

Basic GIS mapping of natural building stone and aggregate deposits in Croatia

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FACULTY OF MINING, GEOLOGY AND PETROLEUM ENGINEERING
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**BASIC GIS MAPPING OF NATURAL BUILDING STONE AND
AGGREGATE DEPOSITS IN CROATIA**

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OSNOVNO MAPIRANJE ARHITEKTONSKO-GRAĐEVNOG I TEHNIČKO-GRAĐEVNOG KAMENA U HRVATSKOJ U GIS TEHNOLOGIJI

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Sažetak

U ovom završnom radu opisane su karakteristike i vrste mineralnih sirovina te je prikazano mapiranje tih polja u geografskom informacijskom sustavu. Poseban naglasak je dan na ležištima arhitektonsko-građevnog i tehničko-građevnog kamena te je objašnjena njihova podjela, upotreba i ležišta u Hrvatskoj. Napravljena je analiza aktivnih i neaktivnih eksploatacijskih polja mineralnih sirovina u Hrvatskoj po broju i tipu. Objasnjeno je što su geografski informacijski sustavi i koja je njihova uloga te je kroz nekoliko primjera pokazana primjena QGIS softwera u geologiji i rudarstvu. Prikazani su koraci pri mapiranju i dane su preporuke za poboljšanje baze podataka što bi rezultiralo većim mogućnostima mapiranja.

Ključne riječi: Geografski informacijski sustav (GIS), arhitektonsko-građevni kamen, tehničko-građevni kamen, ležišta

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1. INTRODUCTION

Mining is a branch of the economy that supplies raw materials to many industrial activities, and includes work on exploration, extraction and processing of mineral resources. Mining in a broader sense also includes the construction of underground rooms and tunnels especially in cases where these works are performed with the use of blasting and other mining procedures. Exploration of mineral raw materials includes works and tests whose purpose is to determine the existence, position and shape of deposits of raw materials, their quality and quantity, and conditions of the exploitation field. Mining works include design, economics and organization, mining measurements, transport and export, environmental protection and ore restoration (Vujec, 1996).

Main goal of this thesis is to present what mineral raw materials are, what their usage is and where they can be found in Croatia. It will explain what Geographic Information Systems are, how to use it and in which purpose. In addition, few active pits of natural building stone and aggregate from Croatia will be mapped in QGIS software.

2. MINERAL RAW MATERIALS

The basic regulation in Croatia concerning mineral raw materials is the Mining Act. It determines the exploration and exploitation of mineral resources located in “*the country or on its surface, on the river, lake or sea floor or below it in the internal sea waters or territorial sea of the Republic of Croatia or in the continental shelf of the Republic of Croatia.*” (Mining Act, 2019).

It is necessary to emphasize the difference between two terms:

- **mineral resources** are concentrations of minerals in the Earth’s crust that can be extracted and processed now or in the future, including unidentified sources or unexplored areas or those that are not currently of interest or are unprofitable
- **mineral reserves** are part of the mineral resources that are currently identified and can be profitably mined under current economic conditions and with existing technology.

After exploitation, the mineral raw material is subject to processing and can be used in the oil, chemical, glass, ceramic, cement, refractory, brick industry, civil stone industry and construction. After processing minerals, raw materials typically are used for plant nutrition, construction of homes and buildings, construction of roads, railways, bridges, metal production and production of electronic equipment (Vujec, 1996).

According to the Mining Act (Narodne Novine, effective from 1.1. 2020.), mineral resources are mineral raw materials, as it says “*all organic and inorganic mineral raw materials that are in solid, liquid or gaseous state in the original reservoir, in sediments, tailings, smelters or natural solutions*”.

Mineral raw materials are divided into four categories (Mining Act, 2019):

1. “***mineral raw materials for industrial processing***: graphite, sulphur, barite, mica, gypsum, chalk, flint, quartz sand, precious stones, bentonite, porcelain, ceramic and refractory clay, feldspar, talc, tuff, mineral raw materials for cement production, carbonate mineral raw materials (limestones and dolomites) for industrial processing, silicate mineral raw materials for industrial processing, all types of salt (sea salt) and salt waters, mineral waters from which mineral raw materials can be extracted, except mineral waters used in medicinal, balneological and recreational purposes or as water for human consumption and other purposes, to which water regulations apply, bromine, iodine and peloids.”
2. “***mineral raw materials for the production of building materials***: crushed stone (amphibolite, andesite, basalt, diabase, granite, dolomite, limestone), sand and gravel for construction purposes from non-renewable deposits, sand and gravel for construction purposes from the seabed, brickyard clay.”
3. “***natural building stone***”
4. “***metallic ore***”.

2.1. Non-renewable nature of mineral reserves

The non-renewability of mineral reserves is a special feature that should be taken into consideration during mining. Determination of the mineral reserves renewability refers to constant exploration and discovery of new deposits, in parallel with the depletion of existing ones. Rational extraction of the existing deposits and striving for possible new discoveries of mineral raw materials is a fundamental determinant of the mining and geological profession. With the development of the global world market, there is a decrease in the production of mineral raw materials in one region and an increase in production in some other regions, which is also contributed by recycling as well as easier procurement on the market. Often, at the same time as the production of certain mineral raw materials decreases, natural raw materials are replaced by other materials, which has the cumulative consequence of falling prices, and often mine closures. This situation also has certain positive effects on mining, especially in terms of increasing competitiveness, improving technology, utilization, efficiency and availability (Faculty of Mining, Geology and Petroleum Engineering, 2008).

2.2. Non-metallic mineral raw materials – industrial

Non-metallic mineral raw materials for building materials are those that are used directly for the construction of buildings, such as crushed stone, sand and gravel and the production of building materials (concrete, brick, asphalt). This is a group of mineral raw materials whose production in Croatia is the largest in terms of quantity, and which, given the price, cannot withstand long transport (Vujec, 1996).

2.3. Metallic ores

Mineral raw materials of metals are classified into two categories: precious metals and industrial metals. Metals have a great range of use and extraction mostly depends on demand. The only metal raw material that is exploited in Croatia is bauxite. It is primarily a raw material for the production of aluminium metals, however, in Croatia it is used exclusively to produce cement (Crnički & Šinkovec, 1993).

2.4. Crushed stone (aggregate)

Crushed stone (aggregate) is a non-metallic mineral raw material that can be determined as one of the most accessible, widespread and most exploited mineral resources. Since the beginning of civilization, it is widely used in construction, agriculture and other industries such as chemical and metallurgy.

Such stone is mined, mechanically crushed and sieved through various sieves. It is exploited and used as crushed stone, semi-processed stone, sand and stone flour. Its composition and properties meet the requirements for usage in construction and civil engineering (Tomašić, 2007).

During exploitation and processing of crushed stone it is crucial that the exploitation field disturbs the landscape as little as possible, and that other possible harmful effects (noise, dust, etc.) remain within the limits of what is tolerable and permissible (Faculty of Mining, Geology and Petroleum Engineering, 2008).

2.4.1. Sand and gravel

Sand and gravel for construction purposes are unbound sedimentary rocks, naturally granulated and fractionated materials. Sand is a natural material made up of finely separated rock particles and minerals. Gravel is the most used material in construction, most often obtained by excavating material from the riverbed. Deposits can be formed as a result of the transport of river sediments or crushing of rocks in the sea, so called, alluvial deposits. If their origin is associated with the melting of glaciers or snow, we call them glaciofluvial sediments. They can also be caused by the influence or activity of winds that can shape the surface – aeolian (Tomašić, 2007).

