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REGIONE AUTONOMA FRIULI VENEZIA GIULIA

Comune di Monrupino
Občina Repentabor

I FOSSILI DEL CARSO
FOSILI NA KRASU
(FOSSILS OF THE CARSO)

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THE EXHIBITION AND BACKGROUND NOTES

by: Curiosi di natura – Soc. coop.

The Carso and its structure

THE ORIGINS

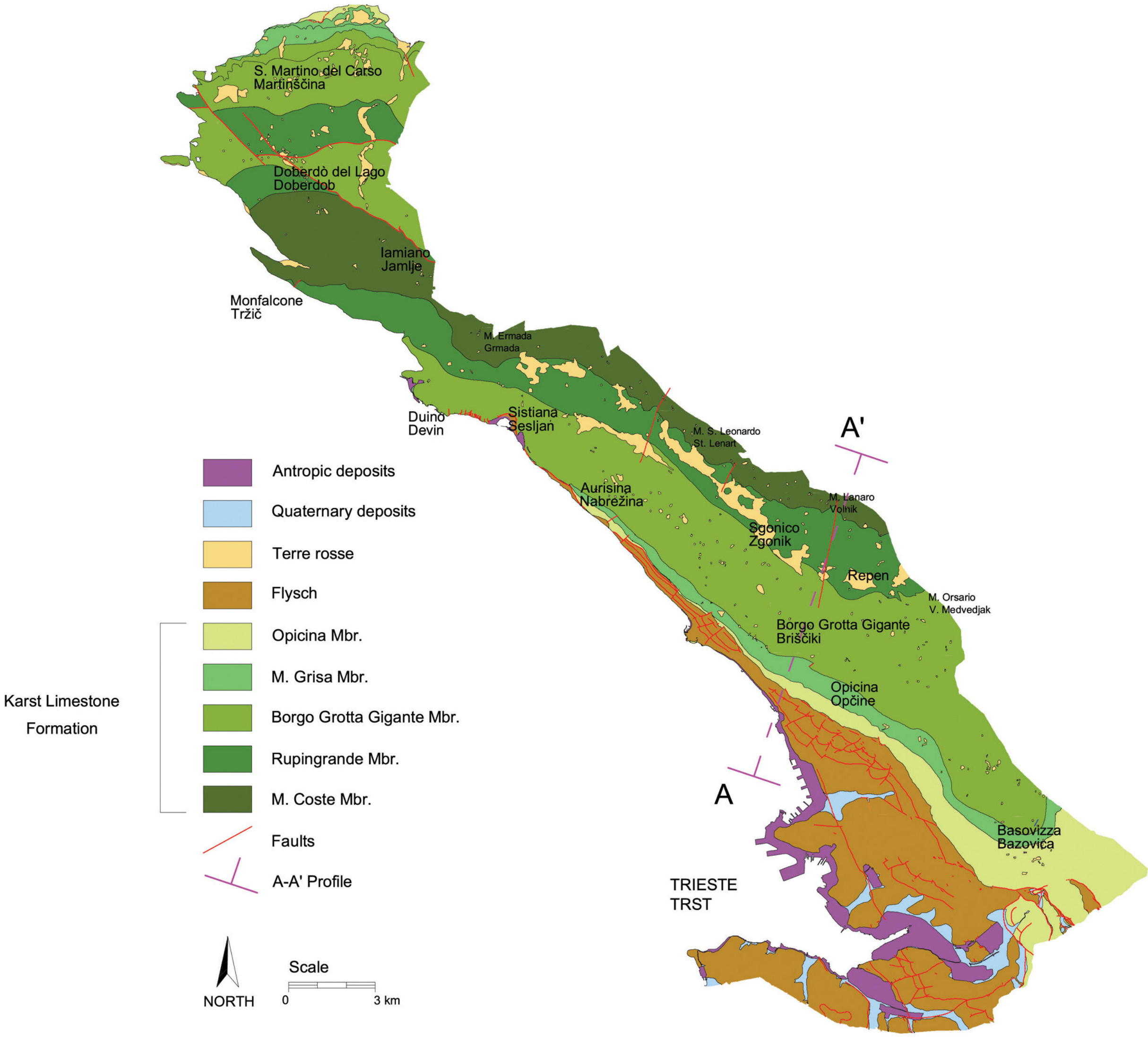
When walking in the Carso, you may not realise that you are actually treading on a “floor” of rocks that formed at the bottom of the sea between 110 and 50 million years ago. Such rocks are known as “sedimentary” rocks because they are made up of sediment particles - for example, shells or skeletons of dead organisms and calcite crystals - which once blanketed the seafloor of certain marine environments (called *“carbonate platform”*).

