	Tomaj PL of Lipica Fm.	50	**62.4**	22.4	**2284**
2003	Gabrovica 2A	Devoto, Biolchi, Jež, Jurkovšek	12.6.2014	Komen PL of Povir Fm.	42	**36.6**	20.1	**2052**
2003	Gabrovica 2B	Devoto, Biolchi, Jež, Jurkovšek	12.6.2014	Komen PL of Povir Fm.	45	**44.7**	21.0	**2144**
2007	MH - Mrtvaški hrib	Devoto, Biolchi, Jež, Jurkovšek	12.6.2014	Komen PL of Povir Fm.	47	**51.1**	21.6	**2202**
2109	Skopo	Devoto, Biolchi, Jež, Jurkovšek	12.6.2014	Komen PL of Sežana Fm.	52	**71.3**	22.9	**2337**
2103	Griza	Devoto, Biolchi, Jež, Jurkovšek	12.6.2014	Fractured limestone of Repen Fm.	46	**47.8**	21.3	**2173**
***the lower Rn values (red values) obtained by the N-type sclerometer were not used for working out the average Rn values**								
Intact rock strength values were determined using the formula proposed by Katz et al. (2000)								
The density values were determined using the formula proposed by Katz et al. (2000)								

Table 5.3 N-type sclerometer tests implemented on the PL natural outcrops in the Kras.

As can be seen from the correlation between the descriptive geological quality assessment and the analyzed values of the limestone strengths (Table 5.2, Table 5.3) the descriptive assessment and the numerical values deviate a lot. Deviations were expected since they arise from the lithological characteristics of the platy limestone beds and sequences. Namely, the PL successions are not lithologicaly homogeneous as a result of their genesis in the natural environment. The lithology and structure of the rock and consequently its geomechanical characteristics are changing among different beds as well as on the level of a single bed of platy limestone.

That is why the analyses have given a broad range of numerical values of the flexural and compressive strength of the samples. The strength probably reflects the structure of the limestone, i.e. the combination of the grain size, packing, lamination, cementation quality in grainy limestones etc.

Very similar discrepancies are noticed from the sclerometer tests. Some measurements from the same outcrop show relatively different values (e.g. Gabrovica). The analysed higher density of platy limestone (Kazlje, Gabrovica, Skopo) and the lower density of fractured Repen limestone (Griža) (Table 5.3) can be explained by the grain size, packing and structure of the rock. Bioclastic Repen limestone (Griža locality) is composed of poorly sorted large rudist bioclasts resulting in a relatively low density, while the miritic structure of the platy limestone from other localities resulted in a higher rock density. Different properties of material compared to the other PL reflects also bending test diagram of Griža semple (fractured Repen) (see report: Analysis of platy limestone chemical and mechanical properties).

In terms of the usage of limestone for roofing, probably the best way to assess the PL quality (long-term resistance to external climatic conditions) is an evaluation according to the

historic usage durability on existing buildings (roofs). From this aspect in the Kras area in Slovenia fractured Repen limestone is of the best quality.

5.3 CONCLUSIONS - PLATY LIMESTONE AS A MINERAL COMMODITY

As a mineral commodity, all four types of platy limestone from the Kras area were evaluated, as well as special types of limestone plates originating from tectonically fractured rocks.
As the most potential for exploitation is the assessed **Komen limestone from the Povir Fm.** occurring in a wider area of Komen in the northern part of the Kras. This type was also commonly used for roofing in this area. The quality of the limestone is assessed as relatively good, although due to the lithologically very heterogeneous platy limestone succession, the quality can vary from locality to locality. According to the broad spatial extent and the distribution of the known abandoned quarries as possible exploitation areas for the renovation of traditional houses, the micro-locations of Gabrovica and Mrtvaški hrib have been proposed. It must be noted that even in the proposed two sites it is not possible to obtain large quantities of high-quality limestone slabs and the current laws do not allow exploitation in this area.
The quality of the **Komen limestone from the Sežana Fm.** and the **Komen limestone with pelagic microfossils** is estimated as medium. The limited quality can be caused by lamination that commonly appears and may predispose the disintegration of plates into thinner slabs. Due to the relatively thin and spatially dispersed PL horizons we do not propose possible exploitation sites in this PL sequences.
Among all PL types, **Tomaj limestone** is assessed as having the lowest potential for further exploitation, although in the past it was used as a building material in the southeastern part of the Kras (e.g. in the surroundings of Dutovlje, Križ, Kazlje). Lamination commonly reduces the resistance of the plates, while common changes of lithotypes and bed thickness within the PL succession also reduce the potential for using the limestone plates. The abandoned quarries of Tomaj limestone are known only from the vicinity of Kazlje village.
Limestone plates (quasi platy limestone) from **fractured Repen and Lipica limestone** were recognized as very resistant to climatic conditions and durable for roofs . In the past they were exploited near Filipčje Brdo village and in the area south of Divača and Povir. The spatial occurrence of this tectonically-related limestone type is very limited. As a possible exploitation locality, the active Griža (Tavčar) quarry near Povir can be proposed.

Generally, it can be concluded that the historical use of platy limestone strictly followed the spatial occurrence of platy limestone in nature. In the northernmost part of the Kras Komen limestone from the Povir Fm. was widely used as a building material. It is exposed in a wider area of Komen (Fig. 5.19.). In the middle of the karst plateau a limited use of Komen limestone from the Sežana Fm. and the Komen limestone with pelagic microfossils was recognized, while in the south-eastern part, roofers used Tomaj limestone (Fig. 5.19). In the southernmost part of the Kras there are no significant occurrences of genuine platy limestone, therefore, as a building material, limestone plates from the Repen Formation which is exposed between Divača and Povir (Fig. 5.19) were used.
However, the possibilities for the further exploitation of platy limestone in the Kras are limited but locations where smaller quantities of limestone plates for renovating cultural heritage objects can be found.

