

# THE HISTORY OF SERBIAN MINING

Slobodan Vujić

With the consent of the author taken from: Serbian Mining and Geology in the Second Half of XX Century, Roots, p. 1-38, Academy of Engineering Sciences of Serbia, Matica srpska and Mining Institute of Belgrade, 2014, 564 p.

## EIGHT THOUSAND YEARS OF LIFE

*The emergence of mining and geology is linked to the efforts of man to subjugate nature to his needs, to use the recourses offered by nature, to produce tools for work and provide existence. A long path has been crossed from the original surface gathering of minerals and one of the greatest human discoveries in history that happened eight thousand years ago, making metal from a piece of rock in the fire. Mining and geology exist inseparably almost as long as the humankind, they have been a pillar of economic, cultural, scientific, technical-technological and general social development. They have developed or stagnated, brought wellbeing or suffering, affected the course of history.*

*Archeology points out that the roots of mining, geology, and metallurgy could be traced back to the Prehistory in the area of Serbia. This is confirmed by numerous archeological sites, special representative monuments of culture – Krivo polje near Ramaća, Rujnik near Niš, Rudna glava near Majdanpek, Mali Šturac (Prlovi) on Rudnik, Belovode near Petrovac na Mlavi, Pločnik near Prokuplje, Stojnik on Kosmaj, etc.*

*The old wisdom that history is the witness of times, the torch of truth and the teacher of life (testis temporum, lux veritatis et magistra vitae) confirms its verity on the example of the history of mining and geology and teaches us that neither development nor history begins from us, that we are only a link in the everlasting process. Therefore, to understand and value the achievements of contemporary mining, it is necessary to consider the timeline of mining and geology development and to establish a connection between the past and the present. With that purpose, this chapter summarizes the overview of the history and development of mining and geology in the area of Serbia, from the Prehistory, over the Roman era, Medieval Age to this day.*

# 1. THE PREHISTORIC ERA

Hundreds of thousands of years had passed since the emergence of the first people using tools from nature, made of wood, bones, and stone, to the original surface gathering of minerals. This assumption is stretchable, not only due to very scarce archaeological evidence, but also due to the different and stretchable interpretation of humankind evolution time. Research of the oldest mining in the area of Serbia started in Majdanpek and Bor in early XX century. Looking for and gathering flint, obsidian and pigment are the sprouts of the mutual beginning of mining and geology. The beginning of mining also includes digging clay for making pottery, fishing tools, weaving tool and heating tools (weights, wheel disks) and for construction purposes. The borrow pits from which a prehistoric man obtained clay are present in all sites of Neolithic settlements of the Central and Eastern Balkans, such as eponymous settlements Vinča-Belo brdo and Starčevo [8]. The Neolithic Age or Younger Stone Age mark the abandonment of nomadic and the beginning of stationary lifestyle, then the emergence of the first permanent settlements with wood, mud and hay huts, animal husbandry and agriculture, stone processing by buffering, making and decorating baked clay objects; figural plastics and objects of cult character appeared as well. Social organization was structured in classes, brotherhoods, and tribes.

The need for clay made prehistoric people raise their settlements in places where they could find clay. In a wider sense, these locations are usually brickyards today, which confirms the fact that they knew how to pick quality clay. Unfortunately, many microlocations where clay was excavated in the Prehistory cannot be determined with precision, but based on the comparative analyses of clay samples and archeological materials, it is reliably known that it was excavated near settlements [9].



*The Neolithic cultures of Europe, the late Neolithic Age (D. Jacanović, M. Korać)*

**Legend:** 1 - Vinča, 2 - Kukuteni Tripolje, 3 - Dimini, 4 - Danilo, 5 - Butmir,  
6 - Culture of striped ceramics, 7 - Neolithic of Northern Europe, 8 - Neolithic of Western Europe

The oldest known gathering and use of flint in the territory of Serbia is Kremenac near the village of Rujnik, near Niš. The site is known for the discovery of artifacts from the Paleolithic period [38].

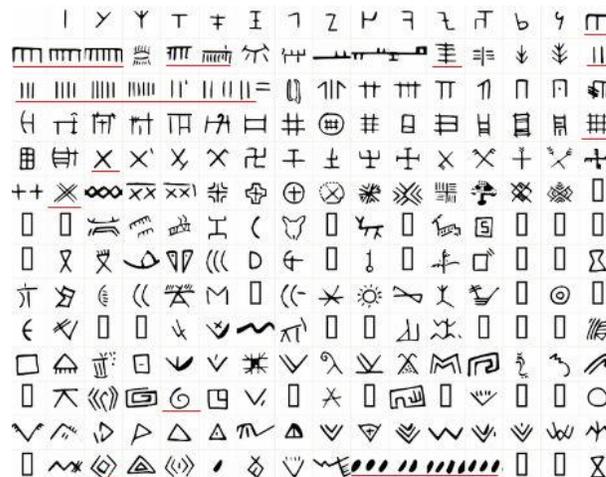
In Krivo polje near Ramaća in the older Neolithic Age (Starčevo culture, mid-VII and the first half of VI millennium BC), it was found that people used opal, chalcedony, and jasper. Eruptive stone used for tools and blades in the Neolithic Age and the early Neolithic Age was used with this aim even later after the discovery of metal – copper

and gold. The experience of making stone tools and weapons was transferred to the Metal Age, metal tools and weapons were made modeled by the most advanced stone shapes.

The archeologically explored settlement of Vinča is considered the highest achievement of the Neolithic culture in Europe. It was the center of the first urban European civilization, with a population that lived in harmony with nature, to whom organization, knowledge, and tolerance were the basic values. The main area of the Vinča culture covered the area of the Central Balkans with the core in Serbia [44]. The Danube with its tributaries the Sava, the Drava, the Tisa, the Tamiš, and the Morava were crucial for the emergence and the development of primarily the Starčevo and then the Vinča culture. This enabled easier movement (communication) and was convenient for the development of hunting, fishing, and agriculture. Dishes and other objects found in Vinča contain written traces. This is considered to be the oldest form of script, called the Vinča script, or know as *Vinčanica* or *Srbica*. The inhabitants of Vinča excavated the mercury ore of cinnabar on Avala, from which they obtained red pigment vermilion, and brought obsidian (volcanic glass) from the Carpathians, which they used as a blade. Although there are very few specified and detailed data on the everlasting process, by collecting scattered archeological proofs, from seven to eight thousand years ago, we come to one of the greatest human discoveries in history – a piece of stone turns to metal at high temperatures (in fire). It should be noted that man had known about metal as a petrographic material before the discovery of melting. This was native copper found in nature and used for making jewelry.

With the lack of surface ores that could be melted, man gradually left primary surface mining and descended into the depth of the Earth where he discovered the world of hidden mineral wealth. The consequences of these great discoveries which laid the foundations of further technical and technological development and which were the beginning of a mutual germ of mining, geology, and metallurgy have not been completely understood even today. Certainly, one should not exaggerate the revolutionary nature of the changes that took place during the period that supposedly lasted for several hundreds of years. The changes were so slow and gradual that the partakers of the process could not have been aware of its significance for humankind. If there is a sense in talking about the incentive with no written traces, the changes were initiated by adapting to and surviving in a not always so friendly environment.

We can notice some similarities of the time with the modern age. This primarily refers to: need for mineral raw materials and metal, accumulating mining, mineral (geological) and metallurgical experiences and knowledge, improving the effectiveness of new metal tools and weapons, although pursuant to today's perceptions we could also say establishing communication and trade with metal.



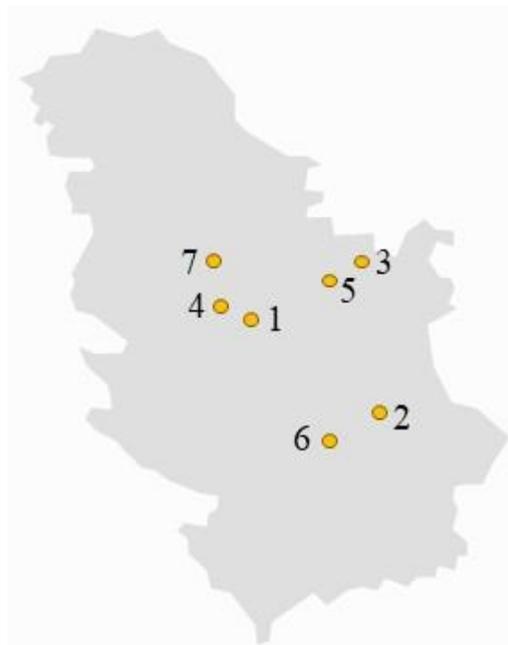
Vinča, Neolithic figure of terracotta and symbols of the letter [44]



*Rudna glava, prehistoric mine shafts [38].*

One of the richest archeological-mining areas of Europe is the territory of Serbia with the sites of the oldest mining works: Rudna glava near Majdanpek, Belovode near Petrovac na Mlavi, Pločnik near Prokuplje, Mali Šturac (Prlovi) on Rudnik, Stojnik on Kosmaj, Jarmovac near Priboj, Deli Jovan, Rujnik etc. These sites represent exceptional monuments of the culture of the beginning of mining, geology, and metallurgy in the Neolithic Age and the early Eneolithic Age.

Archeological finding Rudna glava was discovered only after the contemporary surface exploitation of magnetite on this site had damaged the central most important part of the site. Fortunately, in addition to being damaged, it preserved enough archeological proofs for the reconstruction of the original copper mining. Discovered ceramics and tools people used are made of local materials, and with the fact that there are no traces of other influences, they are clear evidence of the autochthony of knowledge, work, and experience of the miners of Rudna glava [39].



*Numerous archaeological sites indicate that the roots of mining in prehistory in the territory of Serbia.*

**SIGNIFICANT ARCHAEOLOGICAL SITES:**

1. *Krivo Polje near Ramaća,*
2. *Rujnik near Niš,*
3. *Rudna glava near Majdanpek,*
4. *Mali Šturac (Prlovi) on Rudnik,*
5. *Belovode near Petrovac na Mlavi,*
6. *Pločnik near Prokuplje,*
7. *Stojnik on Kosmaj.*



*Reconstruction of work organization [46].*

During the archeological research in the shafts on Rudna glava (1986-1989), academician Borislav Jovanović (Institute of Archeology, SASA) and Ilija Janković (Museum of Mining and Metallurgy, Bor) on the places of use found preserved ceramic dishes, amphorae, an altar with a deer head and original tools: stone hammers (hammers made of pebbles), rakes made of antlers, bone awls and spears. They also found four storage rooms with stone hammers (today we would say toolrooms). It was found that Rudna glava mining belongs to the Vinča culture, the late phase of Vinča-Tordoš II and the early phase of Vinča-Pločnik I. Besides the remnants of the prehistoric mining, the site revealed traces of extracting ores from the later, supposedly ancient period [43].



*Rudna glava – altar, dishes, and tools (1, 2, and 3);  
Zlot – tools made of bones and iron (4 and 5);  
Eastern Serbia – copper axes (6, 7, and 8) [8]*

*Pločnik, figures and  
copper vessel [41].*

The archeological research on Rudna glava makes it possible to understand how the earliest copper mining emerged. Copper (carbonate minerals, malachite, azurite, and native copper) ore offshoots coatings differ from the surroundings in their emerald and red color. This certainly provoked the curiosity of people who hunted game on this location.

We assume that circumstantially a hunter lit a fire on the very offshoot of the deposit, or that he, for some reason, put a piece of ore into the fire. In both cases the result of the exposure to high temperatures was the same, metal melted – copper was obtained. This spontaneous finding and curiosity made man perceive the effect relationship between the ore and the fire and try to do the same again. The attempts were sometimes successful, sometimes unsuccessful, lasted long, probably hundreds of years, until gaining necessary experience, skills, and unified knowledge on distinguishing and discovering minerals and ore melting.

This assumption is supported by the fact that ore was excavated mainly in vertical shafts (pits), i.e. vertical channels of mining lenses 1.5-2 m in diameter. The excavation of lenses starts with the preparation of the terrain around the future shaft. For this purpose people used tools offered by nature; eventually, they were improved, adjusted and shaped. Stone hammers of different sizes and weights were used as the main tool for breaking and crushing ores, pickaxes were made of the crown and frontal horns of antlers, shovels of blade bones of oxen, deer, pigs, or other animals, and wedges of deer horns. Stone axes were used as well, while antlers with two horns were used as racks.



*Pločnik, settlement reconstruction [41]*

By hitting with stone hammers hung on leather belts, ore was broken and extracted to the level of groundwater and in favorable conditions when there was no precipitations and water in shafts. Slight technical improvements were also made and the greatest technological advancement in excavation was achieved by using fire and water for rocks destruction. By heating and sudden cooling (expansion and shrinking), rock falls apart. The application of this technology on Rudna glava is confirmed by larger ceramic dishes found in shafts that were used for bringing water for pouring on heated rocks. Pieces of ore were taken in leather bags to the surface, picked, cleaned (reminiscent of mineral processing today?) and then taken to settlements where they were melted. Melting took place in a hearthstone, and later in small simple furnaces [43]. Ore was also melted in shafts by lighting a strong fire. Melted metal was poured and caught in small shallow ceramic dishes on the bottom of the shaft. The Eneolithic Age spawned stone and ceramic molds for metal casting.

The craftsmanship of a prehistoric miner is confirmed by the depth of shafts, the deepest measuring approximately 20 m, and the number and layout of around 40 discovered shafts indicated that the exploitation of copper ore on Rudna glava was intensive and long-lasting.

The archeological site of Pločnik (1927, Miodrag Grujić, a curator of National Museum in Belgrade; 1996-2008, Dušan Šljivar, an archeologist and Julka Kuzmanović Cvetković, a curator of National Museum of Toplica in Prokuplje) is located near Prokuplje and belongs to the Vinča culture. Pločnik revealed numerous objects and tools of ceramics, stone, and copper. Around the furnaces made of dirt for melting metals, the archeologists discovered bellows and copper pieces, which proves that the inhabitants of Pločnik knew how to find copper ore, how to excavate it, transfer, melt and make tools and weapons. Research revealed neither immediate locations where the ore was excavated nor slag residues resulting from melting. It is assumed that the ore was obtained from an azurite and malachite deposit from the site around Toplica, Kosanica and the Banjska River [41].