2.4.2. Usage

Crushed stone is most often used in construction and civil engineering: for embankment construction, bed construction, for cladding walls, for construction and maintenance of local and commercial roads, for construction of load-bearing layers stabilized by mechanical or hydraulic binders, as crushed masonry stone, to produce concrete and mortar and similar. Sand and gravel are mostly used as a raw material for making bedding for infrastructure, for making plaster, as a component that corrects the granulometric composition of mixtures for concrete, asphalt and others (Dunda et al., 2003).

2.5. Natural stone

Natural building stone is an extremely valuable mineral raw material. Its characteristic is that it can be found in spatially limited or tectonically less disturbed rocks (Dunda et al., 2003).

Natural building stone refers to natural stone of sedimentary, metamorphic and igneous origin, silicate or carbonate composition, with the basic mission of refining and decorating interior or exterior. According to the composition, it can be divided into carbonate and silicate stone and in order to simplify their differences at the market and to make it easier for customers to understand, it is usually divided into “marbles” and “granites”. With this division, natural stone is divided into two groups which differ according to their petrographic and geological characteristics, physical and mechanical properties, durability and usage (Tomašić, 2007).

2.5.1. Carbonate natural stone – “marble”

The common market name “marble” includes rocks of sedimentary and metamorphic origin whose main mineral components are carbonates – calcite and / or dolomite. They can be recognized by a reaction after spilling of hydrochloric acid on the surface, and they are generally lighter in colour. According to Mohs scale, their hardness is 3,0 – 3,5. Carbonate stone requires much more effort and knowledge in application. Numerous damages can occur on carbonate-lined buildings in areas with cold and humid climates or in areas where it is necessary to use technical salt in winter to prevent freezing (Tomašić, 2007).

2.5.2. Silicate natural stone – “granites”

On the other hand, granites include rocks of igneous and metamorphic origin, which are dominated by silicate minerals such as quartz, orthoclase, microcline, plagioclase, pyroxene, amphibole, etc, whose hardness on Mohs scale is 5,5 – 7,0. They can be pink to dark grey, depending on their chemical and mineral composition. They are usually massive and have higher density. Silicate varieties of natural stone are on the market recognized as high quality and very durable, they are also popular because they are highly decorative. Also, in relation to carbonates, exploitation is cheaper by up to 100%, but the costs of processing of the final product can be as much as 500% higher (Tomašić, 2007).

2.5.3. Usage

Today, natural building stone is used in the shape of blocks (monoliths) or in slabs for interior and exterior coating, for memorial and cemetery architecture, sculptures and various craft products. It has the greatest value if it can be separated from the deposit in the form of massive stone blocks suitable for industrial processing. It is necessary to try to cut as many healthy pieces of stone as possible in appropriate dimensions, thereby increasing their market price. It is highly valued and priced if the stone block is without cracks and discontinuities (Dunda et al., 2003).

2.5.4. Location

The natural stone is located in spatially limited, tectonically less disturbed rocks. In Croatia, primarily sedimentary rocks are exploited, and the most important deposits are located in Dalmatia and Istria. Biggest deposits of natural stone are in the sedimentary rocks of the karst area, on the coast. However, the Croatian soil is in the tectonically active area and throughout its geological history has suffered numerous structural deformations. In such circumstances, it is impossible to extract blocks of bigger dimensions from otherwise architecturally known quality materials, such as igneous and metamorphic rocks. Therefore, it is not surprising that our most famous deposits are in the sedimentary rocks of the karst area.

2.5.5. Evaluation

Natural stone can be evaluated according to 5 criteria (Crnković & Bilbija, 1984)

- geological – primarily refers to the possibility of obtaining blocks of economically favourable dimensions (large monoliths) based on the rock's integration and quantity of cracks and fissures
- technological – assessment of possibilities and cost-effectiveness for the exploitation of a particular stone material
- technical – features important for determining physical, mechanical and chemical properties and its durability
- decorative – evaluates aesthetic value as attractiveness and decorativeness of stone
- economical – criteria that combines all criteria together and represents market value of the natural stone.

3. RAW MINERALS IN CROATIA

The analysis of mining activity (until 2008) according to data by Faculty of Mining, Geology and Petroleum Engineering (2008) indicates the following:

- solid mineral raw materials are exploited on the entire territory of Croatia
- highest number of pits are located in Šibenik-Knin County
- exploitation of mineral raw materials is performed on a large number of exploitation fields, some of them are too large and others too small so exploitation is not rational
- production per exploitation field is small, for crushed stone and sand and gravel for engineering purposes it is about 52,000 m³ / year (in 2006);
- there are many inactive exploitation fields, although exploitation fields have been approved
- the ratio of exploitation reserves and annual production of all mineral raw materials today shows that this intensity of exploitation can be maintained for over thirty years and serves as evidence for the possible development of the processing industry (Faculty of Mining, Geology and Petroleum Engineering, 2008)

In Croatia, there were 329 active exploitation sites of non-energy solid mineral resources, on date 1st October 2020. Most of them are stone quarries and the rest are open pits of industrial minerals. Mineral raw materials exploited during 2020 were: natural stone (blocks and slabs), bauxite, brick clay, gypsum, building sand and gravel, carbonate mineral raw materials for industrial processing, ceramic and refractory clay, quartz sand, mineral raw materials for cement production, sea salt, crushed stone and aggregate and tuff (Ministry of Economy and Sustainable Development, 2020).

Geological research has determined that on the territory of Croatia there is not a possibility of discovery of the following raw materials: abrasives (diamond, garnets, corundum), asbestos, borates, precious stones, fluorite, phosphates, kaolinite, magnesite, Na-carbonate, nitrates, sillimanite, St-minerals, vermiculite, wollastonite and perlite (Vujec, 1996).

3.1. Analysis of mining activity in Croatia

Natural stone has been excavated in Croatia from ancient times to the present day, in surface mines in Istria and Dalmatia and has been used to build Adriatic cities, but also cities in Italy (Crnković & Jovičić, 1993). Croatian natural stone is of great quality and being excavated in 90 pits, it still has large production (Table 1). From table 1 it can be concluded that there is a large amount of crushed stone aggregate in Croatia, almost 44% of the total number of mining pits (144 pit). Related to that, there is also a large amount of excavated sand and gravel for construction purposes (53 pits) and mineral raw materials for cement production (5). Being used for various purposes, it is an important part in the mining industry in Croatia but also worldwide.

As mentioned before, metallic ores are not excavated in Croatia, but, as can be seen from table 1, bauxite is still exploited in small quantities (14 080 m³). According to table 1, sea salt is obtained from three pits, on Pag, Ston and in Nin. Sea salt is extracted from water by evaporation in a system of large shallow pools, so the exact amount of mineral raw material cannot be known.

