

A photograph of a stone archway, likely part of a historical building. The arch is constructed from light-colored stone blocks. Above the arch, the wall is covered in dense green ivy. The arch itself is filled with a rough, irregular stone masonry. The overall scene suggests a historical or cultural monument.

NATURAL STONE IN
CULTURAL MONUMENTS

**A GEOLOGICAL
tour of Ljubljana**



By being observant while strolling the streets of Ljubljana, one can recognize many types of rocks and fossils.

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THE GUIDE TO THE 21 SLOVENIAN AND 8 FOREIGN ROCK TYPES, AS WELL AS 11 FOSSIL GROUPS AND 2 TECTONIC STRUCTURES IN LJUBLJANA'S CITY CENTRE.





Prešeren Monument

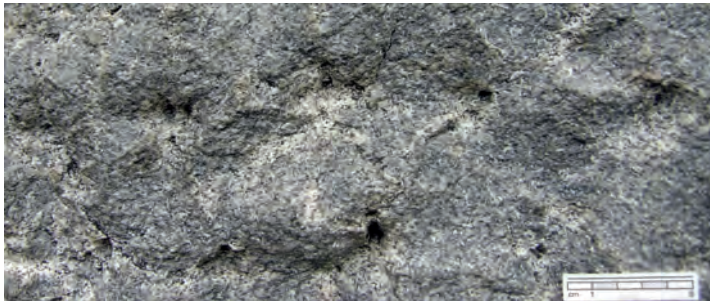
A monument to France Prešeren, Slovenia's greatest poet, 1905.

The monument is made of three types of stone. The low base is made of Podpeč limestone (→ 4, 10, 13, 17). The large, dark, cuboid-shaped pedestals are made of Jablanica gabbro from the Neretva River Valley; it used to be one of the most sought-after stones types, but the quarry is now closed. The light-coloured upper part is made of Permian Baveno granite, quarried in Carinthia or northern Italy. It can be said that the Prešeren Monument represents the composition of Earth's crust, since the largest part of the continental crust consists of granite, and the majority of the oceanic crust is made of gabbro.

Pink-grey **Baveno granite** (*Rosa Baveno*). Granite is a light-coloured, coarse-grained igneous (plutonic) rock formed by the crystallization of magma deep in Earth's crust. It consists of pale pink potassium feldspar, vitreous quartz, bright plagioclases and dark flakes of mica (biotite).



Dark green-grey, almost black **Jablanica gabbro**. Gabbro is a dark, dense, coarse-grained igneous (plutonic) rock formed when basaltic magma is pressed into Earth's crust, mostly along the mid-oceanic ridges. It consists of bright greenish pyroxenes, bright basic plagioclases, and small amounts of amphibole (hornblende), olivine, biotite, and quartz.





Ljubljana Central Pharmacy

Prešernov Trg 5, Renaissance revival building, 1896.

The facade is made of calcareous tufa quarried in the Kokra Valley near Jezersko. Tufa formed in the Holocene; fossil imprints of plants are often preserved in the rock. The quarry is now protected as a valuable natural feature, and quarrying has been stopped.

Calcareous tufa is a light-coloured, highly porous sedimentary rock composed of pure calcium carbonate – calcite. It forms on land near springs from a supersaturated freshwater solution due to temperature changes and carbon dioxide leakage. Crucial for this process are mosses and other aquatic plants that consume dissolved CO_2 during photosynthesis. This reduces carbonate solubility in water and thereby facilitates its excretion in the form of crusts that envelop plants.



Tromostovje (The Triple Bridge)

The central Špital stone bridge dates back to 1842. Arch. Jože Plečnik added the left and right concrete bridges in the years 1929–31.

The central bridge is built from grey Jurassic limestone from the Glinice quarry near Podutik, where it was already quarried by the Romans. The stone was named Glinice limestone (→ 11, 12, 15, 17), after the quarry it originated from. This dense (micritic) limestone is characterized by red calcite veins and rare occurrence of fossil remains.



UniCredit Bank branch

Wolfova Ulica 1, former Mayer department store, 1938.

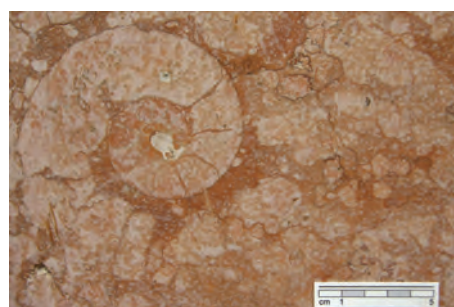
The pillars and the socle are lined with yellow-grey porous Neogene lithothamnian limestone (*litavec*) from Podsused in Croatia. In between them are tufa panels, which are often used instead of *litavec* because of their resemblance.



Litavec formed in a very shallow Middle Miocene sea. It consists of small white globular lumps of red algae – *Lithothamnium*, often accompanied by other shallow-water organisms and small pebbles from the nearby mainland. The holes are caused by the corrosion of limestone and dolomite pebbles. In the socle at Hribarjevo nabrežje, cross sections of *Clypeaster* sea urchins (pictured) and characteristically lamellar oyster shells can be found.

Cross section and the upper surface of a flat sea urchin shell, which is also called a sand dollar (Zittel, 1879).





DEŽELNA BANKA SLOVENIJE BUILDING

Miklošičeva Cesta 4, Former People's Savings Bank, the first real Art Nouveau palace in Ljubljana, 1907.

The facade is lined with red *Rosso Ammonitico* limestone from northern Italy. This Jurassic limestone, which is quarried along the Adige Valley, is among the most common ornamental stones in Europe. The most famous monuments made from this stone are in Verona (Arena) and Venice (Doge's Palace).