The archaeological site of Belevode (1954, Prof. Nikola Krstić, an associate of National Museum in Požarevac) near Petrovac na Mlavi belongs to the Vinča culture. The remains of the material culture in this locality testify to developed craft activities. Diversity and quality of found dishes prove a high technological level of pottery and tools made of flint and stone indicate the selection of the materials they were made of. The most important for this site is the primary copper metallurgy, as evidenced by the discovery of a nearby mine (the source part of Reškovića stream), then large stone hammers used for breaking ore, a ceramic mold for casting chisels, pendants and beads of malachite [41].

Archeological sites that emerged from the past in Rudna glava, Pločnik, and Belevode, as the centers of the beginnings of the skills of discovering, excavating and melting copper ore [36] have helped to solve dilemmas regarding primary common mining, mineralogical (geological) and metallurgical knowledge. These and other sites of the Central and Eastern Balkans have fundamentally changed the earlier understanding of the beginning of mining, geology, and metallurgy, moving the boundary for half a millennium back in the past and proving that the beginnings are way older than we thought. They have also refuted a common belief that original mining knowledge spread from the Near East, over Greek coast, along the valley of the Vardar and the Morava to the upper course of the Danube. They have changed a chronological picture of the emergence of mining in the Prehistory.



*Mali Šturac on Rudnik,  
prehistoric mine shafts and stone hammers [8]*

In addition to Rudna glava, Pločnik and Belovode, although chronologically younger and belonging to the early Bronze Age, the Mali Šturac (Prlovi) mine on Rudnik is also significant for the history of prehistoric mining. At this site, except for carbonate copper ore, rock crystal was located which was used for making jewelry. Found stone hammers on Mali Šturac confirm the existence of mining at this site.

The richness of the territory of today's Serbia in mineral raw materials enabled the establishment of mining and metallurgy centers at the beginning of the Iron Age. In some mining areas, such as the Timok zone, copper mining and metallurgy have been maintained without interruption from the Prehistory, through the Roman and Medieval mining, to the present day.

Since the beginning of mining and copper ore melting, there has been a problem of the disposal of slag resulting from metal melting. Archaeological findings indicate that prehistoric miners solved that in a way that is recommended even today, they used pits in which ore excavation was completed. The rationality of prehistoric miners is reflected in blending damaged metal objects, tools, and weapons. Due to the importance and the value of copper and bronze, damaged items were not thrown away, the metal from which they were made was used as a raw material for melting and creating new tools and weapons.

The emergence of the division of labor and the development of new skills such as pottery and mining created the conditions and triggered some forms of exchange or trade. Exchange varied depending on the distance from the place where it was performed, or the length of the transport of goods. For the exchange of goods such as flint, obsidian, vermilion, copper and later bronze, it was necessary to have some form of organized exchange. We are not aware of the terms of exchange, nor how they were determined, however, there is material evidence which can determine that they come from certain mines or mining areas. We do not even know who the participants in exchange were. For weapons and tools, they may have been nomadic hunters, and for metals maybe nomadic herders, but that is just a guess. After the appearance of permanent settlements, later cities and states, special expeditions were organized for trade and robbery [21].

A more complete and reliable reconstruction of prehistoric mining is not possible due to lack of more detailed data. As a rule, a lot of history - few saved traces. For the lack of data, one of the culprits is time, people say it "destroys the ravages of time"; the longer the period, the lower probability to preserve factography. Another culprit is much more devastating: later civilizations that have destroyed the remains and traces of previous mining operations by their activities.



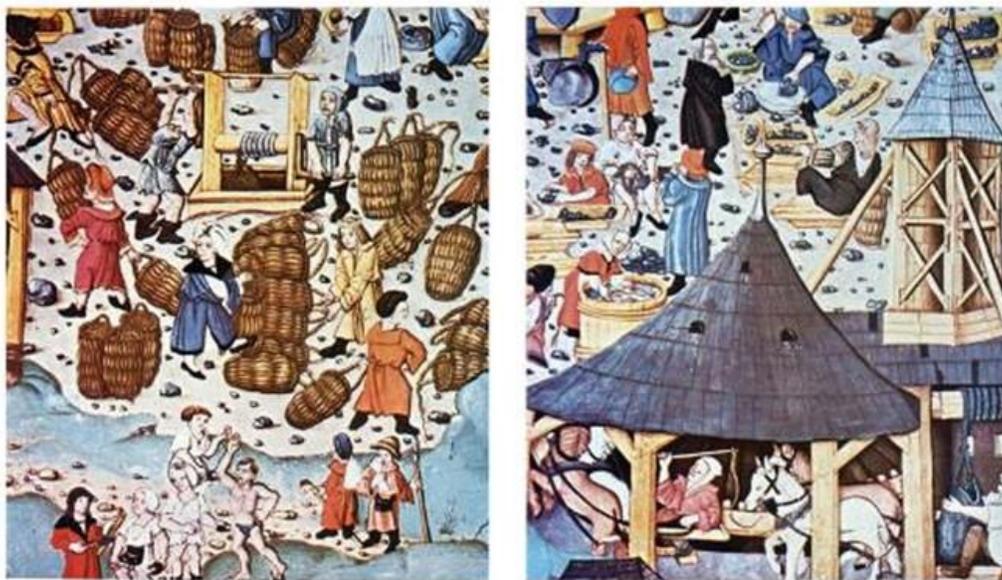
*Tetradrachm Skordisk, coins of the Celtic tribe founded by Belgrade - Singidunum, 3rd / 2nd century BC [47]*

The mining of Illyrian, Thracian and Celtic inhabitants on the territory of Serbia is indirectly testified to only by discovered silver and copper coins that were minted.

## 2. THE ROMAN EPOCH

The Romans were initially agricultural people, predominantly minor farmers who respected the right of ownership. During the strengthening and the expansion, their commitment to land remained, but they were increasingly turning to military and administrative affairs. Trade was left to members of lower social classes, foreigners, and even slaves, and had no high place in the Roman system of values. Mining was developed in all ore-forming areas of the empire.

Archaeological sites of Roman mining and metallurgy, mining shafts, metallurgical furnaces, foundry pots, molds for casting, grime, slag etc. are frequent traces on the territory of the Balkans. Mining-metallurgical activities were especially intensive on the ground of Eastern Serbia. They began at the end of III century and lasted to the first half of V century AD. The invasion of the Huns and the fall of the border on the Danube in 441 suspended mining activities to the last quarter of V and early VI century when the fortifications, cities, and mining were renewed.



*The Roman epoch, picking, cleaning and washing ores, left – an export shaft with a winch for manual moving, right – horse-drawn [26].*

With the invasion of the Avars and Slavs in late VI or early VII century, mining died out. It is noted that the mining centers from the Roman period and the medieval Serbia are in the same areas where mining-related activities took place at the end of the Neolithic and early Eneolithic Age.

With the arrival of the Romans in the regions of today's Serbia, the technology of ore excavation was significantly improved. They no longer used stone hammers and axes but iron tools. The importance of mining to the Roman Empire is testified to by the striking fact that the position of the mines affected the construction of roads, which had to pass through areas of mining activities.

In the territory of today's Serbia, during the Roman rule, the most important mining centers were on Kosmaj (Babe, Stojnik, Guberevac), Avala, Kučajna, Kopaonik, Rudnik, Novo Brdo and Rogozna mountain near Banjska. In IV century AD Rudna glava also became an important center. Insufficient exploration of most of these sites does not allow their detailed discussion, Stojnik and Guberevac have preserved underground galleries and slag dumps, which gives a slightly better reconstructive picture of the mining activities in this period.

On Kopaonik, at the site of Zajačak (Kremiči), a metallurgical complex from the end of III and early IV century was discovered. The most numerous mining operations residues were found on the south side of the site, with a number of furnaces for smelting. The most important Roman metallurgical centers include Kraku Lu Jordan near Kučevo at

the confluence of the Brodica River in the Pek. It was built in late III century and destroyed by fire in late IV century AD. The expansion and strengthening of the Roman Empire are reflected in mints. One of the major mints in the first half of III century was in Viminacium (near Kostolac), which initially minted copper and later silver coins. Metal for the needs of mints was obtained from Kučaj mines ores. Archaeological evidence suggests that the metal from the ores from the territory of today's Serbia was transported to the center of the empire; only small quantities of metal were intended for local use.



Reconstruction [46]



*The most important mining and metallurgical centers in the territory of Serbia during the Roman rule*

The exploitation and processing of clay in the Roman period had special significance. With the arrival of the Romans in our region in I century AD, the construction activity took hold. The main construction materials were stone and brick. The importance of the production of brick is best evidenced by the fact that the brick workshops were primarily military, and then imperial, belonged to the city, and finally became private. The control of brick and pottery products was very strict. All larger military camps had their workshops for the production of bricks, which, as a rule, had to be out of the settlement. As the settlement spread, workshops had to be relocated. They made bricks, water and sewage pipes, construction elements, ceramic products of broad purpose.

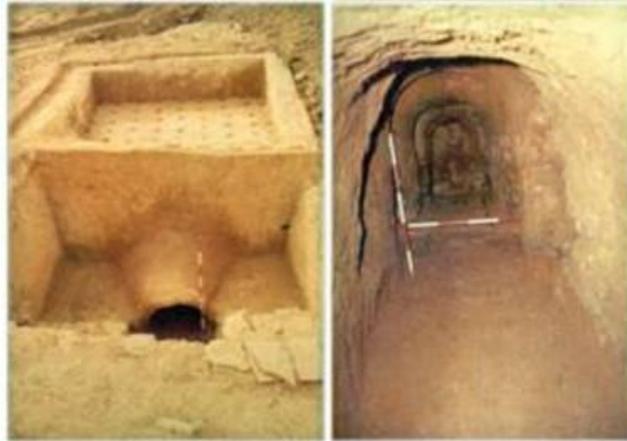


*Coins of Roman money*

In Viminacium, a pottery and crafts center with larger furnaces for bricks and smaller furnaces for ceramics was discovered. As a rule, furnaces from that time were buried in the ground on three sides, and the side with the firebox remained open. Craftsmen center in Viminacium was covered, and on the north side closed with a solid wall, so that the loss of thermal energy was reduced to a minimum. Bricks and other products of clay in Viminacium carried label LEG VII CL. This is the seal of the Legion that made bricks. More such centers were discovered in the territory of Serbia (Niš, Sremska Mitrovica, etc.). Manufacture of bricks and their quality were strictly controlled. The furnace was not allowed to be opened without the presence of an official who separated bricks according to quality. The most quality ones were taken for the needs of the state, then for military purposes, and what remains was used for free trade. Places of clay mining in Viminacium were slightly away from the crafts center.

Most of the data were provided by the archaeological research of smelters and slag dumps for lead-zinc ore. In addition to copper, lead, zinc, and iron, obtaining gold and silver had the highest importance and priority.

Archeological research on Kraku Lu Jordan near Kučevo discovered a crafts center with an iron foundry, which was probably also a center for gold panning from the alluvial deposits of the surrounding rivers of Brodica, Maška and Gornji Pek. At this site, a fortification and plants for making ceramics and metal processing from III and IV century were discovered.



*Viminacium, a ceramic furnace  
and brick furnace tunnel [8].*

An important Roman lead and zinc mine was on the mountain of Rudnik. Archeological traces were destroyed by modern surface mining of lead and zinc ore.

Roman mining on the ground of today's Serbia was a powerful industry. It worked under the special regime and enjoyed the imperial exterritoriality. Every major shoot belonged to the state, i.e. the Emperor and the imperial treasury. The state monopolized the foundries and leased ore excavation. As a substructure of all civilizations, the mining of the Roman Empire as well was overshadowed by the social upgrade and was characterized by certain oppression. It left traces not only in material remains and written documents but and in architecture, fine arts, and literature. So set and organized mining shared the fate of the Empire. It was at its peak during the greatest power, fell during the crisis of the epoch of military emperors, and was reborn under Diocletian in IV century.

### 3. MIDDLE AGES

At the end of VI and VII century began the Slovenian colonization of the Balkan Peninsula. The Slavs and Avars penetrated and spread over the entire Balkans to the Adriatic and the Aegean Sea. After looting and destructing, the Avars mainly withdrew, and the Slavs stayed and by permanent settling took away the territories of the eastern part of the Roman Empire which was later named Byzantine. The whole Balkan Peninsula faced changes in the ethnicity of the population and the rule of the Slovenian tribes was established [36].

On the earliest history of the Serbs in the new environment, except for fragmentary and insufficient archaeological materials, there are no other saved data. According to the testimony of Byzantine Emperor Constantine VII Porphyrogenitus (913-959), the Serbs moved to the Balkans at the time of Emperor Heraclius (610-641) with his consent. By the occupation of land cultivated way back in ancient times, the Serbs were engaged in agriculture, livestock breeding, beekeeping, hunting, and fishing. Numerous archeological findings confirm that metals were widely used for making weapons and tools (hoes, shovels, plows, scythes, sickles), simple smelting furnaces and slag were found, but there is no response to how in the early Middle Age obtained metal [35]. It is certain that from the homeland they brought some experiences on metal processing, especially iron, which was important for the production of weapons and tools. Possible indicators of dealing with mining in the new country are the Slovenian mining terms such as *grno*, *okno*, *ruda*, *rupa*. Some of the terms were taken over by the neighboring nations, e.g. the Hungarians have the elements from Slovenian mining terminology [36].

During the reign of the first Nemanjići, metallurgy of iron, lead, copper, and money forging were developed, but there is no data on mining production. The earliest mention of the Serbian coins dates from the period of the reign of King Stefan the First-Crowned (1196-1227). Silver and copper coins were forged also by King Stefan Radoslav (1227-1233), his son and successor. Samples of the coins point to the fact that the metal from which they were forged came from Serbian mines [36]. A pause from developed Roman mining to its renewal in the Middle Ages lasted for several hundred years.



