DIMENSION STONE DEPOSITS IN CROATIA

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The geology, petrographical composition and properties of dimension stone deposits in Croatia are described. Dimension stone deposits in the conception of mobilistic view of the genesis and structure of Dinarida, as well as after stratigraphic units, are considered. Valuation of the dimension stones of the active quarries is exposed. The marketable categories of dimension stone in Croatia are different varieties of limestones and calcareous clastics, primarily of Cretaceous age, and to lesser degree of Jurassic and Paleogene. The greatest part of deposits is concentrated in the Adriatic carbonate platform or Adriaticum.

Introduction

Dimension stone in Croatia in about 30 quarries, nowadays, exploit the following firms:
- »JADRAN-KAMEN« in Pučišća and Selca, exploits dimension stone on the island of Brač,
- »KAMEN« in Pazin, exploits dimension stone in Istria, and
- »KAMEN-SPLIT« in Split, exploits dimension stone in the continental parts of Dalmatia.

Apart from the mentioned firms, dimension stone exploit also »ZADRUGA« in Matulji, »GRAĐEVNO PODUZEĆE« in Korčula, and some private stone-masons on the islands of Brač and Korčula. From the year 1991 there are no data on the activities of the quarrying of the firm »KAMEN« in Obrovac.

In the nearer past (1950/60) dimension stone was exploited by 10 companies in 50 quarries:
- »GRANIT« in Zagreb, 11 quarries (Bizek near Zagreb, Marići and Romanovac near Obrovac, Velebit Portoro near Gospić, Bogomolja on the island of Hvar, Roza Val on the island of Vis, and the others),
- »INDUSTRIJA JADRANSKOG KAMENA I MRAMORA« in Split, 11 quarries (on the island of Brač, and the continental part of Dalmatia),
- »ISTARKI RUDNICI NEMETALA« in Pula, 11 quarries (in the region of Istria),
- »KAMENOLOM« in Buje, 5 quarries (in the region of Istria),
- »KAMEN« in Pazin, 4 quarries (in the region of Istria),
- »SADRA« in Sinj, 4 quarries (in the region of Dalmatinska Zagora),
- »KOMBINAT VELEBIT« in Rijeka, 3 quarries,
- »ISTARKI BOKSITI« in Rovinj, 2 quarries,
- »VRNIK« in Korčula, 2 quarries, and

- »KLESARSKA ZADRUGA« in Matulji, 1 quarry.

In the last 30 or more years the number of companies and quarries and accordingly the stone varieties have been considerably decreased. Dimension stone quarrying was primarily stopped in deposits of the supporting coloured carbonate and clastic sediments. The mentioned deposits are regularly of small stretching and complex geological structure, with the impossibility of extraction the larger blocks for manufacturing and market. Part of these deposits, regarding the implementation of the new stone carving technology in thin plates-marmetes, would probably be reactivated. That wouldn't be the case in the touristic areas.

The data about our dimension stone deposits could occasionally be found in periodicals and literature.

So Müller (1984) for our regions writes literally this: »Zu behaupten, die gesamte Adriaküste sei ein einziger großer Steinbruch, wäre nicht übertrieben.«...
Similar is with the presentation of our dimension stone in INSK (International Naturstein-Kartei) in 10 volumes (Müller, 1986):
- in the 6th volume of INSK the data on conglomerates Rozalit and Multikolor, breccias Romanovac and Oklad, and porous limestone Vinkurani are present,
- in the 7th volume the data on the coloured limestones Unarot, Rasotica and Crna Krčka are present, and
- in the 8th volume the data on the limestones Lucija, Adria Verde, Grožnjan, San Giorgio, Adria Grigio, Kanfanar, Kupinovo, Diokles and Dolit.

Among the different varieties of our dimension stone in Naturstein Lexikon (Mehling, 1986) are mentioned the following: Adria Grigio, Adria Verde, Dolit, Kanfanar, Multikolor, Marčići, Kupinovo, Oklad, Plano, Rasotica, Romanovac, Rozalit, San Giorgio, Santa Lucia, Seget, Veselje, Vinkurani and Vsine, as well as the types which are not present on market today: Bale, Belgris, Mirna, Salamin, Crna Krčke, Crni Velebit, Glavica, Granitelo, Mosor, Reštovo and Visočani.

The development of dimension stone industry is most evident in growth of stone blocks exploitation:

<table>
<thead>
<tr>
<th>Year</th>
<th>Exploited</th>
<th>m$^3$ of blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td>6,289</td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>7,665</td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>11,060</td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td>15,071</td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>22,360</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>35,360</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>44,120</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>48,374</td>
<td></td>
</tr>
</tbody>
</table>

Of the greatest importance in the forementioned industry are the following companies:
- »KAMEN« in Pazar (21,510 m$^3$ of the exploited blocks in 1985, and 21,825 m$^3$ in 1990), and
- »JADRAN-KAMEN« on the island of Brač (19,150 m$^3$ of the exploited blocks in 1985, and 22,184 m$^3$ in 1990).

The dimension stone industry in Croatia with quarrying and processing of natural resources in the world relation is insignificant, neither 50,000 m$^3$/year in compared to about 10,000,000 m$^3$/year total world production. Only one marketable category of dimension stone in Croatia is calcareous stone, different varieties of limestones and clastites. This is the limitation factor of larger expansion on the world market today.

**Essential preferences to existence of dimension stone deposits**

The definitions of dimension stone: »Building stone that is quarried and prepared in regularly shaped blocks according to specifications« (Bates and Jackson, 1980) and »Stone which is marketed in blocks or slabs of a specified size. Much of it is used for building, either for structural purposes, or for cladding, facing or flagging. The minerals in dimension stones should be stable in humid atmosphere, and the rock should be crystalline or well consolidated. Individual blocks should be free of weakness planes, and if the stone is to be used for structural purposes it should be strong. The principal rock types used as dimension stone are granite, diorite, syenite, sandstone, limestone, some ironstones, gneiss, slate and serpentinite. When a rock mass is being considered for working as a dimension stone, it is important that a sufficiently plentiful supply of material of the same colour and texture is available, and that the stone can be worked with the minimum of blasting, a process that is liable to introduce cracks into otherwise intact blocks. Stone to be used for statuary purposes should generally be attractive, not too hard, even-grained and workable by hand. Marble is probably the best-known stone used by sculptors (Dineley et al., 1976) incorporate the basic demands which rock mass should meet for the existence of exploitable deposits.

The essential preferences to the origin of the dimension stone deposit are genetic processes and postgenetic occurrences. They make condition on:
- decorativity of the stone,
- physical-mechanical properties, and
- rock mass integrity or spacial distribution of the primary and secondary discontinuities.

**Dimension stone decorativity** depends on the whole range of genetic and postgenetic factors, such as:
- quantity and spacial distribution idiochromatic or coloured minerals (hematite, limonite, epidote, chlorite, etc.),
- pigment finely dispersed in alochromatic minerals (hematite in orthoclase),
- pigment differently generated and arranged in stone (graphite in marbl, bitumen in limestone),
- existence of minerals of the special luster (sericite of pearly luster),
- shell fragments and debris different shapes, dimensions, uniformity and heterogeneity, and
- marked texture and fabric characteristics, such as schistosity (without parting along the schistosity planes), eyed structures, feldspar porphyroblasts, strolites, intersections of the coloured veins (with calcite or other minerals filled fractures), micro-folds, etc.

**Physical-mechanical properties of the stone depend especially on:**
- mineral composition and the characteristics of minerals,
- textural elements, especially on spacial distribution of minerals, its shape and dimensions, in elastic sediments on the composition of particles and the characteristics of cement,
- in sedimentary rocks on the degree of lithification,
- intergranular bond,
- defects in crystals, as well as crypto and micro defects in stone, hidden or visible by microscope, as well as macroscopically visible defects (fine fissures),
- porosity and the size of pore space, and
- the freshness of stone.

**The rock mass integrity** depends on discontinuities which stipulate natural fragmentation and separation in blocks of different shape and size. Discontinuities are primary or syngenetic and secondary or postgenetic.
Primary discontinuities are:
- in magmatic rocks cooling joints,
- in sedimentary rocks bedding planes, and primary sedimentary structures (sequences, biostrome, bioherme etc), and
- in metamorphic rocks foliated planes.
Secondary discontinuities are all the fractures of tectonic origin.

All the given suppositions should be supplemented by two fundamental claims: durability of stone and stability of its colour, under the influence of exogen natural and technogenic factors in conditions of urban environment.

Finally, the important factors are the economic exploitation of the manufactured stone blocks, as well as their attractability on the home and world market.