The *Rosso ammonitico* limestone is recognizable by its red colour, nodular structure and numerous fossils, among which ammonites are most common. Ammonites are cephalopods, extinct relatives of the squid with coiled limestone houses. They were the rulers of the seas in the Earth's middle ages (the Mesozoic era). This limestone formed in deep sea (from 200 to 1000 m), its nodular structure being the result of strong currents, interruption of sedimentation and dissolution under pressure during compaction.

BAMBERG HOUSE

Miklošičeva Cesta 16, Neo-Baroque palace by arch. Maks Fabiani for the Ljubljana-based printer Otmar Bamberg, 1907.

The cladding on the ground floor and the oriel above the entrance are made of green andesitic tuff. The tuff was named **Peračica tuff** after the quarries in the Peračica valley in Upper Carniola.

Tuff is formed from volcanic ash of explosive volcanic eruptions. The erupted solid particles are called pyroclasts, and the rocks made of those particles are called pyroclastic rocks. Tuffs are pyroclastic rocks formed from the tiniest particles. Peračica andesite tuff originates from the Oligocene era, from approx. 25 million years ago, when the Slovenian Smrekovec volcano was active.

The two steps in front of the entrance are made from Repen limestone (→ 9, 17) with transverse and longitudinal sections of large rudist bivalves.

On buildings, tuff is recognizable by its green colour from mineral chlorite, and peeling due to poor weather resistance.

BAMBERG HOUSE

3





Nebotičnik (Skyscraper)

Štefanova Ulica 1, at the time it was built, in 1933, the ninth tallest building in Europe.

The building's foundation and the lower lobbies are coated with dark grey and black **Podpeč limestone** (→ 10, 13, 17) from a quarry in Podpeč on the edge of Ljubljana Marshes. Here, stone was already quarried by the ancient Romans, and in order to transport it with boats to Emona (Roman urban settlement in the area of today's Ljubljana), they redirected the Ljubljanica River past the Podpeč quarry.

In the Podpeč limestone panels in the lobby, white cross sections of at least three genera of lithiotid bivalves can be observed. The vertical narrow shells belong to the *Cochlearites* genus. Above the symbolic heads, the *Lithioperna* genus can be seen in long lines with a thin intermediate space. In the panels without lithiotids, there are small terebratulid brachiopods (→ 13) and rarely snails.



The passage and the upper floors of Nebotičnik are adorned with panels of various “karst stones” (→ 9, 17); the common name for limestones of Cretaceous age with cross sections of rudist bivalves. They come from the quarries of Aurisina near Trieste, Lipica and Kazlje in Slovenian Kras, and Rasotica on the Croatian island of Brač.

The passage of Nebotičnik is lined with limestone from Rasotica (island of Brač); it is characteristically brownish grey. At the exit to Cankarjeva Cesta, there are dark panels from Kazlje and light plates from Lipica. In the left-hand corner, above the ground, there is a **nummulitic limestone** panel from the Croatian town of Lupoglav under Učka in Istria. A large part of the Slovenian Littoral region consists of a similar limestone type.

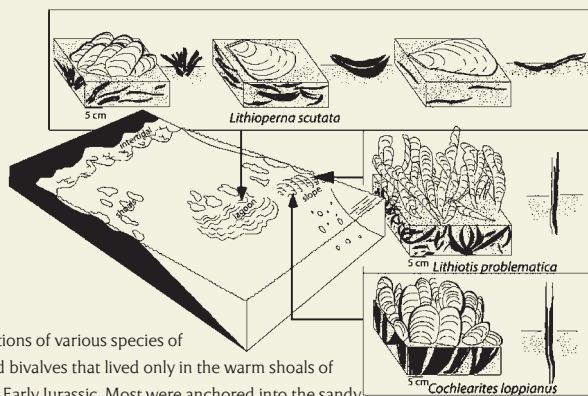


Nummulitids received their name because of their resemblance to coins. In the panel, long transverse cross sections of their big flat and small lenticular limestone shells can be seen. (Bellier et al., 2010; Zittel, 1876)



Nummulitids are an extinct group of large foraminifera. Foraminifera are single-celled organisms with differently shaped shells. Most are microscopic and some live like plankton. Nummulitids lived on the seabed during the Palaeocene and the Eocene. They had lenticular, spirally coiled limestone shells divided into small chambers. The up to 3 cm long cross sections belong to the nummulitids of the *Assilina* genus.

Short and thick in the middle, cross sections of the *Lithotis problematica* shells.



Shells and sections of various species of extinct lithiotid bivalves that lived only in the warm shoals of the seas in the Early Jurassic. Most were anchored into the sandy bottom, similarly as the noble pen shell (Fraser et al., 2004).

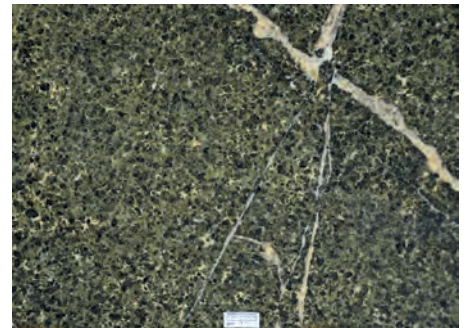




Parliament Building

Šubičeva Ulica 4, the building of the National Assembly of the Republic of Slovenia, 1958.