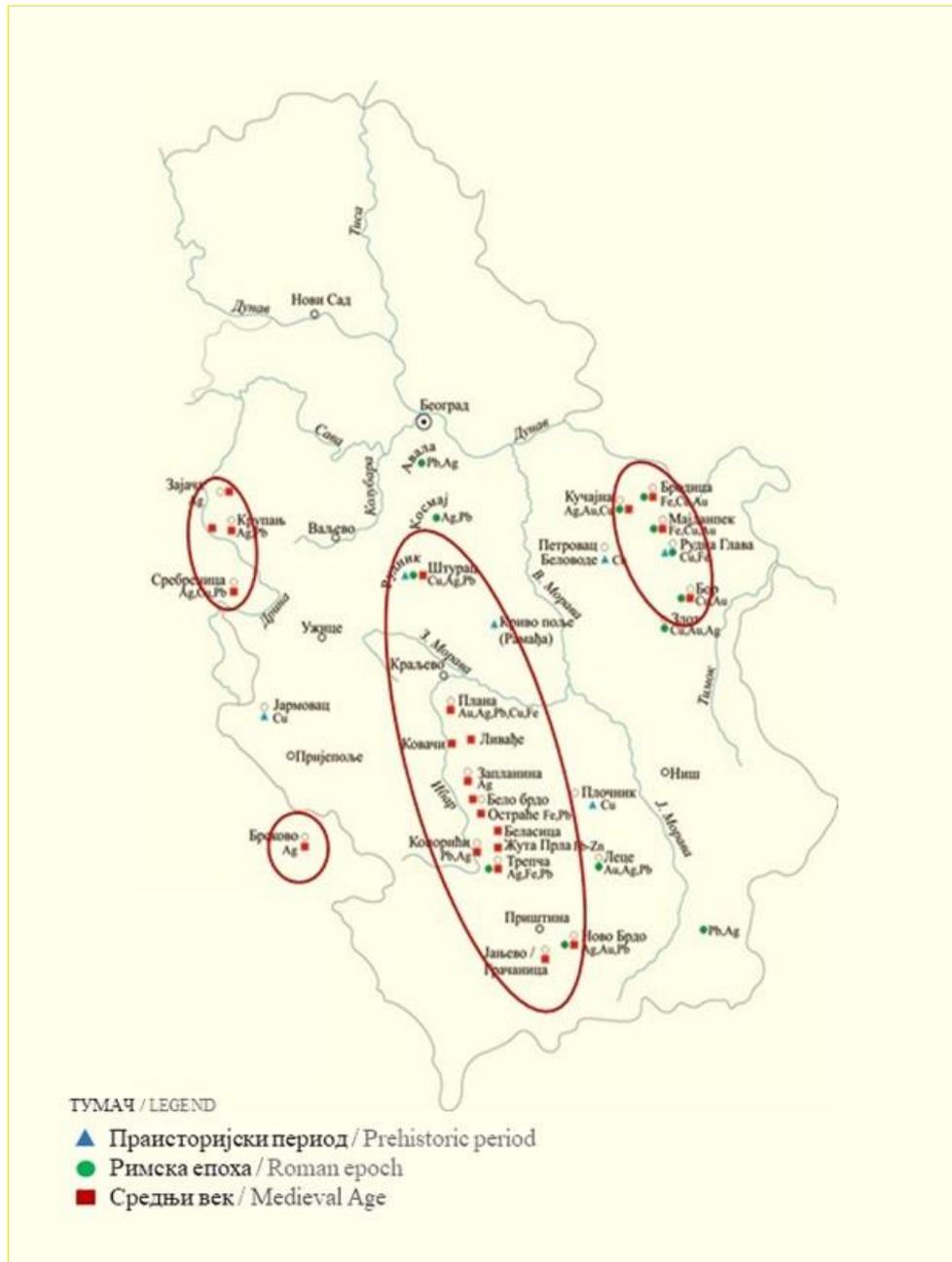
*Serbian state at the time of King Stefan Uroš I and territories of district masters*



*King Stefan Uroš I Nemanja IV (1223-1276) with his son Dragutin, Sopoćani Monastery.*

The launch of the mining production in medieval Serbia started in mid-XIII century with the arrival of the Saxon miners. They quickly restored mines in Serbia and Bosnia, ore-forming locations known from the Ancient and the Prehistoric age.

There are two assumptions on where the Saxons came from and under what circumstances they settled in Serbia. One is that the Saxons came from Transylvania at the time of the Tartar invasion (1241-1242), and the other is that they came as colonists at the invitation of King Uroš I (1243-1276). They are first mentioned in the charter of Uroš I, with the site of action in Brskovo.



*The archeological sites of the Prehistoric mining and more important centers from the Roman Age and the Medieval Age*

Thanks to the Saxons, Brskovo quickly gained the organization modeled by what they brought from their homeland. The Saxons, as Brskovo citizens, participated in the management of the city, enjoyed the autonomy, had their prince, church, clergy and the autonomous judiciary. From Brskovo they moved when needed. They appeared on Rudnik at the end of XIII century, and in Trepča and Novo Brdo at the beginning of XIV century. Their arrival introduced a more advanced production technology and the basics of mining rights. They embedded their knowledge and culture in the Serbian environment, introduced mining terminology, regulated mining centers and the like. Many toponyms preserved in Serbia are reminiscent of the Saxons. In medieval Serbia, gold, silver, copper, lead, zinc and iron ores were exploited. By the strength of the Nemanjići state, it can be concluded that the mines were rich and abundant. Mining was the outline of the wealth, economic, political and military power of medieval Serbia. Travel writers of the time recorded the legend of the wealth of Serbian mines. Frenchman Bouchard in 1332 wrote: "At the moment, Serbia has hundreds of gold mines and as many silver mines. In addition, there are silver mines that are just being discovered." Kratovil in 1454-1455 wrote: "But what is most important regarding Serbia is that gold and silver can be found there as water is found in springs, that along rivers you may find gravel in which there is gold as much as in India; Serbian gold is, by the way, more beautiful," Known gold panning sites on gold-bearing rivers are: the Pek, the Bukovačka river, the Lisičji potok, the Komča, the Rečica. In the valley of the Mlava, next to Novakov stream old shafts and galleries were discovered. In Veliki Bubanj in Jokin stream, pyrite and gold-bearing quartz were discovered.



*King Stefan Radoslav  
(1227–1233)*



*King Milutin  
(1282-1321)*



*Brskovo*



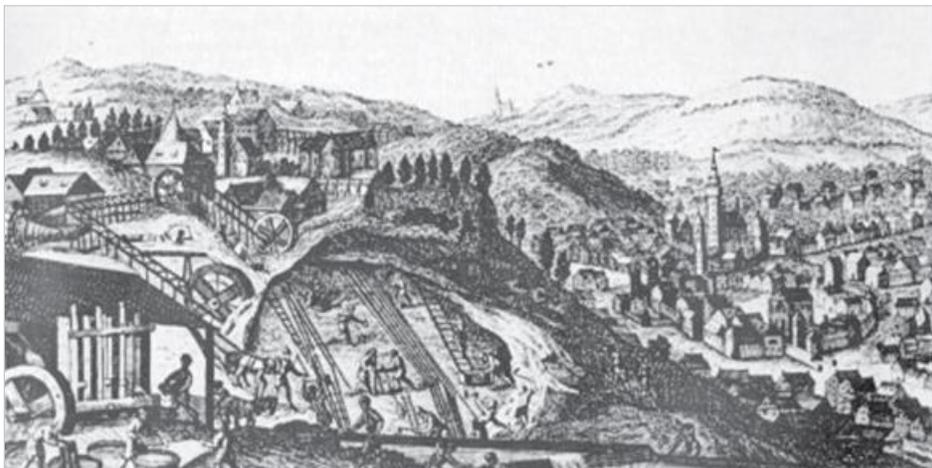
*Emperor Dušan  
(1331-1355)*



*Despot Stefan Lazarević  
(1402-1427)*

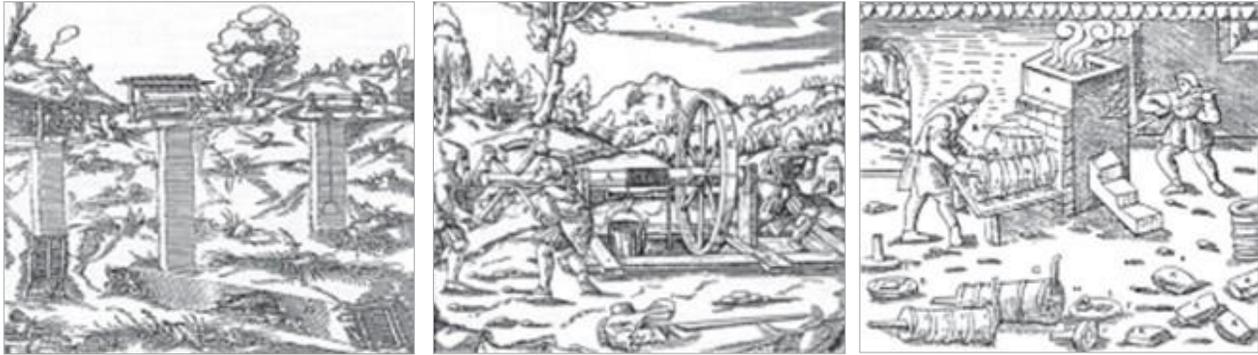
#### *Medieval Serbian coins*

The development of mining and metallurgy caused the strengthening of trade and crafts, raised new cities. There were numerous centers of medieval mining with developed urban life and colonies of traders from Dubrovnik. Mining mechanization and equipment was functionally significantly improved or new was devised, made and introduced. For the sake of safety, miners introduced supporting of underground rooms by wooden supporting units, piston pumps made of hollowed trunks were used for removing water from pits, wooden exporting machinery powered by water, man or domestic animal was used for ore extracting. The use of fire and water for the destruction of rocks and the descent in the exploitation work to a greater depth caused the need for pits ventilation.



*Medieval mining  
center [45]*

For this purpose, miners constructed fans on the principle of bellows or water wheel. In pit transport, they used slope mines and carts, and for the transport of ore to the smelter, they used reinforced horse - or ox - drawn carts. The period also promoted the novelties in the preparation of mineral raw materials, introduced the use of mechanical and hydro-separators and stone wheels for ore fragmenting. Innovations on the existing equipment and machines, design of new structures and construction of equipment are only part of the creativity of medieval miners.



*Medieval mining technique and technology,  
G. Agricola - On Mining and Metallurgy in XII Chapters, 1556*

These are the beginnings of the emergence of new technical fields, mechanics, and mechanical engineering, which will be found in educational programs in engineering schools and the economy only in XIX century.

Written and illustrative material on medieval mining left by Georgius Agricola in his work *On Mining and Metallurgy in XII chapters (De Re Metallica Libri XII)* has an exceptional value for the historiography of European medieval mining, but also for the reconstruction of the picture of Serbian mining industry in the Medieval Age.

It is interesting to compare contemporary and medieval mining machines. The analysis shows that there are no significant differences in functioning, they differ in construction materials. In the Middle Ages, this was predominantly wood, significantly less metal. Today we use metals, alloys, sintered and other contemporary materials. Another difference is the sources of moving, medieval machines were moved by domestic animals or man, and contemporary by electric engines and internal combustion engines. This confirms the old wisdom that neither the world nor the history starts with us.

Due to the growing needs of crafts and trade control, "royal squares" were formed where it was only permissible to trade in goods, and the ruler had a priority during sale or purchase.



**Georgius Agricola** (Glauchau, 1494 - Chemnitz, 1555), real name Georg Bauer, a physician, a philosopher, a diplomat, a writer, a theologian, (al)chemist, a mining expert, an environmentalist, a mineralogist. He enrolled at Leipzig University in 1514, where he studied philosophy, philology, and theology. He continued his improvement and education studies in 1524 at University of Bologna and Padua, then Florence, Venice, and Rome, where he acquired doctor's degrees in medicine and philosophy. During his stay in Italy, Agricola showed particular interest in geology, mineralogy, mining and metallurgy, met practical mining and smelting. Upon his return from Italy in 1526 he worked as a doctor in Chemnitz, and then Joachimsthal, where at the time deposits of silver, cobalt, copper, and lead were exploited. He is the author of very important historical work *On Mining and Metallurgy in XII Chapters (De Re Metallica Libri XII)*. The work was printed in Basel in Latin in 1556. The following year a translation into German was published.

Part of the tax on sales on "royal squares" belonged to the ruler. In XIII century the most important "royal squares" were: Brskovo, Rudnik, Rogozna, Trepča, Novo Brdo and Trešnjica. From XIII to XVI century, numerous mines were opened, here we note only a few: Brskovo, Novo Brdo, Belo Brdo, Koporić, Janjevo (Gračanica), Kučajna, Majdanpek, Trepča, Rogozna, Rudnik, Srebrenica, Zajača, Krupanj, Rudište, Trešnjica, Ostraća, Novi Majdan (Gračanica), Busovača, Plana, Kreševo, Belasica, Zaplanine, Zletovo, Kratovo, Čajniče, Žeravica, Gluhavica etc. [35].

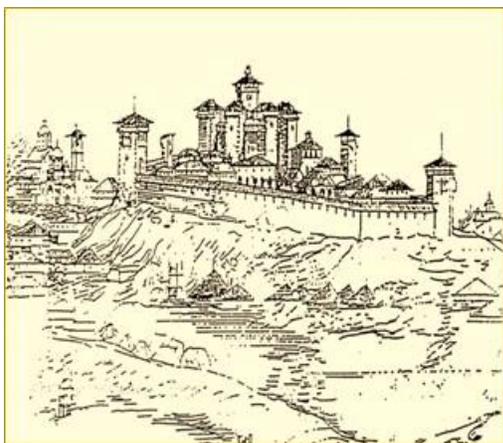


*Despot Stefan Lazarević Nemanja VII (1389-1427), founder's fresco, Manasija Monastery and Code on mines or Novobrdski Code, a set of laws published by Despot Stefan Lazarević on January 29, 1412 (preserved in several copies, the most important is the illustrated copy from XVI century kept in SASA Archive)*

Mints in medieval Serbia could be found in Rudište, Srebrenica, Smederevo, Plana, Trgovište, Ras, Brskovo, Koporić, Zvečan, Prizren, Peć, Priština, Novo Brdo, Skopje, Ohrid, Skadar and Bar [35]. Minting was the privilege of the rulers. Mines were obliged to concede a part of the mined ore to the ruler. It was a tax that was called *urbur* and it was collected by *urburari*.