On the basis of the given preferences and demands comes out that it is not simple on fields to find areas suitable for exploitation of dimension stone, or limits their deposits, as well as find the potential productive zones.

Outline of geology

Croatia is characterised by the variety of petrographic composition and geological structure, but with great differences in spreading of the particular rocks. The spread of magmatic and metamorphic rocks in comparison to sedimentary and especially to carbonate rocks, is small. The spread of magmatic and metamorphic rocks, and postgenetic processes in them are the main restrictive factors of finding the dimension stone deposit of silicatic composition, as well as marble. As opposed to that, spread of the carbonate sediments of different stratigraphic unit represent the basis of the present dimension stone industry, with the rich tradition of exploitation and usage of dimension stone from the ancient times.

Even the superficial look at the simplified geological map of Croatia (after Kranjec, 1974) is sufficient for seeing the differences between geology and petrographic composition of the particular areas (fig. 1). These differences are present in spreading of the particular stratigraphic units, as well as in petrographic composition. The regional division of Croatia is based on these differences, and the whole territory Crnković (1974) divided into 5 regions.

Taking into consideration the mobilistic view of the genesis and structure of Dinarides (Herak, 1991), from the point of view of the potential productivity of lithosтратigraphic units, Croatia can be divided into 6 regions (fig. 2):
- The region of Istria, covers the territory of Istria, and
- The region of Dalmatia, covers the coastal area and islands, as well as Dalmatinska Zagora.
- The region of Hrvatsko Zagorje

The region is conspicuously marked with Mountains Medvednica, Kalnik, Ivančica and Ravna gora, of different petrographic composition and the large range of stratigraphic units, from Paleozoic to Quaternary.

On the Mt. Medvednica dominate the greenschists (para and ortho metamorphites), and argillites, marbleized limestones and marbles. Limestones and dolomites of the Triassic age can be found at the Mts. Medvednica, Ivančica, Kalnik and Ravna gora, while clastites and carbonate sediments with eruptives at the Mts. Medvednica, Ivančica and Kalnik. Along the rims of the mountains it is very important development of clastic and carbonate sediments of Neogene, especially Miocene age.

After Herak (1991) this area belongs to structural complex of the Inner Dinarides or Supradinaricum. The border area of Dinarides and Alpides is on the north, while on the east are Pannonian structures of Pre-Alpine structural complexes. Some of the presented Herak’s thoughts on the situation of the area, are the following:
- ...some parts of the Inner Dinaridic area take position virtually different from the place of their origin...
- ...lack of the clear inner zoning, that is the consequence of the neotectonic desintegration of the prime covering structures, which existence proves the numerous marked but also masked phenomena of allochtony...
- ...appearance of ultramaphites in...Mts. Medvednica and Kalnik are in allochtonic position.
- ...the structure of the Inner Dinarides (Supradinaricum) is very heterogenous, that causes the difficulties in the internal classification...

show that in this area, except the »young« sediments of the Neogene, we can not expect the rock mass wholeness and also not dimension stone deposits.

In this respects, potentially are productive only the carbonate sediments of Miocene (Crnković et al. 1974/75). Those are lithothamnion limestones of the south-western part of Mt. Medvednica and the rim of Mt. Ravna gora in the area of Vinica.

The region of Slavonia

The marked petrographic element of the Slavonian Mountains (Papuk, Psunj, Krndija and Moslavačka gora) is Crystalline. In the part of the Slavonian Mountains Jamčić (1988) separated three complexes; those of »Radlovač«, »Papuk« and »Psunj«, which consist of magmatic and metamorphic rocks of the wide range of textures and compositions. For this area is important the existence of series of orogenesis (Baycal, Caledonian, Laramian) to which are linked prograde and retrograde metamorphoses as well as the corresponding tectonics.

- With the monotoniously gray and uniform grainly granites of the Mt. Moslavačka gora, potentially
Fig. 1 Generalized geological map of Croatia (after Kranjec, 1974)

Legend

1 (Q) Quaternary (Holocene and Pleistocene, unconsolidated clastic sediments, loess)
2 (N) Neogene (Pliocene and Miocene, unconsolidated and consolidated clastic sediments, marls, limestones)
3 (Pg) Paleogene (Oligocene, Eocene and Paleocene, consolidated clastic sediments, limestones, marls, flysch, molasse)
4 (Kd) Upper Cretaceous (significantly developed rudist limestones, dolomites, marls, cherts, flysch)
5 (K1) Lower Cretaceous (limestones, dolomites, clastites)
6 (K) Cretaceous, generally
7 (E) Eruptive rocks (andesite, basalt, diabase)
8 (J3) Upper Jurassic (limestones, dolomites, marls, clastites)
9 (J2) Middle Jurassic (limestones, dolomites, marls, clastites)
10 (J1) Lower Jurassic (limestones, dolomites, clastites)
11 (J) Jurassic, generally
12 (T) Triassic (limestones, dolomites, clastites)
13 (Pz) Paleozoic (greenschists, phyllites, argillites, marromaceous limestones, dolomites, clastites)
14 (C) Crystalline (granites, gneisses, amphibolites)

Perspective for the dimension stone deposits could be considered granites and gneisses of the »Papuk complex«.

After Herak (1991) this area belongs to Pannonian structures of Pre-Alpine structural complexes. They were exposed to strong compression and corresponding desintegration until then of homogenous structural unity. This was the one of the preconditions for the later (Neogenic) differentiated movement of the particular parts, and for the partial changes of the stretching some of them.

Southern and western of these structures, there is the structural complex of Inner Dinarides (Supradinarid). The border line between those two complexes is placed south of the Slavonia’s Mountains, west of Mt. Moslavačka gora, to east of Mt. Kalnik (Herak et al. 1990).
By prospections and researches the existence of the whole «oases» of the rock mass are estimated in the areas of Mts. Moslavačka gora and Papuk. However, the consequences of the still presented processes, which in the geological past took place here, are evident in the mentioned «oases». So Jovičić et al. (1992) describes the tectonics of the «Zebrato» granite deposit: «...Tectonic disturbances are evident through the intensive cracking. ...The complex tectonic elements devide the deposit in the separate units-blocks... with restriction and narrowing of the exploitable fields... and worsen geological conditions of the deposit and negatively influence to the blockage.»

The region of Banija and Kordun

The area in its southwestern part is clearly marked with the interrupted zone of clastites of Younger Paleozoic, general striking NW-SE. The Triassic sediments and the narrow ophiolitic zones of the Jurassic with especially complex structure are of the same stretching (Majer, 1984, and Majer and Lugović, 1985). The significant proportion take the flysch and molasse of Eocene, and the clastic sediments of Pliocene.

This area belongs to the former described Supradinaridic.

In regards to the complex geological structure and the petrographic composition, including the sedi-
Fig. 3 Dimension stone deposits in Croatia

The region of Hrvatsko Zagorje
NEOGENE
b) quarries out of exploitation
1 Vinica
2 Pisana Pečina
3 Ruopanec
4 Bizek and Vrapče potok

The region of Slavonia
GRANITE-GNEISS
b) quarry out of exploitation
1 Samarica
c) deposits on exploration
2 Metla – Ravna Gora
3 Jaakovac – Radetina

The region of Gorski Kotar – Lika – Primorje
CARBONIFEROUS
b) quarry out of exploitation
1 Brutani

TRIASSIC
b) quarry out of exploitation
2 Saint Rok

JURASSIC
b) quarries out of exploitation
3 Cvituša – Lovinac
4 Gradina – Ričice

The region of Istria
JURASSIC
a) quarries on exploitation
1 Kirmenjak
2 Valkarin
CRETACEOUS
a) quarries on exploitation
3 Kanfanar
4 Selina
5 Grožnjan – Koraeriha
6 Saint Lucija
7 Valteria
8 Vinkuran (Cava Romana)
ments of Paleogene and Neogene, there is no possibility of finding dimension stone deposits in this area. The presented statements we base on the description of some, for our consideration, eventually interesting rocks (Majer and Lugić, 1985): «...the major part of amphibolite...has...clearly marked foliation...the whole rock mass is divided into smaller blocks of differentiated movements...some parts suffered intensive deformations...»

The region of Gorski Kotar, Liška and Primorje

It is clearly marked with the general striking of the lithostratigraphic members NW-SE, as well as the predominant sediments of Mesozoic. The northwestern part, Gorski Kotar and Liška characterize the elastic sediments, as well as dolomites and limestones of the Younger Paleozoic. In Mesozoic, from Triassic to Cretaceous prevail the carbonate sediments of marine shallow environments, limestones and dolomites. Lithiotis limestone of Liassic, as well as rudist limestones of Upper Cretaceous indicate the shallow environments. In some parts of Gorski Kotar and Liška dolomites are continually present from the Upper Triassic through Jurassic. The sediments of Paleogene are present in the lesser degree.