At the time, the appearance or texture of what are now hard rocks was that of a loose, soft sediment, like the sand of a river bed or a beach or like the mud that lies at the bottom of the sea.

The shallow and warm waters were rich in oxygen and dissolved salts (carbonates or sodium chloride) and harboured organisms like corals, sponges, molluscs, and calcareous algae, with shells or skeletons made of a mineral composed of calcium carbonate, *calcite*.

But how did this loose and soft *carbonate sediment* become a hard calcareous rock? As the sediment deposited, it was gradually buried under other layers of sediment, and in the process it underwent a series of physical and chemical changes (increase in temperature and pressure, dissolution of minerals, cementation by the minerals dissolved in the water…) which, through time, turned it into proper rock.

Thin section of a carbonate rock
(the larger oval entities are foraminifera)



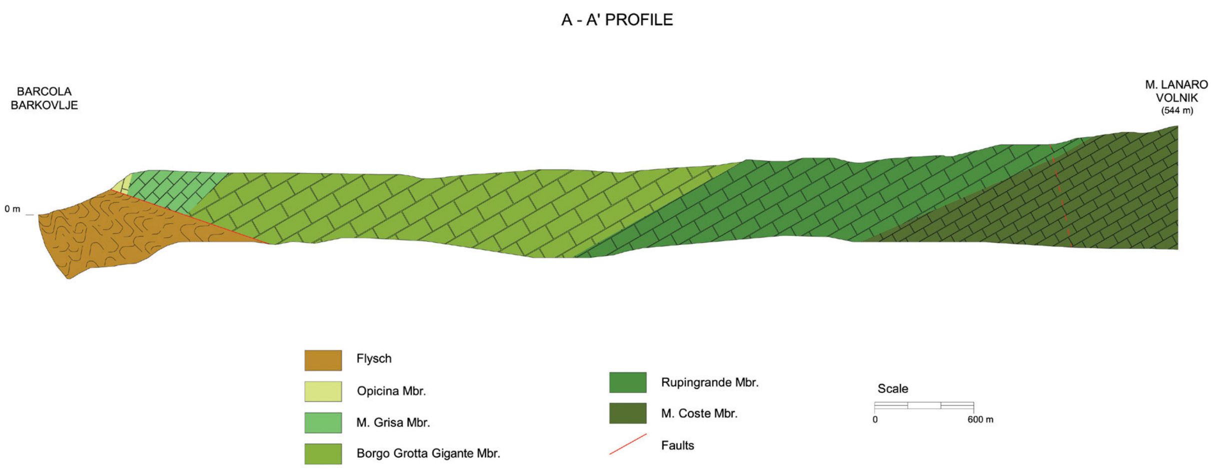
Geological map of the Carso

Credits: University of Trieste

Geological section of the Trieste Carso between Barcola and Mount Lanaro

(the location of the section is shown on the geological map)

Credits: University of Trieste



The sequence of rock layers was folded with the concave surface facing downwards (anticlinal); so the older rocks are now found in the innermost portion or core of the fold. Erosion then flattened the fold, uncovering even the oldest layers.

FROM SEA FLOOR TO DRY LAND

So, over the course of geological time, that is, a very very long time, marine sediments became rocks. These rocks were then pushed up until they emerged from the water.

This happened as a result of the collision between the continents, which drift like huge rafts on the earth's surface. The forces generated by this collision (*tectonic thrust*) deformed and raised the rocks originally lying at the bottom of the sea, and piled them up for thousands of metres.