Mining production and trade with metal took place freely; it was allowed to acquire permanent ownership over a mine, the so-called heritage. Next to mines and mining centers, or squares, customs were placed that were leased by the ruler. Mines could have multiple owners. Allowed division of ownership of a mine was into 2, 4, 8 or 16 parts (*deo, pars, par, pai*). In proportion to the number of parts that they owned, the owners, as members of the mining associations, were entitled to profits, but also had to bear an appropriate part of the costs. Miners are engaged in mines in one of the three ways: (1) Engaging for a definite period; (2) Today, we would say service contract or payment by the length of excavated corridor or the quantity of extracted ore; and (3) *Lemšat*, the owner assigns the miner a part (percentage) of excavated ore. Besides the miners diggers, there were *šafari* who were experiential and professional people who managed work in the mine. The residents of Novo Brdo, the most developed mining center at that time, asked from Despot Stefan Lazarević to pass a law and he formed a body of 24 *good men* who drafted the law. To avoid, we would say, a conflict of interest, the Despot formed a body of professional people who were not from Novo Brdo. Code on mines or Novobrdski law is a set of laws that Despot Stefan Lazarević published on 29 January in 1412. It is a unique monument of the legal science of medieval Serbia which by its legal and historical value exceeds national frames. In addition to the law on mines, the text contains the provisions relating to the organization and life in Novo Brdo. Code on mines of Despot Stefan Lazarević precisely defines the ownership of mines, working conditions in mines, maintenance obligations, the duration of the interruption of work, protective measures, standardized mining tools and accessories. Reminiscent of modern standards? In a broader sense, Code

on mines testifies to the economic power and order of Serbian country at the time. Academician Sima Ćirković notes regarding the Code: "When the Mining Code became known, it turned out that a great number of its Articles had already been translated into Turkish and saved in the Saxon law."



*Novo Brdo, left - reconstruction XIV century,  
right - view of the part of the restored fortress of the upper town [48]*

Thanks to the mineral wealth of medieval Serbia, rulers invested large sums of money in spiritual and cultural uplift, in the construction of magnificent monasteries and churches, their arrangement and rich furnishing. If not for the medieval mineral resources, Serbia today would not have so many monasteries and monastery treasuries. The Novo Brdo mine was the leader by gifts that helped monasteries with large quantities of silver. In Novo Brdo, the so-called *glamsko* silver was excavated, which contains a significant amount of gold, which is why its value is higher. Vojislav Jovanović said: "From the seventies of XIV century, Serbian sources on Novo Brdo are numerous and substantial. Prince Lazar gave (from Novo Brdo, author's note) to Ravanica Monastery 150 liters of silver annually (one liter or libra is 327.9 grams), and to Drenča Monastery 50 liters, which together amounts to app. 1,600 coins." By the decision of Despot Stefan Lazarević, Hilandar Monastery also enjoyed income from Novo Brdo in about 100 liters of silver annually. The Despot donated to other monasteries from Sveta Gora as well, for example, Vatoped with 60 liters, Lavra of St. Atanasije with 20 liters of Novo Brdo silver annually. Despot Đurđe added to Lavra another 60 liters, and to Svimen Monastery he donated 50 liters per year. According to the records of Broquière and Kapistrant, the annual income of Novo Brdo mine was more than 120,000 coins. This information, although refers only to Novo Brdo and may not be completely reliable, clearly highlights the importance of mining for medieval Serbia.

## TURKISH CONQUEST

Turkish conquest of the territory of medieval Serbia and mines did not happen at once; it took about half a century. The first more significant mining center that fell into Turkish hands was Kratovo (1395). The real danger over the Serbian mines from Turkish invaders was felt during the offensive of Murad II (1438-1439). Then, Novo Brdo's importance came to the fore, both in measuring forces in battles with the Turks and in the attention it drew in contemporaries in Europe who followed the events.



Reconstruction [47]

*The Turkish conquest of the territory of medieval Serbia and the mines lasted about half a century. The strength and significance of Novo Brdo is reflected in the determination of the power with the Turks and in turning Europe's attention to events. The conquest of Novo Brdo started in 1412 and the fall of 1441, the agony lasted until 1444 when the city was definitely enslaved and killed. The golden epoch of the mine and the city is over and never returned.*

With the fall of Novo Brdo under the Turkish rule, its golden epoch ended and was never restored, and Novo Brdo - a golden and silver town, was completely forgotten. Ottomans became the lords of all mines in the Balkans in the second half of XV century, but for them, mining was an activity difficult to understand. In line with their tradition and the state regulation, they included mining centers in the Sultan's *has* - a set of goods whose income served for state needs, to finance permanent and hired army for military campaigns. Like the Sultan, civil servants as well, and even deserving individuals and warriors had their *hases*. The organization of such a structure and its lack of interest in investing in improvement and development led to the disappearance of medieval mining.

## 4. XVIII CENTURY

With the fall of Serbian medieval state began the collapse of mining. Miner suspended work and rested mainly from XVII to XIX century. Taking a part of Serbia in early XVIII century, the Austrian military administration, after the conclusion of Požarevac Peace, by order of the court war council, started to open mines. The Austrians were well aware of our mines. In the valley of the Pek they started the works in the village of Crnajka, Majdanpek, and Kučajni, and in Šumadija region they worked on Avala, Kosmaj and Rudnik. They restored the production and exploited copper in Crnajka, copper and iron in Majdanpek, lead and iron on Rudnik and silver-forming lead in Kučajna, on Kosmaj, and Avala for two decades. They unsuccessfully attempted gold panning in the Morava River. Under the Austrian despotism, the population was leaving the occupied regions, causing the lack of manpower to work in the mines which was probably the reason why mining during the Austrian occupation neither advanced nor succeeded.

## 5. XIX CENTURY

After the First Serbian Uprising in 1804, there was the need for lead, iron, copper, silver, gold and gunpowder, and the leaders of the uprising, with Karadjordje at the helm, tried to renew mining in Serbia. But for restoring the complex activity of obtaining and processing ore, there were neither professionals nor skilled labor. Numerous data suggest the efforts to bring professional people and Austria that zealously hindered and prevented that. Quasi-friendly Austria was thoroughly interested in the situations in Serbia and therefore flooded the border area of Serbia, and Serbia, with spies. The first news of mining in Serbia, November 26, 1807, from an Austrian spy from Kovin reads: "In Serbia, there are many professionals, and even more will be recruited. They will work on rich mines whose main location is Rudnik. According to Rodofinikin, these will, as soon as the works are completed, mint their own money. Two Germans have arrived already, but no one knows where they come from."



*The First and Second Serbian Uprising is not only the beginning of the restoration of Serbian statehood, but also the beginning of the re-emergence of Serbian mining. Due to the need for lead, iron, copper, silver, gold, and gunpowder, the insurrection tries to restore mining*

The rebels and the people had to work secretly, which probably resulted in a lack of records on mining activities at that time. Mining cover-up is spoken of in the letter of Russian diplomat Rodofiniki dated 02/11/1808, who says: "I will not talk about silver mines because I cannot tell anything specific about them." Rodofinikin, however, knew everything, two days after he was with two Russians, probably mining experts, on Rudnik.

Prota Mateja Nenadović in his *Memoirs* often wrote about the needs of the insurgents for gunpowder, he rarely mentioned lead. From this, we can conclude that the supply of lead was secured from own mines.

One of the attributes of statehood is own money. Copper and silver were then used for minting. According to A. Ivić, with the report of Petrovaradin commander Hiller, of 24 January 1811, Prince Meternik was sent three coins that Karađorđe forged in Topola in "in great abundance." Ivić found the coins in Vienna and stated this was the money of Ottoman Sultan Selim III from 1789 only made in a more primitive manner. It was minted by a Turkish artisan.

Given that the lack of knowledge and expertise was a major problem, Praviteljstvujušči Soviet (today we would say Government) made a decision in 1806 to bring 35 professional Saxon miners and one engineer. It is not known how many of them came, but in 1806 mining operations began on Avala. Two years later (1808) iron and copper were exploited on Rudnik, as stated "for casting and forging war material." The production of silver is also noted, and they probably obtained lead as well, although there is no record. On Rudnik, two shafts were activated, in Krasojevci (today Bezdan), and at the site called Pećina. The smelter and mint were in Majdanska reka. Lead ore, except on Rudnik, was exploited in the Drina valley, on Avala and Kučajni as well.

Serbia requested help from Napoleon. On August 16, 1809, Karadjordje wrote to him: "Serbia has great wealth in its bosom, with ores of gold, lead, saltpetre, wood for galleys, innumerable cattle that no province in Europe can compete. This belief does not require anything but a few artisans familiar with mineralogical science and trade. " The problem of the lack of professionals is seen from the following data as well. The first manager of insurrectionary mines was Petar Novaković Čardaklija, a hajji, freikorp, and diplomat. As a member of the diplomatic mission in 1807 in Bucharest, he requested from general Michelson two Russian officers "who will train the Serbs in mining operations."

Mining works on Rudnik were managed by Stefan Živković Telemek, who came to Serbia from Vienna as a student of medicine. He was the secretary of the Soviet. Lazar Arsenijević Batalaka wrote about him: "He came to Serbia in mid-1807. A native of Čerević, a village on the other side of Fruška Gora, lying on the Danube. First, he was sent to mines known to have lead ore. This was done with him because he, among other sciences, attended chemistry. " Sima Milutinović Sarajlija mentioned him in 1826 as a distinguished expert although he was not a mining engineer.

Having failed to develop, mining was off with the collapse of the uprising in 1813. In addition to the lack of expertise and knowledge in ore exploitation and processing, failure of the uprising mining could be explained by the fact that ore was obtained from deposits with complex ores of lead, zinc, copper, silver, arsenic and iron, which was an unsolvable problem not only for the time but even much later.

Leading Serbian people of the time deserve respect and admiration for the efforts they made to revive Serbian mining, and in particular for the readiness to take into account knowledge and expertise. The First Serbian Uprising was only the beginning of the renewal of the Serbian state, but also the beginning of new Serbian mining.

After the Second Serbian Uprising in 1815 and diplomatic efforts to obtain as many privileges as possible, until the Edict in 1830 which granted Serbia the autonomy with borders recognized in 1812, followed by the Edict in 1833 which gave Serbia six more nahijas, and the creation of conditions for independent decision-making and opening to the world, the economic steps of Prince Miloš Obrenović were aimed at the reconstruction of mining.



*In the year of the Second Serbian Uprising Davy lamp (Humphry Davy), was designed, whose use significantly reduced the number of accidents in mines.*

Prior to concrete decisions, the Prince in 1834 turned to renowned mining expert Baron Herder, the royal mining manager in Freiberg, to get an expert opinion and assistance to make "the mineral wealth useful for the Serbian fatherland" and asked, through an unknown intermediary (it is assumed that it was Dimitrije Radović, a merchant from Vienna) to suggest a number of mining experts to assist in the opening of some mines in Serbia. Herder

answered the Prince in October 1834 with a suggestion "On the employment of mining experts and workers in Serbian mining." Satisfied with the answer, Prince Miloš invited Herder to come to Serbia and personally see the potential of mineral resources. Through Transylvania and Banat, Herder arrived in 1835, and from 24 August to 31 October, while visiting Serbia, he studied the geological structure, explored the abandoned mines and sources of thermal water. He submitted a report upon returning to Kragujevac to Jevrem Obrenović. Summarized, the report was published in Serbian in 1845 titled *Mining trip to Serbia*, and in German in whole in Pest in 1846 (Herder S. A. W, "*Bergmännische Reisen in Serbien*," Verlag von K. A. Hartleben, Pesth, 1846). It was the first and for a long time the only professional publication on the deposits and mines of Serbia. On Zeljin mountain, near Rudnjak, he discovered a new mineral which he called "milošin" by Prince Miloš.

Upon returning to Freiberg, Herder began to write about the study of Serbian mineral goods, but fell ill and died in 1838. Herder's visit, review and report from the trip to Serbia had a decisive impact on the further course of mining in renewed Serbia. This was the beginning of a new history of Serbian mining.

As much as the prospection of abandoned mines and the proposal he gave in his report were significant for the future of Serbian geology and mining, it was more important that Herder suggested and convinced Prince Miloš that he needed to educate his own mining personnel. In a letter dated 26 April 1837, he proposed to Miloš to send, as soon as possible, young Serbs to study mining at the Mining Academy ("Sobald wie möglich, einige junge Serben auf die Bergakademie zu senden, um hier die Bergwerksmeisterschaften zu erlernen... ") whose education he would take care of when they came to Freiberg.

Then there was a new Herder's letter dated 6 May 1837 dedicated to the same subject in which he detailed the method of education at the Mining Academy in Freiberg, and suggested that the Prince should send at least three to four young men who would spend five years in training, which would be enough to master theoretical and practical knowledge. Annual maintenance would be 250 ducats for each.

Herder's proposal on the education of mining engineers was undoubtedly accepted and in early June in 1837, the Prince sent a proposal to Soviet. At the solemn Assembly on Ascension Day in Kragujevac, a decree was issued "on sending few students of ours to Saxony to study mining." Already on June 12, the Prince's command was published "to send around twenty young men up to 15 years of age to study mining in Saxony," By the end of the month the schools selected 25 young men that should be sent to study in Freiberg in the fall.

Sending young men to study in Freiberg was postponed by the disease and death of Baron Herder in 1838 and Prince Miloš's descent from the throne.



**Sigmund August Wolfgang Baron Herder** (Bikerburg, 1776 - Dresden, 1838), a mining and metal smelting engineer, a geognostician, a lawyer, a son of famous German philosopher and poet Johann Gottfried Herder. The love of young Herder towards mineralogy and geology was inspired by his godfather Goethe, with whom he went for long walks. He graduated in 1800 from the Mining Academy in Freiberg and obtained a doctoral degree in 1802 in Wittenberg. He was one of the leading mining experts of his time, he worked in the mines of Saxony and in other German states and principalities, in the mines of Austria, Transylvania, Hungary, Norway, Poland, and Sweden. He was a professor of the Mining Academy in Freiberg.



*An entrance to the mine of Kučajna,  
the second half of XIX century*

The first track on the education of young Serbs in the field of mining in XIX century leads to Vuk Karadžić, who in 1834 sent his son Sava to the Mining Academy in Petrograd, to study mining as an alumnus of the Russian Empress. Sava died after three years as one of the best students. Vuk, who did not write about mining, by sending his son to study mining showed the understanding of the importance of mining for the future Serbian state. He wrote on Prince Miloš "I do not know whether you know that my late son was in the corpus of senior engineers, where officers are prepared to dig ores and manage quarries, and so I hoped to welcome him, to see him in his field (on Rudnik or Kopaonik mountain) where he would serve to our homeland.

