WP3

PLATY LIMESTONE – GEOLOGIC DEFINITION AND ITS USE AS A MINERAL COMMODITY

Appendix 2.1

Final report for the project area in Italy

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INTRODUCTION

1.1 Overview of the project area – Geographic description

The Italian part of the Carso/Kras is the northernmost edge of the Dinaric karst. From a geomorphological viewpoint, it is an extensive NW–SE oriented limestone plateau, about 50 km long, which extends from the Isonzo River to the Rosandra Valley. It covers covers an area of about 210 km^2. The topography dips gently toward the NW from 665 m (Mt. Cocusso) to sea level (Timavo Springs).

2. COMMON GEOLOGICAL DEFINITION OF (PLATY) LIMESTONE

2.1 Definition, occurrence and depositional environments of limestone

The rocks outcropping in the karstified area of the Adriatic Region testify to the evolution of a carbonate platform deposited continuously from the Triassic to the Eocene. In particular, in the Italian part of the Carso/Kras, this sequence covers rock deposits dating from the Early Cretaceous (about 120 Ma) to the Early Eocene (about 50 Ma), with an overall thickness of about 2000 m. The carbonate rocks are well-bedded limestones and dolomites typical of a shallow marine and platform environment. During its deposition the platform was affected by different subsidence rates, as evidenced by the decrease of the lithostratigraphical unit thicknesses towards the north-west (Figure 1a).

2.2 Geological setting

Structurally the Italian side of the Carso/Kras belongs to the External Dinarides, which is characterized by NW–SE thrusts, reverse faults and high-angle faults; the latter often with a strike-slip component (Figure 1b). These structures are the result of a compressive phase of the Alpine orogenetic cycle (Dinaric Phase) during the Late Oligocene. The thrusts gave rise to the development of a series of overthrustings with a SW vergence tending to the superimposition of the Mesozoic carbonate sequence on the Paleogene turbiditic one (Figure 1a). The continuity of these structures is interrupted by a system of NE–SW anti-Dinaric subvertical faults. Carulli (2011) ascribed the formation and the shaping of the Gulf of Trieste to the Dinaric and anti-Dinaric faults.

The main tectonic structures that affect the Italian part of the Carso/Kras are the Palmanova Line (Amato et al., 1976), or the Trieste Fault (Del Ben et al., 1991) with a NW–SE (Dinaric) orientation. It is located 2-3 km offshore in the Gulf of Trieste, with an overall vertical displacement of about 1,400 m (Busetti et al., 2010). It connects the Dinaric thrusts system of the eastern Friuli Plain to the Črni Kal Thrust in Slovenia (Placer, 2007).

Another important Dinaric structure is the Carso/Kras Thrust (Bensi et al., 2009), which develops along the limestone–flysch contact in the north-western sector of the Carso/Kras, in the flysch slopes of the town of Trieste, and is connected to the Petrinje Thrust. A system of minor thrusts located in the coastal flysch slopes and offshore proceeds towards the south in Slovenia (Socerb, Zanigrad and Hrastovlje thrusts; Placer, 2007).

The thrust system is probably offset by a NE-SW normal fault almost parallel to the eastern coast, and by NE-SW faults located in the middle of the gulf, dividing the northern part characterized by thrusts, backthrusts and Plio-Quaternary tectonic activity, from the southern part characterized by thrusting and an overall less intense deformation (Busetti et al., 2010). Locally the distal part of the thrusts is dislocated by tear-faults, which are strike-slip faults with NE-SW or ENE-SWS orientation (es. Sistiana Line, Monte Spaccato Line, faults of the Rosandra Valley; Cucchi & Piano, 2013).

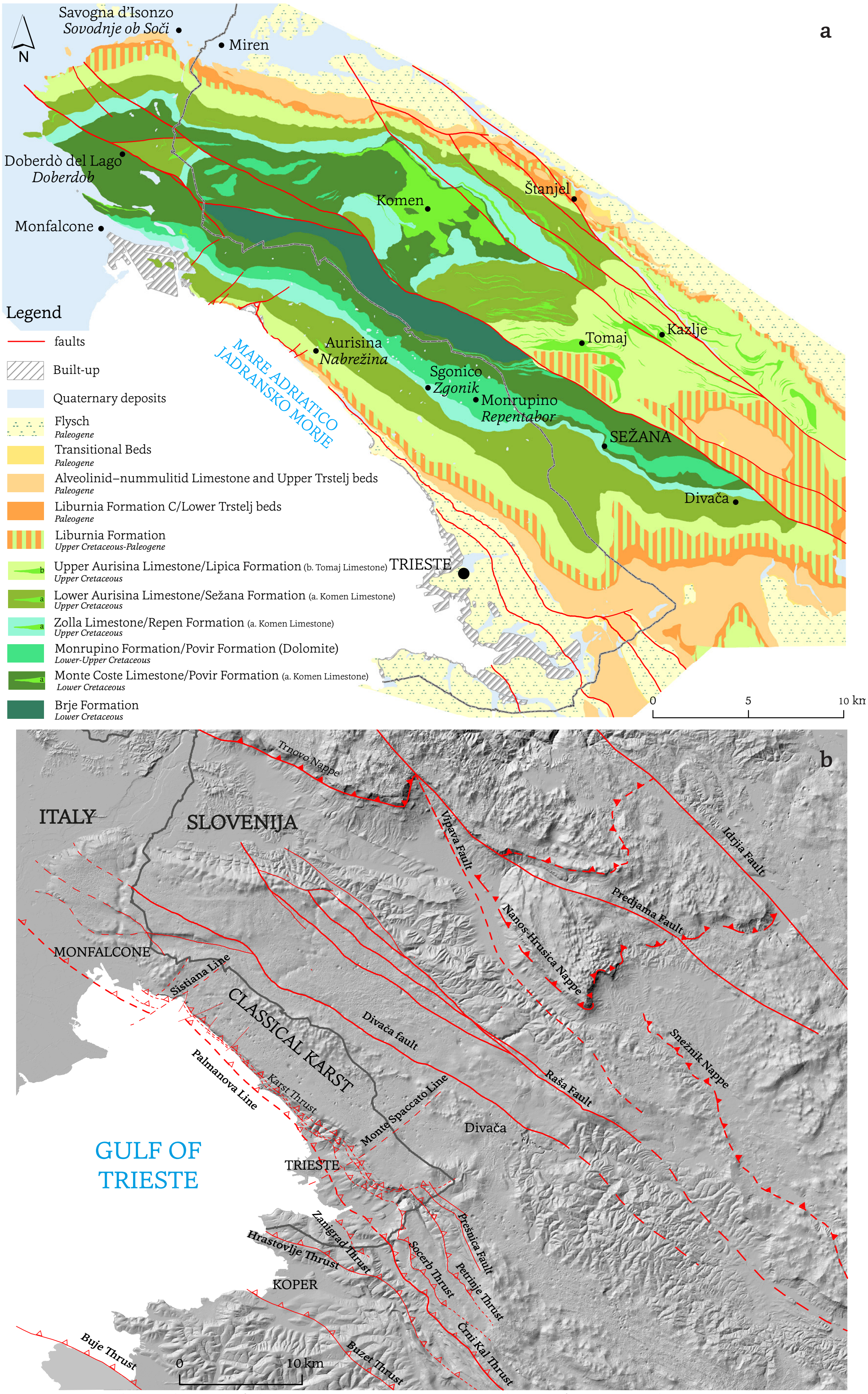


Figure 1: Geological map of the Carso/Kras ITA&SLO (redrawn from: Cucchi & Piano, 2013 - ITA - and Jurkovšek et al., 2010, 2013 - SLO);
b. Tectonic sketch of the Carso/Kras (redrawn from Placer et al., 2010)

2.3 The stratigraphic sequence

The stratigraphic sequence starts with the Lower-Upper Cretaceous formations of Monte Coste Limestone (Aptian-Albian) and Monrupino (Cenomanian).
The Monte Coste Limestone fm. (350-400 m thick, Figure 2) is composed of bedded, locally platy, foraminiferal, dark limestones (mudstone-wackestone), which locally include beds of breccias related to a synsedimentary tectonic phase, and reddish micritic layers of paleokarstic origin. These are overlain by metric boundstone and floatstone with requieniids, packstone with nerineids and storm layers organized in metric cycles. These limestones are characterized at the top by a Carso/Kras dolomitic layer overlain by dark dolomitic breccias formed as the result of the tectonic activity between the Late Albian and Early Cenomanian. The Cenomanian Monrupino fm. (300-700 m thick, Fig. 3) is composed of light-grey and dark-grey dolomites with blackish laminations, black fine-grained crystalline dolomites, with decimetric-metric bedding, with frequent red-yellowish lenses of dolomites and micritic limestones and calcareous-dolomitic alternations (Colizza et al., 1989). They are overlain by dark limestones (mudstone, wackestone, packstone) with rudists, *Chondrodonta joannae* and foraminifers, including platy, laminated limestones with chert and fish fossils - Komen Limestone (Palci et al., 2008).
The fossil content in the Aptian deposits is represented by *Textularidae*, *Miliolidae*, *Nubercularidae*, *Sabaudia minuta*, *Cuneolina tenuis* and *C. camposaurii*, requieniids and nerineids, while for the Cenomanian part, by *Crysalidina gradata*, *Biplanata peneropliformis*, *Broekina balcanica*, *Pseudolituonella reicheli* etc., and radiolitids,*Chondrodonta joannae* and *Neithea fleurasiana*; among the planctonic fauna of the upper part, *Rotalipora*, *Calcisphaerulidae* and *Heterohelicidae* are present. It was deposited in an inner and marginal platform environment, with high-energy episodes. The breccia layers were derived from emersion phases of the platform during the Cenomanian tectonic activities that caused local karstification and erosion of the platform.
The depositional sequence proceeds with the Upper Cretaceous formations of Zolla Limestone (Upper Cenomanian-Turonian) and Aurisina Limestone (Upper Turonian-Campanian).