On the facade of the building, under the windows, there are green panels of Pohorje cizlakite. This stone is unique (endemic) to Slovenia and it is highly valued due to its beauty and rarity. It was named after the village of Cezlak near Oplotnica in Pohorje Mountains, where it was once quarried. Because of the limited quantities, the quarrying of Pohorje cizlakite has been forbidden and the quarry is now protected as a natural monument. The light-coloured trimming is made of different types of limestone from Kras (→ 4, 9, 17). The inside of the Parliament Building is a rich museum, exhibiting the most beautiful specimens of Slovenian natural stone.



Cizlakite is a coarse-grained igneous (plutonic) rock; it belongs to the group of gabbros with an increased silica content. The main minerals are the green pyroxene augite and the dark green, almost black hornblende. In between there are white plagioclases, quartz, and large grains of greyish-white potassium feldspar.



Trg Republike Square

The central and largest square in Slovenia's capital, the work of the arch. Edvard Ravnikar, built between 1961 and 1974.

Almost every inch of the square's surface is covered in Pohorje granodiorite. Facades of both towers and the Maximarket building are lined with panels, and the market is paved with granodiorite bricks and tiles from the Cezlak I quarry near Oplotnica. Due to its looks and durability, granodiorite is the most commonly used outdoor natural stone in Slovenia. Prešernov Trg Square and Mestni Trg Square are also paved with it.

Granodiorite is a grey igneous (plutonic) rock, related to granite (→ 1) with the difference that it contains more calcium and sodium feldspars (plagioclase) than potassium feldspars (orthoclase), and more dark minerals (biotite, hornblende). Pohorje granodiorite is often wrongly referred to as tonalite, which contains even more plagioclase.

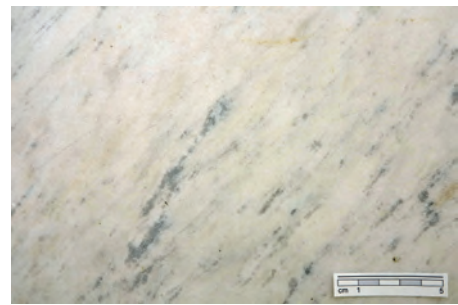
White aplite-pegmatite veins criss-cross through granodiorite. Their composition is the same as that of granite; aplite is formed by very small microcrystals, and pegmatite by very large crystals.



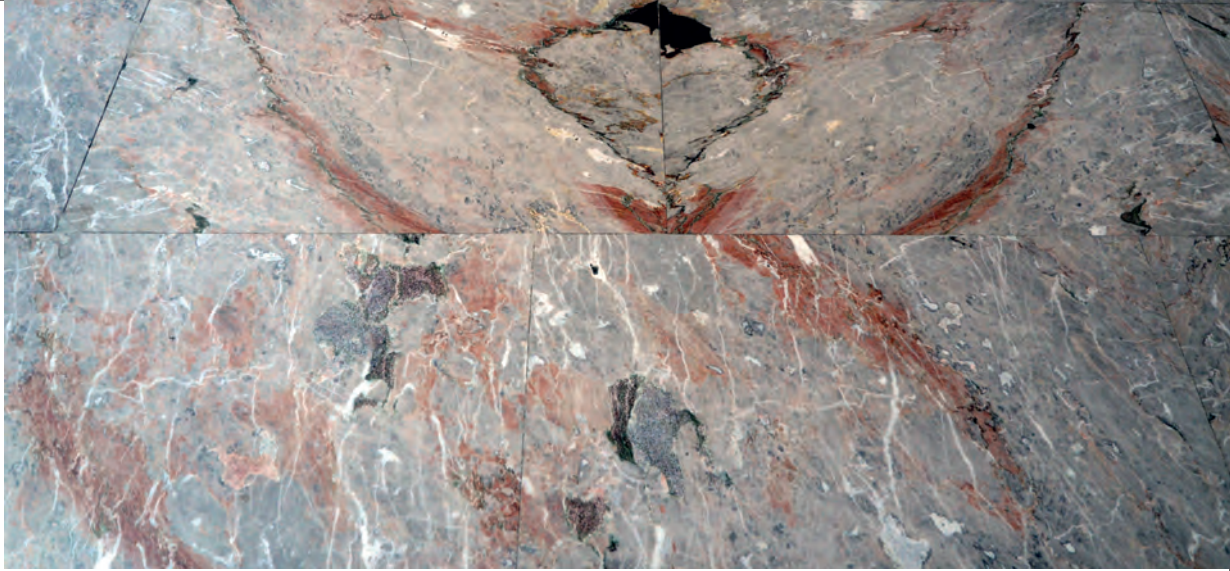
Cankarjev Dom

Erjavčeva Ulica 15, the largest culture and congress centre in Slovenia, named after the Slovenian writer Ivan Cankar, 1983.

The facade is lined with snow-white striped calcite marble from Prilep in Macedonia. In the interior of the Cankar Centre, as many as 2000 m² of surface is covered with panels of Hotavlje limestone (→ 10, 14). Grey and pink varieties of the stone were used.



Marble is a non-bedded metamorphic rock created when limestone or dolomite transform at high temperatures and pressures in Earth's crust. During the metamorphosis, calcite only recrystallizes into larger crystals, but the mineral composition remains the same. Stripes are the remains of admixtures (e.g. clay) in the original limestone.



Because it is so rich in colour, **Hotavlje limestone** is among Slovenia's most prominent ornamental stones. It was named after the village of Hotavlje under the foot of Mt. Blegoš, where limestone is still being excavated in the underground galleries of a modern quarry. Its commercial name, Hotavlje marble, is misleading, since marble is a metamorphic rock, while Hotavlje limestone is a sedimentary rock.