Table 1 Analysis of active mining pits in Croatia by number and quantity (source: Ministry of Economy and Sustainable Development, 2020)

| TYPE OF MINERAL RAW MATERIAL | NUM. OF PITS | RESERVES | EXCAVATED (in 1000 m ³) |
|----------------------------------------------------------|--------------|-------------------|-------------------------------------|
| crushed stone aggregate | 144 | 661947,79 | 10480,69 |
| mineral raw materials for cement production | 5 | 360500,31 | 3507,81 |
| sand and gravel for construction purposes | 53 | 143782,23 | 3183,42 |
| carbonate minerals for industrial processing | 12 | 258209,41 | 1233,68 |
| brick clay | 13 | 27937,65 | 459,43 |
| gypsum | 3 | 47699,46 | 221,63 |
| sea salt | 3 | 0 | 111,9 |
| natural stone | 90 | 24366,9 | 66,75 |
| bauxite | 1 | 750,46 | 14,08 |
| tuff | 1 | 3872,76 | 13,58 |
| ceramic and refractory clay | 2 | 604,93 | 0 |
| quartz sand | 1 | 0 | 0 |
| silicate mineral raw materials for industrial processing | 1 | 452,16 | 0 |
| TOTAL | 329 | 1530124,06 | 19292,97 |

From table 2, showing numbers of closed and inactive mining pits in Croatia, it is visible that there are many closed crushed stone aggregate pits in Croatia (60). That is probably because some of them were no longer economically viable, or their mineral resources were exhausted. Today, bauxite is exploited almost symbolically, in only one pit and its reserves are low, compared to 18 closed pits. In the past, bauxite was mined by surface and underground mines in Dalmatia (near Obrovac, Drniš and Oklaj) and in Istria on smaller deposits. Bauxite is classified as an industrial mineral since it is used to obtain a special high-value type of cement, and not to extract aluminium as is usually the case. Considering that, it can be responsibly claimed that metallic mineral raw materials are not exploited in Croatia at all. It is due to unprofitability – small reserves and low concentration of metals in the ore.

Comparing table 1 and table 2, there are also flint and barite, each with one closed pit, which are no longer excavated in Croatia at all. Coal is also no longer exploited in Croatia. There were five coal pits in Istria, and the last one was closed in 1999. Coal significantly participated in the energy balance of Croatia, strong industry and households used coal. Exploitation conditions were difficult, characterized by poor engineering-geological characteristics of the accompanying deposits (sands, clays) and relatively thin coal seams, which ultimately resulted in their closure (Vrkljan, 2019).

Table 2 Analysis of inactive mining pits in Croatia by number and type (source: Ministry of Economy and Sustainable Development, 2020)

| TYPE OF MINERAL RAW MATERIAL | NUM. OF PITS |
|----------------------------------------------|--------------|
| crushed stone aggregate | 60 |
| bauxite | 18 |
| natural stone - block | 14 |
| natural stone - slab | 12 |
| sand and gravel for construction purposes | 12 |
| quartz sand | 6 |
| brick clay | 6 |
| coal | 5 |
| ceramic and refractory clay | 4 |
| mineral raw materials for cement production | 3 |
| gypsum | 2 |
| carbonate minerals for industrial processing | 2 |
| flint | 1 |
| barite | 1 |
| sea salt | 1 |
| TOTAL | 147 |

3.2.Natural building stone deposits in Croatia

The basic characteristics of the exploitation of natural stone in the Republic of Croatia according to Faculty of Mining, Geology and Petroleum Engineering (2008) are:

- relatively large number of exploitation fields
- relatively small investments in processing facilities (stone slabs, stone accessories etc.)
- suitable locations for export (mostly on the coast)
- low utilization of extracted mineral raw material
- long-term staff training
- slow inclusion of new technological procedures of exploitation and processing.

Natural stone has a very stable and steady production with an annual increase. The amount of exploitation reserves enables an increase of production especially because they are not static but constantly replenished as result of new exploration works and research at approved locations. With the development of processing capacities and application of new technologies, it is realistically to expect an increase in the production of final products (Faculty of Mining, Geology and Petroleum Engineering, 2008).

In zones of natural stone excavation only about 20% of the excavated mass is usable, and everything else is stone residue that is removed during the production of commercial blocks, and it is later processed into commercially acceptable building elements. The remaining mass is a potential reserve of other mineral raw materials, such as crushed stone or carbonate raw materials for industrial processing. This low utilization certainly requires development of new technologies that would increase the efficiency, and thus increase the value of the natural stone and their aggregates. (Faculty of Mining, Geology and Petroleum Engineering, 2008)

3.2.1. Location of exploitation fields of natural stone in Croatia

As mentioned before, there is a significant number of natural stone quarries in Croatia, and the most common is exploitation of sedimentary rock. There are five regions with separate geological features and exploitation of natural stone (Crnković & Jovičić, 1993; Crnički & Šinkovec, 1993; Dunda et al., 2003):

The region of north-western Croatia

In the area of Medvednica green shales were occasionally mined, while platy limestone was mined in the Samobor hills. Lithothamnium limestone from Vinica near Varaždin called “Vinicit”, and one near Zagreb, from Bizek and Vrapče were also excavated.

Slavonia region

It is characterized by a large presence of igneous, metamorphic and sedimentary rocks. This area is the only one in Croatia promising exploitation of igneous and metamorphic rocks as natural stone. Granites and gneisses were occasionally mined in Moslavačka gora, Papuk, and Pšunj. In addition, the Slavonian Mountains represent a potential area for the exploitation of metamorphic rocks (quartzites, amphibolites, gneisses). There is a possibility of mining sedimentary rocks on the edges of these mountains (lithothamnium limestone).

Karlovac - Lika region

Mesozoic carbonate rocks, but there are also some magmatic rocks. Natural stone was exploited near Ozalj. At several sites, dark “lithiotis limestone”, called Negris fiorito, was mined, as well as thickly layered grey limestone of the Middle Jurassic. They remain the only potential materials for natural stone in this area. Lower Cretaceous limestone breccias are known on Velebit.

Istria

Istria is the richest region in the deposits of different varieties of natural stone. These are mainly Late Jurassic and Cretaceous age limestones. The most famous one is known as “Giallo d’Istria” or Istrian Yellow from Kanfanar. Another variety is Kirmenjak or Avorio or “Pietra d’Istria”. Pazin is a stone processing centre.

Dalmatia

In the Dalmatian region there is the largest number of quarries of natural stone, the following areas can be singled out: northern Dalmatia, the area of Šibenik – Trogir, Poljica, the islands of Brač, Hvar and Korčula and the Dubrovnik coast.

The natural stone in northern Dalmatia from Obrovac through Benkovac to Drniš and towards Sinj is connected to Promina-deposits. Plated limestone is mined in the vicinity of Benkovac. In the area of Šibenik to Trogir, natural stone is mostly associated with Upper Cretaceous limestone. In this group are the most famous exploitation fields in Seget, from which parts of Diocletian's Palace in Split and medieval Trogir were built.

On the island of Brač, stonemasonry has a long tradition. Different types of Upper Cretaceous limestones are used, which are often collectively called – “Brač marbles”. The most famous types are “sivac”, “rasotica”, then “veselje”, “san đorđo”, which have their subtypes “makjato”, “venato”, “unito” and “fjorito”. All palaces, houses and churches on the island, Diocletian's Palace in Split, the largest hotels in Dubrovnik, many public buildings in Zagreb, etc. were built with Brač stone.

Medieval Dubrovnik was also built with stone from the island of Korčula of the Upper Cretaceous age. Near Dubrovnik limestones of the “unito” and “fjorito” type called “Visočani” are exploited.”

3.3. Crushed (aggregate) stone deposits in Croatia

Deposits of crushed (aggregate) stone are distributed throughout Croatia. Deposits of igneous and metamorphic rocks are found in Moslavačka gora, Hrvatsko Zagorje, Papuk, Psunj and Gorski kotar, while deposits of carbonate rocks are found in Hrvatsko gorje, Medvednica and Samobor hills and mountain Dilj, Karlovac, Kordun and Ogulin region, the Croatian coast and Istria, Lika, Dalmatia and the islands (Crnički & Šinkovec, 1993)

The largest number of deposits of construction sand and gravel is located within the Tertiary and Quaternary deposits of northern Croatia, along the rivers Drava and Sava. The largest deposits are located in the Mura valley, in Podravina, northern Slavonia and Baranja. The sand pits are also located in Hrvatsko Zagorje, on the southern slopes of Moslavačka gora, on the banks of the Psunj in the Sava valley, on the southern slopes of Zrinska gora, around Sinj and on the islands of Krk, Brač, Hvar, Vis, Korčula and Mljet. Crushed stone is widespread and an important part of mining in Croatia (Crnički & Šinkovec, 1993).