Figure 2: Monte Coste Limestone outcrop, Sales, TS (photo taken by Sara Biolchi)

Figure 3: Monrupino Fm. outcrop, Zolla/Col, TS (photo taken by Sara Biolchi)

The deposition of Zolla Limestone fm. (Figure 4) coincides with a sea level rise between the Cenomanian and Turonian that entirely submerged the Adriatic Carbonate Platform (Vlahović et al., 2005). It is composed of bedded micritic limestones with pelagic fauna (Calcisphaerulidae, Pithonella, planktonic foraminifers, saccocomids, etc.), typical of a low-energy environment, which locally contain bioclastic fragments (Jurkovšek et al., 2013). In the central part a thin platy limestone level, with fishes and rare ammonoids occurs – Komen Limestone (Cavin et al., 2000; Jurkovšek et al., 1996; Jurkovšek, 2010).
The upper part of this formation is formed by economically significant bioclastic limestones. They are composed of recrystallized and washed mudstones grading into rudist floatstones with abundant fossils (radiolitid and caprinid shells). Zolla Limestone fm. is 200 m thick. It ends with a drastic fall in sea level at t he end of the Turonian (Haq et al., 1987), when the deposition of shallow water biomicritic limestones of the Aurisina Limestone fm starts, which according to Jurkovšek et al. (2013) can be divided into lower and upper parts, corresponding respectively to the Sežana fm. (Upper Turonian-Lower Santonian) and Lipica fm. (Santonian-Campanian) in Slovenia. The base is composed of oncoidal limestones characterized by bioclastic rudist lenses typical of an inner platform lagoon where rudists, primarily of the genus *Hippuritella*, gathered in clusters (Tišljar et al., 2002). The central part consists of medium- to thick-bedded limestones (olive-grey biomicrites and biopelmicrites) of a very low to low energy index. The microfossils are mainly benthic. In the upper part foraminifers such as *Pseudocyclammina sphaeroidea,*

Figure 4: Zolla Limestone outcrop, Monrupino/Repentabor, TS (photo taken by Sara Biolchi)

Moncharmontia appenninica, Accordiella conica, Dicyclina schlumbergeri etc. appear. Total thickness is 230-500 m. The depositional environment is a shallow restricted shelf with occasional pulses of littoral and lagoonal conditions and pelagic influences.
The lower part is indicative of a tidal and supratidal environment, while the upper part of a subtidal one. Also in this formation, a platy limestone unit occurs and is composed of mudstone-bioclastic wackestone with chert, rare planktonic foraminifers and fishes – Komen Limestone (Jurkovšek et al., 1996, Cavin et al., 2000).
The upper part of Aurisina Limestone (Figure 5) is composed in the lower part of medium grey, fine-grained bioclastic limestones with small fragments of mollusk and foraminiferal-bioclastic limestones (packstone-floatstone) with rudist fragments, echinoderms and *bryozoans* (Cucchi et al., 1987; Jurkovšek et al., 2013). Among foraminifers, *Keramosphaerina tergestina, Dyciclina schlumbergeri*, *Fleuriana adriatica*, *Murgella lata*, etc. occur. In particular, *Keramosphaer. tergestina* was observed in a well-defined horizon across the Carso/Kras, dating back to Late Santonian (Jurkovšek et al., 1996; Caffau et al., 2001; Venturini, 2005). The light-grey, massive to thick-bedded biomicrite to biosparite (bioclastic floatsone) with partially or completely washed micritic matrix and abundant rudists, corals, hydrozoans and brachiopods is economically important both in Italy and Slovenia. The higher part of the formation is composed of bioclastic micritic limestones with benthic foraminifers typical of the Campanian. Rudist biostromes or beds of rudis boundstones are rarer and thinner. The palaeoenvironment of the upper part of the Aurisina Limestone is a well-aerated open shelf, in the lower part and the l ittoral part of a restricted shelf, mostly in the upper part, with thickness ranging between 150 and 400 m.
The Cretaceous sequence ends with the first part of Liburnia fm. – A – (Maastrichtian).
The other palaeogenic units are then represented by the Liburnia fm. B and C, Paleocene in age, and the Alveolinid-Nummulitid Limestone, Eocene in age.

Figure 5: Very karstified Aurisina Limestone, Duino Cliffs Nature Reserve, TS
(photo taken by Sara Biolchi)

The lower part of the Liburnia fm. (A) is composed of bedded and medium dark-grey, bioclastic, micritic limestones. Rudists such as *Gyropleura*, *Apricardia*, *Bournonia* and *Biradiolites* are common. Among the foraminifers, the most typical are *Murciella cuvillieri*, *Moncharmontia appenninica*, *Rotorbinella scarsellai*, *Fleuryana adriatica* and *Rhapydionina liburnica* (Caffau et al., 1998, Figure 6b). They were deposited in a lagoon environment. An intraformational breccia, from 20 cm to several meters thick, with clasts of Cretaceous limestones, includes the Cretaceous-Paleogene boundary. It has a micritic matrix with organic matter and *Microcodium* (calcification of the roots of terrestrial plants, Figure 6a) and can also contain laminated calcretes, stromatolitic forms, dessic - cation cracks, pores and bioturbation textures. The K/T boundary has been evidenced locally by the disappearance of the Cretaceous species and the subsequent appearance of the first paleocene fossils. Moreover, also geochemical variations (Iridium anomaly and negative shift of ∂C^{13}) and paleomagnetic evidence ($Ch^{29}R$) proves the presence of the K/T boundary (Drobne et al., 1987; Dolenec & Pavšič, 1995; Dolenec et al., 1995; Ogorolec et al., 1995; Pirini Radrizzani et al., 1987; Pugliese et al., 1995; Tewari et al., 2007).
The Danian beds of the Liburnia fm. (B) consist of darker brown to black limestones, slightly marly, with a mudstone-packstone texture and also stromatolitic laminae, with centimetric to decimetric bedding. Among fossils, bivalves, small gastropods, ostracods, calcareous algae such as Dasycladaceae and Characeae, miliolids and other formanifers such as *Banghiana hanseni* are common (Drobne et al., 2007). Its thickness varies from 50 to 130 m in the northern Carso/Kras, while it can exceed 200 m in the southern part. Regarding the paleoenvironment, the platform was exposed during most of the Campanian, as suggested by the widespread paleokarstic evidence. With the *Murciella* horizon the conditions became marine, typical of a protected platform. The following facies are characterized by frequent environmental variations (from marine, to brackish with episodic emersion phases), which end with the *Rhapydionina* marine horizon.

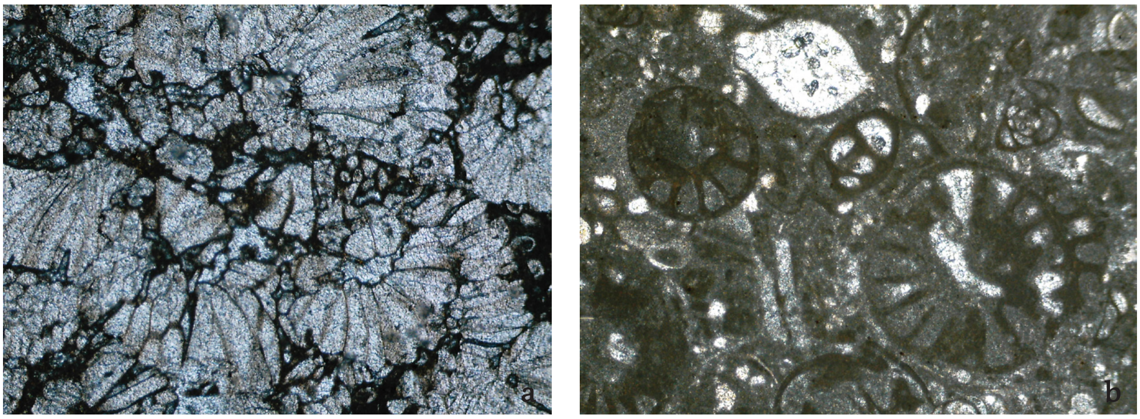


Figure 6: K/T boundary typical features: a. *Microcodium*, b. *Rhapydionina liburnica*, Mt. San Michele, GO (photos taken by Rodolfo Riccamboni)

During the Paleocene, the Danian–Selandian period is characterized by variations in salinity, poor marine circulation and emersion phases.
The upper part of the Liburnia fm. (C) is composed of bedded massive bioclastic limestones (Figure 7a). Its base is marked by a dark-grey emersion breccia with abundant Miliolids in the matrix. They are typical of a subtidal environment with influences from restricted and open shelf conditions. Together with Miliolids, the fossil associations are

represented by foraminifers such as *Periloculina*, *Chrysalidina*, *Miscellanea*, *Coskinolina*, *Fallotella*, algae such as dasycladaceans, small colonies of corals, bryozoans, corallineaceans, bivalves, gastropods and echinoderms, suggesting a deepening trend of the platform or alternatively, its opening (Figure 7b). The age is early Thantetian and the thickness varies between 40 and 150 m. The upper unit is composed of light grey-white massive coral algal limestones and of poorly bedded to massive grey bioclastic limestones (packstone and wackestone). They correspond to a change in the depositional environment with respect to the Lower Beds: an increase in the micritic component (lower energy), a deeper mid-ramp and some occasional increased energy due to storms and/or bottom currents that caused the deposition of fragments and bioclasts. Typical fossils are *Assilina yvettae* and *A. azilensis*, miliolids and algae. They are of Early-Upper Thanetian age, with total thickness ranging between 70 and 250 m.
The carbonate sequence ends with the Alveolinid and Nummulitid Limestone fm. (Figure 8), which is composed at the base of grey, very fossiliferous limestones (mainly packstone), rich in macroforaminifers (*Alveolina* and rare *Nummulites*), in association

Figure 7: a. Inclined beds of Liburnia Fm. B, Duino Cliffs Nature Reserve, TS; b. Gastropod in Liburnia Fm. B, Santa Croce, TS (photos by Sara Biolchi)

with miliolids, corallinaceous algae, corals and echinoderms. They deposited on an open platform with a light deepening trend. The upper part is characterized by open platform facies, such as wackestone/packstone with abundant *Alvelolina*, *Nummulites* and *Orbitolites*, as well as shallow marine environment facies, with moderate hydrodynamic energy such as bioclastic grainstone. The top of the formation can be ascribed to an outer ramp below the base of storm waves. It is Ilerdian in age and is less than 70 m thick in the northern sector of the Carso/Kras and more than 300 m in the southern one (Cucchi et al., 1987; Jurkovšek et al., 2013).

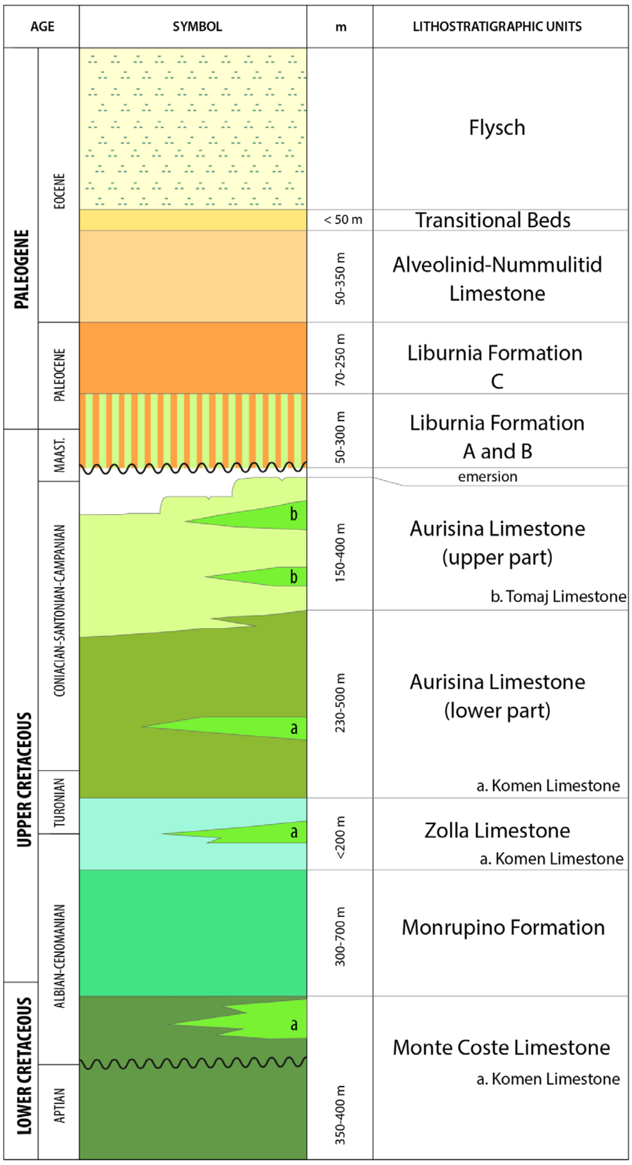
During Eocene the carbonate platform was finally buried by the advancing hemipelagic marls, marly limestones and resedimented carbonates. In fact, at the top of the carbonate sequence, an alternation of limestones and marls, the Transitional Beds, occurs (Tarlao et al., 2005; Otoničar, 2007; Burelli et al., 2008). This unit is composed of peloidal calcisiltites with planktonic foraminifers, bioclastic calcarenites-calcirudites, locally with chert nodules; the upper part is composed of marls, with a substantial decrease in the carbonate content. At the top one or more conglomerate levels occur; they are characterized by rounded clasts of grainstone with macroforaminifers, which are embedded in a marly matrix. The age of these rocks is Middle Ypresian–Early Cuisian and do not exceed 50 meters (Figure 9).