Hotavlje limestone is characterized by non-homogeneous texture and richly varied colour, which ranges from dark grey to grey and pink to scarlet red. The colours are further enriched by veins of reddish claystone and green tuff. Larger nests are filled with bright calcite and tiny grains of pyrite. Often, small grey, dull yellow or purple rhombohedral dolomite crystals, which formed during diagenesis, are strewn across the rock.





Makalonca Restaurant

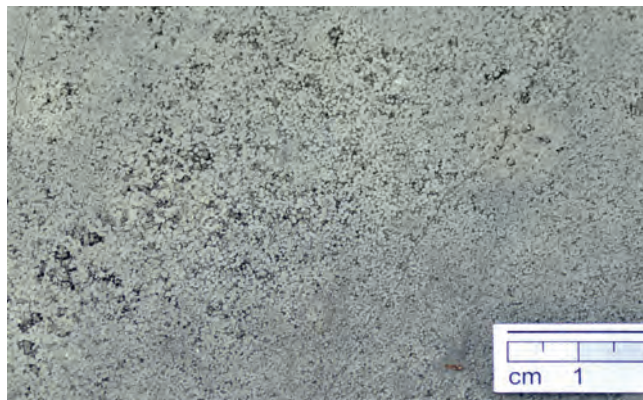
Hribarjevo Nabrežje 19, a former haven on the Ljubljanica River, which Plečnik built together with Gerber's staircase from the remnants of the banks of the Cobbler's Bridge, 1934.

Above both portals of the Makalonca Restaurant, there are a few Tarvis breccia blocks from the Karavanke Mts. Most blocks belong to Podpeč (→ 4, 13, 17) and Glinice limestone (→ 1, 11, 17). The pavement at Hribarjevo Nabrežje is made from flysch sandstone from the Poljane - Puče quarry in Slovenian Istria.

Breccia is a coarse-grained clastic sedimentary rock composed of angular fragments; it is made of older rocks that have been broken down by weathering and erosion. The colourful **Tarvis breccia** is one of the most distinctive rocks in the Karavanke Mts. It was named after the town of Tarvisio in Italy. Breccia was formed in the Middle Permian in dry desert climate. It consists of limestone rubble, which was deposited by torrential streams in alluvial fans and fan-deltas at the foot of the mountain ridge. Light grey to pink pieces are bound together with distinctive red sandy-silt matrix.



Ooid **Podpeč limestone** in the stone wall of Gerber's staircase; Ooids are very small spherical grains with smooth surfaces. A cross section reveals the structure composed of concentric coatings. Ooids are formed in very shallow, warm seas with high energy input from calcite mud, which envelops the grain while rolling on the seabed.



Bluish grey **calcareous quartz sandstone** is an integral part of a sequence of various rocks called flysch. Within the sequence, it is rhythmically interbedded with layers of marlstone and lime sandstone. Flysch was formed in the Eocene by depositions from dense sediment-laden turbidity currents at large underwater landslides in the deep sea. Sometimes, ichnofossils are visible in the sandstone – traces of crawling and burrowing, mostly made by unknown animals in the former sandy seabed.





University of Ljubljana

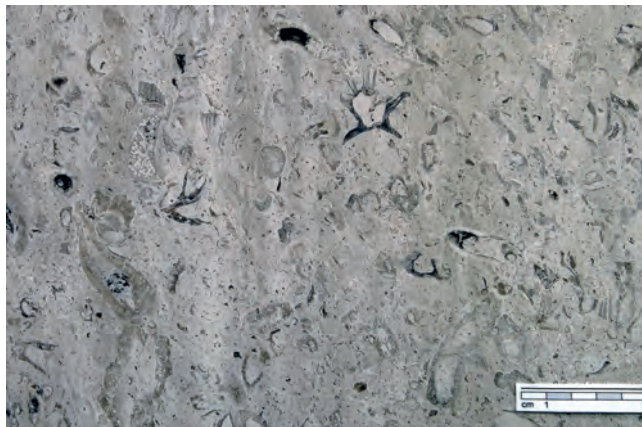
Kongresni Trg Square 12, former Carniolan provincial mansion, since 1919 seat of the University of Ljubljana, 1902.

The yard is paved with Pohorje granodiorite. The perimeter fence and columnar pedestals of statues are made of several types of Cretaceous limestone from the Kras. The statue of Europe in the middle of the garden is made of African gabbro (→ 1).

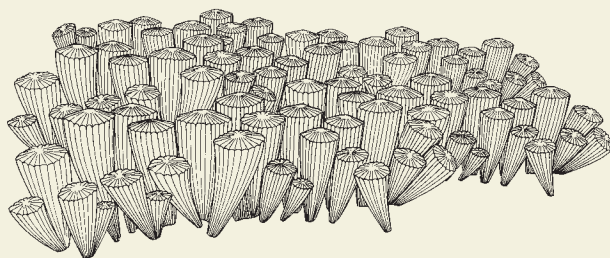
In Lipica in Kras, two different grey limestones are still being quarried; they are called “uniform” (*Lipica unito*) and “rosy” (*Lipica fiorito*) limestone. In *Lipica unito*, rudist bivalves are finely crushed and give the impression of a unified grainy rock, whilst in *Lipica fiorito*, the cross sections of whole rudists resemble flower petals. The same limestone used to be excavated in Aurisina quarries near Trieste. Lipica limestone formed in the Late Cretaceous on the shallow-marine carbonate platform in the marginal areas of the Tethys Ocean. Rudist bivalves were typical inhabitants of these areas.

Rosy Lipica limestone (*Lipica fiorito*) in the pedestal of the monument dedicated to Josip Plemelj. The white spots found in rudist bivalves are the doing of boring sponges. Typical rudist genera are *Katzeria* with ribbed shells, *Biradiolites* and *Radiolites*.