The uplift was accompanied by a process of erosion and disintegration caused by water, wind and ice, which deeply affected the original arrangement of rock layers, sculpting and moulding them into a varied and diverse landscape.

As the continents collided, mountain chains formed at the edges of that ocean basin. The rivers that flowed down from the mountains carried large amounts of silt and mud, which made the sea water turbid and caused the death of the organisms that lived in the carbonate platform.

Over millions of years these sediments too turned into rocks, giving rise to Flysch, a rock formationconsisting of alternating sequences of two *lithotypes*, marls and sandstone, both of which have very different characteristics from limestone.

As a result of tectonic uplift in the Carso, Flysch, the last rock layer to be deposited, now lies beneath the limestone and no longer on top of it as it did when it was still a seafloor sediment. The reason for this is that, during one of the various phases of deformation of the Carso rocks, the limestone, the oldest component, "slid" over the younger Flysch, as can be seen in the coastal area where the layers of Flysch lie underneath the limestone.

THE VARIOUS TYPES OF CARBONATE ROCKS

Not all carbonate rocks are the same. If you observe the rocks carefully you will see that some of them have a fine and uniform grain or *texture*, like mud: these are known as *mud-supported carbonates*. *Grain-supported carbonates*, on the other hand, are made up of large particles of varying size. The seafloor in fact contained both mud and sand, with organisms of different size, so the rock is nothing but a fossil "photograph" of the ancient marine environment.

According to their characteristics (colour, lithological composition, fossil types, layer thickness, etc.), rock layers can be divided into groups, known as *formations and members* (Mb).

Rock formations and members are named after a town, a mountain or a locality where the formation or member is particularly well exposed.

These classifications are used by geologists to produce geological maps (like the one on this poster), in which the geological features of an area can be displayed graphically.

Carbonate breccia
(the angular fragments making up the breccia are clearly shown in the photo)

The Carbonate Formation of the Carso of Trieste is divided into the following five members, listed from the oldest to the youngest:

Mount Coste Member (lower Cretaceous, in part): mud-supported limestones with a layer thickness of approximately 10 cm, dark grey to black with rare fossils (rudists). The limestone layers are overlain by dolostone, a type of rock mainly composed of the mineral dolomite (double carbonate of calcium and magnesium) and carbonate breccias, that is, rocks made up of more-or-less rough and angular fragments of other rocks that have been cemented together.

Rupingrande Member (early Cenomanian to early Turonian): limestone-dolostone breccias at the base. These are overlain by light grey to blackish dolostones arranged in decimetric to metric layers, followed by layers of limestone and dolostone containing rudists.

Borgo Grotta Gigante Member (Turonian, in part, to Maastrichtian): prevalence of light to dark grey grain-supported limestones arranged in thick layers (even over one metre). A special feature of this member is the abundance of rudists.

Mount Grisa Member (Paleocene, in part): dark brown to black mud-supported limestones arranged in decimetric layers and rich in fossils of foraminifera, marine micro-organisms that typically have a mineralised shell and can sometimes grow to a very large size (up to 11-14 cm in length).

Opicina Member (lower Eocene, in part): light grey grain-supported limestones, very rich in foraminifera, arranged in decimetric-metric layers and overlain by very muddy limestones. The foraminifera are easily identified, for example in the limestone along the Strada Napoleonica (Prosecco), where the rocks appear studded with white fossils resembling grains of rice.

"The Carbonate Formation of the Carso of Trieste" [Cucchi F., Pirini Radrizzani C. & Pugliese N. (1987): "The carbonate stratigraphic sequence of the karst of Trieste (Italy)", Mem. Soc. Geol. It., 40, 35-44, Roma].

Fossils and the original environment

THE ORIGINAL ENVIRONMENT

Fossils are remains or sometimes only traces of animals and plants of past geological times. They are the “documents” that form the basis of palaeontology, the science that studies the life of the past.