The drowning of the carbonate platform is followed by the deposition of the turbidite sediments of the Flysch, which is composed of an alternation of silty marlstones and sandstones (Figure 10a). Marlstones are from millimetric to decimetric bedded, while sandstones from centimetric to metric (Figure 10b). The Flysch has been dated back to the Late Lutetian by means of nanoplankton dating (Bensi et al., 2007). The depositional environment was a foreland basin.

Figure 8: Alveolinid-Nummulitid Limestone beds, Opicina, TS (photo by Giovanna Burelli)

Figure 9: Transitional Beds, Moccò, TS (photo by Sara Biolchi)

Figure 10: Folded Flysch beds, a. Dolina, TS, b. Draga S. Elia, TS (photos by Sara Biolchi)



Stratigraphic column of the Italian part of the Carso/Kras

2.4 Geological overview on building limestone on the Italian side of the Carso/Kras

2.4.1 Repen Classico chiaro

The Repen Classico (chiaro) type belongs to the Zolla Limestone fm. and is a very compact limestone made up of elongated fragments of skeletal material (usually about 1 cm in length), immersed in a cryptocrystalline cementing carbonate matrix (biomicrite) Figure 11). It is basically light-grey in color, enlivened by the presence of small dark-grey to light-grey strips, depending on the organic fragments. The organic fraction locally develops in large bands that vary in thickness, which, however, does not alter the homogeneity of the stone. The fossil content is represented by lamellibranchs (Rudists), often deeply worn at the edges, foraminifers, remains of echinoids and algal intraclasts.
From a geomechanical viewpoint, the stone is homogeneous, very compact, frost-proof, with minimal absorption; it has very high mechanical characterization parameters and good wear and impact resistance characteristics. It can be perfectly processed and attains valuable chromatic effects by polishing. This limestone, considering its excellent durability, is suitable for any kind of interior and exterior application. It is extracted in the quarries located close to the villages of Monrupino and Rupingrande in the Monrupino/Repentabor municipality and close to the village of San Pelagio, which is located in the municipality of Duino-Aurisina.

Figure 11: Repen Classico chiaro

2.4.2 Repen Classico Zolla

The Repen Classico (Zolla) type belongs to the Zolla Limestone fm. and is a very compact limestone made up of many fragments of bioclastic material, usually elongated, from some mm to a few cm in length, immersed in a cryptocrystalline cementing carbonate matrix (biosparite) (Figure 12). The basic colour is grey, locally tending to be darker grey, enlivened by dark-grey, light-grey organic material, mainly rudists, which is evenly distributed following bands running sub-parallel to the sedimentation plane. Locally the organic fraction further develops in elongated and curved lens, which give a different chromatic effect, even within the fundamental homogeneity of this lithotype.
From a geomechanical viewpoint the stone is homogeneous, very compact, frost-proof and practically non-absorbent, with very high mechanical characterization parameters and a very good wear and impact resistance. It can be perfectly processed and valuable chromatic effects can be attained by polishing; considering its excellent durability, is suitable for any interior and exterior use. It is also suitable for use in environments where there are problems originating from hot water, vapour, detergent, etc.
It is extracted in the quarries located closed to Monrupino village, in the Monrupino/Repentabor municipality.

Figure 12: Repen Classico Zolla

2.4.3 Fior di Mare

The Fior di Mare type belongs to the lower part of the Aurisina Limestone fm. and is a compact limestone, made up of many fragments of bioclastic materials immersed in a cryptocrystalline matrix (bioclastite) (Figure 13). The fragments range from a few mm to a few cm in length. The basic colour is grey, tending to be hazel due to the very large quantity of fossil remains. The organic material, mainly represented by rudists and gastropods, is generally elongated, rarely sub-circular, tending to be sub-parallel as to sedimentation plane but it is quite evenly distributed.
From a geomechanical viewpoint, the stone is homogeneous, compact, frost-proof, scarcely absorbent, with high mechanical characterization and fairly good wear resistance. It can be perfectly processed and is characterized by excellent brightness and chromatic

effects through high polishing. It is suitable, considering its excellent durability, for interior and exterior facing, borderstones, fittings, etc. As to paving and staircases, it can be recommended for both interior and exterior uses, with the exception of much trodden surfaces. Since the imbibitions coefficient is relatively low, the stone, after tests and analyses, can also be fitted in bathrooms and kitchens, given its high chromatic value.

It is extracted in the quarries located closed to Rupingrande and Rupinpiccolo villages, in the Monrupino/Repentabor municipality.

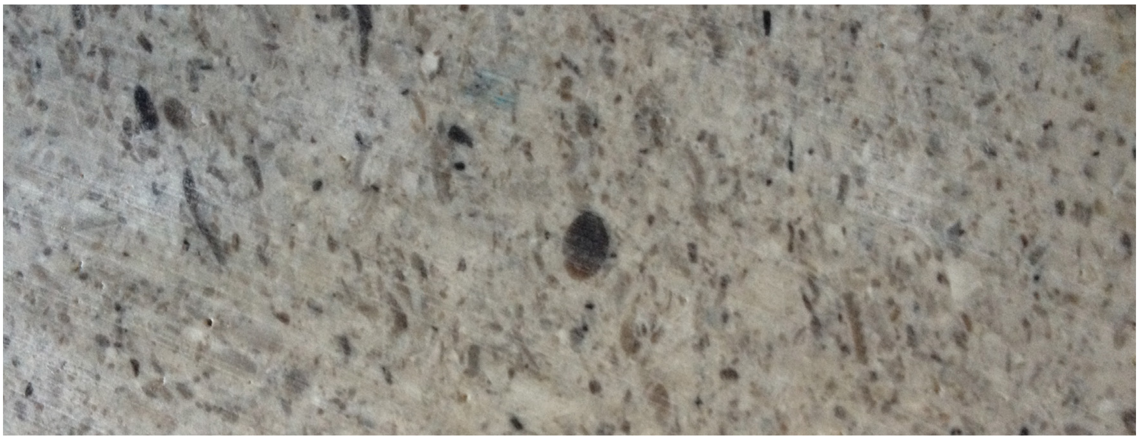


Figure 13: Fior di Mare

2.4.4 Breccia Carsica

The "Breccia Carsica" type belongs to the lower part of the Aurisina Limestone fm. and is composed of polygenic carbonate clasts (calcareous breccia) (Figure 14). These range from 1 mm to some tens of cm in size, but are generally 5 to 8 cm in length. Cement is either very scarce or absent altogether. The clasts present a colour range from white to dark-grey to blackish, but grey-hazel elements prevail. Bedding is faint; weak and minor uneven calcitic veins occur. The fossil content is given by planktonic foraminifers, ostracods, fragments of thick shells of rudists and bioclasts.

From a geomechanical viewpoint the stone is a compact, polygenic, frost-proof breccia with good wear resistance. It can be perfectly processed, and peculiar chromatic and bright effects are obtained by polishing. It is particularly suitable for facing, paving and staircases, interior applications, ornamental and interior fitting works and for objects d'art as well. Sometimes it is also used on exterior after having undergone relevant protection treatments. It is extracted in the quarries located closed to the village of Slivia, in the Duino-Aurisina municipality.

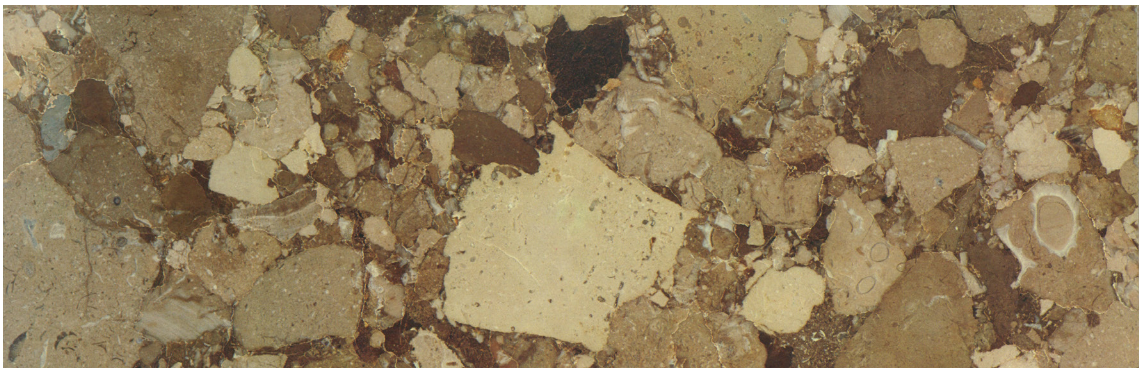


Figure 14: Breccia Carsica

2.4.5 Aurisina Chiara


Figure 15: Aurisina Chiara

The Aurisina Chiara type belongs to the upper part of the Aurisina Limestone fm. and is a compact limestone with a large fraction of small bioclasts immerged in a microcrystalline cementing calcareous matrix (biomicrite) (Figure 15). The basic color is light-grey with dark-grey spots and minor white fragments. Fossil remains, from millimetric to sub-millimetric, often elongated, are quite evenly distributed. Bioclasts have different sizes and are mainly rudists and less frequently bryozoans and ostracods.
From a geomechanical viewpoint the rock is homogeneous, compact, fine grained, frost-proof, slightly absorbent, with high mechanical characterization parameters, good wear and impact resistance and a low thermal expansion coefficient. It can be perfectly processed and highly polished. It is suitable for any exterior or interior use, considering its excellent durability: i.e. for paving, facing, staircases, fittings, decorative works, border-stones and more. Considering its fine grain, it is also suitable for sculpture.
It is largely excavated in the Aurisina exploitation area, in the Duino-Aurisina municipality.

2.4.6 Aurisina Fiorita


Figure 16: Aurisina Fiorita

The Aurisina Fiorita type belongs to the upper part of the Aurisina Limestone fm. and is a compact limestone made up of a very large fossil content, given by fragments of very different shapes and sizes (bioclastite) (Figure 16). The basic color is grey, tending to be grey-hazel, widely enlivened by larger bioclasts generally grey-brown and, to a lesser extent, white. Fossils remains, mainly rudists, are usually elongated, sometimes slightly curved, less frequently sub-circular or sub-elliptical. Also bryozoans, foraminifers and ostracods are present. Their distribution gives the stone a peculiar homogenously chromatic effect.
From a geomechanical viewpoint the rock is homogeneous, compact, frost-proof, slightly absorbent, generally with high mechanical characterization parameters and good wear and impact resistance. The material can be perfectly polished and exhibits bright, highly chromatic effects. Moreover, locally, especially if the “profusion” (chromatic effect given

by the organic fragments) is well developed, pockets (pinholes) or cryptoclases (chinks) can be found among larger bioclasts, which can spoil the technical properties of the materials. The stone, considering its chromatic value, is particularly suitable for interior applications: paving, staircases, facing, furnishings. It can also be used in exterior applications and for ornamental purposes such as borderstones and columns.
It is largely excavated in the Aurisina exploitation basin in the Duino-Aurisina municipality.