The pedestal of Jože Plečnik’s monument is made of *Lipica unito* limestone, and the pedestal of Božidar Jakac’s monument is made of Repen limestone (→ 17).



Rudists are an extinct group of bivalves, perfectly adapted to sessile life in groups. The shape of their shell resembles a cow horn. The two valves are completely different; the big conical valve was usually attached to the seabed, and the small cap-shaped upper valve served as the cover. In the Late Cretaceous, rudists ruled the shallow tropical seas, where their colonies formed rudist thickets and reefs. They went extinct at the end of the Cretaceous.



Drawing: B. Jurkovšek



NATIONAL AND UNIVERSITY LIBRARY (NUK)

Turjaška Ulica 1, one of the most recognizable works by arch. Jože Plečnik, 1936–1941.

It can be said that the NUK is a monument to **Podpeč limestone** (→ 4, 13, 17), Plečnik's favourite stone. It was used in the facade, the entrance lobby, staircase colonnade and the large lobby. The exterior is made of Podpeč limestone, mostly without the typical lithitoid bivalves. On the polished interior surfaces, however, their white cross section is a beautiful adornment to the black stone.



In the lobby's pavement and in the door portal of the Exhibition Hall, Podpeč limestone forms a colour combination with grey, pink and scarlet red Hotavlje limestone (→ 7, 14). The red color is the result of old karstification, when the drop of the sea level led to limestone being exposed on the surface. Reddish weathered limestone (*terra rossa*) filled the karst fissures and gave the rock its colour.



In many blocks of the facade, there are clearly visible traces of tectonic forces. The rock is often fractured and sometimes fault planes are visible. Fault planes are surfaces, along which displacement of adjacent tectonic blocks occur. Due to friction between the blocks, the surfaces are smoothed and often coated with a fibrous mineral coating (usually calcite). Stepped tectonic slickenlines indicate the direction of movement parallel to the fibers.

The cross sections of various large snails are common in Podpeč limestone variety without lithotid bivalves.





Križanke

The former monastery building complex of the German Knights of the Cross has been renewed several times and is now an open-air theatre, 1268–1956.

The Križanke walls are made of greenish-brown Carboniferous conglomerate and sandstone, among which there is also grey flysch sandstone (→ 8). The pedestals and pillars of the entrance portal to the inner courtyard are made of bright Glinice limestone (→ 1, 17); other parts are made of Lesno Brdo limestone (→ 15). The bottom part of the Križanke Church foundations is also made of Glinice limestone, with Lesno Brdo limestone above it.

Conglomerate is a clastic sedimentary rock that is more coarsely grained than sandstone and more roundly grained than breccia. Rounded grains or pebbles were deposited in former river beds. Most pebbles in the Carboniferous conglomerate are quartz, with rare grains of dark chert in between.

The sidewalks around Križanke and in the neighbouring Vegova Ulica are paved with reddish-brown to violet-red quartz porphyry from around Bolzano (Bozen) in South Tyrol. It formed from solidifying lava over a long period of volcanic eruptions in the Early and Middle Permian. An up to 1500 m thick lava crust covered an area of today's northern Italy larger than 2500 km².

Quartz porphyry is an igneous (volcanic) rock characterised by porphyritic texture, i.e. a reddish microcrystalline groundmass containing larger grains (phenocrysts) of grey quartz and pink feldspar (orthoclase).



Light grey Glinice limestone and black Lesno Brdo limestone in the foundations of the Križanke Church (Church of our Lady of Mercy). In Ljubljana, both stones are often used together and both have poor resistance against atmospheric agents. In Glinice limestone this is due to heavy tectonic fracturedness, whereas in Lesno Brdo limestone due to admixture of softer black marlstone.





Roman Wall in Mirje

The south wall of Emona from the 1st century BC.

The wall is mostly made of Carboniferous quartz sandstone which used to be quarried in the slopes of Castle Hill. The dark grey and yellowish brown sandstone with flakes of mica (muscovite) can grade into conglomerate (→ 11). Ancient Romans also used Glinice and Podpeč limestone, as well as karst limestone from Aurisina quarries near Trieste. The upper part of the wall, which is separated from the older wall by a line of pebbles, was renovated by the architect Jože Plečnik and built of sandstone and calcareous tufa.



The portico at the main southern gate of the Roman wall is made of colourful Škofja Loka conglomerate, which was quarried in the Kamnitnik Hill in Škofja Loka. The pillars are not ancient, but rather added by Plečnik.

Škofja Loka conglomerate formed in the Early Oligocene, when torrential streams carried coarse sediment from the edges of a subsiding basin to fill its bottom. It consists of very different types of carbonate and rare chert pebbles, which are very strongly bound by brick-red sandy-silt matrix. Most common pebbles are: grey ooid limestone and light grey dolomite of Jurassic age, dark grey and black Early Cretaceous limestone, red-brown Late Cretaceous limestone, and shale. Less common pebbles are pink Early Triassic ooid limestone.

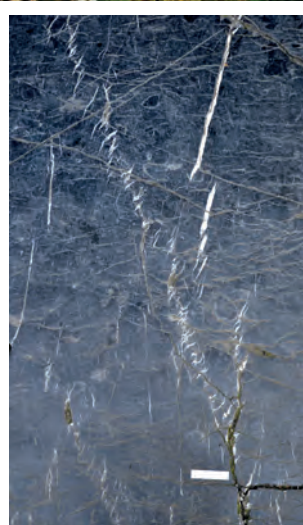
13

LEVSTIKOV TRG
SQUARE

St. Jacob's Church

The first Jesuit church in Slovenia, early Baroque, 1615.