4. INTRODUCTION TO GIS MAPPING

4.1. Definition

The acronym GIS stands for Geographic Information System, which represents a computerized system for maintaining data in geographic space and provides geological information related to specific locations on the map. The term "geographic" implies the availability of data in space that can be expressed by geographical coordinates, so GIS systems are generally limited to two dimensions, namely latitude and longitude (Pahernik, 2006). It is a system of the entire earth's space. It includes the lithosphere, hydrosphere, biosphere and atmosphere. It is also used in remote sensing, various military applications, oil exploration, local government and environmental protection (Perković, 2017).

4.2. Application

GIS has wide application, and the basic features of the use of GIS can be grouped into several groups:

1. Geographic analysis and testing and presentation of results – the ability of GIS in searching databases, logical queries within the database and spatial examination of state and process conditions based on spatial position and relationships, allows a range of different spatial analyses.
2. Improving organizational integration – integrated GIS in an organization allows you to improve the management of the organization and the resources within it. Keeping material and operational records, as well as personnel within a certain organizational unit with a well-designed GIS enables constant monitoring and management of resources.
3. Better decision making – GIS technology is a tool for examining and analysing spatial data in order to support the decision-making process in order to present information. Based on better information, which is based on quality data and analysis, we can make a better decision and it is clear why we can make better decisions using GIS.
4. Mapping – the mapping process within GIS is much more flexible than in traditional cartographic approaches. It is only necessary to pay attention to errors that may occur due to unprofessional map production. The GIS system is a system about the entire Earth's space, so as such it includes the hydrosphere, the biosphere and the atmosphere (Pahernik, 2006).

Therefore, GIS is used by:

- geologists, hydrologists (mapping of ore deposits)
- surveyors (cartography, positioning)
- geophysicists
- geographers (spatial analysis, geographical objects)
- mathematicians and statisticians (topology, geometry, geostatistics)
- computer scientists (metadata, databases, modelling and data storage)

They share certain general spatial data, exchange some information of common interest, and there is data of internal importance characteristic of a particular activity or institution (Pahernik, 2006).

4.3.Elements of GIS

The basis of any information system is a database – a set of organized, logically connected records or files, stored in a computer with automatic search capabilities. In GIS, the basic object of observation is a geographical, or spatial object, objects located in time and space. Such objects are defined by land coordinates, metrics, and topology with associated attributes, all called descriptive data. Data on objects are obtained from direct land surveying, aerial photogrammetric surveying or satellite images with appropriate electronic processing of measurement data (Pahernik, 2006).

Hardware

Hardware can be divided into computers and other devices, such as GPS receiver, total station, satellites, digital photogrammetric camera, digital camera, scanners, data display and printing devices, data storage devices and similar (Pahernik, 2006).

Software

GIS software provides functions and tools for storing, analysing and displaying geographic information, where it is possible to extract four key software components: geo-data entry and manipulation tools, database management system, spatial analysis and visualization tools and user interface for easy access to tools.

Software is divided into two categories:

1. Operating systems – DOS, Windows, Unix, Linux
2. Application software – dedicated programs that are classified into:
 - word processing – Microsoft Office, Corel WordPerfect, Lapis, Macromedia Dreamweaver and others. They are used to create simple documents with pictures, tables and formulas.

- desktop publishing – Adobe (PageMaker, FrameMaker, InDesign (CS3), Corel Ventura, QuarkXPress, Microsoft MS Publisher.) Prepared for printing magazines, books and similar publications.
- raster image processing – Adobe Photoshop, PhotoPaint.
- vector image processing – CorelDraw, Adobe Illustrator, FreeHand.
- CAD (Computer-aided Design) programs – their purpose is the design and production of 2D and 3D graphic models (primarily vector graphics); Autodesk AutoCAD, Bentley MicroStation.
- databases – Microsoft Access, Clipper, DBase, Oracle, Paradox, InterBase, MS SQL
- GIS design – AutoCAD Map, Microstation MGE, ARC / View, Arc / Info, MapInfo, ArcGIS, IDRISI, GeoMedia (Pahernik, 2006).

Data

Success of each GIS project depends on the quantity and quality of the data. The most important is that they are as accurate as possible in order for the system to provide high-quality information (Pahernik, 2006).

Human resources and methods

Implementation of GIS-based projects requires a wider range of experts, from technical specialists to the users who use and apply it. Certain regulations must be obeyed, and all instructions must be carefully followed in order for human resources to become accustomed to the new GIS system (Pahernik, 2006).

5. BASIC GIS MAPPING OF NATURAL BUILDING AND AGGREGATE DEPOSITS IN CROATIA

As mentioned before, GIS can be used for various types of mappings and data entry and it is applicable in general engineering. In the next chapters it will be explained how to use QGIS by mapping a couple of mineral raw materials pits in Croatia.

To use software, it is necessary to instal it on the computer. For this project it was used QGIS software which is free and easily accessible by downloading it on QGIS official page (QGIS, 2021). Many versions are available, and they are constantly updated. In this example it uses the QGIS 3.20.2 Odense version.

5.1. Opening a new project

After launching a program, first there will be a display asking if the user wants to upload some of recent projects or create a new one. If clicked on “new empty project” it will open just a blank page so some map on which it can draw, map and make changes should be uploaded.

In this example a map from Geoportal (Geoportal, 2021) was used. Geoportal is the official webpage of Croatian State Geodetic Directorate, shown on Figure 1. It is possible to find different types of official maps of Croatia by clicking on the menu in the upper right corner and selecting “metadata”. For this project it was used DOF 19\20. DOF stands for digital orthophoto which is a simulation of a photograph taken from an infinite distance looking down.