2.4.7 Aurisina Granitello

The Aurisina Granitello type belongs to the upper part of the Aurisina Limestone fm. and is a compact limestone made up of perfectly classified bioclastic fragments (bioclastite) (Figure 17). The basic color is grey, as a result of the homogeneous distribution of skeletal fragments, which present tone ranges from white to dark-grey, including all middle hues and shades. Skeletal materials, from 1 mm to 1 decimillimetre in size, usually mono- or bimodal-grained, present a spatial distribution where locally a cross-bedding with weak joint corners is detectable. The fossil content is represented by rudists and rarer planctonic foraminifers and algal remains.
From a geomechanical viewpoint, the stone is homogeneous, compact, frost-proof, slightly absorbent, with high parameters of mechanical characterization, good wear and impact resistance and a low thermal linear expansion coefficient. It can be perfectly processed and has valuable chromatic effects that are enhanced with polishing. It is suitable, considering its good durability, for any exterior and interior application: paving, facing, staircases, fittings, ornamental works, border-stones, etc.
It is excavated in the Aurisina exploitation area in the Duino-Aurisina municipality.

Figure 17: Aurisina Granitello

2.4.8 Roman Stone

The Roman Stone type belongs to the upper part of the Aurisina Limestone fm. and is a compact limestone, made up of a very large fraction of bioclasts immersed in a micro-crystalline matrix (bioclastite) (Figure 18). The basic color is very light-grey, weakly tending towards ivory with a large presence (profusion) of fine and even skeletal materials, usually dark-grey and locally white. Fossil remains, mainly rudists and other lamellibranches, mm or sub-mm in size, are evenly distributed.
From a geomechanical viewpoint, the stone is homogeneous, compact, very fine-grained, frost-proof, slightly a bsorbent, with high parameters of mechanical characterization, good wear resistance and a low thermal linear expansion coefficient. It can be perfectly processed and is particularly suitable for statuary and can be highly polished. It is suitable for any interior and exterior application considering its excellent durability. It is largely used for paving, facing, staircases, fittings, ornamental works, border-stones, etc. It is excavated in the Aurisina exploitation area in the Duino-Aurisina municipality.

Figure 18: Aurisina Granitello

All information and pictures of building stones are taken from Cucchi & Gerdol (1985): “I marmi del Carso Triestino”.

2.5 Overview geological map and quarries of building limestone

During the project's geological activities, an Overview geological map at scale 1:250,000 for the project area in Italy was elaborated. It has been cross-border harmonized with the project area in Slovenia. According to their potential of presented geological units for acqui-ring building limestone they have been classified into 4 categories (Figure 19): no potential, low potential, potential and high potential. Low potential types include lower-quality limestone, not commercially but only locally used. Potential types include relatively quality building limestone that could also be commercially used, where abandoned or active quarries occur. High potential types include limestones that are or have been widely commercially used in numerous quarries. **No potential** are those materials such as Quaternary sediments or Flysch. **Low potential** are those examples the low-quality dolomites belonging to the Monrupino Fm and the thin-bedded Liburnian limestones.

Potential are limestones belonging to the Monte Coste Limestone, which are locally used as building stone, though they have never been exploited, and the Alveolinid-Nummulitid Limestone, which has always been widely exploited to produce cements, but can locally appear as a decorative stone element. **High potential** are definitely the Zolla and Aurisina formations, from which limestones have long been and are still widely exploited in several quarries, both in the Trieste and Gorizia/Gorica Carso/Kras.

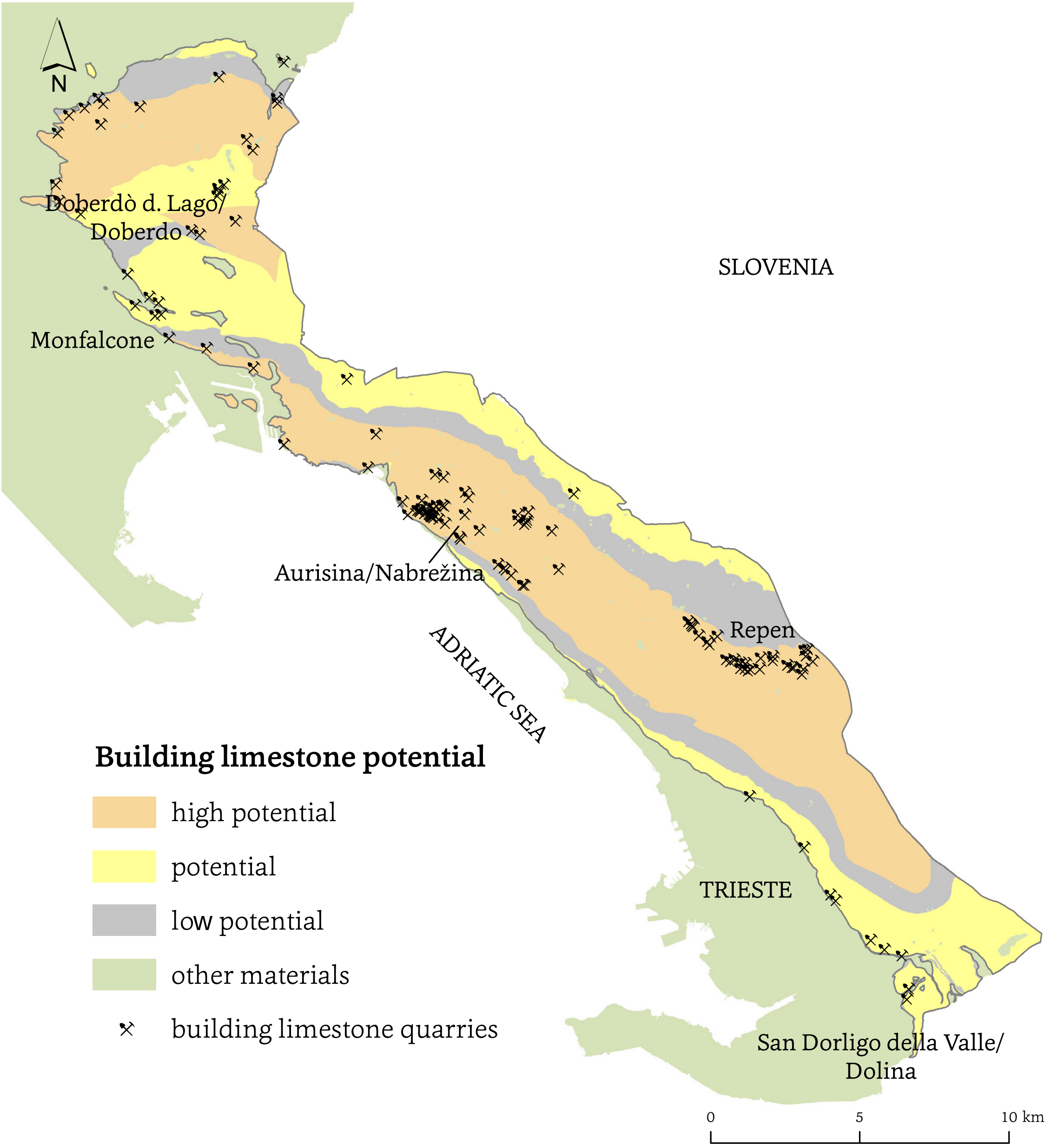


Figure 19: Map showing building limestone potential and locations of the quarries

All quarries located in the Italian part of the study area are listed in Table 1, together with their location, a short lithological description, the potential of the limestone as building stone and their ID number. The latter is fundamental for their representation on the GIS, which was specifically developed for the project.

Table 1: Database with all the limestone quarries in the Italian part of the study area

No._ ID	ID_ GU250	Typical quarries	Name of stone	Basic lithology	Location	building limestone potential *
1001	15	Cava Postir	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone with alternations of platy limestone horizons	Sagrado	3
1002	15	Cava Puia	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone with alternations of platy limestone horizons	Ferletti	3
1003	12	Selz 1	Monte Coste Limestone	Thin-bedded dark limestone	Costa Lunga	2
1004	12	Selz 2	Monte Coste Limestone	Thin-bedded dark limestone	Selz	2
1005	12	Selz 3	Monte Coste Limestone	Thin-bedded dark limestone	Selz	2
1006	12	Selz 4	Monte Coste Limestone	Thin-bedded dark limestone	Selz	2
1007	14	Cava di Via Romana	Zolla Limestone	Light grey bioclastic limestone with alternations of platy limestone horizons	Monfalcone	3
1008	14	Monfalcone 1	Zolla Limestone	Light grey bioclastic limestone with alternations of platy limestone horizons	Monfalcone	3
1009	15	Col 5	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone with alternations of platy limestone horizons	Col	3
1010	15	Rupingrande 10	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone with alternations of platy limestone horizons	Rupingrande	3
1011	14	Cava Milic	Zolla Limestone	Light grey bioclastic limestone with alternations of platy limestone horizons	Le Girandole	3
1012	15	Aurisina 13	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1013	15	Aurisina 14	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1014	15	Aurisina 15	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1015	15	Aurisina 16	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1016	15	Aurisina 17	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1017	15	Cava Romana - Bacino Ivere 1	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1018	15	Cava Romana - Bacino Ivere 2	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1019	15	Cava Romana - Bacino Ivere 3	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1020	15	Cava Romana - Bacino Ivere 4	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1021	15	Cava Romana - Bacino Ivere 5	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1022	15	Cava Romana - Bacino Ivere 6	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1023	15	Cava Romana - Bacino Ivere 7	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1024	15	Cava Romana - Bacino Ivere 8	Upper Aurisina Limestone	Massive light grey bioclastic limestone with alternations of platy limestone horizons	Aurisina	3
1101	15	Doberdò del Lago 1	Lower Aurisina Limestone	Light grey limestone with Rudists	Doberdò del Lago	3
1102	15	Cava Solvay	Lower Aurisina Limestone	Wackstone with Rudists	Doberdò del Lago	3
1103	17	Gabria 1	Liburnia Formation	Light grey limestone with Rudists	Gabria	1
1104	17	Gabria 2	Liburnia Formation	Light grey limestone with Rudists	Gabria	1
1105	14	Devetachi	Zolla Limestone	Light grey bioclastic limestone	Devetachi	3

1106	12	Palchisce	Monrupino Limestone	Not observable	Palchisce	2
1107	17	Poggio Terza Armata 1	Liburna Formation	Grey limestone with Rudists	Poggio Terza Armata	1
1108	17	Poggio Terza Armata 2	Liburna Formation	Grey limestone with Rudists	Poggio Terza Armata	1
1109	15	Poggio Terza Armata 3	Upper Aurisina Limestone	Massive limestone	Poggio Terza Armata	3
1110	15	San Martino del Carso	Upper Aurisina Limestone	Light grey limestone with Rudists	San Martino del Carso	3
1111	15	Polazzo	Lower Aurisina Limestone	Wackstone with forams	Polazzo	3
1112	15	Redipuglia	Lower Aurisina Limestone	Brownish Mudstone with fossils	Redipuglia	3
1113	15	Sagrado 1	Upper Aurisina Limestone	Greyish wackstone with Rudists	Sagrado	3
1114	14	Moschenizza	Zolla Limestone	Light grey limestone locally massive	Moschenizza	3
1115	15	San Michele del Carso	Upper Aurisina Limestone	Grey limestone with planctonic and benthic forams	San Michele del Carso	3
1116	15	Sagrado 2	Upper Aurisina Limestone	Massive limestone with planctonic and benthic forams	S.P. 9	3
1117	12	Costa Lunga	Monte Coste Limestone	Thin-bedded dark limestone	Costa Lunga	2
1118	12	Micoli 1	Monrupino Formation	Not observable	Micoli	2
1119	12	Micoli 2	Monrupino Formation	Not observable	Micoli	2
1120	12	Micoli 3	Monrupino Formation	Greyish limestone characterised by massive rock masses	Micoli	2
1121	15	Villaggio del Pescatore	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Villaggio del Pescatore	3
1122	12	Medeazza	Monte Coste Limestone	Thin-bedded dark limestone	Medeazza	2
1123	15	Bacino Ivere 2	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1124	15	Aurisina 1	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1125	15	Bacino Ivere 3	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1126	15	Duino Scavi	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1127	15	Aurisina Nord	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1128	15	Aurisina 3	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1129	15	Sistiana1	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Sistiana	3
1130	15	Sistiana2	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Sistiana	3
1131	15	Aurisina 4	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1132	15	Strada Costiera	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Borgo San Mauro	3
1133	15	Due Sorelle	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1134	15	Aurisina 5	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1135	15	Aurisina 6	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1136	15	Slivia 1	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	SW Slivia	3
1137	15	Slivia 2	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	SW Slivia	3
1138	14	Monte Straza	Zolla Limestone	Light grey bioclastic limestone	Monte Straza	3