After Herak (1991) this area belongs to the Structural complex of the Dinaric carbonate platform (Dinaricum). It is rather difficult precisely differentiate the relation between Dinaric carbonate platform (Dinaricum) and Adriatic carbonate platform (Adriaticum). The reason is the complex overthrust relations and because the units of Dinaricum are placed directly on the elements of Adriaticum on some localities.

For that structural complex are characteristic the overthrust structure, namely, with the overthrust complexes of the Paleozoic and Triassic on the Jurassic carbonate complexes. On the basis of the presented data, this area, regardless to favourable genetic conditions in formation of the wide range of different varieties of limestone, postgenetic occurrences, that is to say, tectonic units of the overthrust structure and disturbance, are the limiting factors of finding and existence of dimension stone deposits. If there are some deposits, they are characterized by the unfavourable geological conditions.

The region of Istria

The significant stratigraphic-structural element is Jurassic-Cretaceous anticline with carbonate sediments from Upper Jurassic to Lower and Upper Cretaceous. By the north is placed Buje anticline. The remarkable surfaces cover elastic and carbonate sediments of Paleocene and Eocene. The favourable condition of Jurassic-Cretaceous anticline are subhorizontal layers.

After Herak (1991) this area belongs to the Adriatic carbonate platform or Adriaticum. This platform due to its main features has much in common with Dinaricum, so that some of the authors take them as an integral unity. Regardless to some common elements named by Herak, this area and from the point of view of the productive zones and dimension stone deposits, justifies its separation. After Olujic et al. (1972) differently from the conception of Herak (1991) this area represents autochton. From the continental part of Istria, Adriatic stretches across the Kvarner Islands to the south-east, partly surrounding seaside Dinaricum from the southwest.

In this area all the other stratigraphic units except flysch are potentially productive. Dimension stone deposits are placed in the limestones of Jurassic, Lower and Upper Cretaceous as well as in limestones and carbonate clastites of Paleogene.

The region of Dalmatia

It is clearly marked with the significant part of Cretaceous carbonate sediments and carbonate clastites and flysch of Paleogene. The Jurassic sediments are slightly represented on the furtherest south island Lastovo and Mljet, while the sediments of Triassic and Jurassic are represented in the northern part of the region.

This area presents the continuation of Adriaticum. It is structurally different from Istria, and can be divided into three zones. The southern part includes mainly the islands, and it is characterized by clearly...
marked anticlines. For that anticlines is characteristic regularly slighter slope of its northern layers. The central part is characterized by overthrust structures formed by the sediments of Cretaceous and Paleogene. The northern part is of the complex structure with the greater participation of the sediments of Triassic and Jurassic.

The main productive lithostratigraphic member of this area is the rudiste limestones of Upper Cretaceous, although are present a numerous deposits the other stratigraphic levels too.

**Dimension stone deposits**

Dimension stone deposits will be described according to regions (fig. 3), and separated into three groups:
- deposits of current exploitation,
- deposits of temporary exploitation, not exploitable at the present time, and
- deposits in the phase of exploration.

**The region of Hrvatsko Zagorje**

From the point of view of dimension stone exploitation, in this region are only the limestones of Miocene age of interest. At the present time there are no active quarries here, while in the past dimension stone was exploited in four deposits.

**Vinica**

The deposit is situated on the eastern hillside of Mt. Ravna Gora, west of Varaždin. The stone of this area was exploited in the ancient times. It's considered to be the stone of Varaždin's baroque. The stone of Vinica in the past was known even across the borders of our country. Among the deposits, Lithotamnion limestones of Badenian age, in the quarries of Bizek and Vrapčec, in not distant past Lithotamnion limestone represented the building stone of the city of Zagreb, known as (in Mähren), Mokritz (in Krain) and Vinica (in Kroatien).«

There are generally two distinguished types of the yellowgrayish exploitable stone in the deposit:
- porous and soft limestone, recently called Vinicit,
- macroporous and megaporous Lithotamnion limestone.

Petrographically are the carbonate rocks of Vinica determined as: biomicrite and biomicrudite (prevail), recrystallized biomicrite, bioparite, bioparudite and clayish biomicrite.

The deposit could be divided into three parts: Pećina and Kočevec (predominant Vinicit), and Jezero (predominant Lithotamnion limestone) with about 20 old quarries out of exploitation at the present time (fig. 4).

**Pisana pećina**

The deposit is placed on the southwestern hillside of Mt. Ivanšćica, western of Novi Marof, along the ridge stretching E-W. The old quarries with remnants of block extraction are cut in the ridge at some places. In deposit exist 8 layers of different thickness (fig. 5).

**Fig. 5** The dimension stone deposit Pisana pećina, old quarry, vertical section, layers from 2 to 6, layers 1, 7 and 8 absent on this place of deposit, layer 1 eroded, and layers 7 and 8 covered by waste products

Limestones are yellowgrayish and gray colour, porous, soft and shelly. Petrographically are determined as intrabiosparite, intrabisparudite and intrabiomicrosparite.

**Ruospane**

In limestones of Badenian age in the Mt. Varaždinsko topolčko gorje western of Varaždinske toplice (Varaždin spa) there are old quarries with the remnants of block extraction. Badenian is represented by grayish and yellowgrayish, porous and soft limestones. Petrographically are determined as biomicrite, bioparite, biomicrudite and bioparudite.

**Bizek and Vrapčec potok**

Clastic and limestone sediments of Miocene surround Mt. Medvednica from the western, southern and eastern side. Like dimension stone, Lithotamnion limestone was exploited only in the southwestern hillside of Mt. Medvednica, west of Zagreb, in the quarries of Bizek and Vrapčec potok. In not so distant past Lithotamnion limestone represented the building stone of the city of Zagreb, known as
**Bizek stone.** Its characteristics in deposits and on buildings, as well as the influence of the polluted air of urban surroundings on limestone with the formation of plaster was in detail elaborated by Marić (1938).

Nowadays dimension stone is not exploited in these deposits, because these areas are situated in the Natural Park of Mt. Medvednica.

**The region of Slavonia**

For dimension stone exploitation in this region of the greatest interest are primarily magmatic and metamorphic rocks of Crystalline. Those are granites and gneisses.

**Samarica**

The numerous old quarries exist in granites of Mt. Moslavačka gora. In the quarry Samarica, south of Bjelovar, in the past granite was exploited as dimension stone. Granite is fine-grained and of evenly gray colour without special decorativity. For the deposit is of importance the existence of the thick surface weathering crust.

**Metla-Ravnogora**

On the southern slopes of Metla, northeast of Pakrac, experimental exploitation has been carried out. After Jovičić et al. (1992) the quarry is open in porphyroblastic granites (fig. 6). Granite is of greengrayish and pinkgrayish colour and on the subsoil weathering part browngrayish colour. It is characterized by porphyroblastic texture and the marked foliation of mica. Slabs cut opposite or vertical to foliation are of striped appearance, with marked feldspate porphyroblastes and foliation of mica. Because of that granite was commercially called Zebra-to.

![Fig. 6 The dimension stone deposit Zebrato, Ravnogora, experimental exploration stone-pit of granite (photo: D. Jovičić)](image)

**Jankovac-Radetina**

An old little quarry with some small left blocks of granite is placed west of Jankovci on Mt. Papuk. Because of the fact that this location is placed in the Natural park of Jankovci, the explorations are carried out in the eastern part. In the Creek Radetina detailed porphyroblastic granite-gneisses of gray and sometimes of pinkgrayish colour can be found.

**The region of Banija and Kordun**

According to our knowledge in this region in the past there were no dimension stone exploitation, neither, with respect to geology, exists such a possibility.

**The region of Gorski Kotar-Lika-Primorje**

The main characteristics of this region are great spreading of sedimentary rocks of the Mesozoic, a slight presence of sediments of the Younger Paleozoic (Carboniferous, Permian), and the Cenozoic (Eocene, Oligocene) with the general striking of lithostratigraphic units NW-SE with inclination to WNW-ESE in the southern part of region, as well as the complex tectonic framework (fig. 1).

Apart from rare exceptions, the greatest part of dimension stone deposits exploited in the past, or potentially prospective areas are placed in Lika.