The staircase of the main entrance portal is made of **black Lesno Brdo limestone** (→ 15) with white calcite veins; the staircase trimming is made of red-brown Bolzano porphyry (→ 11). The staircase and the linings at the side entrance are made of Cretaceous rudist limestone from Karst. In terms of the number and quality of stone baroque altars and sculptures, St. Jacob's Church is the richest church in Ljubljana.



St. Mary's Column

One of the oldest monuments in Ljubljana from the 17th century. St. Mary's statue was designed by the Slovenian polymath Johann Weikhard von Valvasor, and the column was restored by the arch. Jože Plečnik in 1938.

The column and the large pedestal are made of Podpeč limestone (→ 4, 10). In the individual panels, many variants of this limestone are visible. In addition to the most characteristic one with elongated sections of accumulated lithiotid shells, the most interesting are those with cross sections of brachiopods, gastropods, heart-shaped bivalves and oncoid limestone (→ 17).

The column contains many cross sections of terebratulid brachiopods approximately 1 cm in size. Brachiopods are marine animals with two valves. They resemble bivalves but they differ from them in that the two brachiopods' valves differ in form and size, and the left half of each valve is symmetrical to the right. Brachiopods exist since the Cambrian. While over 30,000 fossil species have been discovered, we only know of about 350 living species.

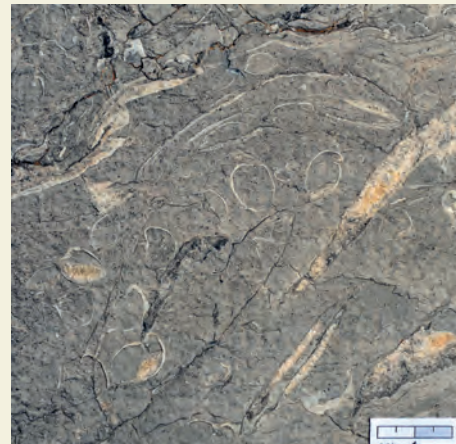
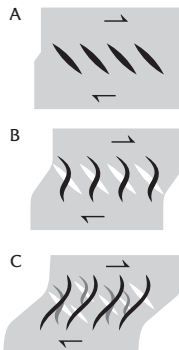
Inside the smaller brachial valve, a spirally coiled brachial apparatus is attached – its function is to support the ciliated feeding organ. Through the larger pedicle valve, a pedicle ("stalk") protrudes and is used to attach to a surface.

The Popular science monthly (1887)



White calcite veins in the Lesno Brdo limestone pavement in front of the main entrance to the Church. Veins are cracks filled with minerals. A shear-type tectonic deformation usually results in an array of parallel veins at an angle of 45° in relation to the shear zone. Further deformation leads to the rotation of veins in the direction of the shear, which is why their ends are bent. New cracks keep appearing perpendicularly to the direction of maximum extension. The result is a network of differently old veins.

Drawing: S. Mozetič





Ljubljana Castle

A medieval fortress on Castle Hill from 1200. Reconstructed and renovated several times by 2005.

The castle building and the fortress against the Turks (Šance) are made of Carboniferous clastic rocks; dark grey quartz sandstone and, more rarely, conglomerate and claystone. The remains of the Roman Emona were also used in construction, which explains the blocks of dark Podpeč limestone.



Most window and door frames are made of light grey Quaternary conglomerate. It differs from the older Carboniferous conglomerate (→ 11) in that it contains mostly limestone pebbles in a colourful sandy-marlstone matrix. It was quarried between Radovljica and Medvode.



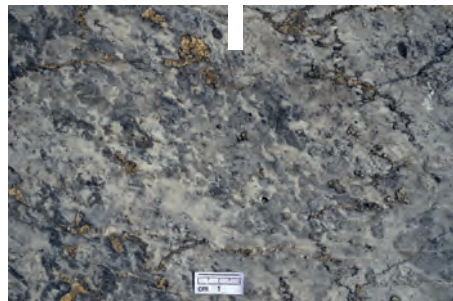
At the top of the lookout tower is a wide columnar fence made of grey Hotavljje limestone (→ 7, 10).

Hotavljje limestone formed in Late Triassic on a reef similar to today's coral reefs. The proof are numerous shallow-marine reef-building organisms found in the stone: sponges (pictured), corals, spines of sea urchins, crusty coatings of cyanobacteria, and rarely molluscs.

The stone benches next to the old fountain (built of Glinice limestone) in the castle garden are also made of grey Hotavljje limestone. On the surface, there is a large clump of coral.



A typical ring-like weathering structure in sandstone. Iron oxide minerals concentrate in dark brown concentric rings. The weathered areas of dark grey sandstone become yellowish brown.



On top of Castle Hill, there are layers of **Upper Carboniferous shale**, which give a special ambient charm to some castle rooms. While constructing the funicular, fossils of plants have been discovered in those layers. At the upper station of the funicular, specimens of tree ferns (*Calamites*, *Lepidodendron*, *Sigillaria*) and gymnosperms (*Neuropteris*, *Linopteris*, *Trigonocarpus*, *Cordaite*) are exhibited. They originate from Upper Carboniferous layers in the Sava Folds between Ljubljana and Litija. They formed in the swamp forest along the wide river delta. Claystone is the most finely grained clastic sedimentary rock formed by solidification of clay.





Cathedral of St. Nicholas

Ciril-Metodov Trg (Cyril and Methodius Square), the most important Baroque church in Ljubljana by arch. Andrea Pozzo, 1706.