1139	18	Cava San Giuseppe	Alveolinid and Nummulitid Limestones	Thin-bedded light grey limestone with macroforaminifers	San Giuseppe	2
1140	18	San Antonio in Bosco 1	Alveolinid and Nummulitid Limestones	Thin-bedded light grey limestone with macroforaminifers	San Antonio in Bosco	2
1141	18	Cava Scoria	Alveolinid and Nummulitid Limestones	Thin-bedded light grey limestone with macroforaminifers	San Antonio in Bosco	2
1142	18	Bagnoli	Alveolinid and Nummulitid Limestones	Thin-bedded light grey limestone with macroforaminifers	Bagnoli	2
1143	18	Bagnoli 2	Alveolinid and Nummulitid Limestones	Thin-bedded light grey limestone with macroforaminifers	Bagnoli	2
1144	18	Trieste 1	Alveolinid and Nummulitid Limestones	Thin-bedded light grey limestone with macroforaminifers	Trieste	2
1145	18	Cava di San Giovanni	Alveolinid and Nummulitid Limestones	Thin-bedded light grey limestone with macroforaminifers	Trieste	2
1146	18	Trieste 2	Alveolinid and Nummulitid Limestones	Thin-bedded light grey limestone with macroforaminifers	Trieste	2
1147	18	Trieste 3	Alveolinid and Nummulitid Limestones	Thin-bedded light grey limestone with macroforaminifers	Trieste	2
1148	14	Rupinpiccolo 1	Zolla Limestone	Light grey bioclastic limestone	Rupinpiccolo	3
1149	14	Rupinpiccolo 2	Zolla Limestone	Light grey bioclastic limestone	Rupinpiccolo	3
1150	14	Rupinpiccolo 3	Zolla Limestone	Light grey bioclastic limestone	Rupinpiccolo	3
1151	14	Rupinpiccolo 4	Zolla Limestone	Light grey bioclastic limestone	Rupinpiccolo	3
1152	14	Rupinpiccolo 5	Zolla Limestone	Light grey bioclastic limestone	W Rupingrande	3
1153	14	Cava Petrovizza	Zolla Limestone	Light grey bioclastic limestone	W Rupingrande	3
1154	14	Rupingrande 1	Zolla Limestone	Light grey bioclastic limestone	W Rupingrande	3
1155	14	Rupingrande 2	Zolla Limestone	Light grey bioclastic limestone	S Rupingrande	3
1156	14	Rupingrande 3	Zolla Limestone	Light grey bioclastic limestone	S Rupingrande	3
1157	14	Rupingrande 4	Zolla Limestone	Light grey bioclastic limestone	S Rupingrande	3
1158	15	Ex Puric	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	S Rupingrande	3
1159	14	Rupingrande 5	Zolla Limestone	Light grey bioclastic limestone	S Rupingrande	3
1160	15	Rupingrande 6	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	S Rupingrande	3
1161	15	Rupingrande 7	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	S Rupingrande	3
1162	15	Branova Java	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	S Rupingrande	3
1163	15	Rupingrande 8	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	S Rupingrande	3
1164	14	Rupingrande 9	Zolla Limestone	Light grey bioclastic limestone	S Rupingrande	3
1165	14	Col 1	Zolla Limestone	Light grey bioclastic limestone	Col	3
1166	14	Col 2	Zolla Limestone	Light grey bioclastic limestone	Col	3
1167	15	Col 3	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Col	3
1168	15	Col 4	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Col	3

1169	15	Cava Carlo Skabar	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Col	3
1170	15	Cava Vecchia	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Monte Orsario	3
1171	15	Monte Orsario	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Col	3
1172	15	Babce Sud	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Col	3
1173	14	Babce Nord	Zolla Limestone	Light grey bioclastic limestone	Col	3
1174	14	Babce Nord	Zolla Limestone	Light grey bioclastic limestone	Col	3
1175	15	Santa Croce 1	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Santa Croce	3
1176	15	Santa Croce 2	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Santa Croce	3
1177	15	Santa Croce 3	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Santa Croce	3
1178	15	Santa Croce 4	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Santa Croce	3
1179	15	Santa Croce 5	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Santa Croce	3
1180	15	Santa Croce 6	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Santa Croce	3
1181	15	Santa Croce 7	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Santa Croce	3
1182	15	Aurisina 7	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1183	15	Aurisina 8	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Aurisina	3
1184	15	Aurisina 9	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Aurisina	3
1185	15	Aurisina 10	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Aurisina	3
1186	15	Slivia 3	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Slivia	3
1187	15	Cava di Slivia	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Slivia	3
1188	15	Monte Scozza	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Monte Scozza	3
1189	15	Grotta Caterina 1	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Aurisina	3
1190	15	Grotta Caterina 2	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Aurisina	3
1191	15	Aurisina 11	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Aurisina	3
1192	15	Aurisina 12	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	Aurisina	3
1193	15	San Pelagio 1	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	San Pelagio	3
1194	15	San Pelagio 2	Lower Aurisina Limestone	Medium to thick-bedded grey bioclastic limestone	San Pelagio	3
1195	18	Peci	Alveolinid and Nummulitid Limestones	Thin-bedded light grey limestone with macroforaminifers	Peci	2
1196	15	Sagrado 3	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Sagrado	3
1197	14	Cava Devetachi	Zolla Limestone	Light grey bioclastic limestone	Devetachi	3
1198	12	Cava Selz	Monte Coste Limestone	Thin-bedded dark limestone	Selz	2
1199	12	Monte sei busi	Monrupino Formation	Massive grey bioclastic limestone	Monte sei busi	2
1200	12	Monte San Leonardo	Monte Coste Limestone	Thin-bedded dark limestone	Monte San Leonardo	2
1201	15	Sistiana 3	Upper Aurisina Limestone	Massive light grey bioclastic limestone	Sistiana	3

Figure 20: Active Aurisina Limestone quarry in "Cava Romana", Aurisina, TS (photo by Matteo Biagi)

Figure 21: a. Active quarry, Aurisina Cave, TS, b. abandoned quarry, Slivia, TS (photos by Matteo Biagi)

Figure 22: Abandoned quarry, San Pelagio, TS (photo by Matteo Biagi): together with Aurisina Limestone; the *Stalattite* type is also exploited in this quarry

Figure 23: Abandoned Aurisina Limestone quarries, Monrupino, TS (photos by Stefano Devoto)

3. GEOLOGICAL RESEARCH ON PLATY LIMESTONE

3.1 Geological definitions of platy limestone

Platy limestone is a thin-bedded, generally dark-colored, laminated and fine-grained limestone. Bed thicknesses range from 1 to 10 cm, usually between 2 and 5 cm. They occur in limited sedimentary bodies (lenses and horizons) within other bedded limestone types of Carso/Kras formations. Their fossil content is generally characterized by marine fossils, mainly fishes (Figures 24 and 25), plants and reptiles, as documented in the literature in localities such as Polazzo, Monfalcone and Trebiciano. These platy limestones are known as Komen Limestone, Polazzo shale or Komen fish shale (Scisti Ittiolitici di Comeno). These layers were deposited in different environments, from deep and shallow lagoons to tidal flats.

Figure 24: Fish fossil from Trebiciano, TS (photo by Franco Cucchi)

Figure 25: Fish fossil in Komen Limestone, Slovenia
(courtesy of Soc. Adriatica delle Scienze)

3.2 Methodology of detailed geological investigation and mapping

In the Italian part of the RoofOfRock study area platy limestone outcrops are rare, espe-cially if compared to Slovenia, Croatia and the BIH countries. They mainly outcrop as spa-tially limited layers, alternating with massive limestones (Figures 26 and 27). They occur in almost the entire stratigraphic sequence of the carbonate platform and are both Cre-taceous and Paleogene in age.

In order to recognize and classify platy limestone horizons, an extensive field survey was carried out along the Italian study area. In particular, field campaigns have been conducted based on previous geomorphological and geological maps, produced by the University of Trieste in the last decade. As outcrops are limited and often hidden by soil and human activities, particular attention was given to exploitation areas and quarries where outcrops are evident. According to the objectives of WP5, a field form for identification of exploitation areas was prepared, including a section, that lists the quantities and the qualities of platy limestone outcrops.

Figure 26. Typical outcrop of platy limestone in the Gorizia Carso/Kras (photo by Sara Biolchi)

Figure 27. Platy limestone outcropping along the coast at Duino (TS) (photo by Stefano Furlani)

Figure 28. Fractured limestone at Monrupino/Repentabor (TS) (photo by Sara Biolchi)

3.3 General and spatial distribution of platy limestone on the Italian side of the Carso/Kras

3.3.1 Platy limestone outcrop map

The above-cited outputs of laboratory and field activities have been inserted into a map to illustrate the occurrence of main platy-limestone outcrops. Outcrops are rare, small (2 m at most) and difficult to follow and map due to intense vegetation and soil cover. On the map of platy limestone occurrence (provisional scale 1:50.000) significant outcrops are presented with polygons, while very small local outcrops are presented as points/ localities.

Moreover, the potentiality of platy limestone outcrops has been evaluated in order to assess whether the site could be considered as a potential quarrying area (Figure 29).

Potential platy limestone classes are determined according to the following criteria:

- "Low potential PL class" corresponds to the "Platy-limestone horizons in massive calcareous outcrops" class, as defined in the field form;
- "Fair potential PL class" corresponds to the "Extensive platy-limestone rock masses" class, as defined in the field form regarding exploitation areas;
- "High potential PL class" corresponds to the "Totally platy-limestone rock masses" class, as defined in the field form regarding exploitation areas.

3.3.2 Lithology

Platy limestone is thin-bedded, generally dark-colored, laminated and fine-grained limestone. Bed thicknesses range from 1 to 10 cm, usually between 2 and 5 cm.

In the Italian part of the project study area, platy limestones have been observed only as limited lenses and horizons within other thick-bedded limestones. The main observed texture is mudstone, often laminated. During the field activities carried out for the RoofOfRock project, only poor rudist shell fragments and foraminifers were evidenced. Locally another type of platy limestone is widely used for roofing. It is a fractured limestone and its platy occurrence is related to a dense systems of nearly parallel structural discontinuities (Figure 28). This facies is widespread throughout the territory and is well exposed in the superficial horizons of quarries as well as along road outcrops; and was not represented on the map.