**CARBONIFEROUS**

Clastic sediments, reddish sandstones and fine-grained conglomerates were exploited in the surroundings of Brušani in Lika, and locally used in the building of houses as ashlar.

**TRIASSIC**

The smaller part of Triassic sediments belongs to clastic development, but the greater to carbonate,
mainly to dolomites. In the big area of dolomites is illusory trying to find the possible dimension stone deposits.

In the vicinity of Saint Rok in Lika, in nearer past, the carbonate conglomerates as dimension stone were exploited. Conglomerates are of reddish to grey colour. In rock mass five exploiting layers of thickness from 0.5 to 1.0 m, can be separated (fig. 7).

JURASSIC

Of the greatest spreading in this region are carbonate sedimentary rocks, limestones and dolomites of the Jurassic. Dimension stone deposits are situated in limestones of the Lower and Upper Jurassic.

The remarkable member of Lower Jurassic (Middle Lias) is very decorative Lithiotis limestone. Lithiotis limestone is dense, dark-gray to black with longish white remnants of the shell Lithiotis problematica. This limestone is petrographically determined as biomicrudit i.e. coquina. Regularly in under wall and/or hanging wall there are dense dark-gray to black limestones, sometimes with the larger, whitish skeleton debris. Those limestones are petrographically determined as biomicrites, biopelmicrites, biomicrudites and biointrasparites. Pigment of the enumerated limestones is bituminous matter, and consequently of the strictly restricted usage for interior coverings.

Lithiotis limestones with the belonging rocks were exploited in the following quarries:

- Cvituša, near Lovinac, layer 1.2 m of thickness (fig. 8), and
- Gradina, near Ričice, layer 3 m of thickness.

As perspective can be separated the areas Mazin-Lapac and on Alan, north of Obrovac.

The stone, on market known as Velebit Portoro, was exploited in the vicinity of Gospić, in nearer past. It is the dense limestone of brown-gray, dark-gray to brown-black colour. The special decorativity to the stone gives the intersection of whitish, yellowish, brownish and reddish veins, that dapple it. The deposit consists of 6 layers, in total 3.75 m of thickness. Petrographically are determined as micrites, pelmicrites, biomicrites, coinosparites and dolomitic dismicrites.

Of the Upper Jurassic age are dense, dark-gray, partly oolitic limestones, west of Brinje. The layers are 30-80 cm of thickness. The polished surface of oolitic variety is of the spawny appearance. Petrographically are determined as oosparite and biomicrite/biosparite. The deposit is of the restricted area.

Near Donji Lapac, the stone commercially known as Unarot was exploited. It is red to red-brownish limestone, partly of the conglomeratic appearance. In calcite matrix are the oval intraclasts or mud pebble. Petrographically is determined as intrasparite.

CRETACEOUS

Near Prozor, southeast of Otočac, on the occasion of archaeological excavation, the ancient quarry was discovered (Šarić, 1980). The site is earlier known and in literature described as carved in rock »stone benches« and »wathering-places carved in stone«.

The ancient quarry is illustrated in detail (fig. 9). The quarry is opened in brown-grayish brecciform limestone, dappled with whitish and reddish veins, and petrographically determined as brecciated micrite and biomicrite.
North of Obrovac, in the sediments of Lower Cretaceous are exploited the stones on market known as Romanovac and Tulovac or Kastania. After Jovičić et al. (1988) this stones belong to dense brecciated limestone and limestone breccias. The Romanovac type is of reddish, while Tulovac of dark brownish-gray colour. The both types are intersected with the veins of calcite. Petrographically are determined as micrites, intramicrites and intrabioticrites.

Limestone breccia Muškovci was exploited southwest of Gračac. The breccia is of brown-gray colour, with intersection of whitish and reddish veins.

The yellow-gray breccia form limestone of Upper Cretaceous age was exploited west of Karlovac in Rešovo.

In sediments of the Lower Cretaceous, as potentially productive areas can be separated Markovićevo, northeast of Otočac, and Glavica, along the road Otočac – Dabar (Crnković et al., 1979/80), where the decorative brecciaform limestones of brown-gray, gray and brownish colour, intersected with whitish veins and lenses of calcite, can be found.

The stone is according to its appearance similar to the materials of the ancient quarry near Prozor. The space disposition of natural discontinuities on the location of Markovićevo is unfavourable (fig. 10). But regardless to this fact, the stone blocks separated along measured natural discontinuities according to its shape and magnitude are unfavourable (fig. 11), but also favourable (fig. 12).

**Fig. 10** Potentially productive area Markovićevo, unfavourable space disposition of natural discontinuities – planes of fractures (after Crnković et al., 1979/80)

**Fig. 11** Potentially productive area Markovićevo, unfavourable shape of block separated along measured natural discontinuities, the block is three-sided prism

**Fig. 12** Potentially productive area Markovićevo, favourable shape and magnitude of blocks separated along measured natural discontinuities

PALEOGENE

The sediments of Paleogene that cover smaller area are mostly clastic. Limestone are rarer.

Not far from Bunići, northeast of Lički Osik, were exploited yellow-grayish foraminiferal limestone as ashlars. Petrographically is determined as cataclastic biomicrite/biosparite.

As potentially productive areas in sediments of the Paleogene we can separate Oštrac west of Kosinj-
ski Bakovac and Kosinjski Bakovac, where redish, pinkish, pink-grayish, yellow-gray and of the «coffee with milk colour» limestone breccias intersected with pinkish veins can be found.

The region of Istria

The region of Istria is built up of sedimentary rocks of the Upper Jurassic, Lower and Upper Cretaceous, Paleocene and Eocene, and of Quaternary (fig. 13).

Upper Jurassic limestones form the core of the Jurassic-Cretaceous anticline and they are at the same time the oldest strata found at the surface in Istria.

Lower Cretaceous sediments lay concordant on Jurassic limestones. They consist of limestones interchangeably for early-diagenetic and late-genetic dolomites.

Upper Cretaceous limestones have typical neritic elements of sedimentation in shallow sea water with an expansive development of rudistic fauna.

Paleocene sediments are discordant and transgressive to the eroded surface of Cretaceous limestones, and Eocene sediments was sedimented continuously on Paleocene.

Quaternary sediments were formed by mechanical, chemical and biochemical weathering of carbonate and flysch base.

Some of the characteristics of geology important for dimension stone deposits can be partly explainable from tectonic outline of Istria. In tectonic structure of Istria together with Jurassic-Cretaceous anticline are conspicuous the tectonic break Savudrija-Buzet or anticline Buje and thrust nappe structures of Mts. Čićarija and Učka along the direction Kornačno-Labin-Lupoglav (fig. 14). Tectonic lines with the prominent horizontal shifts practically segmented the area of Istria. The striking horizontal movements from the point of view of dimension stone deposits are important because the exploitable beds are interrupted and shifted horizontally. Therefore their continuation after interruption, regularly, need not be searched along the vertical cuts, but in the lateral sense.

The region of Istria is characterized by the numerous dimension stone deposits which are situated in limestones and clastites of Upper Jurassic including Lower and Upper Cretaceous till Eocene (fig. 15).
Crnković, B. & Jovičić, D.: Dimension Stone Deposits

The exploitable deposits will be shown according to the stratigraphic belongings.

UPPER JURASSIC

The core of the western Istrian anticline is built of the sediments of Upper Dogger, Oxfordian, Kimmeridgian and Tithonian. The sediments of Upper Jurassic are elaborated and described in detail (Tišljar, 1976 and 1978, Tišljarić et al. 1983, Velički Tišljar, 1988).

To Kimmeridgian belong perireefal and shallow marine limestones (biosparites, bioparredites, intrasparsites, oosparites and biomicrites), and to Tithonian belong peritidal and lagoonal cyclic deposition of micrites, desiccation breccias, intraformational pebble conglomerates, intrasparsites and oncolites (fig. 16).

Fig. 15 Dimension stone deposits in Istria

UPPER CRETACEOUS

The stone is dense, whitish, grayish, ivory, brown-grayish and from green to blue tones. It is characterized by stylolites, parallel to bedding. Stylolites are particularly evident in the

Fig. 16 The Kirmenjak quarry, desiccation cycles in the Tithonian limestones (after Tišljarić et al., 1983)

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>C</td>
</tr>
</tbody>
</table>

In the limestones of Upper Jurassic, dimension stone known as Orsera or Vrsarian or in the past known as “la pietra bianca in strati a Orsera” (Sospido, 1922) is exploited. The stone is dense, whitish, grayish, ivory, brown-grayish and from green to blue tones. It is characterized by stylolites, parallel to bedding. Stylolites are particularly evident in the

33 Pazin
34 Trž, Ukotići
35 Sorbar
36 Merići
case of sawing the stone vertical to bedding and stylolites. In respect to colour the following types can be distinguished: white, ivory, gray and green. The stone is polished to the high lustre.