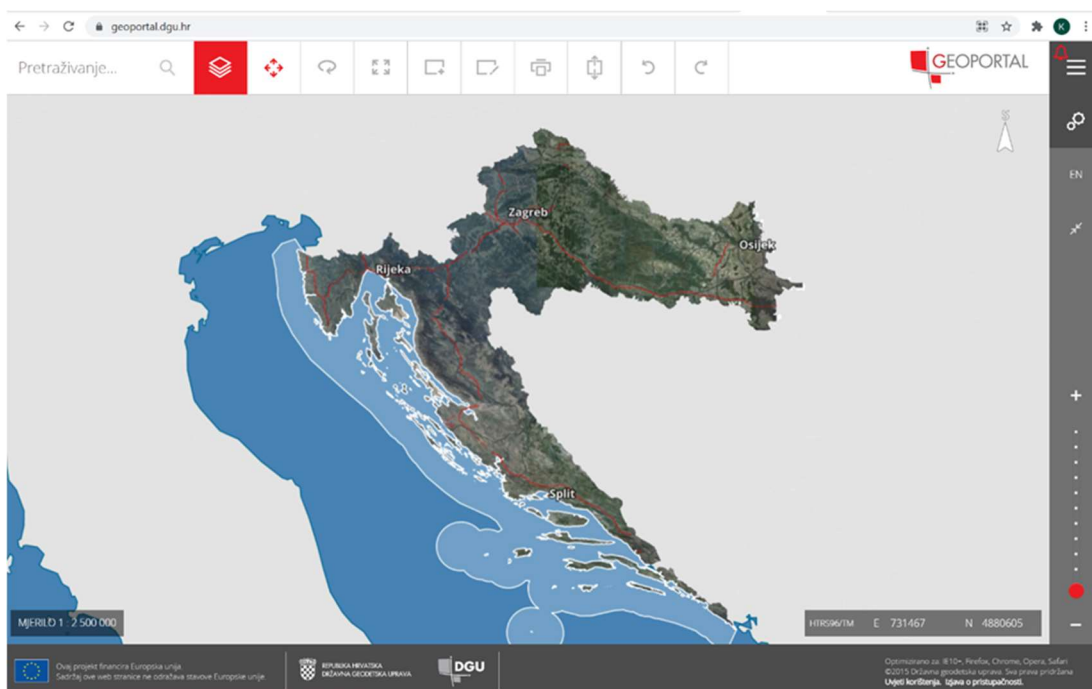


Figure 1 Geoportal main page

5.2. Adjusting the project properties

Since 2004, the Croatian Terrestrial Reference System for the epoch 1995.55 – HTRS96, was introduced as new official positional reference coordinate system of Croatia, and for the needs of detailed state cartography was adopted Gauss–Krüger transverse Mercator projection coordinate system – HTRS96 / TM. It is important to use that projection in every project, otherwise the map can be situated wrong. Sometimes it needs to be adjusted manually. Figure 2 is showing the pop-up window in which the coordinate reference system can be adjusted. To open this, click “project” in the upper left corner and “properties” afterwards. In this window, option “HTRS96/Croatia TM” must be selected.

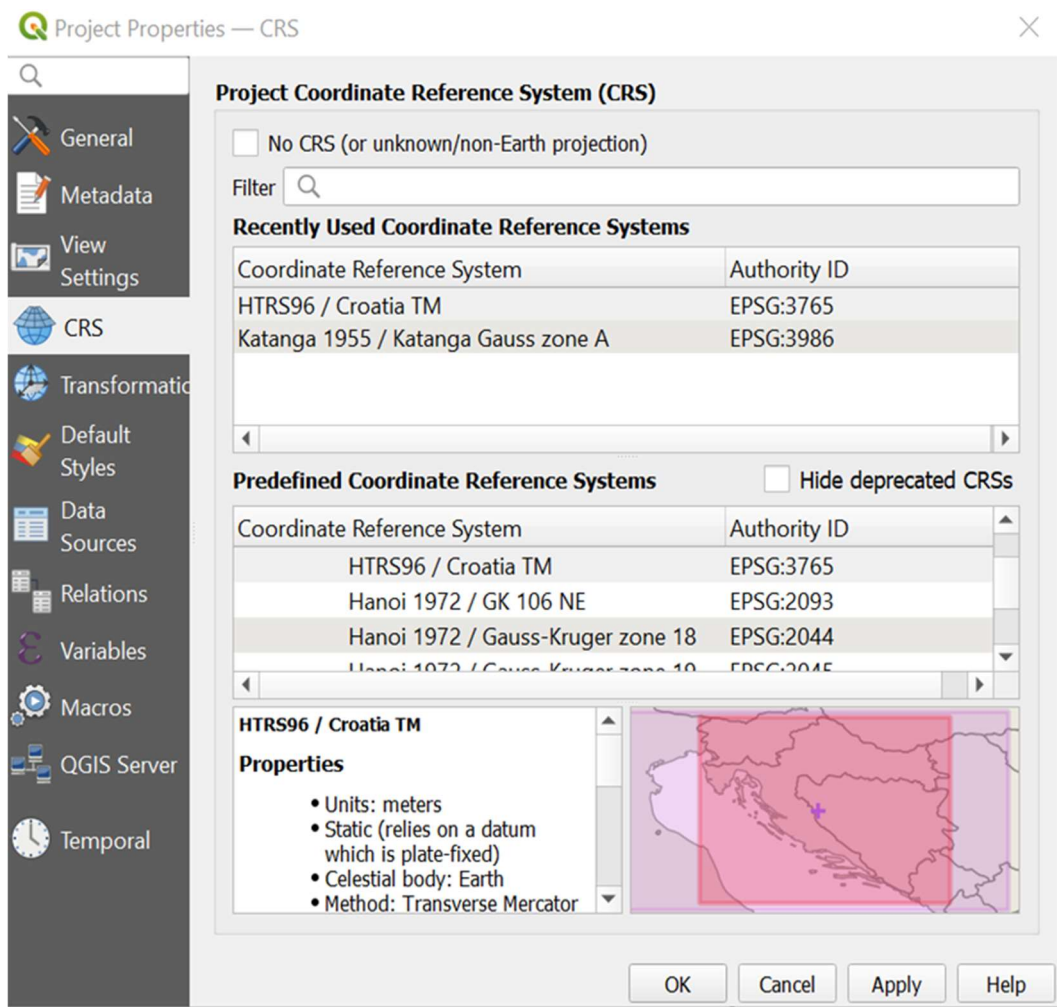


Figure 2 Project properties pop-up window

Figure 3 shows the map uploaded in QGIS. Now the borders and geographical occurrences are clearly visible and the map is situated correctly, so it is easy to explore and map the desired objects. Useful tools are “zoom in” and “zoom out” so some smaller segments can be seen and “zoom full” to get this view from Figure 3, where the whole object is located and centred inside the working area.

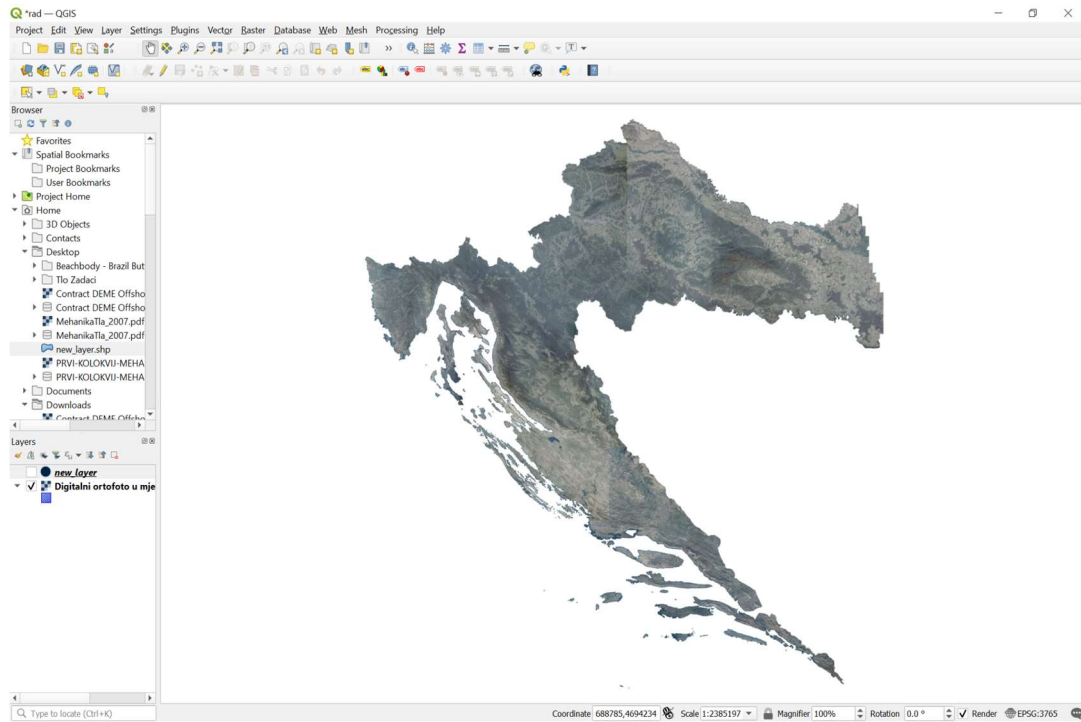


Figure 3 DOF of Croatia uploaded in GIS

5.3.Preparing location data

If the exact location is known, some mark can be easily put on the desired position. To do that, the first step is to open a new layer in which it is possible to change something on the previously uploaded map. That can be done in the “browser” toolbar on the left side of the window showing computer locations, by right clicking on desired location where it will save and select “new” and “shapefile”, as Figure 4 shows. That will create a new layer. The shapefile format is a digital vector storage format for storing geometric location and associated attribute information, which is the exact what will be done in this project example.