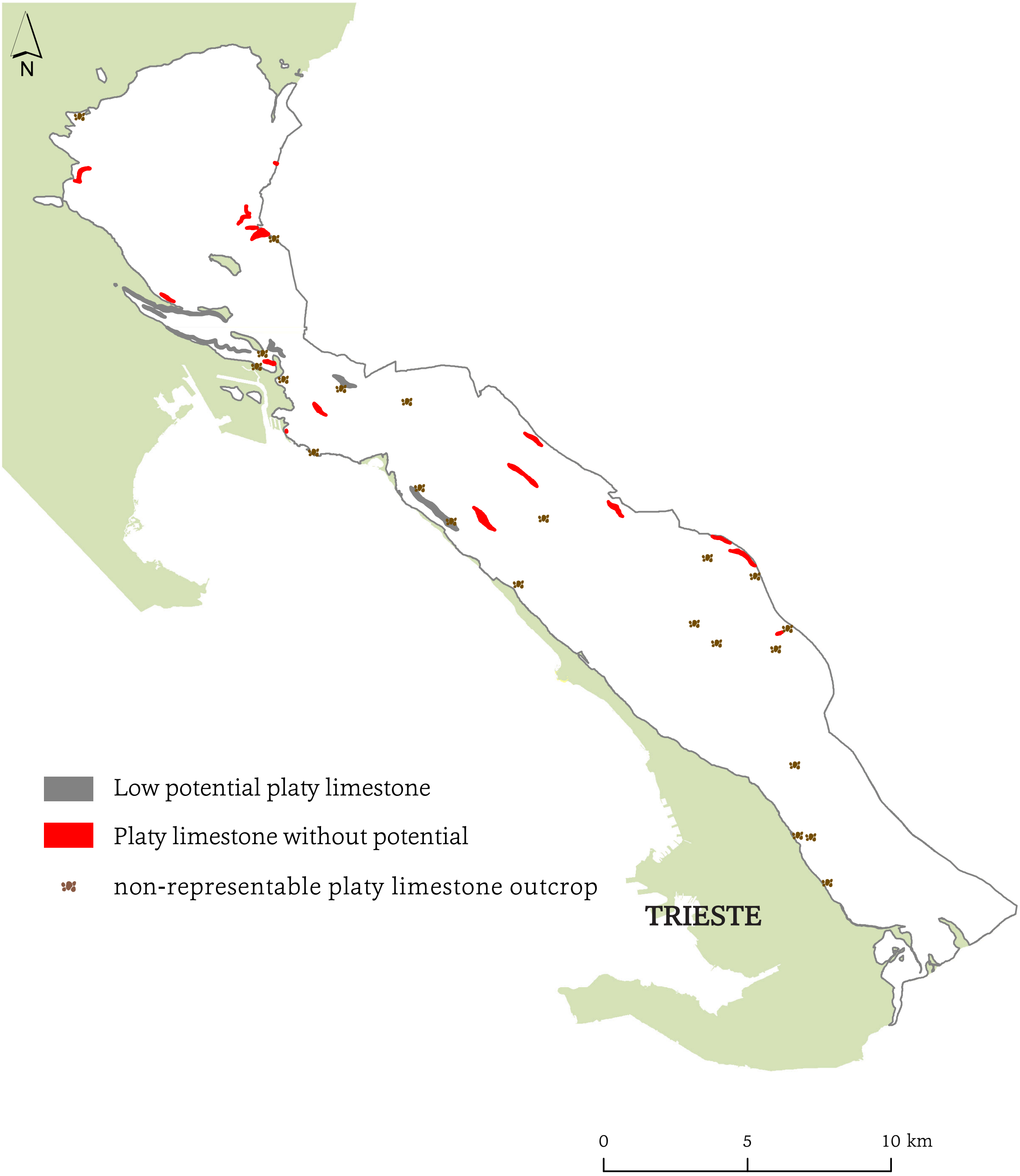


Figure 29: Map of the platy limestone outcrops in the Italian study area with indication of their potential as mineral commodity

3.3.3 Stratigraphy and age

Platy limestone horizons occur within carbonate sequences of Monte Coste Limestone (Aptian-Albian), Zolla Limestone (Upper Cenomanian-Turonian) and Aurisina Limestone formations (Coniacian-Santonian-Campanian). They may occur also in the Paleogene units such as Liburnia (Paleocene-Lower Eocene) and Alveolinid-Nummulitid Limestone (Lower Eocene) formations.
In the Monte Coste Limestone layers of platy, laminated limestones with chert and fish fossils – Komen Limestone – occur (Palci et al., 2008). They have been observed in several limited outcrops along the border between the Trieste Carso and the Kras in Slovenia. In the central part of the Zolla/Repen Limestone fm. a thin platy limestone level with fishes and rare ammonoids has been defined and described in Slovenia by Jurkovšek et al. (1996), Cavin et al. (2000) and Jurkovšek (2010) and defined as Komen Limestone. It corresponds to a global oceanic anoxic event during the Cenomanian-Turonian transgression. This layer has been also evidenced in Italy in the surroundings of Monrupino and Prepotto (TS), Lisert and Monfalcone (GO, Figure 30), but due to their limited outcrops and intense vegetation cover their spatial extent and thickness can not be estimated.

Figure 30. Komen Limestone belonging to the Zolla/Repen Limestone fm. at Via Romana quarry, Monfalcone, GO (photo by Stefano Devoto)

The lower part of the Aurisina Limestone presents a platy limestone unit composed of mudstone-bioclastic wackestone with chert, few planktonic foraminifers and fishes. It was named Komen Limestone by Cavin et al. (2000) and Jurkovšek et al. (1996). This unit has been observed (though without fossils) in Italy between Auri-sina and Prepotto and in the Gorizia Carso/Kras close to the border with Slovenia (Miccoli and Ferletti villa-ges, Figure 31) and at Polazzo (Fogliano-Redipuglia). In this latter locality some fish, turtle and plant fossils have been described. Due to their limited outcrops and intense vegetation cover, their spatial extent and thickness can not be estimated.

Figure 31. Komen Limestone of the Aurisina Limestone fm. at Puia quarry, Ferletti, GO (photo by Sara Biolchi)

The upper part of the Aurisina Limestone displays another layer of platy limestone: about 40 m thick, it is composed of bituminous, thin-bedded, platy and laminated limestones of dark-grey to black color. Within this layer chert nodules, fossil plants, fishes, vertebrates, ammonoids and conifers have been described (Jurkovšek & Kolar-Jurkovšek, 1995 and 2007). Named Tomaj Limestone, this facies evidences a slightly deeper depositional environment and can be associated with the Santonian-Campanian transgression of the Adriatic Carbonate Platform (Gušić & Jelaska, 1993; Jurkovšek et al., 1996). It has been observed in Italy at Trebiciano, Santa Croce, Aurisina (Figure 32) and at Villaggio del Pescatore (Figure 33), the latter being an important "geosite".

Figure 32. Tomaj Limestone of the Aurisina Limestone fm. at Aurisina Cave, TS
(photo by Santo Gerdol)

Figure 33. Tomaj Limestone of the Aurisina Limestone fm. at Villaggio del Pescatore, Duino-Aurisina, TS, where the famous Antonio dinosaur was discovered
(photo by Rodolfo Riccamboni)

Figure 34. Platy limestone layers alternated with thick-bedded limestone of the Liburnia Formation, Padriciano, TS (photos by Sara Biolchi)

The Paleocene Liburnia Fm. contains rare layers of platy limestone characterized by a very dark blackish color, a mudstone texture and very intense lamination (Figure 34). Their thickness doesn't exceed 0.5 m. They have a very rich fossil content and were exploited in the past for their coal.

4. QUALITY AND POTENTIAL FOR USE

Concurrently with the description of geological aspects and occurrences, the RoofOfRock project focuses on platy limestone as a mineral commodity. Thus one aim of the project is to identify possible extraction sites of platy limestone within the Adriatic Carso/Kras. The historical spatial distribution of usage together with issues related to cultural and natural heritage have been also studied. Moreover, the stratigraphic position, age, and major sedimentological and paleontological characteristics of various platy limestone units have been determined both in situ and in the laboratory.
Potential quarrying areas are identified based on recognized potential and outcrops of all types of platy limestone previously defined on 1:50,000 maps.
The quality of selected samples has been assessed using field observations and geomechanical analyses.

4.1 Historical use of platy limestone

Limestone has always played a crucial role in the cultural heritage, landscape and economy of the Carso/Kras areas. The Carso/Kras represents a well-defined geological unit, with unique geological, geomorphological and hydrogeological characteristics.
In the miscellaneous writings of Bishop Tommasini we can read:
"*...sopra li coperti da poco in qua hanno introdotto gli coppi di terra cotta, che prima facevano con lastre di pietra viva cavate sottili in alcuni luoghi, e se ne vedono tutte le case antiche, ed anco le chiese coperte di queste tegole di pietra..*".
"*Le case di Pinguente sono coperte di tegole o coppi di terra cotta, eccetto il duomo, quatro chiese e due case private che sono coperte di lastre sottili di pietra viva. Le case di fuori dei contadini, sono per lo più coperte di paglia di sorgo o segala*".
Traditionally only churches and some Carso/Kras rural houses had limestone roofs, while farmers' houses were covered with straw or rye sorghum.
In his "Guida alla Carsia Giulia", Cumin established an initial classification of Carso/Kras house types and mapped their distribution. He described an "Italic type house" represented by two variants: one in the flat area of the lower valley of the Isonzo river, the other on the Carso/Kras plateau and in the Istrian foothills. The second is a down-scaled version of the first with certain modifications. This is primarily due to the minor agricultural activity and to the characteristic shape of the small parcels, which were very widespread in the area. According to Cumin, on the Trieste-Gorizia Carso/Kras the houses roofed with stone slate were usually a single story with a detached stable.
If the building was a single-story a trap door granted access to the attic. If, however, the building had two floors an internal staircase was built to reach the attic. This type of house has been defined as "Slavic-Alpine".
The outputs of the field activities performed for the RoofOfRock Project have been crucial for the assessment of potential mining activities and in the completion of a census of all quarries occurring in the territory.

Figure 35: Gabrovec Carso/Kras House, Prepotto, TS (photo by Rodolfo Riccamboni)

Figure 36: Tpical gutter made of stone, Prepotto, TS (photo by Sara Biolchi)

Figure 37: San Giovanni in Tuba church, Foci del Timavo - Timavo Springs, TS (photo by Sara Biolchi)

In the past authentic quarries as well as small local outcrops named “jave” located closer to the villages were used to extract slabs of platy limestone. Plates were in fact easier to exploit thanks to their dense cleavage than the massive limestone beds. Limestone slabs were obtained by means of picks, levers or occasionally chisels, and were then used for roofing and for constructing walls and hearths.
Figures 35 to 37 show use of limestone as a traditional material for roofing, decorative elements and building-stones in the Carso in Italy.

4.2 Assessment of platy limestone as a mineral commodity

Fieldwork allowed an assessment of the quality and quantity of each type of platy limestone. The evaluation of their use as a mineral commodity and the identification of the potential quarrying areas has been discussed both between partners and among the experts of the UniTS project team.
Platy limestone horizons occur in 4 geological units:
a) PL in Monte Coste Limestone fm.
b) Komen PL with pelagic fossils of Zolla/Repen Limestone
c) Komen PL of Aurisina Limestone (lower part)
d) PL (Tomaj) of Aurisina Limestone (upper part).
Moreover, almost everywhere fractured (cleaved) limestone slabs can be observed.Tens of quarries with limited horizons of platy limestone have been evidenced. Although massive limestone extraction is of primary interest they can also provide limited quantities of platy limestone materials. They are mainly located in the northern part of the study area, in particular in the Gorizia Carso/Kras and the surroundings of Aurisina. In addition, it was also evidenced that special type of limestone slabs, so called fractured limestone, was excavated as building material. In this case, superficial weathering together with faulting and fracturing on massive limestone beds, enabled the excavation of some plates sufficient size for roofing (Figure 38).