Today is exploited in two quarries:
- Kirmenjak (3 km southwest of Žbandaji), and
- Valkarín (5.5 km southeast of Poreč),
on market known as Kirmenjak stone.

In nearer and farther past the exploitation was carried out in these quarries too (fig. 15):
- Zlatni rt, the deposit southwest of Rovinj, not exploited because of tourism and the protection of environment,
- Funtana, northern of Vrsar,
- Radmanii, northern of Vrsar,
- Gradine, south of Kirmenjak,
- Bralčići, in the vicinity of Gradine,
- Mondelaco, north of Rovinj,
- Signori, NW of Rovinj,
- Soline, NW of Rovinj,
- Kloštar, east of Vrsar,
- Monteriko, southeast of Vrsar, and
- Limski kanal.

**LOWER CRETACEOUS**

To the lowest part of Lower Cretaceous belong dolomites with a few interbedded micrites, pelmicrites and stromatolites (Berriasian). In these sediments, the nonactive quarry Fantazija (east of Rovinj, today geologically protected object), is situated.

After Tišljar et al. (1983) Valangian-Hauterivian sediments are fenestral micrite/biomicrite, biopelmicrite, pelmicrite/pelsparite, intrasparite, stromatolite and onciclite.

Barremian sediments are white to yellowish biopelmicrites, intrasparites, fenestral micrites, pelsparites/pelmicrites and stromatolites, as well as sporadical peritidal breccias and mud pebble conglomerates.

Aptian sediments in lower part are mainly composed of subtidal to lagoonal limestones. Higher part of Aptian is characterized by sporadical and short emersions with formations of intraformational breccias and mud pebble conglomerates. Occasionally, there are thin layers of oncicles which contain algal ball oncoids, intraclasts, as well as gastropodes and micritized foraminifera.

Albian is characterized with deposition of large quantities of detritic limestones. Biomicrites, rudist coquinas, microcoquinas and biostromes appear sporadically.

In the limestones of Lower Cretaceous of numerous quarries »Giallo d'Istria« or »Istrian yellow« was exploited.

From, in the past numerous quarries, today is Istrian yellow exploited in the quarries of Kanfanar and Seline. After Tišljar (1976) in the Kanfanar quarry is visible the rythmic alternation of micrite and oncicle (fig. 17). The two cycles may be distinguished:
- long cycle represented by a micritic layers and several oncicle layers, and
- short cycles contain micritic layers with macroids and strata built up of macroid dominantly.
It is lacking on north in the Heraki area, and their total thickness is about 14 m in the Dvigrad area (fig. 19). This is result of different paleoenvironmental conditions and frequent changes of some lithostratigraphic units.

**UPPER CRETACEOUS**

Upper Cretaceous sediments are represented by perireefal and reefal limestones.

After Tišljarić et al. (1983) lithological composition of the Cenomanian limestones in souther Istria is quite uniform. Thick biostromal layers with local bioherms built up of large rudist shells, and large masses of rudist fragments of different size and roundness, forming coquinas, coquinites and microcoquinites. Textural difference among these rudist limestones are particle size, roundness, sortness and quantity of matrix and cement.

The mechanism of genesis of the described types of limestones is explained and illustrated by Tišljarić (1976) at the example of dimension stone deposit Valtura (fig. 20).

Senonian limestones are represented by thin micrite layers which alternate with biostromes or bioherms of rather small size, and thin bedded micrites in alternation with foraminiferal biocalcarenites and intradacitic limestones.

In the limestones of Upper Cretaceous there are numerous dimension stone deposits, of which are today active the following:

- **Saint Lucia**, in the anticline of Buje, with varieties of »unitō« and »fiorito«, depending, whether the stone contains fine skeleton debris of rudist, or larger rudist skeleton in fine grained matrix, of different nuances of gray colour, often banded structure from the thin layers of the bituminous matter,

- **Grožnjan-Kornerija**, in the vicinity of Marušići, whitish to yellowgrayish colour, skeleton debris gives to the stone grained
Fig. 20 The Valtura quarry, depositional environments of rudist limestones Turonian age (after Tišljar, 1976)

- Ponte Bracano, in the valley of the River Mirna,
- Saint Stjepan, in the valley of the River Mirna, the only quarry with the underground exploitation in the past, for which Marić (1951) wrote, that this big quarry in Istria takes the significant place in civil engineering,
- Mirna-Bazgalji, south of Pazin,
- Saint Magdalena-Culen brdo, south of Pazin,
- Lovrinič, south of Pazin, redish, pinkish, grayish and brownish limestone and limestone breccia,
- Planik, not far from Laniše, shelly limestone,
- Goli otok (island), breccia of orange colour with calcite-hematite and limonite cement, and limestone, and
- Krk (island), limestone breccia.

EOCENE

At the present moment, dimension stone is not exploited in the sediments of Eocene. In the further and nearer past limestone conglomerates, breccias and limestones were exploited in numerous deposits, some of them here mentioned:

- Istranka, in the past exploited in the vicinity of Lupoglav, nummulitic limestone of dark brown colour with numerous light skeletons of large nummulites, and others large benthic foraminifers, pigmented with bituminous matter, the stone of great decorativity and remarkable appearance,
- Granitello-Gračišće, in the past exploited near Gračišće, nummulitic breccia, lower units of Turbidite sequence, of grayish and brownish colour, with greenish nuances,
- Mandorlato, nummulitic breccia, lower units of Turbidite sequence, of yellow-grayish and grayish colour, the quarry situated in the town of Pazin,
- Mandorlato and Unito, nummulitic breccia, lower units of Turbidite sequence, of yellow-grayish colour and bluish nuances, in the past exploited near Trvž (locations: Brtoška, Stenice, Čize),
- Ukotići, near far from Trvž, nummulitic breccia,
- Sorbar, northeast of Marušić, limestone conglomerate of brownish colour, and
- Merišće, northeast of Jeličići, marmorized limestone breccia of whitish and pinkish colour, intersected with yellow calcite-limonite veins.

The region of Dalmatia

The greatest spreading in this region enclose sedimentary rocks, rudistic limestones of the Upper Cretaceous age. As far as dispersion is concerned,

<table>
<thead>
<tr>
<th>Properties</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength dry samples, MPa</td>
<td>138.5</td>
<td>149.0</td>
<td>223.0</td>
<td>136.0</td>
<td>101.0</td>
<td>72.0</td>
</tr>
<tr>
<td>Compressive strength water-saturated samples MPa</td>
<td>113.5</td>
<td>124.5</td>
<td>162.0</td>
<td>110.5</td>
<td>66.5</td>
<td>63.0</td>
</tr>
<tr>
<td>Compressive strength after 25 cycles of freezing and thawing MPa</td>
<td>103.0</td>
<td>104.0</td>
<td>149.5</td>
<td>106.5</td>
<td>42.5</td>
<td>68.0</td>
</tr>
<tr>
<td>Resistance to grinding (Boehme method) cm²/50 cm³</td>
<td>16.1</td>
<td>19.3</td>
<td>19.1</td>
<td>23.7</td>
<td>45.1</td>
<td>44.3</td>
</tr>
<tr>
<td>Density, kg/m³</td>
<td>2700</td>
<td>2714</td>
<td>2713</td>
<td>2630</td>
<td>2712</td>
<td>2700</td>
</tr>
<tr>
<td>Bulk density, kg/m³</td>
<td>2677</td>
<td>2615</td>
<td>2688</td>
<td>2557</td>
<td>2294</td>
<td>2380</td>
</tr>
<tr>
<td>Porosity, %</td>
<td>0.85</td>
<td>3.65</td>
<td>0.92</td>
<td>2.78</td>
<td>15.42</td>
<td>11.85</td>
</tr>
<tr>
<td>Water absorption, %</td>
<td>0.77</td>
<td>0.94</td>
<td>0.20</td>
<td>1.30</td>
<td>5.78</td>
<td>4.00</td>
</tr>
</tbody>
</table>

1 Orsera, Kirmenjak; 2 Istrian Yellow, Kanfanar; 3 Istrian Yellow, Selina; 4 Saint Lucija; 5 Valtura Unito; 6 Vinkuran Statuario
the carbonate clastic rocks of Paleogene follow to the greater extent. The other lithostratigraphic units are represented to the lesser degree. Therefore it is logical that greatest number of dimension stone deposits are placed in various varieties of rudistic limestones.