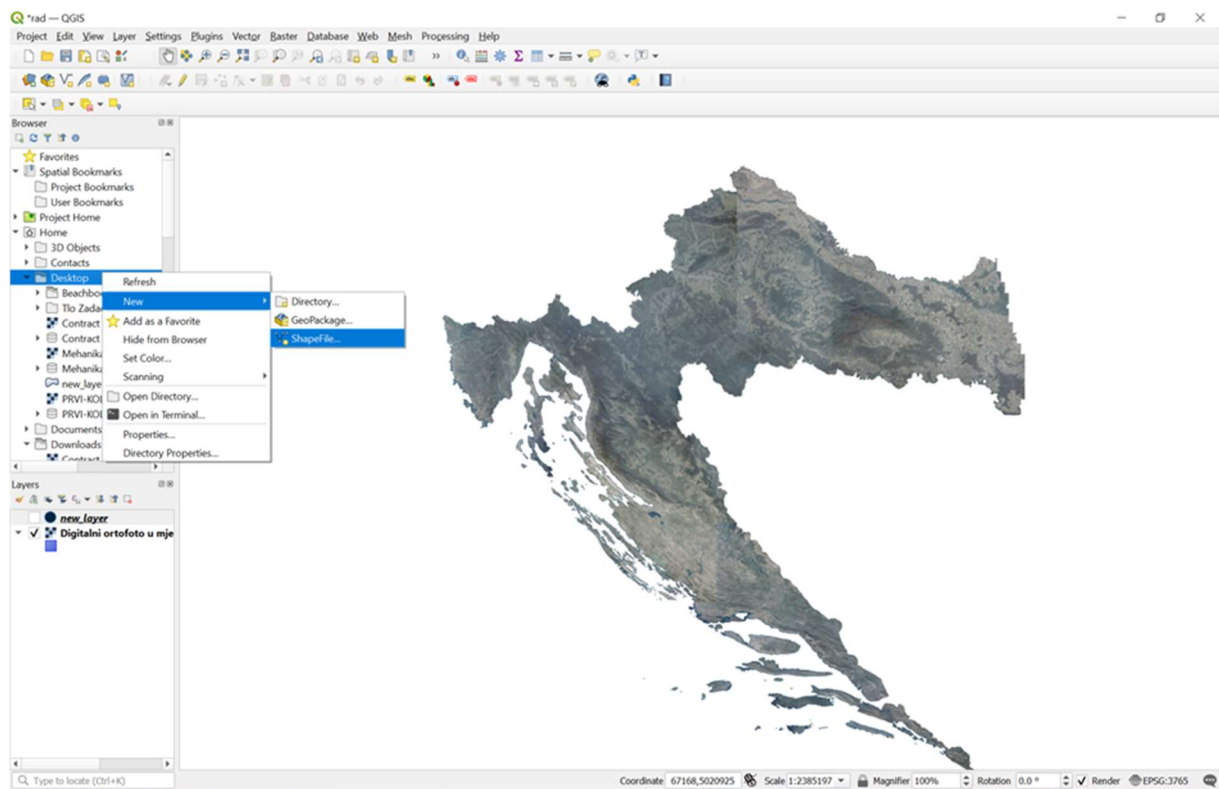


Figure 4 Opening new layer and shapefile in the example project

To map every exploitation field in Croatia it is mandatory to have more information about the position, such as exact address or coordinates. Unfortunately, in Croatia there is no such documentation.

Ministry of Economy and Sustainable Development is reviewing the list of active and inactive exploitation fields every year but, as it's shown on Figure 6, there are only few information which are publicly available – name and address of the company, which is doing exploitation works on the field, name of the exploitation field, labels, type of the mineral raw material and county in which the exploitation field is. It would be a lot easier to map fields and work on databases if there is more information about the field and its mineral raw material.

The possible solution is to update the database and collect more information about the pits. That would open a possibility to map every mineral raw material exploitation field without any additional research and do all sorts of statistical work or compare data from previous years using just maps.

Popis neaktivnih eksploatacijskih polja u Republici Hrvatskoj

| | | | |
|-------------------|--------------------------------------------|-------------|-------------|
| Trgovačko društvo | DRAGA-SADRA d.o.o. Sinj (Grad Sinj) | Glavice 696 | 21 230 Sinj |
|-------------------|--------------------------------------------|-------------|-------------|

| NAZIV EKSPLOATACIJSKOG POLJA | OZNAKA | MINERALNA SIROVINA | ŽUPANIJA |
|------------------------------|--------|--------------------|----------------------|
| KOIČA GREDA | E3 74 | Gips | Splitsko-dalmatinska |

Ukupno eksploatacijskih polja: 1

| | | | |
|-------------------|------------------------------------------|-----------|---------------|
| Trgovačko društvo | GEO-5 d.o.o. Rovinj (Grad Rovinj) | Carera 59 | 52 210 Rovinj |
|-------------------|------------------------------------------|-----------|---------------|

| NAZIV EKSPLOATACIJSKOG POLJA | OZNAKA | MINERALNA SIROVINA | ŽUPANIJA |
|------------------------------|--------|--------------------|----------|
| ROVINJ | E2 84 | Boksit | Istarska |

Ukupno eksploatacijskih polja: 1

Figure 5 Example, two mineral raw materials pits from the List of inactive exploitation fields in Croatia (source: Ministry of Economy and Sustainable Development, 2020)

5.4. Mapping

Coordinates of the location can be used for precise mapping. For example, in this project quarry Tresni Breg, with address Ružići b. b., 51217 Klana, Croatia, will be mapped. The stone material in the Tresni Breg Quarry is of limestone origin. The quarry produces a concrete aggregate (aggregate fraction size: 0/4; 4/8; 8/16; 16/22 and 16/32 mm), an aggregate for bituminous mixtures and surface treatment of roads, airfields and other traffic areas (aggregate fraction size: 0/4; 4/8; 8/11; 8/16; 16/22 and 16/32 mm), aggregate for unbound and hydraulically bound materials for use in construction and road construction (aggregate fraction size: 0 / 32 and 0/63 mm) (GP Krk, 2021).

To get coordinates in HTRS96 format the easiest way is to type the address in Geoportal and read them off. Of course, there are many other ways, it is also possible to use GPS coordinates and translate them to HTRS96. For this example, the coordinates are Y 329029.33, X 5033238.96. If entered in this QGIS project in command “coordinates”, which is the first command from the left-hand side on the bottom task bar with properties, the map will zoom on the exact position. By using the 1:1000 scale, the quarry is easily visible, as shown on Figure 6. To scale, it is necessary to choose wanted parameters on the “scale” command, which is on the left side of the bottom task bar.