Figure 38: Example of fractured limestone generated by a very dense system of fractures. Outcrop along the regional road n. 55, Sablici, GO (photo by Rodolfo Riccamboni)

Extensive field activities have been carried out in the frame of the RoofOfRock Project in order to characterize the main properties of outcrops and classify the geomorphological features of both active and abandoned quarries (such as their position in the landform and their current status).
According to WP3 (geology), WP5 (natural heritage) and WP6 (legislative) objectives, a field form was prepared to describe the limestone quarries of the whole Carso/Kras area of the Adriatic region. This form includes sections regarding the location of the quarry, its morphological characterization, the type of limestone, the occurrence of layers of platy limestone, the attitude of bedding and the paleontological content.
Moreover, the exploitation activity areas have been overlain with safeguard areas using GIS applications in order to exclude the possibility of conflict with legislative issues.
In Italy, the main legislation dealing with natural heritage and the possibility of quarrying falls under Nature 2000, the Landscape Obligation, the Hydrogeological Obligation, the occurrence of Nature Reserves and of Geosites (Figures 39 and 40).

Figure 39: The outcrop of platy limestone where the Antonio dinosaur was discovered has been under protection since 2008 (photo by Sara Biolchi)

Figure 40: "Torrioni di Monrupino" became a "geosite" and is now protected. Formerly, these platy limestones were exploited for local buildings, Monrupino/Repentabor, TS (photo by Franco Cucchi)

4.4 Platy limestone potential

In the Italian part of the Carso/Kras, authentic platy limestone quarries are absent. Where platy limestones crop out their spatial extent and thickness are insufficient for exploitation. On the contrary, massive limestone quarries are very widespread and have been largely exploited since Roman times.
Based ona detailed quarry inventory produced for 1:5,000 geomorphological maps of Carso/Kras areas (RAFVG, 2009), new field activities were conducted in order to recognize potential platy limestone outcrops for future exploitation, according to WP3 (geology) WP5 (natural heritage) objectives.
Some abandoned quarries with some layers of platy limestone have been identified in the Italian Carso/Kras, where quarrying activities of interest are of exclusively massive limestones (Figure 41).
Some limestone slabs occur locally on the quarry surfaces, but they are the combined result of weathering and fracturing. In many abandoned quarries some small slabs are also present as waste materials.
Quarries with layers of platy limestone and general related information, which have been surveyed during RoR field activities, are listed in Table 2.
The major part of these quarries with limited platy limestone horizons is now inactive and under protection (hydrogeological and landscape obligation and Nature 2000). Consequently their exploitation is seriously impeded.
A limited number of massive limestone active quarries are scarcely exploitable for platy limestone, as the quantities are insufficient to warrant for future exploitation.

Figure 41: Puia quarry, Ferletti, GO (photo by Stefano Devoto)

Table 2: List of quarries with platy limestone layers in the Italian part of the Carso/Kras and main outputs of RoofOfRock field activities

ID_ QUARRY	COUNTY	MUNICIPALITY	LOCATION	STATUS	DIMENSIONS (approx.)	POTENCIALITY	GEOLOGICAL FORMATION	SLOPE	IMPORTANCE OF FOSSILS	REBOUND VALUE	CLASSIFICATION
1001	Gorizia	Sagrado	Sagrado	abandoned	357x251	Low Potential	Aurisina Limestone (lower part)	>45°	low	48	Basal quarry
1002	Gorizia	Doberdò del Lago	Ferletti	abandoned	158x79	Low Potential	Aurisina Limestone (lower part)	>45°	low	60	Basal quarry
1003	Gorizia	Ronchi dei Legionari	Costa Lunga	abandoned	258x143	Low Potential	Monte Coste Limestone	>45°	low	56	Middle quarry
1004	Gorizia	Monfalcone	Selz	abandoned	34x32	Low Potential	Monte Coste Limestone	>45°	low	40	Middle quarry
1005	Gorizia	Monfalcone	Selz	abandoned	40x23	Low Potential	Monte Coste Limestone	>45°	low	44	Middle quarry
1006	Gorizia	Monfalcone	Selz	abandoned	32x18	Low Potential	Monte Coste Limestone	>45°	low	37	Basal quarry
1007	Gorizia	Monfalcone	Monfalcone	abandoned	152x115	Fair Potential	Montrupino Fm.	>45°	high	45	Basal quarry
1008	Gorizia	Monfalcone	Monfalcone	abandoned	95x42	Low Potential	Zolla Limestone	20°- 45°	low	50	Basal quarry
1009	Trieste	Monrupino	Col	abandoned	127x36	Fair Potential	Aurisina Limestone (lower part)	>45°	low	NO	Basal quarry
1010	Trieste	Monrupino	Rupingrande	abandoned	94x71	Low Potential	Aurisina Limestone (lower part)	>45°	low	44	Quarry pit
1011	Trieste	Sgonico	Le Girandole	active	185x45	Low Potential	Zolla Limestone	>45°	low	52	Summit pit
1012	Trieste	Duino-Aurisina	Aurisina	abandoned	265x34	Low Potential	Aurisina Limestone (upper part)	>45°	low	50	Summit pit
1013	Trieste	Duino-Aurisina	Aurisina	abandoned	131x65	Low Potential	Aurisina Limestone (upper part)	>45°	low	50	Quarry pit

1014	Trieste	Duino-Aurisina	Aurisina	abandoned	30x20	Low Potential	Aurisina Limestone (upper part)	>45°	low	36	Quarry pit
1015	Trieste	Duino-Aurisina	Aurisina	abandoned	35x30	Low Potential	Aurisina Limestone (upper part)	>45°	low	39	Quarry pit
1016	Trieste	Duino-Aurisina	Aurisina	abandoned	not available	Low Potential	Aurisina Limestone (upper part)	>45°	low	NO	Quarry pit
1017	Trieste	Duino-Aurisina	Aurisina	active	147x78	Low Potential	Aurisina Limestone (upper part)	>45°	low	57	Quarry pit
1018	Trieste	Duino-Aurisina	Aurisina	active	not available	Low Potential	Aurisina Limestone (upper part)	>45°	fair	57	Quarry pit
1019	Trieste	Duino-Aurisina	Aurisina	active	165x29	Low Potential	Aurisina Limestone (upper part)	>45°	fair	57	Quarry pit
1020	Trieste	Duino-Aurisina	Aurisina	active	170x75	Low Potential	Aurisina Limestone (upper part)	>45°	fair	57	Quarry pit
1021	Trieste	Duino-Aurisina	Aurisina	active	90x60	Low Potential	Aurisina Limestone (upper part)	>45°	fair	57	Quarry pit
1022	Trieste	Duino-Aurisina	Aurisina	active	116x50	Low Potential	Aurisina Limestone (upper part)	>45°	fair	57	Quarry pit
1023	Trieste	Duino-Aurisina	Aurisina	active	300x280	Low Potential	Aurisina Limestone (upper part)	>45°	fair	57	Quarry pit
1024	Trieste	Duino-Aurisina	Aurisina	active	not available	Low Potential	Aurisina Limestone (upper part)	>45°	fair	57	Quarry pit

4.5 Mechanical characteristics of platy limestone

Platy limestones are composed of various lithotypes. Rocks are often laminated and very heterogeneous between the layers as well as within the individual layer. Therefore it is difficult to evaluate mechanical characteristics in general for the entire PL sequence.
A Schmidt hammer was used to define the in-situ properties of platy limestone material (Figure 42).
The hammer measures the rebound of a spring-loaded mass impacting against the surface of the sample. The test hammer hits the rock material/concrete at a defined energy. Its rebound is dependent on the hardness of the rock and is measured by the test equipment. By referencing a conversion chart, the rebound value can be easily transformed to determine the Intact Rock Strength (IRS).
The rebound values measured in exploitation areas are listed in Table 2. Seldom N-Type sclerometer measurements were not performed for security reasons. The lower IRS values of the platy limestone compared to the massive limestone IRS indicates a lower resistance of the material.
Fractured limestone slabs usually have better characteristics, but it is difficult to excavate regular slabs of appropriate dimensions for roofing due to an intense system of fractures.

Figure 42: Schmidt Hammer in-situ test, S. Martino del Carso, GO (photo by Stefano Devoto)

4.1.1 SAMPLES SENT FOR LABORATORY ANALYSES

Five samples of limestone have been collected from the roofs of five different buildings: Trebiciano, Rupingrande, Basovizza and Rupinpiccolo (2 samples), in order to identify quality and age-related changes on limestone slabs used on roofs. They were analyzed by the IDA laboratory, which performed observations using an optical microscope, analysis of the chemical composition by Fourier transform infrared spectroscopy and the preparation of thin sections. The main results are listed in Table 3.
The sample collected from Rupinpiccolo 17 exhibited an anomaly, because the superficial patina taken from the surface resulted is composed of calcium sulphate dehydrate (gypsum), which is probably the result of pollution.

Table 3: Summary of results obtained by IDA laboratory analyses

SAMPLE	microscopic observations	infrared spectroscopy	SEM/EDS analyses
Trebiciano 107	degradation due to exfoliation, layering and lichens on the stone surface; damages in the structure due to the occurrence of lichens, whose growth caused fissure of limestone crystals	UV lights points out structural alterations and deposition of crystallized CaCO3 in the fissures	
Rupingrande 31	no significant degradation; greysh thin patina; fractures of the structure are visible up to 1 mm beneath the exposed surface	UV lights point out the fractures, where recrystallized carbonate is probably present; roots of lichen colonies are visible on the surface	
Basovizza – Kosovel 28	thick lichen colony on the stone surface; thin dark patina due to the presence of lichens	UV light highlighted a strong red fluorescence of the lichen, attesting to its activity and optimal photosynthetic capacity	
Rupinpiccolo 4	no significant degradation; micro fractures and layering; lichen colonies occur on the stone surface, together with fissures	UV light points out a strong orange absorption in the crack due to infiltrations of solubilized and recrystallized CaCO3	no changes in composition in the observed fissure; assumption of solubilized and recrystallize carbonate deposited in the fissureno
Rupinpiccolo 17	yellowish-beige patina; no biological degradation; beige patina on the sample surface	different UV absorption in several zones of the surface due to the different structure of the recrystallized carbonate on the sample surface	changes in the carbonate composition or structure on the surface, confirming UV absorption by recrystallized CaCO3

5. SHOW–CASE HOUSES

Five particularly well-preserved buildings have been selected as show-case houses whose architectural features have been carefully described (Figure 43). The lithostratigraphical characteristics of stone elements have been examined to determine the rock type and their possible source areas. The results of this study, as well as the study of five show-case objects in the Kras in Slovenia, have been published by Pieri & Biolchi (2014): "PlatyLimestone - 10 case studies in the Classical Carso/Kras", prepared and financed in the framework of RoofOfRock project.

Figure 43: Location of the five case studies in Italy

5.1 Overview of localities – geographic description

One building is located in Trebiciano, three in the village of Repen and one in Santa Croce. All buildings represent significant cultural and religious heritage. They were also chosen due to their well-preserved platy limestone roofing and instances of good practice in the Carso/Kras context.