Most living beings, when they die, slowly disappear without leaving any trace. For an organism to become a fossil, it must protected from decay and its remains must not be dismembered and dispersed by atmospheric agents (water or wind …). This generally happens when its body is covered by sediment, in which it becomes “trapped” and therefore “preserved”.

Fossils can be found buried and preserved inside sedimentary rocks, that is, rocks composed of sediments: grains of sand, mud, fragments of rock, but also animal shells and skeletons.

By studying fossils we can reconstruct the environment of the past: where the Carso lies today, between 100 and 50 million years ago was a sea with warm, shallow, oxygen-rich waters, an environment similar to today’s tropics. These conditions promoted the development of different forms of animal and plant life, including corals, molluscs and sea urchins.

Many of these organisms have shells or skeletons composed of calcium carbonate. When the animal died, these shells or skeletons sank to the bottom of the sea where, over the course of millions of years, they gave rise to extensive fossil deposits.

Some organisms were mobile; others lived attached to the sea floor and grouped in colonies of millions of individuals. These animals had calcareous skeletons which, as the colonies expanded, formed natural reefs, like coral reefs.

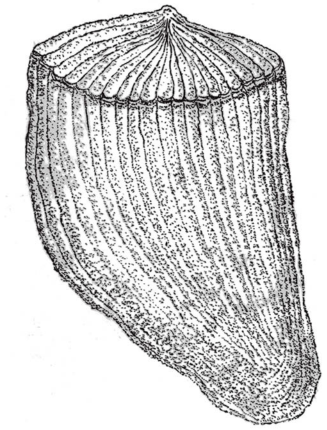
Beyond these barriers, which might stretch over large distances and reach several hundred metres in height, lagoons formed that were connected with the open sea by channels through which the tides flowed in and out (called “tidal channels”).

As the reefs grew taller, the sea floor sank, so the conditions of life in the sea and the variety of natural habitats remained virtually unchanged over time. This process resulted in the formation of very large, uniform deposits of fossils.

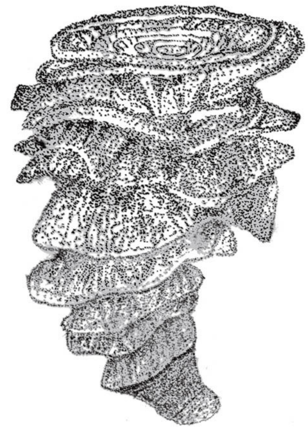
The waves and the tides would break off fragments of the reef, and the tides transported the detritus and the organisms not anchored to the sea floor into the lagoons, accumulating them where the currents were weakest. These deposits then became cemented by the calcium carbonate contained in the water in the form of a dissolved salt.

The transformation of these marine sediments gave rise to the rocks that now make up the Trieste Carso. The area included in the municipalities of Monrupino-Repentabor and Sgonico-

Zgonik is almost entirely made up of limestones and dolostones that were deposited in marine environments between 100 and 50 million years ago.



Hippuritidae



Radiolitidae

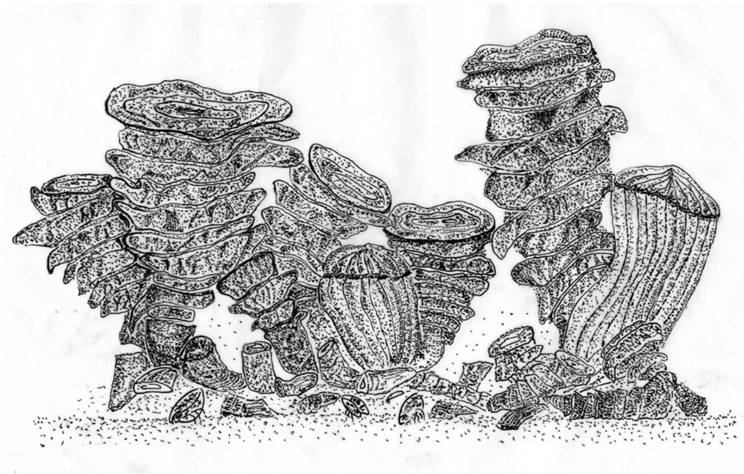
THE FOSSILS

The most typical fossil of the Carso – now extinct for 65 million years – is the rudist, a bivalve mollusc that had one very elongated, conical valve and the other one almost flat, the operculum. The larger valve was fixed to the sea floor, whereas the other acted as a “lid” which, by opening and closing, allowed sea water to enter and the mollusc to catch its food.