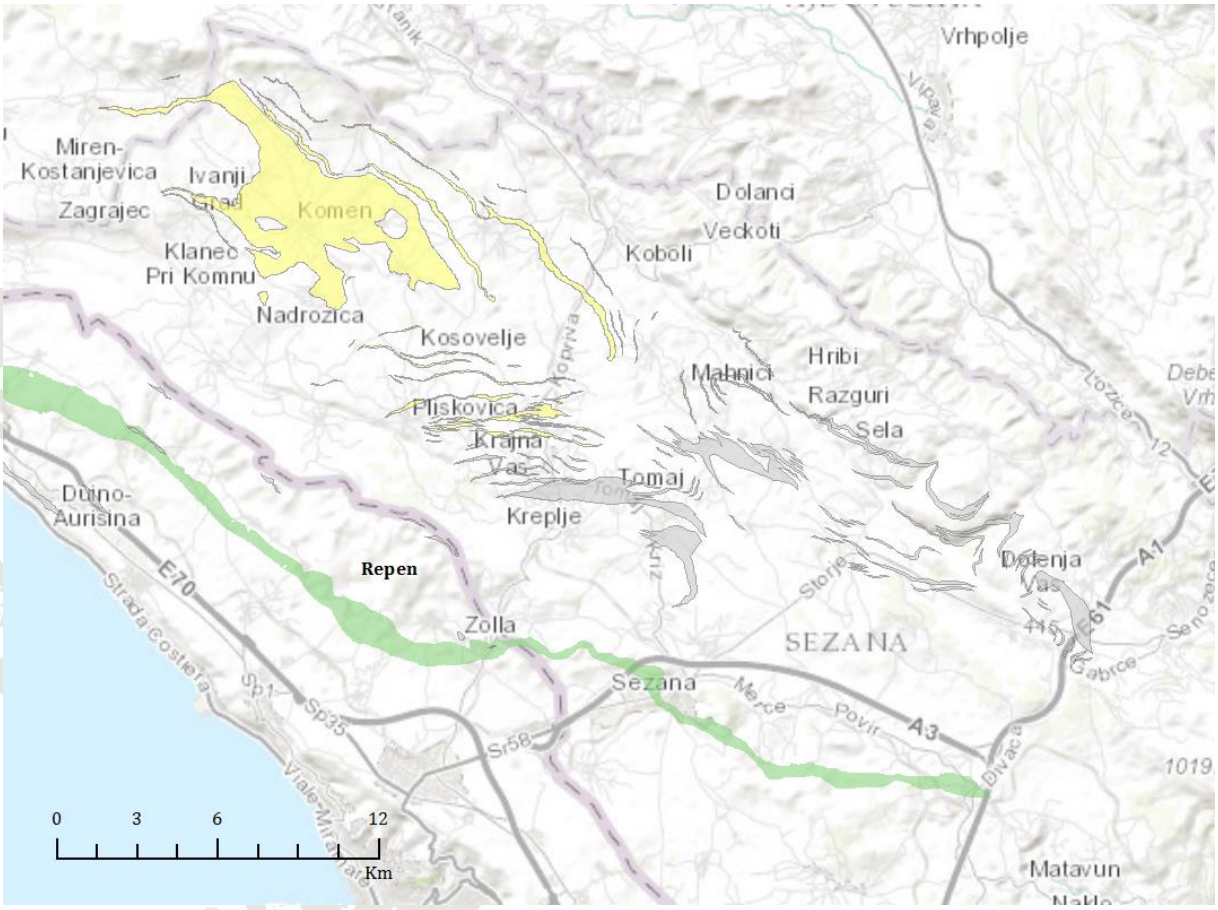


Figure 5.19 The spatial occurrence of platy limestone types and fractured limestone in the Kras. Komen platy limestone from the Povir and Sežana Fms. and Komen platy limestone with pelagic microfossils (in yellow) are exposed in the northern and middle part of the Kras. Tomaj limestone occurs in the sout-eastern part (grey colour). Fractured Repen limestone type can be found in a narrow belt between Divača and Sežana (green colour).

5.4 PLATY LIMESTONE AS NATURAL HERITAGE

Platy limestone occurrences on the surface are characterized almost everywhere by the outstanding landscape. In the Kras they are represented mostly by dry-walls and vineyards. Within the last geological project activity, platy limestone was also evaluated from the perspective of natural heritage. All available archive paleontological material from the platy limestone successions was reviewed and evaluated, while some representative fossil findings from public and personal collections were photo-documented. In addition, some selected and the most promising sites were visited and sedimentologically and paleontologically investigated in detail. Platy limestone was as natural heritage evaluated in detail within the framework of WP5 (natural heritage).

Numerous small quarries of platy limestone were operating in the Kras at the turn of the nineteenth to the twentieth century. During their excavations, the locals often found fossils of vertebrates (fish and reptiles). These materials are now stored in many museums across Europe. Among researchers reporting on fossils found in the Komen and Tomaj beds, were Heckel (1850, 1856), Meyer (1860), Steindachner (1860), Kner (1863, 1867), Bassani (1879, 1880), Kornhuber (1983), D'Erasmo (1946, 1952), Calligaris (1988, 1992, 1993), Calligaris et al. (1994), Arbulla (2002) and others. Because of the fish content and the shaly appearance

of the rock, Gorjanović-Kramberger (1895) introduced the term “ichthyoferous shales” into the scientific literature. As the platy and laminated limestones with fossils occur in different stratigraphic levels within the platform shallow-water carbonates, most researchers also dealt with the problem of their age that had been unsolved for decades.
During the last decade of the previous century, the studies of fossil fauna and flora from the platy and laminated limestones from the Slovenian part of the Kras were reviewed and they coincide with the extensive amelioration works on the Kras as well as mapping for the geological map of the southern part of the plateau (Jurkovšek 2008, 2010, 2013, Jurkovšek at al. 1996, 2013). These studies revealed the stratigraphic position and age of the different platy and laminated horizons of the area. Besides fish and reptiles, the study also included other fossil groups: flora, ammonoids, bivalves etc. (Jurkovšek & Kolar-Jurkovšek 1995, 2002, 2007, Pleničar & Jurkovšek 1997b, Summesberger et al. 1996a, 1996b, 1999a, 1999b, Dobruskina et al. 1999, Cavin et al. 2000, Jurkovšek et al 2001, Buffetaut et al. 2002, Caldwell & Palci 2007, Palci & Caldwell 2007, Palci et al 2008, Jurkovšek & Križnar 2011). The paleontological content of the platy limestone is included within the scope of valuable natural (geological) heritage, which in a way restricts the use of PL for its wider use.

In general, important paleontological findings were recorded in all four types of platy limestone in the Kras area. As presented below, the richest macro-fossil occurrences are known from the Komen limestone from the Povir Formation and from Tomaj limestone. The localities of the Mrtvaški hrib and Zaleškovje quarries near Kazlje are proposed as geo-sites.
All the localities of important fossil findings described in the following text are presented in the web-GIS application. The GIS - based database also includes all the important photo material from these localities.