TRIASSIC

There are no dimension stone quarries in the sediments of triassic age. In them of some interest can only be the smaller part of limestones of the Middle Triassic age, what mention Kieslinger (1932) when describes «Bunte Alpenmarmore» and refers location »Muc bei Spalato (Trias)«. North of Muč is situated the narrow zone of unbedded limestone (Ladinian) of the east-west striking.

JURASSIC

In sediments of the Lower Jurassic near Trilj, occasionally was exploited Lithiotis limestone, on market known as Negris florito. Geological conditions of the deposit are unfavourable, with vertical layers. As dimension stone, apart from Lithiotis limestone, the surrounding limestones of completely black colour could be exploited, but without significant decorativity.

Southeast of Drniš, in the sediments of Lower Jurassic, the limestone Crna Krčka was exploited. After Tislijar (1980a) in the tectonic block of smaller area, the thickbedded, dark-gray to black limestone dappled with redish and yellowish veins and stylolites used to be exploited. Because of tectonic framework and density of discontinuities, only tombolones and smaller blocks can be taken out. The use of this stone is strictly limited to covering of interiors. Not far from this quarry Lithiotis limestones are spreading.

On the southwest slopes of the Mt. Dinara, east of the Četina River, are situated thickly bedded, dense limestones of white colour with stylolites, alike to the stone on market known as biacone and Hoch Jura, as well as limestones of gray and brown-grey colour, investigated on several locations. In the area of Česma, the explorational drilling was carried out. The thickness of layers vary from 0.75 to 2.5 m. Petrographically are determined as pelmicerites and micrites.

CRETACEOUS

The slightly dispersed sediments of the Lower Cretaceous age in continental part and the islands of Hvar and Korčula are not significant from the point of view of dimension stone exploitation. All the deposits are placed in different varieties of the Upper Cretaceous limestones.

One of the varieties is yellowish-whitish and brownish-grayish dense limestone, massive or thick bedded, on the market known as Dolit. This limestone is exploited in the deposit Donji Dolac east of Bugopolje. Petrographically is determined as micrite and brecciated micrite. Because of the tiny and space restricted cracks, it is recommended to use them primarily for production of thicker slabs and elements. Limestone of same quality is Dicmi, in the past was exploited in Dicmo on the northern part of Kruševsko polje.

From the Ancient times, through the Middle Age, till present days in exploitation is whitish limestone, on spots of bluish nuances, well known as Seget. The deposit is on the hill of Saint Ilija near Trogir. This is one of the rare quarries in our region, where the exploitation was carried out by English company in 1920/30 (Marić, 1930 a). Petrographically is determined as biosparite, but the skeleton debris is not macroscopically observed.

In continental part of this region important are fosiliferous rudist limestones which consist of the abundance skeleton debris, in the first place, rudists of different dimensions, roundness and sorting. The fragments of skeleton are regularly of darker yellowish and brownish nuances, differing from the calcite matrix, that visually emphasize their decorativity. Petrographically are determined as biosparite.

The limestones of that sort are nowadays exploited in the quarries:
- Vsine, NNE of Vsine, west of Trogir (figs. 21 and 22), and
- Plano, NE of Trogir,

while the following quarries were exploited in the past:
- Voluja, in the bay of Voluja south of Marina, petrographically determined as biosparite and fosiliferous dismicrite,
- Okrug, western part of island Čiovo, petrographically determined as dismicrite, while people of that time called it »glassy«, because the surfaces of calcite cleavage reflect the beams of light, and therefore glaze, the quarry is placed in the touristic zone,
- Mosor, on the northern slopes of the Mt. Mosor, south of Donji Dolac,
- Dubrava, north of Sibenik,
- Kremenovo, near Dubrava, and
- Krševine and Krtoline, east of Dubrava.

The deposit of fossiliferous and partly rudist coquina limestones Vrdovo on the southern slopes of the Mt. Dinara, north of Sinj, was in the phase of investigation.

The Fantazija stone exploited southeast of Donji Dolac differs from the enumerated dimension stones. The stone is of brecciated and marbled appearance, wax lustre, yellowish-gray and brownish colour, with greenish nuances.

After Jović et al. (1989) the dimension stone deposit Boristića on the island of Dugi otok is placed in rudiste limestones of Upper Turonian-Lower Senonian age. Three types of limestones can be visually separated in the deposit:
- graybrownish limestone, stylolitic biomicrite, lower bed,
- white rudiste limestone, petrographically determined as biomicrite/biosparite and biosparrudite, exploitable layer of 20-odd m thickness,
- white plate limestone, biosparite and biopsarrudite, hanging bed.

In the region of Dalmatia, regarding the dimension stone exploitation, the island of Brač takes a significant place, being famous of «the marble of Brač».
The island is almost completely built of the carbonate sediments of Upper Cretaceous age (Turonian-Senonian), and than slightly dispersed foraminiferous limestones and clastites of Eocene.

In the tectonically-structural sense the island is asymmetric anticline, where layers along the northern limb slightly plunge the north. Because of that structure all dimension stone deposits, from the ancient times till nowadays, are dispersed on the northern and eastern side of the island. Therefore exploitation covers the wide zone of the east-west striking (fig. 23).

From the point of view of dimension stone exploitation of the forementioned zone, from Splitska on west to Povlja on east, after Tomasić (1979), we can distinguish lower beds and hanging beds (fig. 24).

Lower bed is exploited not far from Pučišća in the open-pit quarry, beneath the sea level. This is dolomitic limestone Sivae (Gray stone), petrographically determined as dolomitic micrite/biomicrite. On the market are known two varieties of stone: Adria Grigio Macchiato (Adria gray spotty) and Adria Grigio Venato (Adria gray veined). The first is of homogenous structure, uniform gray colour, and the other is intersected with darker-gray veins and oval stains.

In hanging beds alternate vertically and laterally fossiliferous rudiste limestones of the »unito« and »fiorito« type (fig. 25). The limestone of »unito« (monotonous) type contains fine-grained skeleton debris of the uniform dimensions. Limestone of the »fiorito« (blooming) type in fine-grained skeleton debris contains large skeletons of rudiste and other fossils. Limestones are of different yellowish-gray nuances. It's decorativity is marked with skeleton debris which is of regularly darker nuances than the
The island of Brač
UPPER CRETACEOUS
a) quarries on exploitation
1 Punta and Barbakan (Veselje unito, Veselje fiorito), and Sivac (Adria Grigio)
2 Kupinovo (Kupinovo unito, Kupinovo fiorito, Diokles), and Kupinovo novo
3 Zeevo and Glave (San Giorgio)
4 Zagani Dolac (Rasotica)
5 Dragonjik
6 Dračevica
7 Pražnica
b) quarries out of exploitation
8 Splitska and Skrip
9 Postire and Rasohe
10 Lozna
11 Saint Nikola
UNIDENTIFIED AGE (younger from the Upper Cretaceous)
a) quarry on exploitation
12 Oklad

The island of Hvar
UPPER CRETACEOUS
b) quarries out of exploitation
1 Pkonj Do and Kršna Luka
2 Bogomolje
3 Saint Nedjelja
4 Vranković

The island of Korčula
UPPER CRETACEOUS
a) quarry on exploitation
1 Humac
b) Quarries out of exploitation
2 Krkonča
3 Uskorusica
4 vrbovica
5 Vaja
6 the small islands of Vrnik, Kamjenjak, Badža and Sutvara

matrix. Petrographically are determined as biomicrite/biosparite and biomicrudite/biosparrudite.