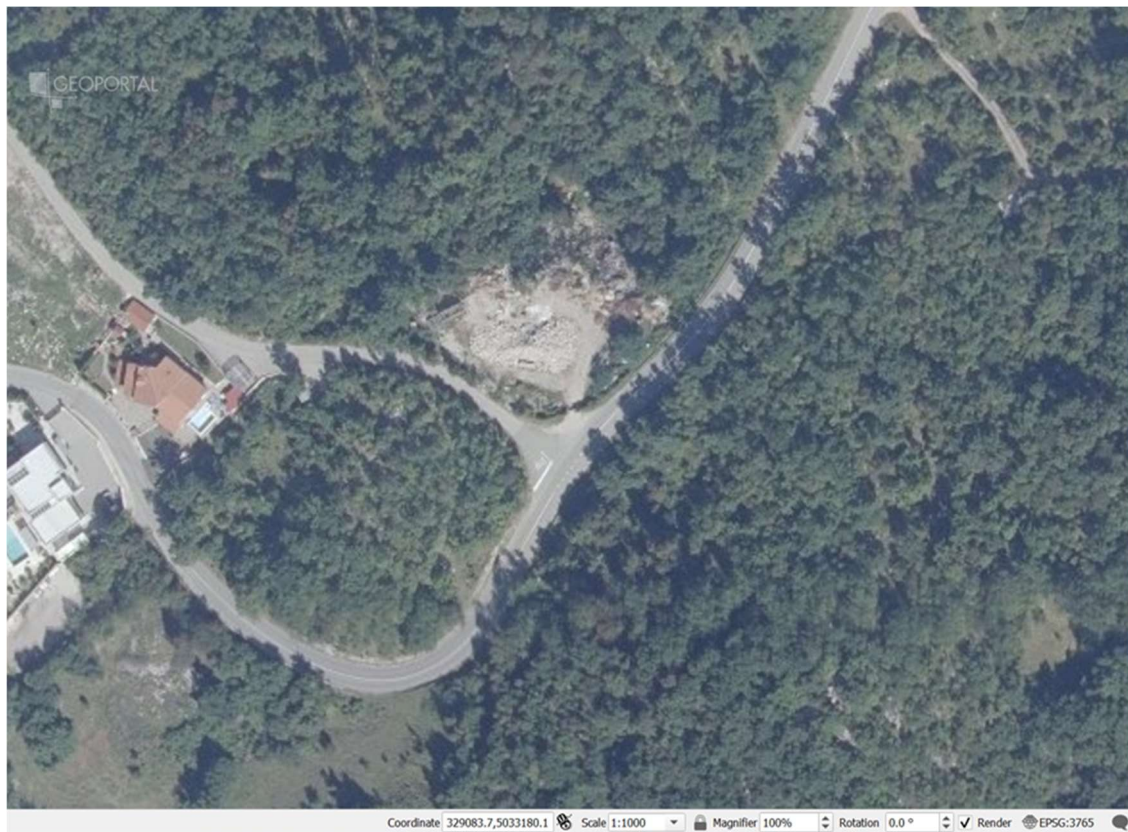


Figure 6 Location of Tresni breg quarry on the map of Croatia

New layer is empty until some changes are made. After location is determined, as already explained in the previous paragraph, it is necessary to click on command “toggle editing” whose icon is a yellow pencil laying on the Vector toolbar. Without selecting that, it is not possible to do any changes on the map. Next command is “add point feature” which is also on the Vector toolbar and click on the wanted location to leave a mark.

It is possible to change the size, colour, shadows and symbol of the marker which will label desired location. It can be done by right clicking on the previously open layer and selecting “layer properties”. That will open a list of properties which can be adjusted, as shown on Figure 7, to change preferences of labels, using tabs “symbology” and “labels”.

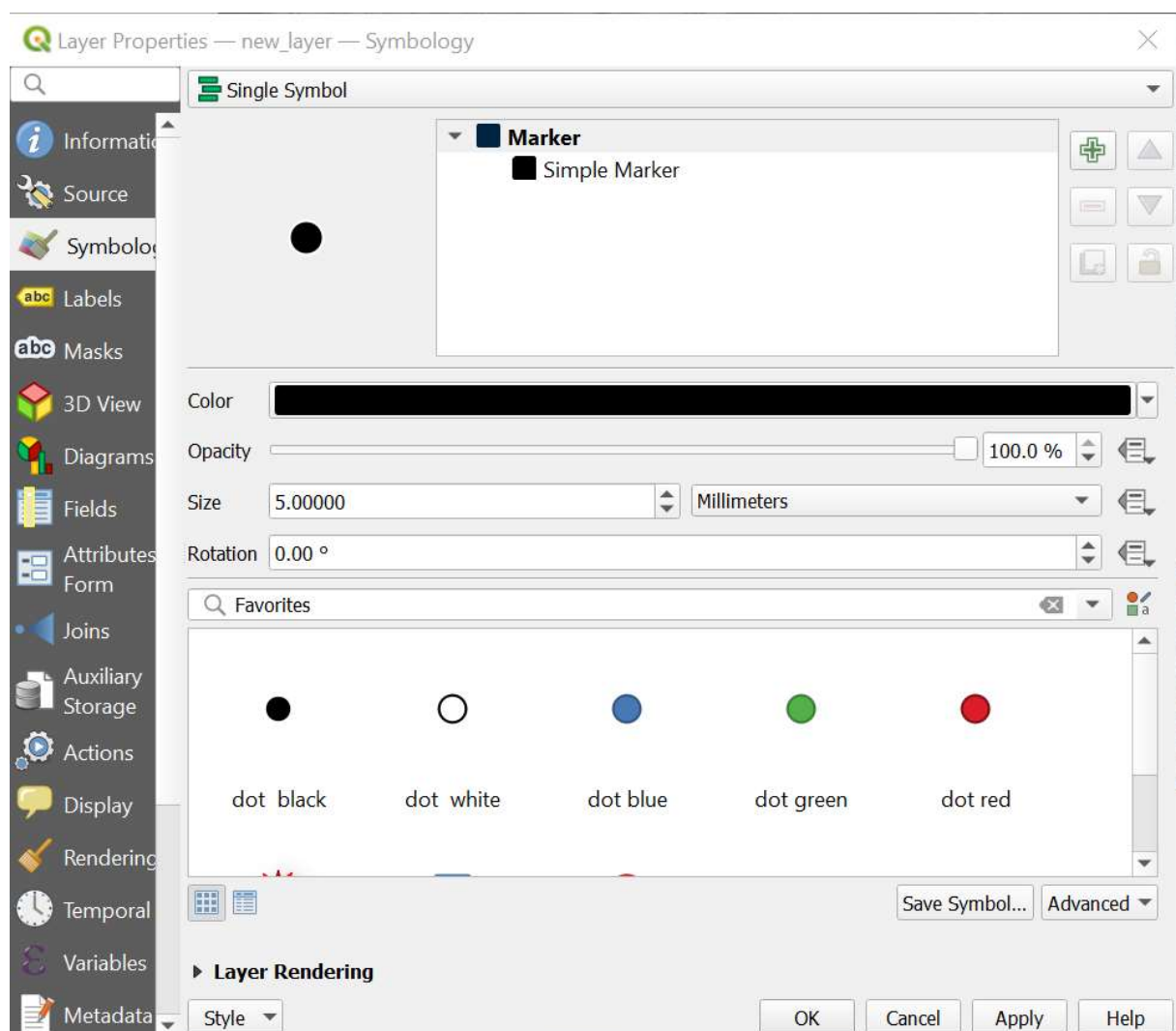


Figure 7 Layer properties window

Next example is Jadrankamen d.o.o. quarry Pučišća in Pučišća municipality on island Brač. It is a natural stone quarry, types of stone exploited there are Veselje Unito, Veselje Unito A and Veselje Fiorito which are all limestones of sedimentary origin, white or lighter in colour (Jadrankamen, 2021). Figure 8 is a label with edited text showing Pučišća quarry on the map of Croatia.