5.4.1 KOMEN LIMESTONE FROM THE POVIR FORMATION

Within the oldest type of Komen limestone in the Kras vertebrates, primarily fish (Figs. 5.20 to 5.23) and reptiles are the most important macrofossils. Among land plants, mainly remnants of conifers were found. Fossil fish findings were most common in the wider area of Gabrovica and Coljava villages.

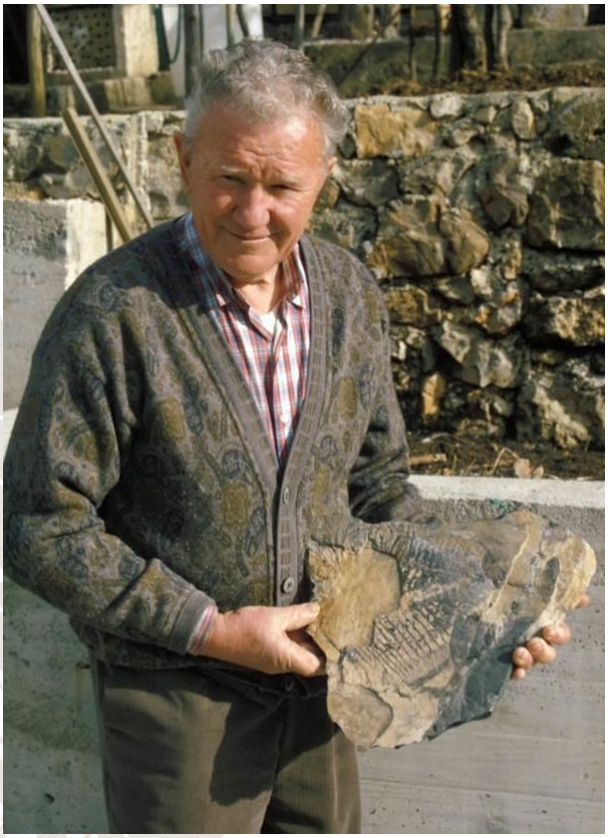


Figure 5.20 Local people often find fossils of fish in the Komen limestone around Gabrovica.

Figure 5.21 Fossil fish *Chirocentrites* sp. from the Komen limestone from the Povir Fm., NE of Gabrovica village.

Figure 5.22 The skeleton of a small fish from the Komen limestone from the Povir Fm. in Gabrovica village.

Figure 5.23 The skeleton of a small fish in the Komen limestone from the Povir Fm. between Gabrovica and Coljava villages.

5.4.1.1 GEO-SITE MRTVAŠKI HRIB

We recommended the Mrtvaški hrib locality as a geo-locality because of its abundance of fossils and interesting characteristic sedimentological features, recognized in the Komen platy limestone sequence.

General information about the geo-locality

Name of the area: Mrtvaški hrib
Locality ID (web GIS database): 2007
Category: Geological paleontological site
Area of the proposed locality: cca. 500 m2
Coordinates: Lat: 45°49'42,61'' (45,828503°); Lon: 13°44'38,52'' (13,744034°)

The locality is situated along the regional road connecting Komen and Škrbina, immediately a few metres east of the road (Fig. 5.24). At the proposed geo-locality, Komen platy limestone from the Povir formation is exposed in up to 2m high road cuttings in the local gravel road. Near the location, several smaller abandoned delves of platy limestone could be found. The limestone beds are in a sub-horizontal position. The thickness of the thin to very thin beds varies from 1cm to 20cm. Its parallel and hummocky lamination is the most common sedimentary structure (Fig. 5.25). Alternations of mudstones and cyanobacterial laminites

prevail among the lithotypes, while fine-grained skeletal packstones also occur locally. At the locality and its wider area, fossil fish have often been found (Fig. 5.26).

However, the sedimentological and paleontological features of the Komen platy limestone from the Povir Formation at the Mrtvaški hrib locality are an important element of its natural heritage. They need to be preserved and appropriately presented to the public.

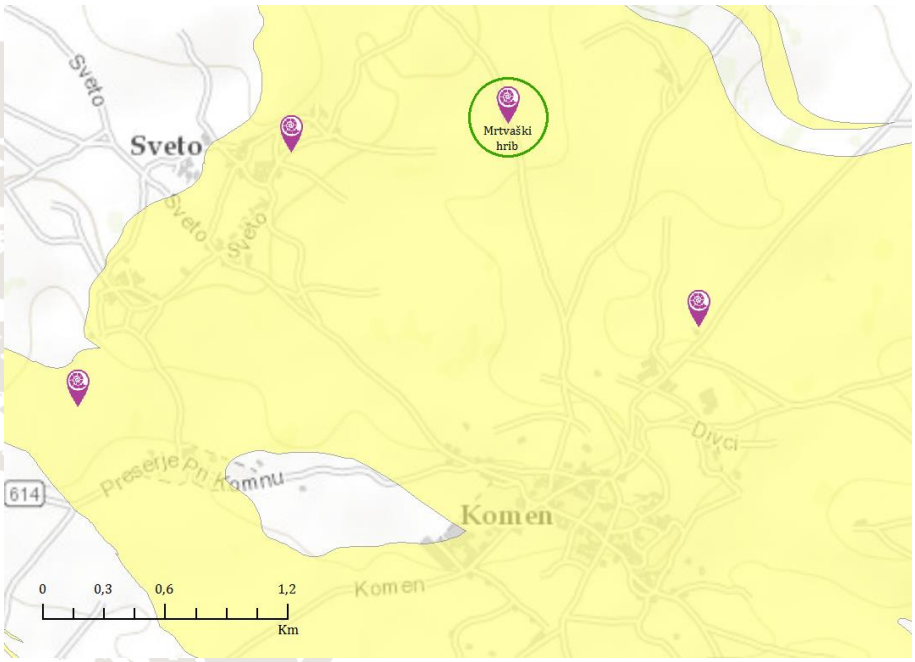


Figure 5.24 A green circle marks the proposed Mrtvaški hrib geo-locality situated between Komen and Škrbina.

Figure 5.25 Parallel and hummocky (upper part) laminated Komen PL from the Povir Fm. at the Mrtvaški hrib locality (Kras, Slovenia)

Figure 5.26 A fish skeleton from the Komen limesone from thePovir Fm. near Mrtvaški hrib.