The regency of minor Prince Mihailo together with the Soviet decided to send a few boys for schooling. The number depended on the cost of education, and the intention was to send the best and the poorer. They chose four: Ivan Matić (1817-?) from Jadar, Djordje Branković (1819-1869) from Belgrade, Stevan Pavlović (1820-1862) from Šabac and Vasilije Božić (1820-?) from the village of Čumić. As the scholars of the Ministry of Education, on 13 October 1839, they went to study at the Mining Academy in Chemnitz (Austria). Chemnitz was chosen instead of Freiberg due to lower costs of schooling. Despite poor previous academic preparation, poor initial knowledge of German and more than modest scholarships, Serbian students studied hard and completed their studies within the deadline. The first Serbian mining engineers returned from studies in December 1844 and in January 1845 were immediately sent to work in the Department of Trade of Ministry of Finance, led by Jovan Gavrilović. He, however, failed to employ them, and soon there was a conflict with him. Djordje Branković during 1849 completed a year of service in the State Geological Institute in Vienna, and thus officially became the first Serbian geologist.

This was the beginning of schooling of Serbian mining engineers. By the end of XIX century, mining studies were completed by 18 Serbian engineers at prestigious European mining academies and universities in Freiberg, St. Petersburg, Pshibram, Leoben, Clausthal, Berlin, Paris, Yekaterinoslav, Zurich, Liege, and Mons.

Ami Boué came to Serbia with a French geologist and topographer, a Czech botanist and zoologist, for the research of the Balkans in the spring of 1836. Prince Miloš welcomed them and organized all local authorities to be at their service during the trip. They began geological in other studies in Belgrade, on the way to Krarujevac they visited Avala and Kosmaj, after Kragujevac they visited Rudnik, Kopaonik, Novi Pazar, Peć and Priština, and then continued to explore Macedonia, northern Greece and western Bulgaria. From Bulgaria over Piroć and Bela Palanka he arrived in Sokobanja where Prince Miloš stayed.

He researched Rtanj as well, then via Kragujevac, Paraćin, and Jagodina he returned to Belgrade and traveled to Vienna. Boué, namely, crossed the Balkans five times alone or with companions.

Boué stayed in Serbia again in 1837 and 1838 to explore the areas of Majdanpek, Golubac, Požarevac, Niš, Leskovac, Vranje, Priština, Prizren, Fruška Gora, Krupanj, Valjevo, Novi Pazar, Plave and other. He researched the sources of thermal and mineral water in Brestovačka, Gamzigradska, Niška, Ribarska, Vranjska, Jošanička, Lukovska, Bukovička, Višnjicka Banja, Sokobanja and Palanački kiseljak.

During the following two years, he was arranging the notes and collected documentation and prepared for publishing a book on the Balkans; it was *European Turkey*. The integral work entitled *La Turquie d'Europe* was published in Paris in 1840. In terms of its contents, it included the geography, geology, statistics, ethnology, customs, archeology, trade, religion of the Balkan Peninsula. That same year, Boué published the second part of the book dedicated only to geological research called *A Geological Sketch of European Turkey (Esquisse géologique de la Turquie d'Europe)*. With this work, Boué became the founder of the geology of the Balkan Peninsula. In order to create favorable and clearly defined legal conditions for the development of mining, Prince Mihailo passed the Mining Law in 1866 which regulates the operation and administration of the Serbian mines. Pursuant to Article 20, the V section of the Ministry of Finance had to take care of mining. Mining remained under its management until 1884, when Ministry of National Economy was established. Since 1919, Ministry of Forests and Mines had been in charge of the mines, and after the Second World War, Ministry of Mining took over the role.

In liberated Serbia, Majdanpek was the first mine in which the production started in 1847. Funds large for the time were invested (over nine million) and much was expected. The idea was to create grounds for the industrialization of Serbia by the production of iron and copper in Majdanpek. Majdanpek thus became the center of all geological and mining studies in Serbia. For a decade of work, the objective was not achieved, the attempt was unsuccessful and expensive. It was a great material damage to Serbian mining and weak economy from which the country would not recover for a long time.

Kučajna was opened in 1849, but the works were soon suspended. A similar thing happened with mines on Avala and Kosmaj in 1854. After these experiences, for half a century every state initiative in connection with mining was overshadowed by failure. Therefore, a decision on granting concessions to private investment in geological exploration and ore exploitation was made.



**Ami Boué** (Hamburg, 1794 - Vienna, 1881), a doctor by education, a geologist, ethnologist, geographer, naturalist and archaeologist by occupation. He grew up and was educated in his native Hamburg, continued his education in Edinburgh, Geneva, and Paris. During the studies of medicine in Edinburgh, he became interested in geology and attended courses in mineralogy and crystallography. He began to engage in geological research in Scotland. After finishing his medical studies in 1817, he settled in Paris, where in 1820 he published a *Geological essay on Scotland (Essaigéologique sur l' Ecosse)* where he for the first time methodically described volcanic rocks. He was one of the founders of the French Geological Society in 1830 and its chairman in 1835. In Paris, in 1840 he published a scientific study titled *European Turkey* in four volumes (*La Turquie d'Europe* Vol. I-IV) on 2,247 pages. This work was published in German (*Die europäische Türkei*) in 1890.

He was a correspondent of the Serbian Learned Society. In 1849 he published the first ethnological map of the Balkan Peninsula.



*A geological map  
of Felix Hoffmann, 1892*



*The Mining Law of  
Price Mihajlo Obrenović, 1866.*

Among the first were the concessionaires were Felix Hoffmann (1830-1914), a mining engineer, Ilija Milosavljević Kolarac (1800-1878), a merchant and donor, and Milan Piroćanac (1837-1897), a lawyer and politician. Hoffmann in 1862 bought concessions for Kučajna mine and the other two that same year took concessions for the exploration of ores in the valley of the Drina. In Kučajna, he built an exemplary mine and foundry for lead and zinc, but after ten years he faced business problems and suspended the production.

Coal as an energy source became significant with the invention of the steam engine (James Watt, 1764) and its application for moving ships (the first steamboat, Robert Fulton, 1807; our part of the Danube was crossed in 1834 by the first steamship "Agro," 52 horsepower, 242 tons of capacity; French-Serbian steamboat company, established in 1856, with four steamboats operated until 1864 on the Danube, the Sava, and the Morava), railways (the first steam locomotive, George Stevenson, 1818), machines in mines and industrial plants (the beginning of industrialization). This affected a great increase in iron consumption.

On the northern slopes of Fruška Gora, the first exploitation of coal in Serbia started. There were small mines from which coal was periodically extracted from the shoots, assumingly near Sremski Karlovci and Čerević. Coal mine Vrdnik, on the south side of Fruška Gora, the oldest Serbian coal mine, was opened in 1804. Until 1894 it belonged to Ravanica Monastery in Vrdnik. Subsequently, the mine changed its owner several times, More serious research of the deposits began in 1871 resulted in the construction of the main shaft in 885, by the expansion of the exploitation shaft and more organized and mass production.

In 1846, coal was excavated in shoots near Smederevo, in the village of Dobra on the Danube, and in Ripanj near Belgrade it was explored in 1850. This was not accidental, steamboats had already sailed on the Danube and coal was needed for their driving.



*The beginnings of coal exploitation on the northern slopes of Fruška Gora, Čerević, XVIII century (lithography)*

In Miliva near Despotovac, coal began to be taken out in 1837, in the Senje mine in 1853 and in Misača near Arandjelovac a few years later, and so on.

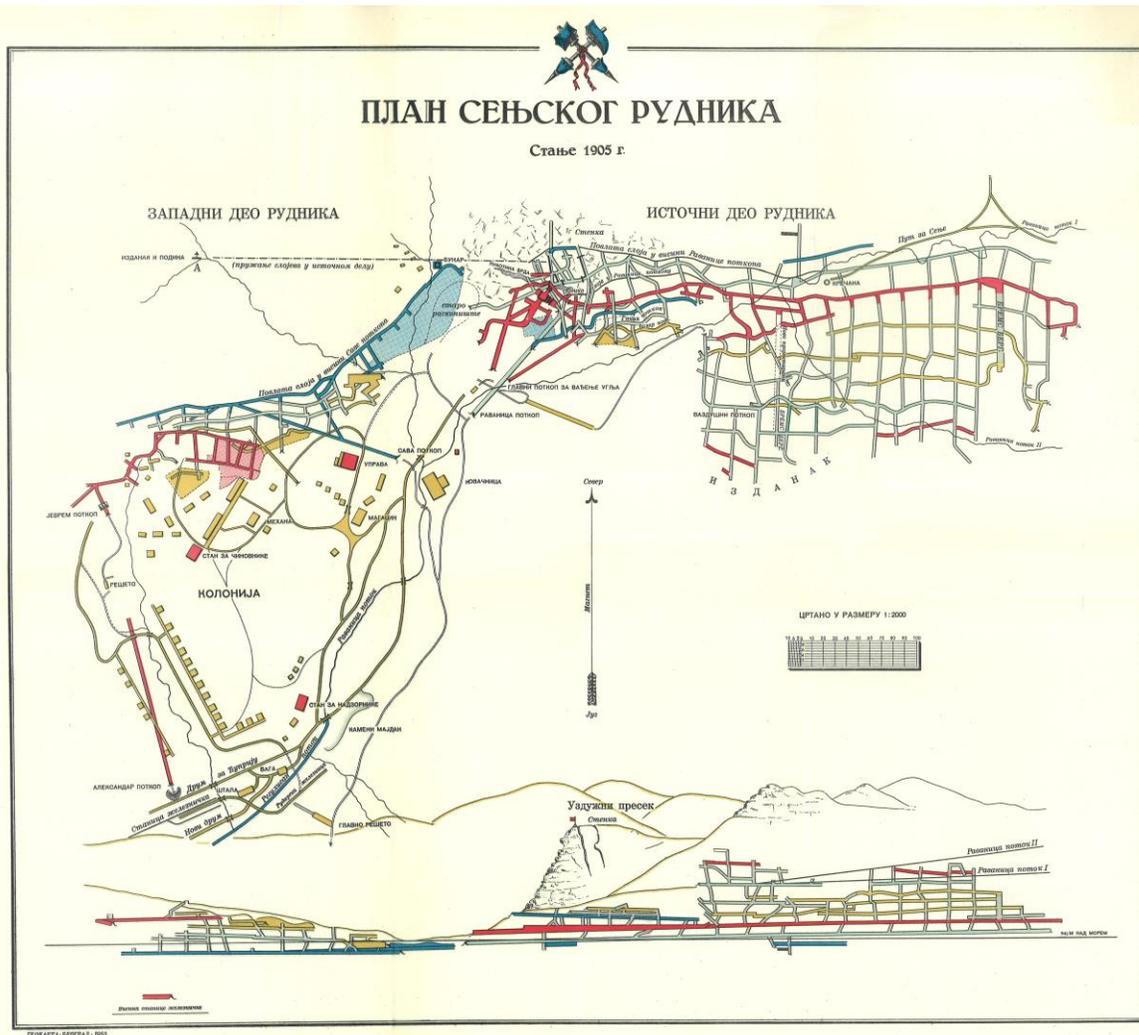
The story of the discovery of coal deposits in the Senje mine is interesting. In the vicinity of the village of Senje, while pig herding, Lazar Pandurović found a strange-looking stone and accidentally put it in the fire. The stone turned into flames and embers, Lazar called it "unhealthy stone." Being curious, he took a few pieces of "unhealthy stone" and took them to Čuprija to determine what kind of stone that was.

The opening of the Senje coal mine started in 1853 by building a foundry in Kragujevac which had to be supplied with high in quality fuel. "Ministry of Finance - Mining Department" made a decision on the opening of a coal mine, and with this assignment sent engineer Vasilije Božić to the field. The opened mine was named Majdan Aleksandrovac after Prince Aleksandar Karadjordjević (1806-1885). After Aleksandar's descent from the throne (1858), the mine got a new name - Majdan at Senje, and current name Senje mine is from recent times. After the preparatory work in the field, clearing, and cutting of woods, surface mining was started in the shoot of the coal seam. The first 26.320 okas, or 33.7 tons of coal were shipped to the foundry on 12 May 1854, in 98 carts. We should note that in the first decades of XIX century coal, copper, iron, lead, etc. were measured as wheat in okas. The metric cent was introduced in 1870, and since 1910, coal has been measured in tons.

In the Senje mine, coal was firstly seasonally exploited, only in favorable weather conditions from spring to autumn. Except for a short period (1869-1874), the mine has so far always been in the hands of the state. The construction of mining facilities and buildings for the accommodation of miners began in 1861 years. To the decision on the construction of railway Belgrade-Niš, Ministry of Finance, in charge of the mine, reacted by inviting Felix Hoffman to investigate and determine the boundaries of coal deposits. Hoffmann did his work from June to August in 1874 and submitted the findings to the Ministry. By releasing (1884) railway Belgrade-Niš, the need for brown coal significantly increased due to steam traction. To facilitate the delivery of coal, a narrow-gauge railway Čuprija – Senje mine was built and put into operation in 1892. The railway was extended in 1908 to Ravna reka. The control over the Senje mine in 1894 was taken over by the Directorate of State Railways. With the aim of selling fine coal, a briquetting plant was constructed in 1897 in Čuprija, and two years later a mechanical screening plant as well. In addition to works in mines Aleksandar, Ravanica and Sveti Sava, the construction of shaft Joksimović and research works in Buljina bara began in 1898.