Numerous quarries are placed from the western to the eastern part of the island:
- Splitska, Škrp, Postire and Rasohe, out of exploitation,
- Punta and Barbakan near Pučišća, on market known as Veselje unito and Veselje fiorito,
- Kupinovo, and Kupinovo novo, east of Pučišća, on market known as Kupinovo unito, Kupinovo fiorito and Diokles.
- Lozna, east of Kupinovo, out of exploitation.
- Fossiliferous rudiste limestones in the eastern part of the island are of yellowish, yellow-whitish and yellowish-grayish colour. Sometimes, on surface, because of intraclasts and fine-grained skeleton debris are of the spawly appearance. They contain skeleton debris of rudistes and foraminifers, as well as intraclasts in micrite and sparite matrix. Petrographically are determined as biomicrite/biosparite, biotramicrite/biointrasparite and dolomitic biomicrite/biosparite. The varieties of unito and venato are differed. The variety of venato contains dark brown bituminous and dolomitic enriched veins. On market the stone is known as San Giorgio Unito and San Giorgio Venato, and exploited in the quarries Zerevo and Glava.
- In the vicinity of Selce, in the past period, the stone of same quality was exploited in the quarries Saint Nikola and Glavice.
- On the eastern part of the island, in Zagani Dolac near Sumartin, there is the rudiste limestone deposit of remarkable decorativity, known on marked as Rasotica. In darker brown matrix, the lighter fine-grained and larg skeletons of rudiste, and banded accumulations of bituminous matter accentuate the decorativity. Sporadically, near fractures, limestone is of lighter nuances, most probable because of bituminous matter oxidation, under the influence of rain circulations. The stone of Rasotica is petrographically determined as bituminous biomicrite/biosparite, and biomicrudite/biosparrudite. The use strictly restricted to covering of interiors, because of fading, under activity of exogene, oxidating factors.
Table 25 The Punta quarry, vertical section of hanging beds (after Tomashic, 1979)

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIII e</td>
<td>multi-bench</td>
</tr>
<tr>
<td>VII e</td>
<td>stone unit type</td>
</tr>
<tr>
<td>VI e</td>
<td>stone fiorito type</td>
</tr>
<tr>
<td>V e</td>
<td>F fracture</td>
</tr>
<tr>
<td>IV e</td>
<td>MF dense micro-fracture so-called »books«</td>
</tr>
<tr>
<td>III e</td>
<td>u.</td>
</tr>
<tr>
<td>II e</td>
<td>f.</td>
</tr>
<tr>
<td>I e</td>
<td>u.</td>
</tr>
</tbody>
</table>

Not far from Nerezišća, fossiliferous rudiste limestone is exploited in the Dragonjik quarry. The stone is of yellowish whitish and yellowish-grayish colour, with clearly marked grained skeleton debris, and therefore alike to the stone varieties called »Graniello« (grained). Petrographically is determined as dolomitic biointramicrite/biointrsparite and biomicrite/biosparite.

North of the Dragonjik quarry in the wider surroundings of Dračevica, there are several quarries in which private stone-masons exploit the stone. The small quarry of nicely brownish and the colour »of coffee with milk« is placed near Pražnica.

After the short elaboration of the main characteristics of dimension stone deposits, we should take a look at the incorrect interpretation of the part of these deposits in the monograph of Gušić and Jelasko (1990). The mentioned authors described carbonate sedimentary rocks of the island according to formations. In the Dol Formation they described the stone Sivac, commercially called Adria Grigio, which they identify with the stone Zečevo and Glava, commercially called San Giorgio. They literally write »... in the quarries of Glava and Zečevo quarrymen pick stone (home term for stone extraction) similar to Sivac. The similarity includes some differences, which wouldn't necessarily be sufficient for the different commercial name of dimension stone. Therefore, it would be extremely unusual that the quarrymen from Seleia also pick the Sivac, because of that this kind of stone is there for the need of world market named San Giorgio.«

But it is not correct! There are important and essential differences between the types of stone commercially called Adria Grigio and San Giorgio:
- in stone appearance and decorativity of the polished surface, Adria Grigio or Adria Gray, as its name tells itself, is of gray colour and in the same time »maciato«, which means spotty, with clearly marked oval and longish darkgray spots, and venato with clearly marked darker gray veins; San Giorgio is of yellowish-whitish and yellowish-grayish colour, not spotty, but of swamply appearance, with fine-grained but evident skeleton debris, while venato has darker brown veins pigmented with bituminous matter;
- in genesis and the environmental conditions of the sedimentation, both sediments could be of the same age, and deposited in the same time, but in different conditions, that resulted in the described visual differences; Adria Grigio is exclusively micrite limestone, deposited calcite mud, while darker gray oval and longish spots are remnants of the worm boring in that mud; such bio-activity is not evident in the stone San Giorgio, its main components are fine-grained skeleton debris and intraclasts;
- therefore it is logical that two in its essence and visually different limestones represent two different facies and have different commercial names.

On the island of Hvar, after Majer and Crnković (1977), in the quarries of Križna Luka, Pokonji Do and Bogomolje, whitish limestones were exploited. Coloured limestones are also dispersed and were exploited in the past:
- Saint Nedjelja, red-yellowish and greenish-gray limestone breccia, and
- Vranković and the bay of Jagodna, pinkish striped limestone.

On the island of Vis, in Labotovo, was exploited greenish limestone of pinkish and greenish nuances, on market known as Roza Val.

The island of Korčula is also known of its dimension stone exploitation.

In the present time the only active quarry on the island is Humac, southeast of the town Korčula. After Jović et al. (1991) three types of limestone can be separated in the deposit:
- dense gray limestone, lower bed,
- fossiliferous rudiste limestone of orange colour, exploitable layers thickness from 0.8 to 1.7 m,
- thick bedded rudiste limestone, hanging bed.
Exploitable layers petrographically are determined as biomicrite/biosparite and biomicrudite/biosparrudite.

In nearer and further past exploitation was carried out in these quarries too (fig. 23):
- Krkmača, not far off the quarry Humac; where two types of exploitable fossiliferous limestones can be separated in the deposit of olive-gray and gray colour, petrographically determined as biomicrite, biopelmicrite and biointramicrite,
- Oskorušica, west of the town Korčula, fossiliferous limestone of light gray and rosy-gray colour, petrographically determined as biomicrite/biosparite, biopelmicrite and biorudite,
- Vrbovica, on the north part of the island, with two types of fossiliferous limestones, of whitish rosy and brownish colour so called Pigavac, petrographically are determined as biosparite and biopsarrudite
- Vaja, in the bay of Vaja west of Ročišće, white limestone.

The exploitation was carried out in the quarries of the small islands of Vrnik, Kamenjak, Badija, Sestrice and Sutvara, east and northeast of Korčula.

From the enumerated most significant is the island of Vrnik (fig. 26). The height of old multi-benches quarry is 50 m. The fossiliferous rudiste limestone of unito and fiorito types, of whitish rosy and grayish rosy colour, petrographically are determined as biomicrite/biosparite and biomicrudite/biosparrudite.

Of the deposits in continental part of the region, we should mention Visočani, northwest of Dubrovnik. In the deposit fossiliferous rudiste limestone was exploited, visually alike to the stone from the quarries near Pučišća on the island of Brač. During the aggression and violence of chetniks 1991/92 all the plants are partly looted, and partly destroyed, while the quarry is demolished, therefore we fear that it would be out of use for the longer time.

PALEogene

The sediments of Paleogene cover the remarkable area in the northwestern part of the region, that would in another parts stretch in a form of narrow zones, mostly in overlap faults. In the northwestern part the general striking of Paleogene is NW-SE with the change in striking WNW-ENE and partly to W-E in central part, that would in the southern part take the same striking NW-SE. In the Paleogene mostly are represented carbonate clastic sediments, to the lesser degree limestones, with flysh as important lithostratigraphic member.

Dimension stone deposits are primarily situated in differently coloured limestone conglomerates of the Promina formation. The colour of conglomerate depends on the colour of pebbles and cement. Conglomerates are thickly bedded with the conspicuous layer's discontinuities. Sporadically in deposits alternate thinner and thicker layers of limestone.
The following dimension stone deposits are in the clastic sediments of Paleogene:

- **Marići**, east of Obrovac, thickly bedded, conglomerate of grayish and pinkish colour,
- **Gradina**, east of Obrovac, out of exploitation,
- **Rozalit**, near Pakovo Selo, SSW of Drniš, conglomerate of pinkish colour, after which got the name; the deposit of exchangeable layers of conglomerates from 0.5 to 6 m thickness, and layers of redish limestones from 0.3 to 1 m of thickness (fig. 27).

We should mention here the limestone-dolomitic breccia **Oklad**, south of Novo Selo on the island of Brač, of unidentified age. The breccia lie discordant on the Senonian limestones and it is evident younger than the limestones of the Senonian age (fig. 28). It is of different nuances of gray and brown-gray colour and contains angular fragments of limestones and dolomites of the Upper Cretaceous base. The pigment of breccia is of bituminous matter, therefore its application is restricted to covering of interiors.