5.4.2 KOMEN LIMESTONE WITH PELAGIC MICROFOSSILS

Microfossils are abundant in the Komen limestone within the Repen Formation. Planktonic foraminifera and numerous calcispheres and pithonellas are the most important. Among the macrofossils, mainly fish (Figs. 5.27, 5.28, 5.29) and rare ammonoids occur. They were found in the area of Mali Dol, Kobjeglava and Tomačevica villages.

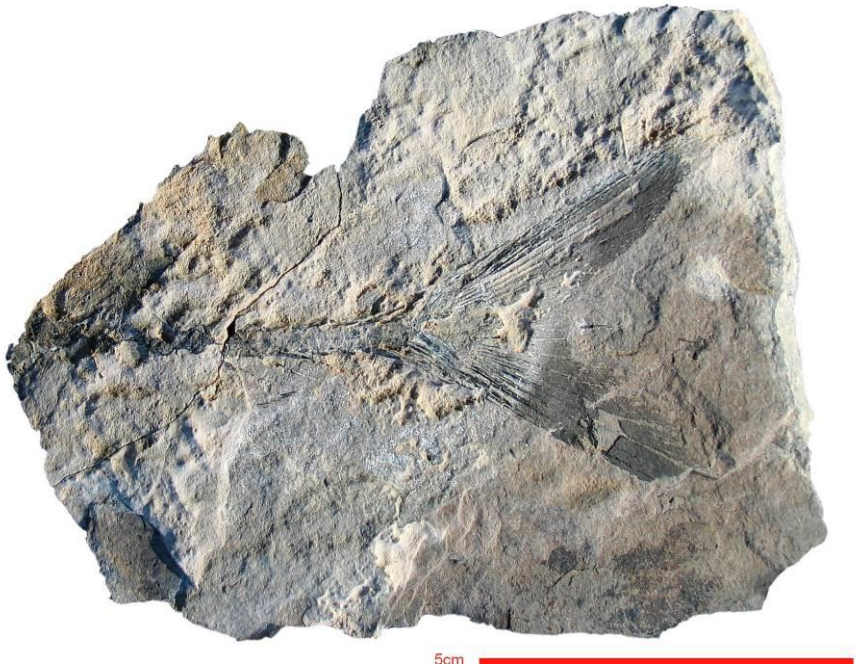


Figure 5.27 A fish skeleton from the Komen limestone with pelagic microfossils near Mali Dol village.

Figure 5.28 A P*tychodus* sp. shark tooth from the Komen limestone with pelagic microfossils near Kobjeglava village.

Figure 5.29 An *Enchodus sp.* lower jaw with a tooth from the Komen limestone with pelagic microfossils near Tomačevica village.

5.4.3 KOMEN LIMESTONE OF SEŽANA FORMATION

Fish and land plant fossils (gymnosperms) also represent the most common macrofossils in the Komen limestone from the Sežana Formation (Jurkovšek et al., 1996; Cavin et al., 2000). Fish skeletons were found especially near Skopo village (Figs. 5.30 and 5.31).

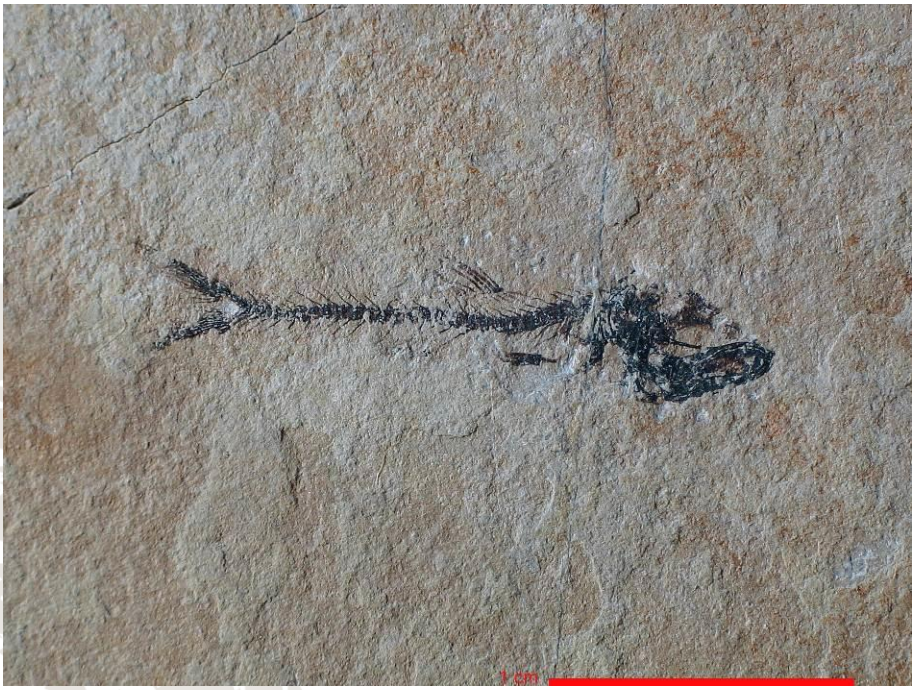


Figure 5.30 A skeleton of a small fish from the Komen limestone from the Sežana Fm. near Skopo village.

Figure 5.31 A fish tail from the Komen limestone from the Sežana Fm. near Skopo village.

5.4.4 TOMAJ LIMESTONE

Besides fossil land plants, fish and other vertebrates, imprints of the soft parts of ammonoids, ammonoids with aptychi in their body chambers and the mass mortality of fish are very common macrofossils in Tomaj limestone. They were found at many localities in the southeastern part of the Kras: near Dobravlje, Šepulje, Križ, Filipčje Brdo, Kazlje etc. (Figs. 5.32 to 5.36).