The socle of the cathedral and the portal of the main gate are made of black Lesno Brdo limestone. The socle is partly built with blocks of more lightly coloured Glinice limestone (→ 1, 17). The small pillars in front of the church are made of the brecciated variety of this stone. The statues of saints in the outer niches of the cathedral are made of **Moravče sandstone**. This is a light-coloured, green to yellow-grey Miocene quartz sandstone from around Moravče.





Seminary Palace

Dolničarjeva Ulica 4, Baroque building by arch. Carlo Martinuzzi, 1714.

The entrance portal to the seminary with its two stone giants is made of **black Lesno Brdo limestone**. It was quarried in several quarries between Drenov Grič and Lesno Brdo, after which it is named. It left a huge mark on Slovenian architecture, especially in the Baroque period.

Lesno Brdo limestone is distinguished by its uniform black colour, which is enlivened by numerous white calcite veins. It formed in the shallow lagoon environment in the Late Triassic (Carnian) and it often contains numerous fossils. The most common are bivalves *Trigonodus carniolicus* and *Myophoria kefersteini*, and snails.



A typical Lesno Brdo limestone appearance revealing its poor durability. Interlayers of the softer black marlstone (sedimentary rock made from clay and calcium carbonate) are less resistant to weathering and cause rock decomposition.



PLEČNIK'S MARKET HALLS

Adamič-Lundrovo Nabrežje Quay, one of the most beautiful covered food markets in Europe, by arch. Jože Plečnik, 1940.

In the arcades of Plečnik's trade market, between blocks of grey Podpeč limestone (→ 4, 10, 17), blocks of pinkish-grey and yellowish Škofja Loka platy limestone stand out. This limestone was excavated in a number of quarries south of Škofja Loka.



Škofja Loka limestone is most easily recognizable by nodules and thin layers of black chert. The limestone formed in Early Jurassic at the margin of a deep-marine trench. Chert nodules in it were created by silica concentrations during diagenesis (changes in the already solid rock).

Robba Fountain

Baroque Fountain of the Three Carniolan Rivers (Ljubljana, Krka and Sava) by sculptor Francesco Robba, 1751. In 2006, the original was replaced by a replica and has since been stored in the National Gallery.

The fountain is made of three types of stone. The figures are made from Carrara marble (→ 7), which has been quarried continuously for over 2,000 years. Quarries north of the city of Carrara in Tuscany have already been exploited by the Etruscans, but today, they span the surface of as many as 67 km² and encompass approximately 200 open pits and 50 underground mines.

The obelisk above the fountain is made of pink Lesno Brdo limestone, while the bowl of the fountain, the stairs and the columns are made of grey Lesno Brdo limestone.

Due to its homogeneity and exceptional purity (it is formed almost exclusively from calcium carbonate without impurities), **Carrara marble** is one of the most well-known and prized natural stones. This snow-white to pale blue coarse-crystalline Italian marble was used to build many buildings of major importance (eg. the Roman Pantheon) and sculptures (like Michelangelo's David).



In addition to black Lesno Brdo limestone (→ 13, 15), **variegated Lesno Brdo limestone** is still being quarried near Lesno Brdo. This pink and grey type of limestone is slightly older than black limestone; it formed in the same age and a shallow reef environment as Hotavlje limestone (→ 7, 10, 14). It is very difficult to distinguish limestones from the two sites, the only exception being the scarlet red variety, which can only be found in Hotavlje.



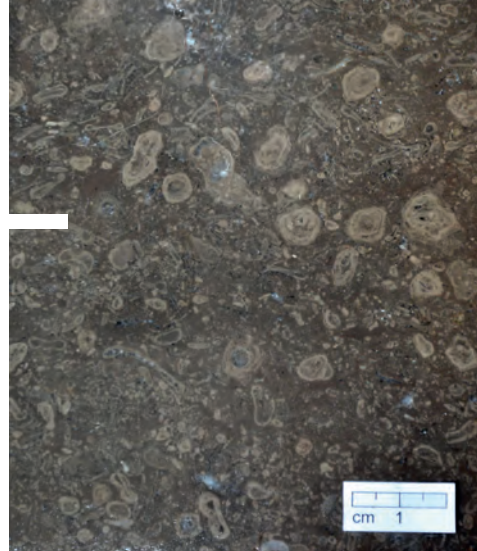


Town Hall

Building from 1484, reconstructed in Baroque style by architect Gregor Mašek in 1718.

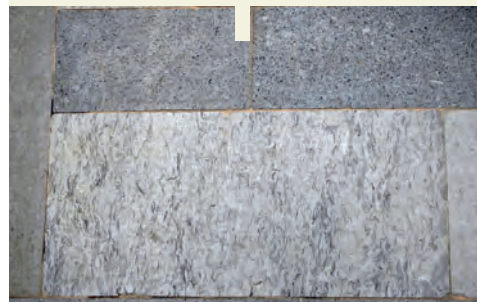
The Town Hall is a veritable museum of Slovenian stone. The staircase is made of Podpeč limestone (→ 4, 10, 13), in some areas with an accumulation of lithotid shells. Podpeč limestone is also present in the arcade balcony, where it is combined with black Lesno Brdo limestone (→ 15).

Several pavers are made of oncoïd Podpeč limestone; oncoïds are spherical lumps of different sizes. A cross section reveals that irregular concentric coatings are wrapped around a central nucleus, which can be a tiny foraminifer, small snail, shell fragment or some other sediment grain. Similar to oncoïds are the ooids (→ 8); they differ in size and shape (ooids are smaller, of the same size, spherical and smooth). Oncoïds are formed in very shallow, warm seas with high energy input from organic coatings of cyanobacteria or algae that envelop grains and attach carbonate mud. Oncoïds can reach the size of several centimetres.