The Senje mine, a miner in front of the entrance to the Aleksandar mine, the second half of XIX century



The Senje coal mine, the mine plan, 1905

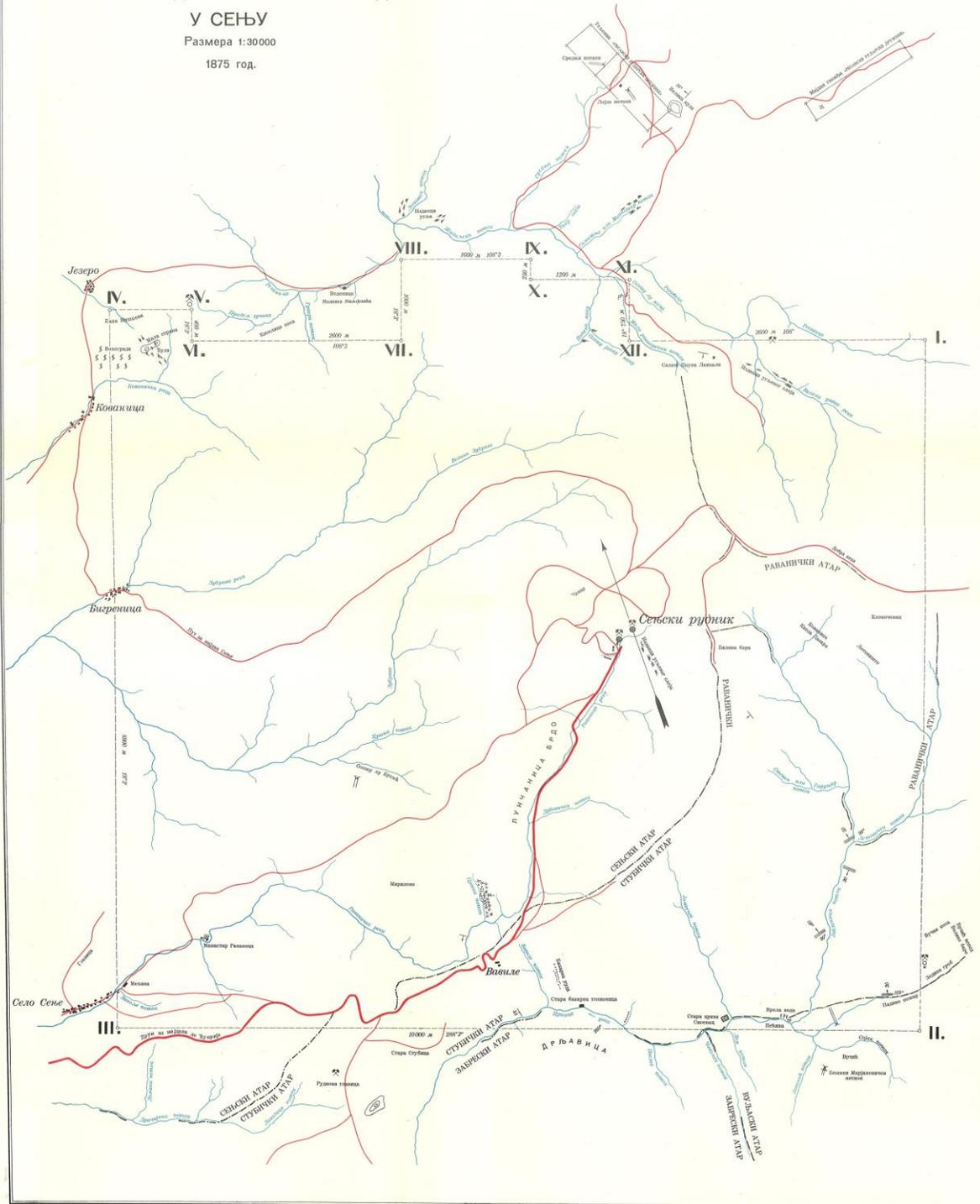
# ПЛАН

ОГРАНИЧЕЊА РУДНОГ ПРОСТОРА ЗА ДРЖАВУ

У СЕЊУ

Размера 1:30000

1875 год.



ГЕОКАРТА - БЕОГРАД - 1993

The Senje coal mine, plan limits ore field (1875)



*The Senje mine, export shaft Joksimović,  
the end of XIX century*



*A composition on railway Senje mine – Čuprija (narrow-gauge railway of a width of 0.75 m, 21.3 km long)*

Work technology was primitive, and the miners came to work in their own clothes. They wore a coat, *šubara* (a type of winter hat), or *šajkača* (Serbian national hat) and *opanci* (traditional peasant shoes). With bullock's cars or caravans, the coal was shipped to the railway and foundry in Kragujevac. By all accounts, the coal was not interesting for the general consumption in then underdeveloped Serbia rich in forests.

Besides the railway and foundry, the gradual increase in interest in coal in Serbia was affected by the construction of the first industrial steam plants (mills, sawmills, breweries, distillery etc.), and in particular by the appearance of steamboats on the Danube.

Based on the publication of Jevrem Gudović, the Chief of the Mining Department, Ministry of Finance of the Principality of Serbia, "a permit to various parties to freely explore coal in Požarevac county and Ramski county, in Požarevac district" was issued in 1870. This document does not mention Kostolac, but the "Register of places in Serbia with various ores and mines" states that in 1872 the approval for the exploration of coal in Kostolac, Rečica and Poljana was granted. From the "Overview of activities in mining, from 20 June 1865 to the end of May 1872" shows that in Požarevac county, until May 1872, only one free right to the exploration of coal was issued, and it was in Kostolac. The *Serbian Newspaper* of November 3, 1873, published the news that Ministry of Finance had given privileges to dig coal in Kostolac. The privilege (concession) was issued on 50 years to Franja Všetčki for the space of the Kostolac coal mine, which occupies 31 ore fields, 100,000 m<sup>2</sup> each. Coal production in the pit of Stari Kostolac officially began in 1873, when 15.050 charcoal cents, or 301 tons, were produced. The following year, the production was tripled, and coal was exported to Vojvodina and Romania.

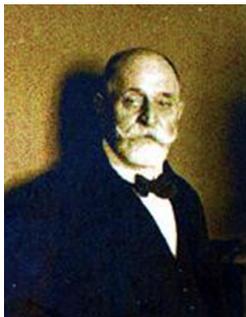


**Felix Hoffmann** (Moldova Nouă, 1830 – Bela Crkva, 1914), a mining engineer, the most respected mining expert of Serbia in the nineteenth century, came from a prominent mining family. He studied mining in Chemnitz. He first stayed Serbia in 1856 when he visited Majdanpek, Rudna glava, Kučajna, Aleksinac, Paraćin, Požarevac. At the invitation of Prince Mihajlo, Hoffmann moved to Serbia in 1862. After the business failure with Kučajna, he worked in the civil service as a geologist. During the geological examination of the route of railway line Belgrade-Niš, he discovered several iron deposits near Ralja and coal deposits in the area of the Pčinja and the South Morava. He is responsible for detecting locations of auriferous sediments on the Pek River, deposits of mercury on Avala, copper in Bor. He opened the gold mines of Blagojev kamen and Deli Jovan, coal mines in Resavica nad Melnica. In the Senje mine he stayed on several occasions and contributed to its development.

Georg Weifert purchased a part of concessions and became a co-owner of the mine, and later on May 20, 1881, he paid off his partner Všetěčki and became the sole owner of the coal mine. It was an important event for the mine and Serbian mining. Weifert rapidly upgraded the mine into the most prominent one thus taking a significant role in restoring Serbian mining. Since the mine with five undermains of a cross-section of 6 m<sup>2</sup> and a total length of 1,900 m had problems "about arranging the mining district" and extracting coal in horse-drawn wagons, Weifert in 1883 hired experienced mining expert Franja Šistek to be the mine manager. With consultations with Felix Hoffman, Šistek in a short time reorganized and stabilized the production in the mine, he did it so well that Weifert in 1885 filed a request for the extension of benefits for 10 new mining fields. Since the beginning of the work of coal mine in Kostolac, there had been the question of fine coal sale. Weifert solved the problem by building "a brick factory with two furnaces and machines for the production of 500,000 bricks or tiles" in 1885 in Kostolac, as stated in a written document. A joint-stock company from Požarevac in 1883 opened a new coal mine named Klenovnik in Kostolac. With the advent of steamships on the Danube, the construction of the railway with steam traction, the beginning of industrialization with steam machines, Weifert, as a shrewd businessman, realized the upcoming importance and value of an energy source such as coal on time.



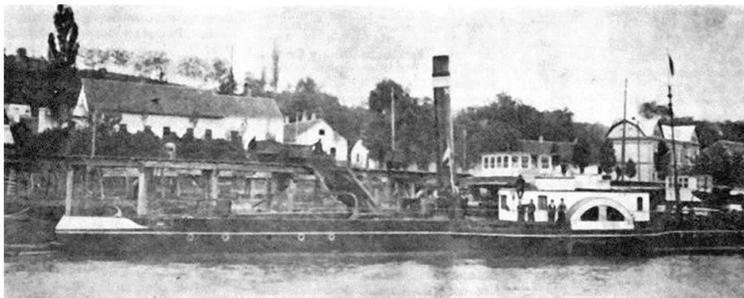
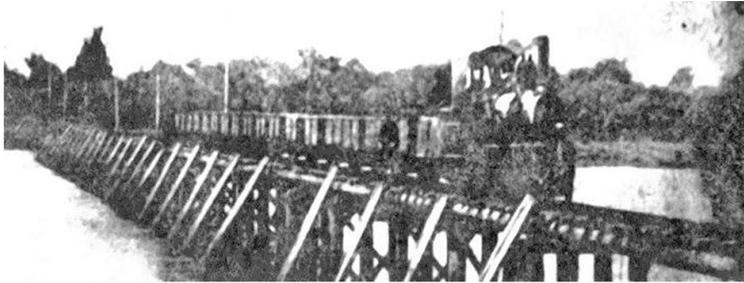
*Old Kostolac, entered the mine and transported coal in a pit, at the end of the XIX century.*



**Georg Weifert** (Pančevo, 1850 - Belgrade, 1937), an industrialist, a banker, a major investor and a pioneer of Serbian mining construction at the end of the nineteenth and early twentieth century, a patriot, a soldier and a warrior, one of leading Freemasons in Serbia and Yugoslavia of his time. From 1883 to 1889, the Vice-Governor, and since 1890, for about three decades, the Governor of the National Bank of Serbia, after the First World War the Governor of the National Bank of the Kingdom of Yugoslavia. He was also the honorary President of money institute "Beogradska zadruka." During the withdrawal of the Serbian forces over Montenegro and Albania in 1915, he successfully organized the evacuation of the gold backing requirements of the dinar (bars and objects of gold) over Durrës to Marseille. Throughout the war, the National Bank of Serbia was functioning, thus providing the existence of Serbian statehood even outside its territory. He is also known as

the creator of the modern brewery in Serbia. He owned the coal mines Stari Kostolac, Bogovina and Dobra Sreća. He invested the money obtained from beer and coal production in the exploration of gold and other mineral resources throughout Serbia. Thanks to his business intuition, understanding, persistence, and investments that led him to the brink of bankruptcy, in 1902 the most important polymetallic copper ores mines in Serbia were discovered at the site of Čoka Dulkan (Dulkan hill) near Bor.

This was the immediate cause of his interest in coal and investment in mines Stari Kostolac, Bogovina and Dobra sreća. Realizing the profitability of work with coal, Weifert patiently invested the profit generated from coal in geological exploration of gold in eastern Serbia.



*Kostolac, transport and loading of coal on a ship on the Danube, late XIX century*

The search for gold-bearing deposits was led by the Šistek's team upstream along the Bor River which discovered the location of Čoka Dulkan (Dulkan hill), Tilva mika (Mala stena) and Tilva roš (Crvena stena). Experienced mining experts Hoffmann, Šistek and Jaroslav Kučera knew how to interpret yellow to red "iron hats" that covered the hills, or to understand the messages that nature left in this way. Under the operational leadership of engineer Jaroslav Kučera, who was entrusted the task, the research was continued in 1898 in the belief that the goal (gold) was closest to the site of Tilva roš.

After four years of researching, the results were not satisfactory, the gold content was on average 0.5-3.0 grams per ton of quartz. The duration of research and large investments led Weifert to the brink of bankruptcy, but he did not give up. In consultation with Hoffman, Šistek changed the spatial target and excavated in the village, on the right bank of the Bor River below Čoka Dulkan. This yielded a result - at 120<sup>th</sup> meter in the excavation of the ore body, instead of "yellow" they found a rich cradle of "red gold" - copper in October 1902. This was a great event for all as this found the most precious deposit in Serbia. Thus Weifert, Hoffmann, and Šistek entered permanently into the history of Serbian mining leaving an indelible mark.

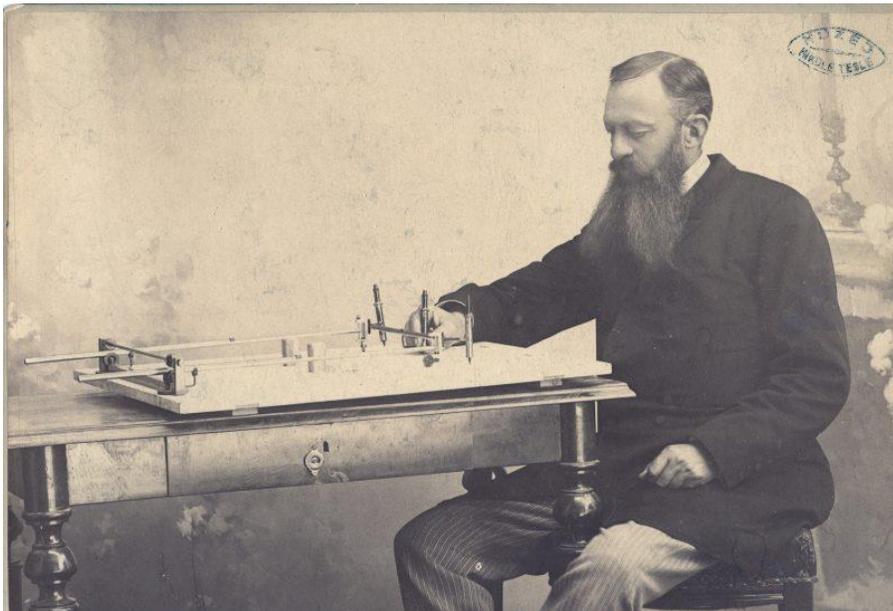


**Franja Šistek** (Plzen, 1854 - Bor, 1907), a prominent mining expert. He came to Serbia at the invitation of G. Weifert at beginning of the ninth decade of XIX century, for whom he worked until 1904. That year the Bor mine changed its owner and Šistek started working for the French shareholding company. Under his administration, the coal mine in Kostolac shortly became the most organized mine in Serbia. By Weifert's order, at the end of XIX century, with the technical support of F. Hoffmann, he conducted research in eastern Serbia. Exploring the gold, in the mine of ore body Čoka Dulkan, in 1902, he discovered a rich copper deposit. It is assumed he was awarded the Order of the Cross of Takovo for the results of work in Kostolac (see the photograph).

The return of young educated professionals, although insufficient by number, in the second half of XIX century, was remarkably reflected in the opening and development of mines, the planning and guidance of the exploration of mineral resources, the establishment of geoengineering standards in facilities construction (railways, roads, bridges and other structures), the modernization of mining laws and normative regulatory regime, the modernization and establishment of an operational organization of the state administration for mining, and what is particularly significant - in laying the foundations of the educational and scientific development of the mining, geological and total Serbian engineering and the establishment of the Serbian Learned Society, and then the Serbian Royal Academy.