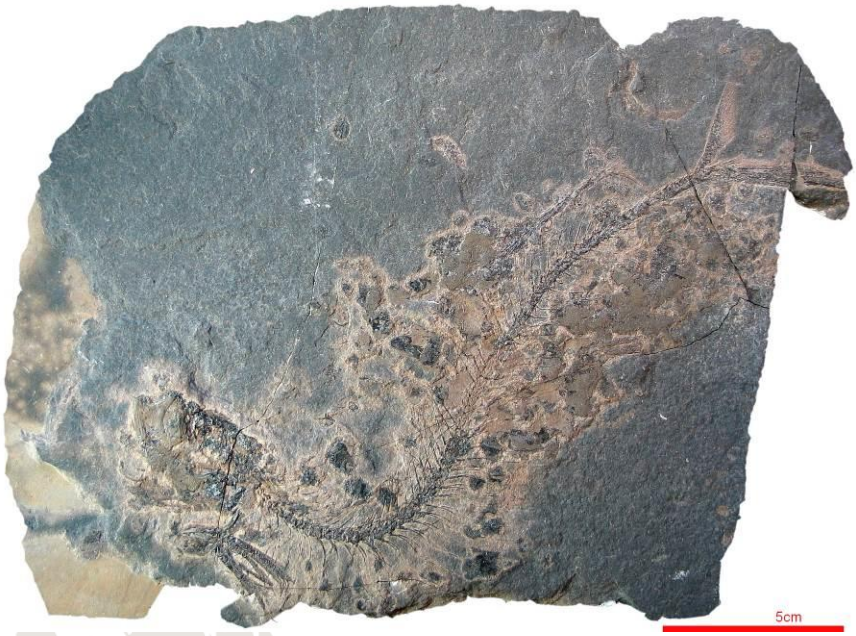


Figure 5.32 A *Chirocentrites microdon* fish from the Tomaj limestone in Dobravlje village.

Figure 5.33 A fossil turtle from the Tomaj limestone in Dobravlje village.

Figure 5.34 An ophiuroid or asteroid from the Tomaj limestone near Filipčje Brdo village.

Figure 5.35 The lower and upper ammonoid jaws of the family Placenticeratidae from the Tomaj limestone near Šepulje village.

Figure 5.36 A Euteleostei indet. fish mass mortality event from the Tomaj limestone near Križ village.

5.4.4.1 GEO-SITE ZALEŠKOVJE (KAZLJE)

The abandoned quarry at Zaleškovje of Tomaj limestone is recommended as a geo-locality due to thefossil abundance and interesting sedimentological features recognized in the limestone sequence.

General information about the geo-locality

Name of the area: Zaleškovje
Locality ID (web GIS database): 2019
Category: Geological paleontological site
Area of the proposed locality: cca. 1000 m2
Coordinates: Lat: 45°45'21,97'' (45,756102°); Lon: 13°54'41,40'' (13,911501°)

The proposed geo-locality is situated in the forested area approx. 400m southeast of the centre of Kazlje village, 200m east of the local gravel road (Fig. 5.37). Thin-bedded Tomaj limestone composes the up to 4m high vertical walls in an abandoned quarry. The 2 to 20cm thick beds are in a sub-horizontal position (Fig. 5.38).

The limestone is usually dark coloured, bituminous and laminated. Mudstone to wackestone lithotypes prevail, while thicker beds can also be composed of calcarenite to calcisiltite bioclastic lithofacies. Chert nodules and lenses occur locally.

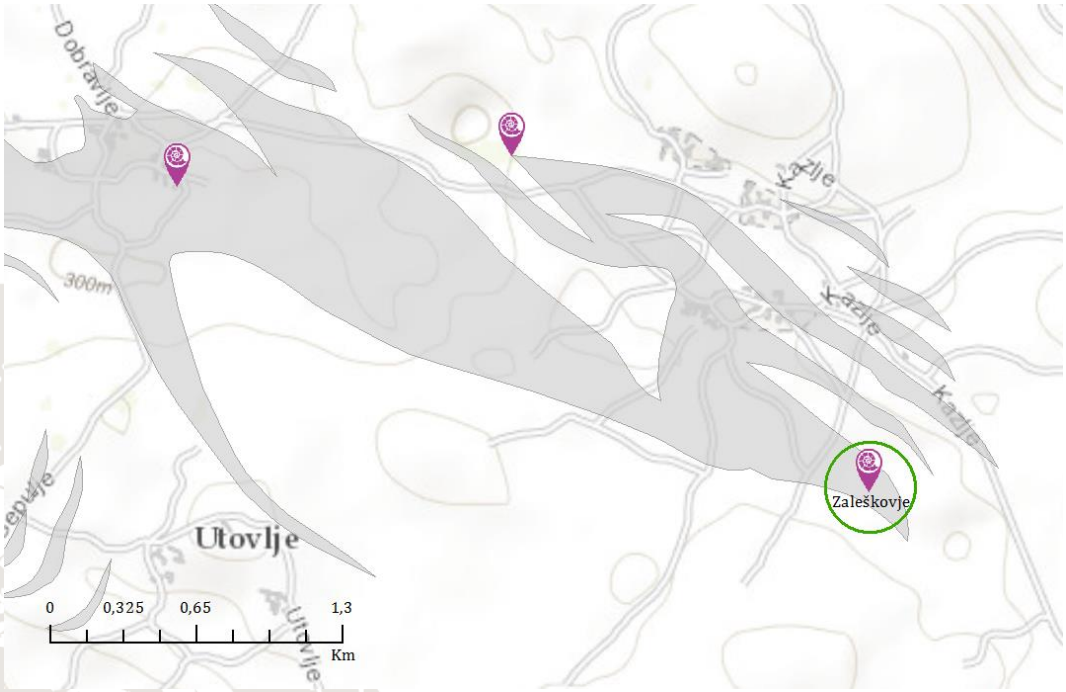


Figure 5.37 A green circle marks the location of the Zaleškovje abandoned quarry SE of Kazlje village.

Figure 5.38 An outcrop of Tomaj limestone in the Zaleškovje quarry.

Fossil land plants and ammonoids are very characteristic fossils in the Tomaj limestone at the Zaleškovje geo-locality (Figs. 5.39 to 5.45).

As the Tomaj limestone is not recognized as very potential limestone as a building material and the proposed Zaleškovje geo-locality represents a very important paleontological site, it may also be completely protected as a natural heritage site.

Figure 5.39 A *Magnoliaphyllum* sp., Tomaj limestone, Zaleškovje quarry.

Figure 5.40 An *Araucarites* sp., Tomaj limestone, Zaleškovje quarry.

Figure 5.41 A *Brachyphyllum* sp., Tomaj limestone, Zaleškovje quarry.

Figure 5.42 A *Pagiophyllum* sp., Tomaj limestone, Zaleškovje quarry.