The main courtyard area is paved and lined with light grey *Lipica unito* and *Lipica fiorito* limestones (→ 9) as well as dark-grey Cretaceous limestone from Kopriva in Kras with fragmented rudist shells and darker grains.

The pillars of the inner arcaded courtyard, wall-edge and window-frame ornaments, and dark grey and brownish pavement panels are all made of **Podpeč limestone** in combination with different types of light-coloured karst limestone (→ 4, 9). Some have beautiful cross sections of conical snail houses (pictured), small brachiopods and bivalves.

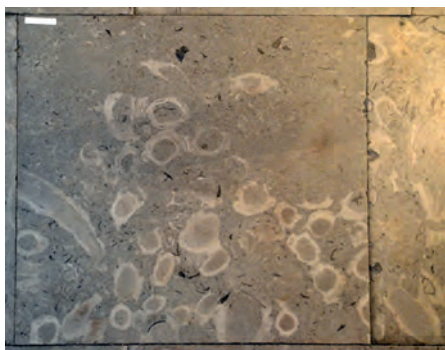




The figure on the Narcissus Fountain (by F. Robba) in the arcade atrium is made of white marble from Zreče on Pohorje Mts., the trees and rocks are made of pink Lesno Brdo limestone, while the base is built of black Podpeč limestone. A few panels in the pavement in front of the fountain are made of Peračica tuff (→ 3). The fountain in the middle of the atrium is made of Glinice limestone.

The pavement in the left, Historic Atrium is made of light-grey **Repen limestone** with numerous cross sections of very large rudist bivalves (→ 9) and thin black shells of chondrodont bivalves. Most rudists belong to the Caprinidae family.

Repen limestone is very fine grained and high quality karst stone, which is why it is most often used besides the Lipica limestone. It is excavated in several quarries between Monrupino in Italy, and Sežana and Divača in Slovenia.



Caprinids are a family of rudists with thick shells with narrow longitudinal channels. They lived in shallow rough seas. After dying, water currents swept them into deeper sea, where Repen limestone formed.

Sketch: B. Jurkovšek



Souvan House

Mestni Trg Square 24, Baroque house from the late 17th century, reconstructed in Biedermeier style by architect Francesco Coconi in 1827.

The large entrance portal is made of **Glinice limestone** (→ 1, 17); in both ribbed pillars, the cockade texture is clearly visible. It was named after the interchanging of differently coloured crystal rings, which resembles cockades – concentric symbols or ribbons.

Cockade texture is the result of calcite secretion in former small karstic cavities. White calcite was secreted from a pure calcium carbonate solution, but if the solution contained more iron oxides, the calcite ring turned red.



A geological tour of Ljubljana – Natural stone in cultural monuments
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Cover photo: Late Baroque portal from Glinice limestone at the southern wall of Križanke.

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EON	ERA	PERIOD	EPOCH	AGE (million years)	SLOVENIAN NATURAL STONE	FOREIGN NATURAL STONE
PHANEROZOIC	CENOZOIC	QUATERNARY	HOLOCENE	0.01	Jezersko calcareous tufa	
			PLEISTOCENE	2.6	Quaternary conglomerate	
		NEOGENE	PLIOCENE	5.3	Moravče sandstone Pohorje granodiorite Pohorje cizlakite	Lithothamnian limestone, CRO
			MIOCENE	23		
		PALEOGENE	OLIGOCENE	34	Peračica tuff Škofja Loka conglomerate Istrian flysch sandstone	Nummulitic limestone, CRO
			EOCENE	56		
			PALEOCENE	66		
	MESOZOIC	CRETACEOUS	UPPER	101	Lipica limestone Repen and Kopriva lms.	Aurisina limestone, IT and Rasotica limestone, CRO
			LOWER	145		
		JURASSIC	UPPER	163	Podpeč limestone Glinice limestone Škofja Loka platy limestone Black Lesno Brdo limestone Variegated Lesno Brdo lms. and Hotavlje limestone	Rosso Ammonitico lms., IT
			MIDDLE	174		
			LOWER	201		Carrara marble, IT
		TRIASSIC	UPPER	237		Jablanica gabbro, BIH
			MIDDLE	247		
		LOWER	252			
	PALEOZOIC	PERMIAN	UPPER	260	Tarvis breccia	Bolzano quartz porphyry, IT Baveno granite, IT(?)
			MIDDLE	272		
			LOWER	299		
		CARBONIFEROUS	UPPER	323	Carboniferous sandstone, conglomerate and claystone	
			LOWER	359		
		DEVONIAN		419		
		SILURIAN		443		
		ORDOVICIAN		485		
		CAMBRIAN		541		
PRECAMBRIAN	PROTEROZOIC			2500	Pohorje marble	Prilep marble, MAC
	ARCHEAN			4000		

The streets of Ljubljana are a unique geological museum in the open. Most important cultural monuments were built or decorated with natural stone. Ever since the ancient times, natural stone has been used to construct buildings, monuments and fountains. By combining stones of various colours, the prestigious character of buildings is emphasized.

Natural (architectural and ornamental) stone is the most authentic connection between geology on one hand, and archaeology, architecture and art history at the other, i.e. a connection between natural and cultural heritage. Elaborate patterns in rocks, an example of nature's artistic expression, can easily compete with human artistic masterpieces.

We tore the stone from our mountains, our hands formed and smoothed it: saxa loquuntur (*rocks speak*). –
Architect Jože Plečnik, 1926



Mestna občina
Ljubljana

LJUBLJANA.
Zate.