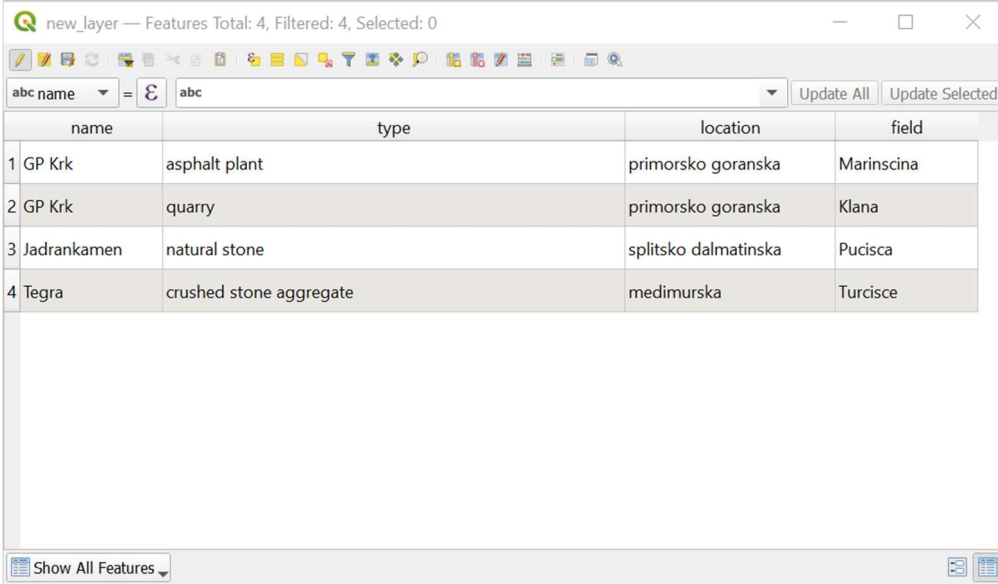


Figure 8 Jadrankamen quarry on island Brač

5.5. Setting up the attribute table

To put even more information, it is necessary to “open attribute table”. There it is possible to manage features of the marked layer. Figure 9 shows features of the attribute table of the chosen layer with four examples. There is added name of the pit owner, type of plant or mineral raw material which is exploited, county and name of the field. It is possible to add more data of various types if needed and do all sorts of data processing.

QGIS is a very useful software not just for locational mapping but also for linkage between location and its features. It is another reason why it would be helpful to have more information about every mineral raw material pit in Croatia, so all can be connected within one project and using one computer program.



| | name | type | location | field |
|---|-------------|-------------------------|----------------------|-------------|
| 1 | GP Krk | asphalt plant | primorsko goranska | Mariniscina |
| 2 | GP Krk | quarry | primorsko goranska | Klana |
| 3 | Jadrankamen | natural stone | splitsko dalmatinska | Pucisca |
| 4 | Tegra | crushed stone aggregate | medimurska | Turcisce |

Figure 9 Attribute table example

5.6.Finishing works

Figure 10 is showing the final product of work on mapping in QGIS. There is still a primary layer with DOF and an additional “new layer” which contains new data. They can be switched on and off by clicking on the box next to the name of the layer in “layers panel”. Many more layers can be added when working on complex projects to differentiate features or map various geolocations.

At the end, it is important to save the project by clicking on “project” in the upper left corner in the “menu toolbar” and then on “save”. That will irreversibly write over the primarily uploaded document.

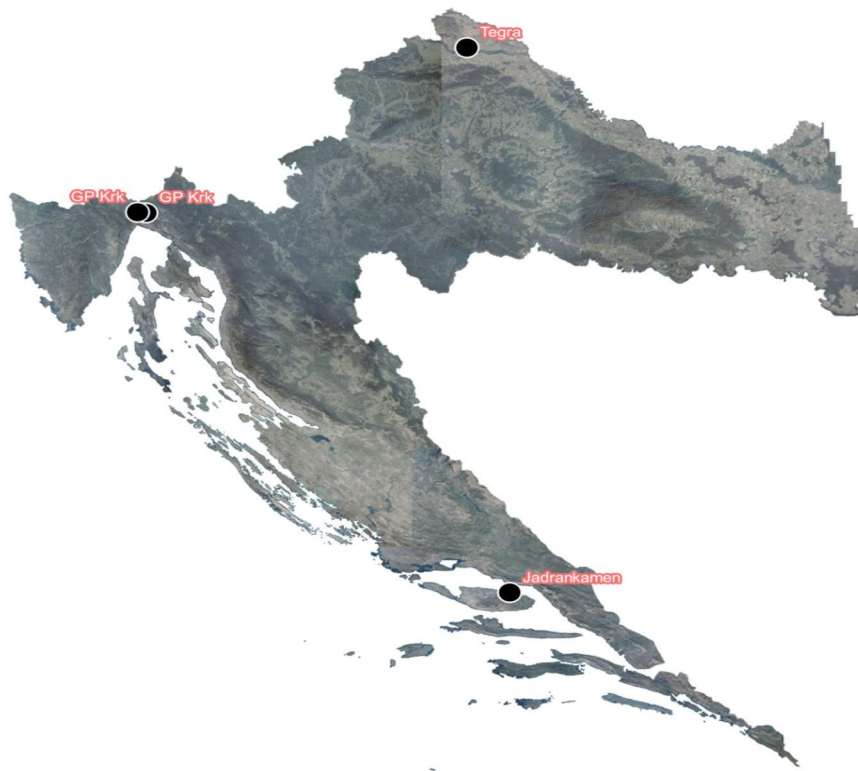


Figure 10 Map of Croatia with labels

6. CONCLUSION

This thesis describes basic commands in GIS software in order to map mineral raw materials in Croatia. GIS has a wide range of usage in engineering in general, and it can also be very useful in mining engineering and geology to map various geological occurrences or any type of object on the Earth's surface, show changes through time or use points and polylines to present or section important features. However, there is room for improvement. By adding more publicly available data about location and similar important features of the pits, greater analysis could be done.

It also explained what mineral raw materials are and how they are divided into categories. Special emphasis was put on natural stone and crushed aggregate stone, its usage and deposits in Croatia. Using data from the Ministry of Economy and Sustainable Development, analysis was made based on the number of active and inactive mineral raw materials pits. By comparing the numbers of pits and exploited quantities, it is visible that natural stone and crushed aggregate stone are very important mineral raw materials for Croatian economy and industry.

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U Zagrebu, 13.09.2021.

Klementina Kos, studentica

RJEŠENJE O ODOBRENJU TEME

Na temelju vašeg zahtjeva primljenog pod KLASOM 602-04/21-01/121, URBROJ: 251-70-11-21-1 od 27.04.2021. priopćujemo vam temu završnog rada koja glasi:

BASIC GIS MAPPING OF NATURAL BUILDING STONE AND AGGREGATE DEPOSITS IN CROATIA

Za voditeljicu ovog završnog rada imenuje se u smislu Pravilnika o izradi i ocjeni završnog rada Doc.dr.sc. Ana Maričić nastavnik Rudarsko-geološko-naftnog-fakulteta Sveučilišta u Zagrebu

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