Figure 5.43 An ammonoid of the Placenticeratidae family with the aptychus in the living chamber, Tomaj limestone, Zaleškovje quarry.

Figure 5.44 An Ammonoid, Tomaj limestone, Zaleškovje quarry.

Figure 5.45 A *Haplopteryx stachei*, Tomaj limestone, Zaleškovje quarry.

5.4.5 CONCLUSION

On the basis of the available archived paleontological material, fossil collections and detailed field-work, platy limestone occurrences were evaluated from the aspect of natural heritage. In the Kras area platy limestone exposures on the surface can usually be recognized as a flat landscape with vineyards and dry-walls. The most common findings of fish, reptiles and land plants are known from the Komen limestone in the wider area of Gabrovica and from the Tomaj limestone over a wider area of Tomaj. Two locations, Mrtvaški hrib and Zaleškovje, we propose as geo-sites.

Significant elements of natural heritage that should be properly presented to the public and also locally protected may be sometimes in conflict with the exploitation of platy limestone as a building material. However, according to the historical data it can be noticed that the majority of fossils were found during the excavation of platy limestone in small quarries which means that without excavation these fossils would never have been found. Therefore excavation of a small amount of platy limestone for the reconstruction of typical karst architecture is not estimated to have a too drastic effect on a sensitive environment but the digging should be done under the organized paleontological monitoring of the competent institutions.

6 GEOLOGICAL GUIDELINES AND RECOMMENDATIONS

6.1 INTRODUCTION

The detailed geological investigation of the platy limestone has revealed a widespread occurrence of platy limestone in the northern and central part of the Kras, the north-western part of the RoofOfRock project area in Slovenia. Platy limestone was traditionally exploited for local use in the Kras area, and there are many examples of best practice of its usage. Limestone plates are commonly of low quality, while at some locations their quality is assessed as appropriate for use as a building material (e.g. the Komen limestone from the Povir Formation near Gabrovica). In the Kras four different platy limestone types were identified: the Komen limestone from the Povir Fm., the Komen limestone with pelagic microfossils, the Komen limestone from the Sežana Fm. and Tomaj limestone. They are all from the Cretaceous age and were deposited in deeper lagoons or spatially limited intraplatform basins within shallow water carbonate platform environments. Local environmental, geological and geomorphological conditions have resulted in some important differences between the various types of platy limestone. Horizons of PL are up to a few tens of metres thick, while in many places their thickness is only a few metres. The spatial distribution of platy limestone outcrops on the surface to a large extent depends on the relation of geological (bed dip) and morphological (slope dip) features. In the Kras dip of the limestone beds is gentle (10 to 20 degrees) and the surface is relatively flat, therefore, platy limestone is exposed over wide areas. The platy limestone quality is closely related to the lithological heterogeneity of the PL successions. It should be noted that even single limestone beds are not lithologically homogenous, as a result of the genesis in the depositional environment. It is worth mentioning that in the southern and central part of Kras in Slovenia, a special type of limestone plate of relatively good quality was widely used for roofing. It was named fractured limestone as its origin is tectonically related. The use of fractured Repen limestone and Lipica limestone was recorded in the southern part of the Kras.

The historical use of platy limestone as a building material has been following a rule of using local sources of material as was possible. The plates used in buildings mostly originate from local sources, situated in the vicinity of the buildings.

6.2 RECOMMENDATIONS AND GUIDELINES

In the Kras area in Slovenia there is no active quarry where the exploitation of platy limestone would be possible. According to the spatial and natural characteristics (e.g. occurrence, quality and reserves) and the traditional use of limestone plates, geological recommendations and guidelines are suggested as listed below.

a) Limited use of stone from abandoned quarries for the renovation of local houses

Given the complex procedure for the legal exploitation of the natural stone and the fact that parts of the Kras region are under special restriction for mining activity (Natura2000, Ecologically important areas), the geologists recommend some exceptions in permitting excavation procedures.

Platy limestone was traditionally exploited in the area for its local use. Many abandoned quarries were recorded as well as many examples of best practice of the local limestone use.

We propose re-opening one abandoned quarry of platy limestone. The exploitation should be restricted for only renovating local traditional architecture and under the control of the (at least local) authorities and under strict monitoring of fossil findings. According to its spatial extent, sufficient quality and reserves, it is assessed that in the Kras smaller amounts of Komen limestone from the Povir Fm. could be exploited near Gabrovica and Mrtvaški hrib.

Figure 5.46 A small delve of Komen platy limestone near Gabrovica

b) Use of fractured limestone from an active commercial quarry in the Kras area

A review of the use of limestone plates as architectural building material revealed that especially in the southern part of the Kras a special type of limestone plates were used for roofing. According to the geological definitions this type of limestone is not classified as platy limestone as its platy appearance is not related to its genesis (processes of deposition and diagenesis) but is of tectonic origin. Dense systems of parallel tectonic fissures/fractures enable the excavation of thin, 3 - 10cm thick, high-quality limestone plates (Fig. 5.47). This type of limestone plate was excavated in the limestone sequences of the Repen and Lipica Formation. The rudist bioclastic limestone plates from Repen Fm. were used for roofing in a wider area of the southern Kras. They were excavated in a narrow belt of the Repen Formation where abandoned quarries were also evidenced within the framework of this project. In central Kras, the fractured limestone of the Lipica Formation was also used locally for roofing.

As a possible option of acquisition of relative quality limestone plates, we propose the excavation of fractured Repen limestone in the Repen Formation. This type of limestone is exposed in a wide belt between Divača and Sežana. The most perspective location is an active Griža (Tavčar) quarry near Povir.

It should be noted that this stone occurs in a relatively limited area of the southern Kras. Quarrying of limestone plates along fractures, even with modern equipment in an active quarry, could be a complex, time consuming and expensive process, therefore, with this technology only a limited amount of plates for renovating the roofs can be acquired.

Figure 9.47 Fractured Repen limestone in the Griža (Tavčar) quarry near Povir village, Kras, Slovenia

REFERENCES

ARBULLA, D., 2002. Ittioliti. Pesci fossili nelle collezioni del Museo Civico di Storia Naturale di Trieste. Museo Civico Storia Naturale, 114 pp., Trieste.

BASSANI, F., 1879. Über einige fossile Fische von Comen. Verh. k.k. geol. R.-A. 9, 204-205, Wien.