Lyceum, which was established in Kragujevac in 1838, was transformed into Higher School on September 24, 1863. The teaching staff educated at leading European academies, institutes and universities gave the school a high reputation of European scale. The staff included our most eminent scientists of the time: Ljubomir Klerić, Jovan Žujović, and Jovan Cvijić.

A multidisciplinary approach, the breadth of research, engineering, innovative, inventive, educational, theoretical and experimental work, as well as the breadth of general knowledge embellish the work of Ljubomir Klerić.



**Ljubomir Klerić** (Subotica, 1844 - Belgrade, 1910), a mining engineer, a scientist, a university professor, an academician, was born in a family of German immigrants in Subotica. After moving to Belgrade, the family changed its name Kler to Klerić, and his name Julius to Ljubomir.

He was educated in Subotica and Belgrade. He enrolled in Technical Faculty of Higher School in Belgrade in 1862. After two years of studying as "a state alumnus," he was sent to study mining at the

Mining Academy in Freiberg (MAF). In the winter semester of 1867/68, he switched to the Zurich Polytechnic to study mechanical engineering. The following year, he completed the mining studies at the MAF and went to specialize at the Mining Academy in Berlin, while gaining some practical experience in German mines in Westphalia, Saxony, and Upper Silesia, and in Příbram in the Czech Republic.

He returned to Belgrade in 1870 where he worked as a clerk in the Mining Department of Ministry of Finance of the Principality of Serbia. He stayed in Germany and France in 1872 and patented the construction of drilling equipment with a rope, which quickly became widely used. The following year, with Rafael Hoffmann (the older brother of Felix Hoffman), he came to Serbia and geologically explored Venčac, Rudnik, Kosmaj. On Avala, he found mercury deposits. He was engaged in a geological survey of the route of railway line Čuprija-Aleksinac and many similar tasks. In Oran in Africa, he successfully conducted the exploration of iron deposits. He constructed a telemeter, a polar pantograph, a tractoriograph and tools for drawing curves of the second order. Klerić was elected regular Professor of Mechanics and Science of Machines in Higher School in 1875. In 1880, the course was

divided into Theoretical Mechanics and Science of Machines, with Klerić taking over the former. He was highly engaged in improving and promoting higher education, he was the Dean of the Faculty of Engineering, he founded the Department of Descriptive Geometry with Projective Geometry and Graphostatics, he was the Minister of Education and Religious Affairs, the Minister of National Economy, a member of the State Council, of the Commission for the transformation of Higher School into University in 1905. He was elected regular member of the Serbian Learned Society in 1872, and by a decree of King Milan Obrenović in 1887 he was appointed a member of the Serbian Royal Academy (SRA) together with fifteen colleagues. In March 1888, he held the inaugural speech "On the theory of compensation". He was elected Secretary of the Committee for natural sciences of SRA in 1891. He proposed Nikola Tesla for a corresponding member of SRA in 1894.

Klerić is the author of numerous scientific papers, books and a university textbook titled *Theoretical Mechanics I-III*. He participated and stood apart by his courage in the Serbian-Turkish and the Serbian-Bulgarian war. He was awarded the Medal of Bravery and the Cross of Takovo; Belgian King Leopold II awarded him the Order of Leopold.

To show respect and remembrance for the name and work of Ljubomir Klerić, the Department of Mining, Geology and System Sciences of the Academy of Engineering Sciences of Serbia established in 2012 a Charter with his name for lifetime achievement in the field of mining, geological and system sciences and engineering.

The outset of geological school in Serbia is associated with Josif Pančić, who held the first lecture in geology on Natural and Technical Department of the Lyceum in 1853. The first scientific work of Serbian geologists was published in 1854 in Vienna. This conceived modern geological science and school in Serbia, but our first educated geologist and the founder of Serbian geological school and science is Jovan Žujović.



**Jovan Žujović** (Brusnica, 1856 - Belgrade, 1936), a geologist, a university professor, a scientist, an academic, a politician, a diplomat and a statesman. He received his education in Nemenikuće and Belgrade. He began his studies at the Polytechnic in 1872 in Zurich, returned to Serbia in 1873 and continued the studies at the Natural Mathematical Department of Higher School, from which he graduated in 1877. In the autumn of the same year, he went to Paris to continue his education at the Sorbonne, in the field of natural sciences and anthropology. From Paris, in 1880 he brought the first polarization microscope and introduced microscopic tests of rocks in our region. That same year he was elected secondary school teacher at the Department of Mineralogy with Geology in Higher School in Belgrade. He taught Mineralogy, Geology, and Paleontology. He became a full professor of Higher School in 1883. His following years were extremely fruitful in the creative sense, he wrote the

basic geology textbooks, founded the Geological Institute of Higher School (1889), created the geological map of Serbia (1880-1900).

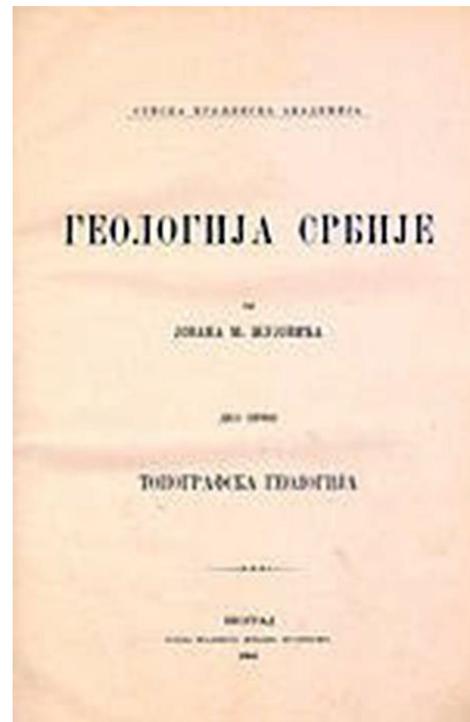
Apart from *Letopis Matice srpske* that appeared as a literary and scientific journal in 1824, our and southeastern Europe's oldest scientific journal *Geological Annals of the Balkan Peninsula* was initiated by Žujović and his associates in 1888 to publish the results of scientific research. The journal has been published without major interruptions from 1889 until today. In order to be accessible to a wide circle of scientists, the first six books were printed in their entirety in French, German and Serbian. By gathering the members of the editorial staff and other geologists, in 1891 the Serbian Geological Society was formed being one of our oldest scientific associations.

He was one of the founders of Museum of the Serbian Land (today Museum of Natural History in Belgrade). He introduced the teaching of agogeology at Faculty of Agriculture, doing a creditable job for its establishment. At the Technical University, he taught Applied Geology.

During the establishment of the Serbian Royal Academy (according to the Basic Law of the Royal Serbian Academy of November 1, 1886), King Milan Obrenović with a decree dated April 5, 1887 appointed the first 16 members of the Academy: Josif Pančić, Dimitrije Nešić Jovan Žujović and Ljubomir Klerić (natural sciences); Stojan Novaković, Milan Kujundžić, Svetislav Vulović and Svetomir Nikolajević (philosophical sciences); Čedomilj Mijatović, Milan Đ. Milićević, Ljubomir Kovačević and Panta Srečković (social sciences); Ljubomir Nenadović, Matija Ban, Mihailo Valtrović and Davorin Jenko (arts). As the youngest among them, Jovan Žujović became the Secretary of the Academy, and Josif Pančić was elected President. From 1915 to 1921, Žujović was the President of the Serbian Royal Academy.



*Jovan Žujović: Sketch of the geological map of the Kingdom of Serbia, 1886*



*Jovan Žujović: The cover of The Geology of Serbia*

When preparing the establishment of the Belgrade University in 1905, he was appointed a full professor, one of the eight, who then chose other teachers of the University. From that position, he withdrew immediately after the establishment of the University. On behalf of the Serbian Royal Academy, he spoke at the opening ceremony of the university.

His most significant scientific and professional papers include: *Geologische Übersicht des Königreiches Serbien*, 1886, Vienna; *Petrographic Mineralogy*, 1887; *Petrography I-III*, 1889, 1895; *Fundamentals for the Geology of the Kingdom of Serbia*, 1889; *Sur les roches éruptives de la Serbie*, 1893, Paris; *Sur les terrains sédimentaires de la Serbie*, 1893, Paris; *Geology of Serbia I-II*, 1893, 1900; *The Geological Structure of the Surroundings of the Village of Boljetin*, 1921; *Lessons in Geology*, 1922; *General Geology*, 1923; *Les roches éruptives de la Serbie*, 1924; *Genesis of the Earth and our Homeland I-II*, 1927, 1929; *Supplying Villages with Water Sources and Wells*, 1931.

Jovan Žujović was very politically active. He was a member of the Senate (1901), an MP, the Minister of Education and Religious Affairs on two occasions (1905 and 1909-1910) and the Minister of Foreign Affairs of Serbia (1905). During World War II, he worked as a special envoy of the Serbian government in Paris in the Mission of organizing

Serbian schools for refugee students and collecting aid. Žujović as a volunteer participated in the Serbian-Turkish war, in the Drina Region Brigade. He was awarded: the Order of Sveti Sava of the first and third degree, the Order of the White Eagle of the fourth degree, the Cross of Mercy, and he was also an officer of the French Legion of Honor and an officer of the Educational Academy.



**Svetolik Radovanović** (Prčilovica, 1863 - Belgrade, 1928), a geologist, a scientist, a university professor, an academician. He was educated in Kučevo, Gradište, and Kragujevac, and then in Belgrade, where he finished gymnasium. He studied at the Natural Mathematic Department of Faculty of Philosophy in Belgrade (1881-1985). He continued his education in paleontology and geology in Vienna at Faculty of Philosophy, where in 1891 he passed with the highest grade "a two-hour doctoral examination in geology, paleontology with chemistry, and earned the title of" Ph.D. in philosophy" and became our first Ph.D. in geology and paleontology.

Upon returning to Serbia in 1891 he got a job of "a state geologist" in the Mining Department of Ministry of National Economy. He participated in the formation of the Serbian Geological Society, was its secretary and with J. Žujović and S. Urošević since 1893 the member of the editorial board of the *Geological Annals of the Balkan Peninsula*. At the suggestion of J. Žujović, in 1897 Radovanović was elected professor of Higher School, where he enthusiastically began to work. Together with Žujović, he did much to reorganize the Geological Institute, to modernize teaching and build the foundations of modern education at the University of Belgrade. Besides his professorial duties, since 1902 for two years he astonishingly successfully tenured as the Chief of Ministry of National Economy.

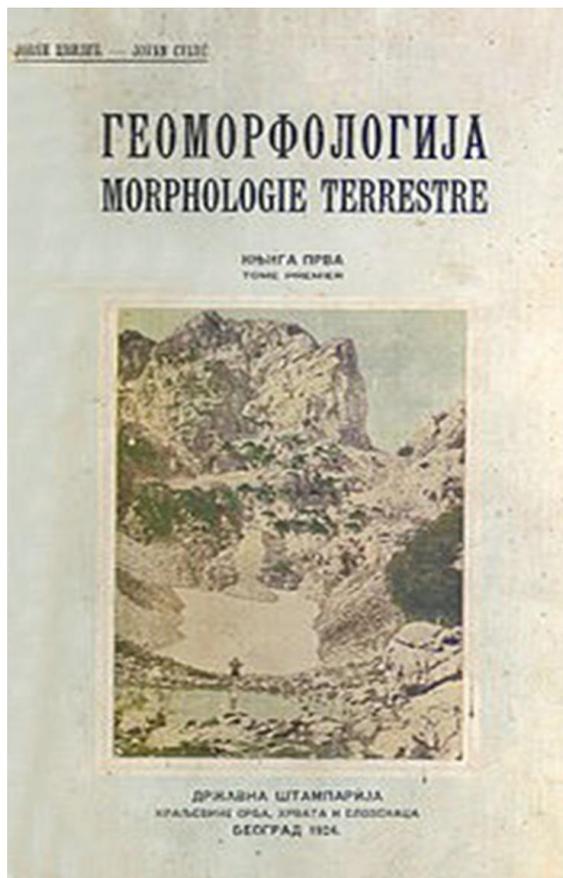
During that time he reorganized the administration of the Mining and Forestry Department, conducted Forests Act through the parliamentary procedure, contributed to the adoption of the Regulation of the brotherly safe of miners (for miners' insurance) and printed the Mining map of Serbia. At the invitation of Faculty of Philosophy in 1905, he returned to the Geological Institute of the newly established University of Belgrade and remained at the helm until his retirement. From 1906 to 1909 he was the Dean, and the year after that, the Vice-Dean of Faculty of Philosophy. He achieved outstanding scientific results, his works on the study of the Jurassic sediments of eastern Serbia are famous, he has begun the development of the detailed geological map of Serbia, he studied the seismicity of our regions and together with J. Mihajlović he made the Serbian Earthquake Catalog for 1901-1907. Thanks to this work, Serbian Seismological Service was included in the order of modern services in Europe.

He was the founder of the Serbian hydrogeology, his most important work in this domain is monograph *Underground Water*, one of the first systematized hydrogeologies in the world. He published over 80 scientific papers in the fields he dealt with. In World War I, he suffered a severe tragedy, his son died of injuries. By the end of 1916, he stayed with his family in Athens and then in Paris, where he served as a senior commissioner for refugees. After the war, at the peace conference, as an expert in mining, he was a member of the Yugoslav delegation.

After returning to desolate and destroyed Belgrade, he got down to work on rebuilding the University and the Geological-Palaeontological Institute. He received numerous awards for scientific, academic and professional work. He was elected corresponding member of the Serbian Royal Academy on February 5, 1897, and he became a full member on 31 January 1902. He was the holder of the Karadjordje's Star, the Order of Sveti Sava, the Order of the Romanian Star and the Cross of the Red Cross.