Among the rudists was a thicker and stronger variety (*Hippuritidae*), similar to a cow-horn, and better suited to resist to the force of the waves, and another with a thinner shell (*Radiolitidae*), which preferred the quieter environment of the lagoon.

The sea currents transported shell fragments through the tidal channels and deposited them where the waters were calmer. Rudist colonies developed on these deposits. The first individuals in the colony arranged themselves horizontally because of the sea currents; then other individuals would settle vertically on top of them, forming bunches or *bouquets*. At that time rudists, which ranged in size from a few dozen centimetres to over half a metre, were the main reef-builders, unlike today when reefs are predominantly built by corals.

The large gastropods (*Nerineids* and *Acteonellids*), which crawl along the sea floor, preferred quiet waters and lived at the outlet of the tidal channels and inside the lagoons where the current was constant and not too strong.



Reconstruction of a rudist colony

COLOURED FOSSILS

Fossils do not normally preserve the original colour of the living organism because of oxidation and the action of the sun which tends to discolour exposed parts. Their colour, however, provides clues about the kind of environment the organisms lived in or about the way they became fossilized.

For example, coloured fossils are common in grey limestone, typical of an original environment that was poor in oxygen. Gastropods are only coloured on their ventral surface, which indicates that they became fossilized in the same position as when they were alive, since the atmospheric agents progressively discoloured the other parts that were not protected.

Fossil gastropods with their original colour

Many gastropod shells found around Monrupino have preserved their original colour. Some shells show different designs and patterns: wavy or zig-zag lines, small triangles or spots, or one or more transverse bands. Colours varied from ochre to reddish to brownish, and the colouring largely depended on the type of food the gastropod had access to.

For all these reasons, once a fossil has been found it needs to be immediately protected from oxidation and sunlight, otherwise its colour will tend to fade.

Also, it's important to know that all fossils, regardless of size, are considered palaeontologic heritage and property of the State, and that any activity dealing with fossils is regulated by the law.

Stone with rudists

NOT ONLY FOSSILS

A close look at some of the rocks of the Carso will reveal small dark spheres, one or two millimetres in diameter: these are ooliths. Viewed through the microscope they show an onion-like structure, with a central nucleus (which might be a grain of sand, a shell fragment, a pellet of organic material…), surrounded by concentric layers of carbonate. Ooliths developed in marine settings characterised by shallow water and strong currents, especially tidal currents.

The original nuclei were carried by the tide from cold-water areas to areas where the water was warmer and rich in calcium carbonate, which precipitated in even layers around the nucleus. The process repeated itself with each tide, leaving the ooliths a little larger each time.

GLOSSARY

Gastropods: class of molluscs that live on land, in fresh water and especially in the sea. They have a shell composed of a single valve and a very thick foot with a flat sole for crawling. Gastropods comprise snails, slugs and several marine animals known for their shells.

Bivalves: molluscs with a body enclosed in a shell consisting of two valves (from the Latin *bi* and *valvae–arum* 'wings of the door'), connected to each other by ligaments. Mussels and clams are examples of bivalves.

Corals: tiny animals belonging to the *phylum* of Coelenterates. They have a soft body, but produce a hard skeleton made of carbonate calcium. They live in colonies of millions of individuals and their skeletons give rise to coral reefs. Corals live under water, but in shallow water, because they harbour within their tissue unicellular plants that require light for photosynthesis.

THE CARBONATE PLATFORM

“Carbonate platform” is a general term used to denote a thick sequence of carbonate sediments that has formed in shallow seawater. Although carbonate platforms may develop in a range of contexts, the environmental conditions suitable for their survival are narrower.