BASSANI, F., 1880. Contribuzione alla fauna ittiologica del Carso presso Comen in Istria. Atti. Acad. Sci. Ven.-Trent.-Istr. 7/1, 1-15, Padova.

BUFFETAUT, E., JURKOVSEK, B. & KOLAR-JURKOVSEK, T. 2002. A fossil feather from the Upper Cretaceous of Kras (Slovenia). – C. R. Palevol., 1, 705-710, Paris.

CALDWELL, M. W. & PALCI, A., 2007. A new basal mosasauroid reptile from the Cenomanian (U. Cretaceous) of Slovenia with a review of mesosauroid phylogeny and evolution. Journal of Vertebrate Paleontology, 4, 863-880.

CALLIGARIS, R., 1988. I rettili fossili degli strati calcarei ittiolitici di Comeno e dall'isola di Lesina. Atti del Museo Civico di Storia Naturale di Trieste 41, 85-125, Trieste.

CALLIGARIS, R., 1992. I pessci fossili dei calcari ittiolitici di Comeno e di facies a questa correlabili conservati nelle collezioni del Museo civico di Storia Naturale di Trieste. - Atti Mus. civ. Stor. Nat. Trieste, 44, 57-111, Trieste.

CALLIGARIS, R., 1993. Acteosaurus crassicostatus nuova specie di Dolichosauridae negli strata calcarei ittiolitici di Comeno. Atti del Museo Civico di Storia Naturale di Trieste 45, 29-34, Trieste.

CALLIGARIS, R., KRIVIC, K. & PLENIČAR, M., 1994. Fosili Tržaško-Komenskega Krasa. Ostanki živih bitij izpred 95 milijonov let. Prirodoslovni muzej Slovenije, 40 pp., Ljubljana.

CAVIN, L., JURKOVŠEK, B. & KOLAR-JURKOVŠEK, T. 2000. Stratigraphic succession of the Upper Cretaceous fish assemblages of Kras (Slovenia). Geologija, let. 43, str. 165-195.

D'ERASMO, G., 1946. L'ittiofauna Cretacea dei dintorni di Comeno nel Carso triestino. Atti R. Accad. Sc. fis. mat. 3a 2/8, 1-136, Napoli.

D'ERASMO, G., 1952. Nuovi ittioliti cretacei del Carso Triestino. - Estratto dagli Atti del Museo Civico di Storia Naturale Trieste, 18/4, 81-122, Rocca San Casciano.

DOBRUSKINA, I., JURKOVŠEK, B. & KOLAR-JURKOVŠEK, T., 1999. Upper Cretaceous flora of Slovenia. Annales 9/2, 243-256, Koper.

GORJANOVIĆ - KRAMBERGER, C., 1895. Fosilne ribe Komena, Mrzleka, Hvara i M. Libanona uz dodatak o oligocenskim ribama Tüffera, Zagora i Trifalja. Djela Jug. akad. znan. um. 16, 1-67, Zagreb.

HECKEL, J.J., 1850. Beiträge zur Kenntniss der fossilen Fische Österreichs. Abhandlung I mit Atlas. Denkschr. k. Akad. Wiss., Math.-naturw. Cl., 201-242, Wien.

HECKEL, J.J. 1856. Beiträge zur Kenntniss der fossilen Fische Österreichs. Abhandlung II. - Denkschr. k. Akad. Wiss., Math.-naturw. Cl., Eilfter Band, 187-274, Wien.

JEŽ, J., OTONIČAR, B., FUČEK, L. & OGORELEC, B. 2011. Late Cretaceous sedimentary evolution of a northern sector of the Adriatic Carbonate Platform (Matarsko Podolje, SW Slovenia). Facies 57, 447–468.

JURKOVŠEK, B. 2008. Geološka karta severnega dela Tržaško-komenske planote 1:25.000 = Geological map of the northern part of the Trieste-Komen plateau (Slovenia) 1:25.000 [Kartografsko gradivo]. Ljubljana, Geološki zavod Slovenije.

JURKOVŠEK, B. 2010. Geološka karta severnega dela Tržaško-komenske planote 1:25.000 = Geological map of the northern part of the Trieste-Komen plateau (Slovenia) 1:25.000. Tolmač. Ljubljana, Geološki zavod Slovenije.