5.2 Overview of selected objects

Carso/Kras House Museum – Rupingrande/Repen 31, Monrupino/ Repentabor (TS):

This typical courtyard Carso/Kras home presents a walled farmyard and a stone portal gate (Figure 44). It consists of two floors with external stone stairs, a wooden gallery, a jutting roof and interior fireplace kitchen. The house was probably built during the end of the XVIII century. Its present appearance goes back to 1831, the time of the last additions and corollary renovation. Subsequent building work was exclusively aimed at its conservation. The NAŠ KRAS cooperative society bought the building on 29th April 1968 and restored the house. The museum opened in September 1968. Now the roof, wooden gallery and northern façade need some restoration work.

Figure 44: the Carso/Kras House taken from the inner yard (photo by Sara Biolchi)

Carso/Kras HOUSE - Rupingrande/Repen 20, Monrupino/Repentabor (TS):

This typical courtyard Carso/Kras home consists of a walled farmyard and a stone portal gate (Figure 45). It consists of two floors with external stone stairs, wooden gallery, jutting roof and interior fireplace kitchen. The Trieste Province bought the building on 8 March 1974 and restored the house in 1977. Its original volume and construction have been preserved. However, the historic room arrangement has not been preserved. The stone roof has been reconstructed in concrete masonry. The wooden gallery needs some restoration work, and many elements unrelated to the house should be removed.

Figure 45: the Carso/Kras House taken from the inner yard (photo by Fabiana Pieri)

LJENČKICA'S HOUSE – Trebiciano 107, Trieste (TS):

This is a typical single -cell Carso/Kras home with added kitchen (spahnjenca) and inner oven (Figure 46). The house cannot be precisely dated, but very probably dates back to the end of the XVIII century. In the 1838 building protocol it is described as a stable with courtyard. In the 1924 "Status animarum" of the Trebiciano church it was reported that the Ljenčkica-Slavec family lived in this house. We conclude that it was first a stable and subsequently transformed into a dwelling house around the end of 1800. The Slovensko kulturno drustvo Primorec bought the building in 1999 and restored the house. The spahnjenca kitchen is well preserved thanks to its recent restoration.

Figure 46: Ljenčkica's House (photo by Fabiana Pieri)

SAINT ROCCO AND SAINT SEBASTIANO CHURCH, Santa Croce 1013, Trieste (TS):

This is a small, simple church with a rectangular plan and a stone belfry above the entrance (Figure 47). The presbytery has a ribbed vault. Near the gate is a stone statue representing a Mendico, made by a local stone mason named Dusak. The church was built in the XVII century (1646) as a vow to escaping the plague. Its original volume, construction and historic inner arrangement have been preserved. In 1990 a bituminous layer was positioned between the wooden roof sheathing and the škrle (roof shingles). Today the building exhibits structural weaknesses.

Figure 47: The church before being secured (photo by Divulgando s.r.l.)

ASSUMPSION OF THE BLESSED VIRGIN PARISH – COMMUNITY HOUSE – Zolla/Col 2, Monrupino/Repentabor (TS):

This is a single-cell Carso/Kras house with external stone stairs and inner kitchen. It was built at the beginning of the XVI century in response to the Turkish raids on the Carso/Kras plateau. It was badly restored between 1983 and 1990. Consequently, a few years later the stone roof collapsed (Figure 48).

Figure 48: Community House (photo by Sara Biolchi)

5.3 Methodology

5.3.1 Selection of show-case objects

The stone elements were chosen as the result of close collaboration between geologists (WP3) and architects (WP4), giving importance to the objects made of platy limestone and to those exhibiting peculiar architectural, historical and lithological relevance.

5.3.2 Methodology of detailed geological investigation of selected objects

The fossil content and lithological characteristics of the stones have been analyzed in detail in order to recognize the source lithostratigraphical units and source areas. The data was entered in the field-description sheets that contain both architectural and geological information, such as the name of the stone, its age, source geological units, fossil content, texture and source area. Furthermore, all data was finally entered into GIS-based attribute tables.

5.4 Geology

5.4.1 Selected objects and selected architectural elements

Stone architectural elements such as the main roof, the portal gate roof, the window frames, doorpost, pavements, corner stones and walls were chosen for their detailed geological descriptions.

5.4.2 Geology of building limestone

Show-case 1 - Carso/Kras HOUSE MUSEUM – Rupingrande/Repen 31, Monrupino/Repentabor (TS): The roofs of the main house (Figure 49), of the cornice and the portal gate (Figure 50a) are made of platy limestone.

Figure 49: Main roof of the Carso/Kras House (photo by Sara Biolchi)

The other stone elements, such as gallery shelves, cornerstones, window frames (Figure 50b), doorposts, stairs and pavements (inside *škrle*, outside *šeliž*) consist of light-grey thick-bedded limestones with abundant rudist shell fragments.

Figure 50: a. Main entrance with decorated stone doorpost and portal gate made of platy limestone; b. window frame with stones of Zolla and Aurisina Limestone (photos by Fabiana Pieri)

Show-case 2 - Carso/Kras HOUSE - Rupingrande/Repen 20, Monrupino/Repentabor (TS): The roof of the main house (Figures 51a and b), the roof cornice and portal gate shelf are constructed of platy limestone. The house is built entirely from heterogeneous and heterometric stone blocks. Architectural elements such as the gallery shelves, window frames, doorpost, portal gate and the portal gate shelf are constructed of cut, shaped and treated light-grey massive limestones with abundant rudist shells, both complete and in fragments (Figure 51c). They originate from the Zolla and Aurisina Limestone formations.

Figure 51: a. The Carso/Kras House taken by the main road of Repen; b. the platy limestone roof taken by a drone; c. window frame with stones of Aurisina Limestone (photos by Fabiana Pieri and Stefano Furlani)

Show-case 3 – LJENČKICA'S HOUSE – Trebiciano 107, Trieste (TS): The house was built using different eterometric blocks of light-grey massive fossiliferous limestones alternated with grey and dark-grey micritic limestones (Figure 52a). Platy limestones were used only for the spahnjenca kitchen roof and are of mixed origin: light-grey fossiliferous and dark-grey micritic limestones (Zolla and Aurisina Limestone formations) as well as sandstones belonging to the Flysch formation (Figure 52b).
The doorpost and the right window frame are constructed of Aveolinid and Nummulitid Limestone (Figures 52c and d). The left window frame, however, is composed of stones belonging to the Aurisina Limestone (Aurisina Fiorita variety, figure 52e). For the other two window frames, sandstones were also used (Figure 52f).

Figure 52: a. Ljenčkica's house, b. *Spahnjenca* roof made of slabs of various stones (both limestones and sandstones), c. Doorpost of Alveolinid-Nummulitid Limestone, d. Window frame of Alveolinid-Nummulitid Limestone, e. Window frame of Aurisina Limestone, f. Window frame of Aurisina Limestone and sandstone (photos by Fabiana Pieri and Sara Biolchi)

Show-case 4 – SAINT ROCCO AND SAINT SEBASTIANO CHURCH – Santa Croce 1013, Trieste (TS): Platy limestones belonging to the Upper Part of Aurisina Limestone cover the main roof of the church (Figure 53a). These are both of stratigraphical and tectonic origin. The other elements, such as the corner stones (Figure 53b), the doorpost (Figure 53c) and the window frames are fashioned from light-grey thick-bedded bioclastic limestones with abundant rudist shells, both complete and in fragments, belonging to the Aurisina Limestone, mainly of the Aurisina Fiorita variety. The Mendico statue (Figure 53d) is entirely carved in Aurisina Limestone stone (Upper part).

Figure 53: a. Platy limestone roof, sustained by scaffolding, b. corner stones coming from Aurisina Limestone, c. the main entrance, d. the mendico statue, fashioned from Aurisina Limestone stone (photos by Fabiana Pieri and Sara Biolchi)

Show-case 5 – ASSUMPSION OF THE BLESSED VIRGIN PARISH - COMMUNITY HOUSE – Zolla/Col 2, Monrupino/Repentabor (TS): The roof has been rebuilt with slabs of platy limestone (Figure 54a). The other elements, such as the walls, window frames (Figure 54b), doorpost, external stairs and well rim are constructed of stones coming from the Zolla Limestone (Repen Classico and Repen Zolla varieties). The decorated sitting place was carved in the Fior di Mare variety of Aurisina Limestones (Figure 54c).

Figure 54: a. Community House, b. window frame of Aurisina Limestone, c. decorated bench fashioned from Aurisina Limestone (Fior di Mare) block, d. the important Monrupino sanctuary (photos by Fabiana Pieri and Sara Biolchi)

5.4.3 Provenance/source areas of used limestone

Show-case 1: The stones belong mainly to the Zolla and the Aurisina Limestone formations, from which Repen (both Classico and Zolla varieties) and Fior di Mare stones respectively are extracted. The quarries are located in the municipalities of Monrupino and Sgonico.
Show-case 2: The stones belong to the Zolla and Aurisina Limestone formations. The quarries are located in the Monrupino and Sgonico municipalities, where Repen and Fior di Mare types represent the typical stones.
Show-case 3: The stones belong to all of the lithostratigraphical units. The whole Carso/Kras region, comprehensive of the Flysch exploitation basin, can be considered the source area for the stones.
Show-case 4: Together with some abandoned quarries close to the village of Santa Croce, the Aurisina exploitation basin is believed to be the source area for the stones of this little church.
Show-case 5: The stones were excavated in many quarries in the municipality of Monrupino.

5.5 Final considerations

A detailed geological study of the five selected show-case objects revealed the use of different limestone types from the immediate vicinity of the villages. Massive limestone blocks mainly originate from Aurisina and Zolla Limestone fms., while the Alveolinid-Nummulitid Limestone or sandstones were used only in the village of Trebiciano. The latter is located far from the most well known exploitation areas, in a poor area of the ancient Carso/Kras, at the transition between the Carso/Kras plateau and the city of Trieste, where the Flysch prevails.
Limestone plates used for roofing originate partly from the platy limestone of Aurisina Limestone fm., while part of the slabs of fractured limestone come from different geological units.
Since there are no platy limestone quarries in the vicinity of the selected buildings we can hypothesize that in the past the inhabitants collected the slabs from limited outcrops or from the waste materials gathered around the quarries.

Conclusions

The Italian part of the study area of interest to the Roof the Rock Project has been investigated in order to characterize and map all of the platy limestone outcrops.
One of the main issues of the project was in fact to study its use in the past (and possibly in the future) in the local architecture, as it is very widespread among Carso/Kras house roofing and dry stone walls.
Unfortunately this project region lacks appropriate reserves of this precious material that could otherwise represent a typical mineral commodity for Carso/Kras heritage. No typical platy limestone quarries have been identified in the Italian Carso/Kras. On the other hand, massive limestones are highly appreciated and have long been exploited owing to their beauty and their excellent geomechanical properties.
The most widely used stones come from Aurisina Limestone (Aurisina Fiorita, Fior di Mare, Aurisina Chiara varieties) and Zolla Limestone (Repen stone), which are exploited in several quarries of the municipalities of Aurisina, Monrupino and Sgonico.
In the past, platy limestone slabs were mainly excavated from local small outcrops or from those quarries where they had been gathered as waste materials. Other slabs that have been used for roofing and for dry stone walls are mainly of tectonic origin, and called fractured limestone.
In addition to limestone, sandstone slabs too are very common and were also locally used for roofing, especially close to the limestone-flysch contact belt.
As there are no authentic platy limestone quarries or areas of outcropping with high potential, we established that the Italian Carso/Kras is not suitable for the exploitation of such.

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