**Final considerations**

After Crnković and Bilbija (1984) dimension stone and its deposit are evaluated by means of:

- geological criteria (size of deposit, the possibility to extract blocks, uniformity of appearance of the stone mass in its deposit, and the quantity of the stone mass),
- technological and economical criteria (quality of blocks and possibility of economical industrial processing),
Table 2 Mechanical and physical properties of dimension stone, Dalmatia (data: Institute of Civil Engineering of Croatia, Zagreb)

<table>
<thead>
<tr>
<th>Properties</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
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<tr>
<td>Compressive strength dry samples, MPa</td>
<td>115.7</td>
<td>140.5</td>
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<td>106.4</td>
<td>119.0</td>
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<td>243.4</td>
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<td>140.0</td>
<td>192.0</td>
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<td>Compressive strength water-saturated samples MPa</td>
<td>103.8</td>
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<td>143.3</td>
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<td>Compressive strength after 25 cycles of freezing and thawing, MPa</td>
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<td>Resistance to grinding (Boehme method) cm²/50 cm²</td>
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<td>29.3</td>
<td>32.2</td>
<td>29.7</td>
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<td>Density, kg/m³</td>
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<td>2690</td>
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<tr>
<td>Porosity, %</td>
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<td>3.33</td>
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<td>Water absorption, %</td>
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<td>4.09</td>
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<td>0.16</td>
<td>0.15</td>
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</table>

1 Seget; 2 Plano; 3 Vrsine; 4 Veselje Unito; 5 Kapinovo Diokles; 6 Sivac-Adria Grigio; 7 San Giorgio; 8 Rasotica; 9 Dolit; 10 Adria Verde; 11 Oklad; 12 Rozali; 13 Multikolor; 14 Alkasin

- Technical criteria (applications of the stone, depending on its physical and mechanical properties, and its durability), and
- Criteria of decorativity (the general appearance of the stone, it is very important for the stone's marketability).

The sum of all these values of a deposit leads to its assessment and ranking as:

- Of international importance,
- Of restricted international importance,
- Of national importance, and
- Of local importance.

On the basis of these criteria after Iveković and Crnković (1987) the active quarries of dimension stone are evaluated on Table 3.

Table 3 The evaluation of dimension stone

<table>
<thead>
<tr>
<th>geological criteria</th>
<th>distribution compared to size of deposit</th>
<th>technological criteria</th>
<th>technical criteria</th>
<th>criteria of decorativity</th>
<th>whole evaluation</th>
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<tr>
<td></td>
<td>deposit of large development</td>
<td>deposit of middle development</td>
<td>deposit of limited possibility</td>
<td>deposit of extraordinary possibility</td>
<td>block utilization 65-95%</td>
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<td>Orsera - Kirmenjak</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Istrian Yellow - Kanfanar</td>
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<td>+</td>
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<td>+</td>
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<td>Saint Lucija</td>
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<tr>
<td>Vinkuran</td>
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<td>Veselje - Punta</td>
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<td>Adria Grigio</td>
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<td>Rasotica</td>
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<td>Rozali</td>
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<tr>
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<td>Vrsine</td>
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<tr>
<td>Alkasin</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Multikolor</td>
<td>+</td>
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Ležišta arhitektonskog kamena u Hrvatskoj

B. Crnković i D. Jovičić

Prema kraćim ili opštim definicijama (Bates and Jackson, 1980 i Dineley et al., 1976) arhitektonskim kamenom smatramo onu prirodnu tvorenju koju vadinom iz stijenske mase u pravilno oblikovanima blokovima i koja se odlikuje odgovarajućim svojstvima. O šrokom rasponu genetskih i postgenetskih procesa i čimbenika ovisi dekorativnost kamena, njegova fizička i mehanička svojstva i cjelovitost stijenske mase u ležištu.

Hrvatska se okarakterizira raznolikošću petrografskog sastava i geološke grade. Različitost grade pojedinih njenih područja uočavaju se na geološkoj karti (sl. 1). Na temelju mobilističke koncepcije geneze i grade Dinarića (Herak, 1991) a sa stanovišta postojanja ležišta arhitektonskog kamena, Hrvatsku možemo podijeliti u šest regija (sl. 2). Ležišta arhitektonskog kamena opisana su po tim regijama i litostatografskim jedinicama.

Regija Hrvatsko Zagorje

Prema Herak (1991) regija pripada strukturnom kompleksu Unutarnjih Dinarića ili Supradinariću. Iz opisa grade toga kompleksa i provedenih istraživanja, kao potencijalno produktivne naslage izdvojamo karbonatne sedimete miocena (Crnković et al., 1974/75). U toj su se regiji u daljoj ili blizoj prošlosti kao arhitektonski kamen eksploitarali porozi i mekan vipecni te litotamnijski vapnenci u ležištima Vinača, Pisana Pećina, Ruopana, Bisek i Vrapče potok (sl. 3).

Regija Slavonija


Regija Banija i Kordan

Regija pripada Supradinariću. S obzirom na geološku grade i intenzivne deformacije smještenja (Majer, 1984 i Majer i Lugović, 1985) u toj regiji nema mogućnosti nalaza ležišta arhitektonskog kamena.

Regija Gorski Kotar, Iika i Primorje

Regija pripada strukturnom kompleksu Dinarske karbonatne platforme, Dinariću. Intenzivna tektonika i navlačne strukture (Herak, 1991) su ograničavajući čimbenici nalaza vičih ležišta arhitektonskog kamena. Klastični sedimenti karbona kod Brunaša eksploitarani su i kao klesanci lokalno korišteni u gradnji stambenih objekata.

Karbotami konglomerati kod Šv. Boka eksploitarani su kao arhitektonski kamen u prošlosti.

U juri je značaj kao arhitektonski kamen liitosit vapnacen, eksploitaran u Cvitoši, kraj Lovinca, u Gradini kraj Riječa. Gusti vapnacen smješten, tammisne i smjescno boje prolanar bjelim, žučkim, smješten i crvenkastim čilicama, komercijalno nazvan Velebit portoro, eksploitarao se nedaleko Gospića. Nedaleko Donjeg Lapca eksploitarao se crveni do crvenkastosmedasti vapnacen, mjestimice konglomeratičnog izgleda, komercijalno nazvan Unarat.

Kredne starosti je brežulčki vapnacen kraj Prozora jugoistočno od Otočca u kojemu je otkriven antički kamenolom (Šarić, 1980). Sjeverno od Obrovca eksploitaraju se crvenkasti i smještani brežulči vapnenci i vapanacne breće Romanovac i Tulovac ili Kastanija.

Regija Istra


U vapanecima donje krede eksploitarali se Istarski žuti u kamenolomima Kanfanar i Seline. Protezaj Istarskog lutog utvrđen je detaljnim istraživanjima ekipa Instituta za geološka istraživanja 1982/84. godine (sl. 18). Autori zahvaljuju članovima ekipa gospodi I. Velici, B. Sokacu i J. Tišljaru, što se dozvolili da se u ovom dijelu te objave objave podaci i karta iz njihovog izvještaja prezentiranog poducevaju na kartu.

U naslagama gornje krede eksploitarali se rudnici vapaneci Sveta Lucija, Grožanj-Kornerija, Valtra i Vinkuran. Tamsosmedać u posebno dekorativni umučuti, poznati na tržištu kao Istranka, eksploitarali su se u blizoj prošlosti kraj Lapelovca.

Regija Dalmacija

U ovoj regiji koja također pripada Adrijatiku danas su u naslagama gornje krede eksploitaraciom obuhvaćeni rudnici vapaneci, u kojima se nalaze aktivni kamenolomima u kontinentalnom dijelu i u otocima. U kontinentalnom dijelu u okolici Trogira nalaze se kamenolomima Seget, Plano i Vrsaca. Na otoku Braču, od brojnih poznatima ležišta u prošlosti, eksploitaracije je danas uglavnom koncentrirane u okolici Puriča (kamenolomima Svac, Punta, Barban, Kapinovo i Kapinovo novo), poznat arhitektonski kamenovi Adria Machiato, Veselje unito i fiorto, Dioklets, kao i Selca (kamenolomima Zeećevo, Glave i Zaganj dolac, poznati arhitektonski kamenovi San Giorgio i Rasotica), a aktivni su još kamenolomima Dragonjik kraj Nerežica i Priznaka. Na otoku Korčulu aktivni je kamenolom Humac, a po brojnim neaktivnim kamenolomima poznat je otok Vrnik.

U sedimentima paleogenog u kontinentalnom dijelu regije eksploitarali se Jadranski zeleni u Puličima, konglomerat Rozalit u Pakovom selu te povremeno konglomerat Multikolor i dekorativni vapnacen Alkasst nedaleko Sinja.

Arhitektonski kamen koji se danas eksploitarali danai na tržištu vrednovan je prema kriterijima: geološkom, tehnološkom, tehnikom i dekorativnom (Crnković i Bilbij, 1984). Na temelju obavijenog vrednovanja (Iveković Crnković, 1987) dio arhitektonskog kamena je ograničen svjetskom, a dio nacionalnom značenju (tablica 3).