Under ideal environmental conditions a carbonate platform is a delicate, efficient and productive ecosystem, but it becomes very fragile if these conditions change. Because of their close relationship to the biological world, carbonates prefer the warm, clear and sunlit waters of tropical seas, where they live at a maximum depth of a few dozen metres. Further important parameters are water clarity and salinity, which explains why virtually none of the *carbonate depositional systems* is found close to the mouths of large rivers.

In oceans and tropical or subtropical seas, two different environmental conditions exist where the deposition of carbonate sediments is extensive and massive:

- shallow waters, characterised by a high rate of sedimentation (around 100 cm in 1000 years);
- deep waters, where the sediments build up gradually (around 10 cm in 1000 years) by decantation (that is, the slow settling of particles through the water column down to the sea bed) of the calcareous plankton contained in the superficial waters of oceans.

The rate of production of carbonate sediment remains practically constant up to a depth of 10-15 m; below that level the rate decreases rapidly at first and then more slowly.

The factors that control the production and dissolution of carbonate sediment are the concentration of carbon dioxide (Co_2), pressure, the temperature of the water and the sunlight that filters into the sea.

The Trieste coastline
composed of carbonate sediment

DOLOMITIZATION

Dolomieu, a small village near Grenoble, is the origin of the name given to dolomite, a mineral composed of double carbonate of calcium and magnesium. In fact, in 1791 the French naturalist Deodat de Dolomieu was the first to describe a *dolomitic* rock or *dolostone*, that is, a rock composed mainly of the mineral dolomite. The interest in these rocks has increased considerably over the past 50 years, both because dolostones make up a large part of the exposed sedimentary rocks worldwide and because of their importance for the economy (as the major reservoirs of hydrocarbons).

Dolomitization is the process whereby a calcareous rock (carbonate rock mainly consisting of the mineral *calcite*, which is made up of calcium carbonate) turns into dolostone (carbonate rock mainly composed of the mineral dolomite).

Dolomite, which is characterised by an orderly arranged crystalline structure, does not form, apparently at least, in present-day carbonate platforms. Researchers have synthesised it in the laboratory but under controlled conditions of very high pressure of carbon dioxide and very high temperature, conditions that do not exist on the earth's surface. It is therefore believed that the majority of ancient and modern dolostones are the result of the transformation of a pre-existing carbonate sediment, and that a only negligible amount of dolostone is primary, that is, formed by direct precipitation from water.

So most dolostones are thought to have originated from the replacement of magnesium with calcium, a process that took a very long time, whether the sediment was still loose or already *lithified* (turned to stone). This replacement occurs through the dissolution of calcium carbonate and the simultaneous precipitation of dolomite from an aqueous solution through the loose or solid sediment.

Knowledge about recent dolomitization processes and studies on ancient dolomite sequences allow us to distinguish between early dolomitization (*syndepositional*), occurring at the same time as the loose carbonate sediments deposited on the platform, and late dolomitization, which occurred after the sediment had solidified.

Late dolomitization obliterates the original texture of the rock and its fossils, and generally produces coarse crystalline dolostones.

Often only a portion of the rock undergoes dolomitization, but in some cases the process may affect the entire rock.

Dolostone textures are as many and varied as are the process of dolomitization. As a very general rule, replacement dolostones are mosaics of crystals having more or less the same size.

Dolomitic rocks are normally much more porous than calcareous rocks because the dolomitization process tends to generate and preserve porous spaces owing to the larger ionic radius of the calcium ion relative to the magnesium ion. The dolomite outcrops of the Trieste Carso are generally crystalline, coarse-grained and fairly porous.

To summarise, dolomitization is frequently a "destructive" process that alters the original constituents of rocks turning them into porous crystalline mosaics (and the largest reservoirs of oil worldwide).

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Credits cartography: University of Trieste

Geological map of the Carso (based on surveys by DiSGAM – University of Trieste, Agreement with R.A.F.V.G., Ref. no. 8504/2005 for the production of a Geological Map (Geo - CGT) at scale 1:10,000.

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Photos: Barbara Bassi, Giovanna Burelli

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