JURKOVŠEK, B., 2013. Geološka karta Krasa 1: 100.000 = Geological map of Kras (Slovenia) 1: 100.000. Ljubljana: Geološki zavod Slovenije, ISBN 978-961-6498-41-8. *http://www.geo-zs.si/podrocje.aspx?id=505*.
JURKOVŠEK, B., & KOLAR-JURKOVŠEK, T., 1995. Zgornjekredni skat *Rhinobatos* iz Lipiške formacije pri Dobravljah (Tržaško-komenska planota, Slovenija). Annales 7, 161-170, Koper.
JURKOVŠEK, B. & KOLAR-JURKOVŠEK, T., 2002. Kras – pokrajina terana in fosilov: kaj kažejo najnovejša raziskovanja. Kras, 45, 37-39, LjubljanaJURKOVŠEK, B. & KRIŽNAR, M., 2011: Rešena paleontološka uganka iz tomajskega apnenca. *Proteus*, 2011, 73/ 7, 301-307.
JURKOVŠEK, B. & KRIŽNAR, M., 2011. Rešena paleontološka uganka iz tomajskega apnenca. Proteus 7/73, 301-307, Ljubljana.
JURKOVŠEK, B., TOMAN, M., OGORELEC, B., ŠRIBAR, L., DROBNE, K., POLJAK, M. & ŠRIBAR, LJ. 1996. FORMACIJSKA GEOLOŠKA KARTA 1:50.000 JUŽNEGA DELA TRŽAŠKO-KOMENSKE PLANOTE. Ljubljana: Inštitut za geologijo, geotehniko in geofiziko, 143 str.
JURKOVŠEK, B., KOLAR-JURKOVŠEK, T. & CAVIN, L., 2001. Fishes in the Late Cretaceous fossil assemblages of Kras (Slovenia). In: Tintori, A. (ed.): 3rd International Meeting on Mesozoic Fishes: Sistematics, Paleoenvironments and Biodiversity. Serpiano – Monte San Giorgio, 26-31 August 2001, Abstract book, Serpiano.
JURKOVŠEK, B. & KOLAR-JURKOVŠEK, T. 2007. Fossil assemblages of the Upper Cretaceous Komen and Tomaj Limestones of Kras (Slovenia). Neues Jahrbuch für Geologie und Paleontologie. Abhandlungen, vol. 245/1, str. 83-92.
JURKOVŠEK, B., CVETKO TEŠOVIĆ, B. & KOLAR-JURKOVŠEK, T. 2013. Geologija Krasa = Geology of Kras. Ljubljana. Ljubljana: Geološki zavod Slovenije, 205 pp., ISBN 978-961-6498-42-5.
KNER, R., 1863. Über einige fossilen Fische aus den Kreide- und Tertiärschichten von Comen und Podsused. Sitzungsber. math.-naturw. Cl. k. Akad. Wiss. 48/1, 126-148, Wien.
KNER, R., 1867: Neuer Beitrag zur Kenntniss der fossilen Fische von Comen bei Görz. Sitzungsber. math.-naturw. Cl. k. Akad. Wiss. 56, Wien.
KORNHUBER, A., 1893. *Carsosaurus Marchesettii*, ein neuer fossiler Lacertilier aus den Kreideschichten des Karstes bei Komen. Abhandl. k.k. geol. R.-A. 17/3, 1-15, Wien.
MEYER, H., 1860. *Acteosaurus Tommasinii* aus dem schwarzen Kreide - Schiefer von Comen am Karste. Paleontographica 7 (1859-1861), 223-231, Cassel.
PALCI, A. & CALDWELL, W. M., 2007. Vestigal forelimbs and axial elongation in a 95 million-year-old non-snake Squamate. Journal of Vertebrate Paleontology, 27/1, 1-7.
PALCI, A., JURKOVŠEK, B., KOLAR-JURKOVŠEK, T. & CALDWELL, M.W. 2008. New palaeoenvironmental model for the Komen (Slovenia) Cenomanian (Upper Cretaceous) fossil lagerstäte. Cretaceous research, vol. 29/2, str. 316-328.
PLACER L (1981) Geološka zgradba jugozahodne Slovenije (Geologic structure of southwestern Slovenia). Geologija 24:27-60
PLACER L (1998) Contribution to the macrotectonic subdivision of the border region between Southern Alps and External Dinarides. Geologija 41:223-255
PLENIČAR, M., JURKOVŠEK, B., 1997a. Rudisti iz Lipiške formacije v kamnolomu Lipica I = Rudists from the Lipica Formation in the Lipica I quarry. Annales 11, 115-140, Koper.
PLENIČAR, M., & JURKOVŠEK, B., 1997b. Eksogire s Tržaško-komenske planote. V: Horvat, A. & Zupančič, N. (eds.), 13. posvetovanje slovenskih geologov = 13th Meeting of Slovenian geologists, Ljubljana 1997. Geološki zbornik, 13, 87-99, Ljubljana.

PLENIČAR, M., JURKOVŠEK, B., 1998. Zgornjesantonijski rudisti osrednjega dela Tržaško-komenske planote = The Upper Santonian rudists of the central part of the Trieste-komen Plateau. Razprave 4. razr. SAZU 39, 3-53, Ljubljana.

PREMRL, B. 2003. Kamnita strešna kritina stavb na Primorskem in izvor gradiva zanjo. Uprava RS za kulturno dediščino, Restavratorski center, Zavod za varstvo kulturne dediščine Slovenije, Ljubljana.

PREMRL, B. 2005. Kamnita strešna kritina stavb na Primorskem II, aplikativna raziskava. Uprava RS za kulturno dediščino, Restavratorski center, Zavod za varstvo kulturne dediščine Slovenije, Ljubljana, 115 str

PREMRL, B. 2005. Kamnita strešna kritina stavb na Primorskem II, aplikativna raziskava, priloge. Uprava RS za kulturno dediščino, Restavratorski center, Zavod za varstvo kulturne dediščine Slovenije, Ljubljana.

STEINDACHNER, F., 1860. Beiträge zur Kenntniss der fossilen Fische Österreichs. I. Über einen neuen Vomer-ähnlichen Fisch von Comen am Karst. Sitzungsber math.-naturw. Cl. k. Akad. Wiss. 38 (1859), 763-788, Wien.

SUMMESBERGER, H., JURKOVŠEK, B. & KOLAR-JURKOVŠEK, T., 1996a. Aptychi associated with ammonites from the Lipica-Formation (Upper Cretaceous, Slovenia). Ann. Naturhist. Mus. Wien 97 A, 1-19, Wien.

SUMMESBERGER, H., JURKOVŠEK, B. & KOLAR-JURKOVŠEK, T., 1996b. Association of aptychi and ammonites in Upper Cretaceous carbonates of Slovenia. IV Intern. Symp. Cephalopods present and past. Abstract Volume, 161-162, Granada.

SUMMESBERGER, H., JURKOVŠEK, B.& KOLAR-JURKOVŠEK, T., 1999a. Upper jaws of Placenticeratidae from the Karst Plateau (Upper Cretaceous, Slovenia). *Ann. Nat.hist. Mus. Wien, Ser. A Mineral. Petrogr. Geol. Paläontol. Anthropol. Prähist.*, December, 101 A, 119-122.

SUMMESBERGER, H., JURKOVŠEK, B.& KOLAR-JURKOVŠEK, T., 1999b. Rollmarks of soft parts and a possible crop content of Late Cretaceous ammonites from the Slovenian karst. In: Olóriz, F. & Rodriguez-Tovar, F. J. (eds.): *Advancing research on living and fossil cephalopods development and evolution : form, construction, and function : taphonomy, palaeoecology, palaeobiogeography, biostratigraphy, and basin analysis*. New York: Kluwer, 335-344.

VESEL, J., 1979. Repen. Geologija 22/1, 117-126, Ljubljana.

VESEL, J., STRMOLE, D., SENEGAČNIK, A., PAVŠIČ, J. & PAVLOVEC, R., 1987. Naravni kamen: Kamnarsko geološki leksikon. Geološki zavod – Inštitut za geologijo, geotehniko in geofiziko, Združenje slovenske kamnarske industrije, Odsek za geologijo, 100 pp., Ljubljana.

VLAHOVIĆ, I., TIŠLJAR, J., VELIĆ, I. & MATIČEC, D. 2005. Evolution of the Adriatic Carbonate platform: Paleogeography, main events and depositional dynamics. Paleogeography Paleoclimatology Paleoecology, vol. 220/3-4, str. 333-360.