**Jovan Cvijić** (Loznica, 1865 - Belgrade, 1927), a geographer, a geomorphologist, an ethnographer, an anthropologist, a scientist, a university professor, an academician. He received his education in Loznica, Šabac, and Belgrade. He finished First Belgrade High School, in the famous generation with Milorad Mitrović, Mihailo Petrović Alas, and other renowned men, on which a novel was written and subsequently they even got a movie named "Professor Kosta Vujić's Hat." He completed his studies in 1888 at the Natural Mathematical Department of Higher School in Belgrade. A year later, as a state alumnus, he began studying physical geography and geology at the University of Vienna, where he defended his doctoral dissertation in 1892 on the results of the study of karst phenomena in eastern Serbia, Istria, and the Adriatic coast. The doctoral dissertation titled *Karst phenomena (Das Karstphänomen)* brought him fame in the international scientific community. Thanks to this work, the world considers Cvijić as the founder of karstology. The work was translated into several languages and was published in Serbia in 1895. Upon his return from Vienna in March 1893, he became a full professor at Faculty of Philosophy in Higher School of Belgrade. At first, he taught physical geography and ethnography, then just geography. In the first ten years of his career, he mainly dealt with geology with great success. After the cancellation of Higher School, Cvijić was one of the first eight (appointed) full professors at the newly formed University of Belgrade (founded in 12/10/1905). At the Sorbonne in 1917 and 1919, he lectured on the Balkan countries and peoples.



The cover of Cvijić's *Geomorphology*, 1924

Jovan Cvijić played a significant role in the reform of education; he helped to establish the Department of Ethnology and decisively influenced the opening of Medical, Agricultural and Theological Faculty in Belgrade. He was twice elected Rector of University of Belgrade (1906/07, and 1919/20). He was also elected corresponding member of the Serbian Royal Academy in 1896 and became its full member in 1899. He was the President of the Serbian Royal Academy from 1921 to 1927. He is the founder of the Serbian Geographical Society, to which he bequeathed his estate. After World War I Cvijić helped to determine the political boundaries of new Yugoslav state using his scientific understanding of demographic and anthropology-geographic research as arguments in the negotiations. In late 1918, the Serbian government appointed him the first expert for ethnographic boundaries, and in early 1919 he was appointed President of the territorial section of the state delegation at the Peace Conference in Paris. Thanks to the professional ethnographic arguments (he made ethnic-geographic maps of Yugoslav countries of 1918-1919) and the advocacy of Mihajlo Pupin, then already politically influential and world-renowned scientist, the boundaries of new state Kingdom of Serbs, Croats and Slovenes were established.

Cvijić dealt with research work for 38 years, he took numerous research expeditions on the Balkan Peninsula, the Southern Carpathians, and Asia Minor, which yielded significant scientific works. He is considered to be the founding father of Serbian geography. In addition to dealing with geography, he dealt with geomorphology, tectonics, paleogeography, neotectonics, ethnography, anthropology, history, etc. The two-volume *Geomorphology* of Jovan Cvijić gives a geomorphological presentation of the Balkan Peninsula, and today is the starting point in landscape research. He has published hundreds of scientific papers. One of the most important works is *The Balkan Peninsula*. As a world-renowned scientist, he was the holder of numerous awards. He was a member of eight Academies of Sciences, 16 geographical and nature societies, an honorary doctor of the Sorbonne and Charles University in Prague, an honorary member of many geographical, ethnographic, natural and other societies throughout the world, he received 10 medals. Today, a kind of saffron and a peak on Rudnik mountain (1,132 t) bear Cvijić's name.

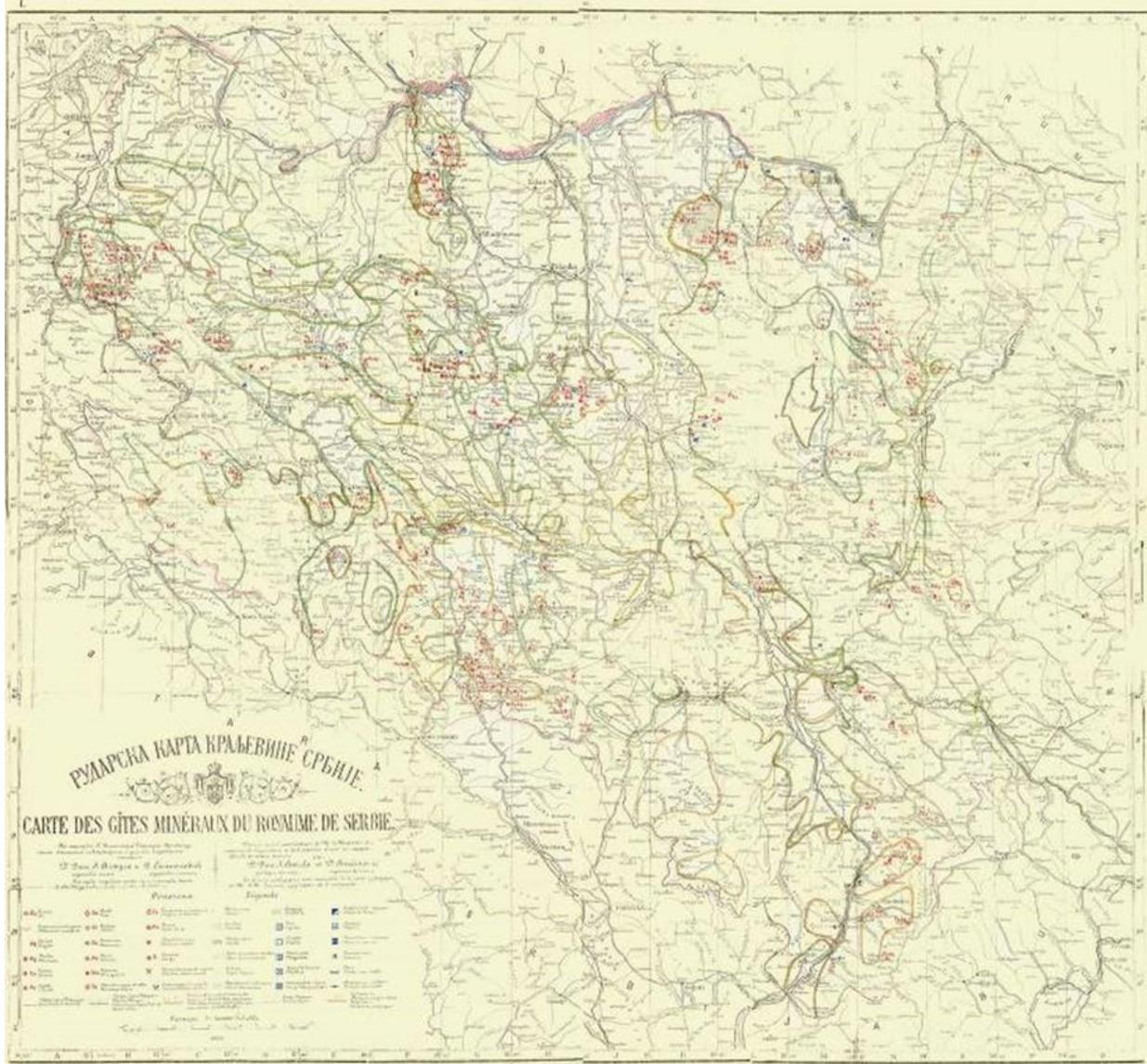
At the turn of XIX century, a significant contribution to the development of Serbian mining and geology was made by



**Dimitrije Antula** (Belgrade, 1870-1924). He completed his studies in geology in 1891 at the Natural Sciences and Mathematics Department, Faculty of Higher School in Belgrade.

He worked as a secondary school teacher and professor in The Third Male High School in Belgrade. During the specialization at the University of Vienna from 1894 to 1896, he explored the large Abih's collection of Cretaceous fossils from the Caucasus and defended his doctor's thesis on the topic of *Über die Cephalopoden der unteren Kreide des Kaukasus* 1896. With its publication in 1899 in Vienna, the thesis has entered the order of world classics on Lower Cretaceous cephalopods. He was a state geologist in the Mining Department of Ministry of National Economy 1897-1919 and the Director of General Mining Directorate in Belgrade from 1919 to 1924.

At Technical Faculty in Belgrade, he taught Technical Geology with Mineralogy from 1907 to 1922. He organized the mining section of the Kingdom of Serbia at the World Exhibition in Paris in 1900, and then at exhibitions in Liege (1905), Milan (1906), London (1907) and Turin (1911). After World War I, he led the renewal of the mining economy of the Kingdom of Serbs, Croats, and Slovenes until his sudden death. He was involved in regional geology, biostratigraphy, the exploration and exploitation of mineral resources in Serbia. In the book about mineral deposits in Serbia, he synthesized everything that was known about them until the beginning of XX century. He is the author of the mining map of the Kingdom of Serbia, (1900), book *Mining Legislation in Neighboring and Foreign Countries* (1909), and book *Geological Research in Timok Andesite Massif* (1909).



*Dimitrije Antula: The mining map of the Kingdom of Serbia, 1900*

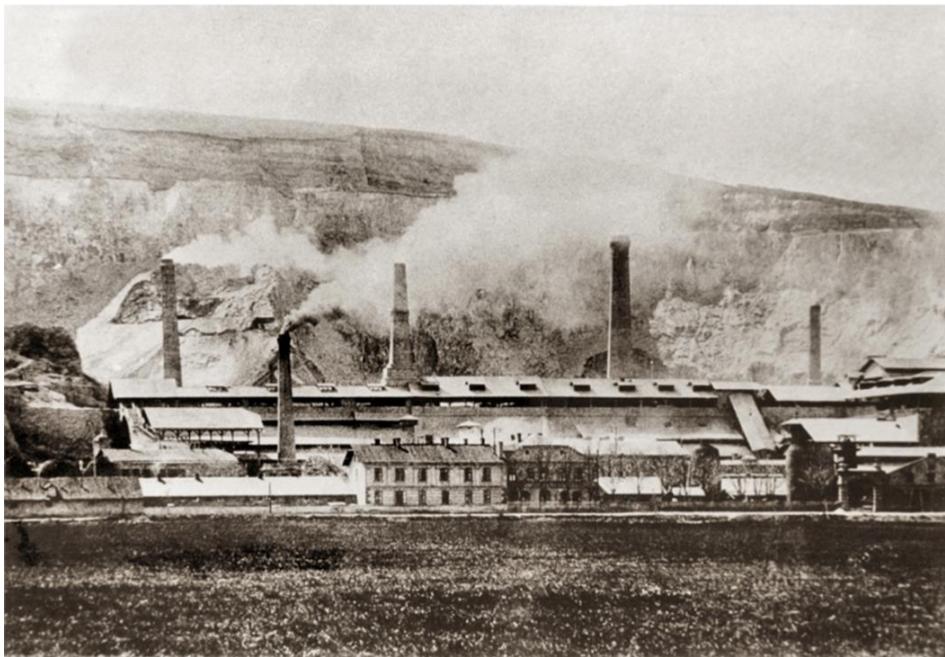
To show respect and remembrance for the name and work of Dimitrije Antula, the Department of Mining, Geology and System Sciences of the Academy of Engineering Sciences of Serbia established in 2012 a Charter with his name for supreme engineering achievements in the field of mining, geological and system sciences.

With the growth of demand for coal in the second half of XIX century, new mines were being opened. *Coal mine Vrška čuka - Avramica*, the first written document on the research and quality of Vrška čuka coal, was compiled by S. Lozanić in 1881. Thanks to Lozanić and the research of J. Žujović (1882-1886), the first underground mining works started in 1884 on the site of Prlita. In addition to Lozanić and Žujović, later research of geological structure, tectonics, and energy resources of Vrška čuka was participated by a pleiad of prominent Serbian geologists J. Popović, V. Petković, M. Pavlović, K. Petković, N. Pantić and others. Brown coal mine Vlaška close to Mladenovac was opened in the 70s of XIX century, and stone coal mine Aliksir near Brza Palanka was opened in 1888. Geological research of coal in the Aleksinac basin started in the 80s, and the production in 90s of XIX century; for example in 1899, 5,172 tons of coal were produced.

Antimony, non-ferrous and precious metal ore mines are being opened. Surface exploitation of richer deposits of antimony in Bare, Zajača, was conducted from 1895 to 1937 when it was suspended due to the large influx of water. Nikola Milanović, a Belgrade trader, in 1884 got privileges for mining antimony ore in deposit Brasina, Zajača. At the end of XIX century began the exploitation of quartz veins with antimony in the area of Bujanovac, the village of Trnovac.

At the site of Babe Kosmaj in the Roman and Medieval period, the silver-bearing lead was excavated and melted. The remains of slag formed by melting the ore, particularly at the mouth of streams Pruten and Zminjak, were mined from 1872 to 1889. The material processed was some 270,000 tons of slag with a lead content of 4-5% and a high content of silver in a smelter erected by the Austrians on the site.

Standards rising in the construction of facilities entailed the need for appropriate building materials. In 1855, Josif Čik got concessions for the exploitation of marl and started producing cement in Beočin; he milled baked marl in a water mill. By modernizing production in 1869 Čik founded a factory named "The first Srem factory of Portland cement and hydrated lime of Josif Čik in Beočin", with the annual production of around 40,000 tons of cement. The exploitation of marble on Venčac began in 1881.



*Cement Factory in Beočin, the end of XIX and beginning of XX century.*

The development of Serbian mining and geology in XIX century, between the two milestones, the First Serbian Uprising and the discovery of the rich deposits of "red gold" in Bor, has two stages. The first stage in the first half of XIX century is the stage of initial staggering and efforts to activate collapsed Serbian mining. The second stage begins by realizing the necessity of the education of professionals and the beginning of sending young people to study at reputable European academies and universities. This, in conjunction with the beginnings of industrialization, the construction of the railway and the advent of steamships on the Danube, yielded significant results in the last decades of XIX century. New mines were being opened, the foundations were being laid and a professional, scientific and academic rise started, when geology made a step forward in relation to mining. The beginning of the education of mining engineers in Serbia and the formation of mining institutes waited for the end of the Second World War.

## 6. THE FIRST HALF OF XX CENTURY

At the beginning and during the first half of XX century the trends started in the last decade of XIX century were continued. Serbia with modest economy showed no intent to adequately valorize its mineral-raw material wealth. There was interest in the exploitation of non-ferrous and precious metals, gold, silver, copper, lead, zinc and antimony. All major mines were in the hands of foreign capital, whose basic business principles were contained in the rule to derive great benefits with small investments. The then mining operated in such circumstances,.

At the beginning of XX century, an event of importance far-reaching for the development of Serbian science and university education took place. Namely, University Law was passed. A Decree of the Law was signed on 27 February 1905 by King Petar I. The law granted the autonomy of the University, claiming that "teachers are free to expose their teachings." Instead of Higher School, University of Belgrade was founded, and the Faculties of Higher School – Faculty of Philosophy, Law and Technical Faculty were declared the university faculties. According to the Law, the teaching staff of Higher School was disbanded and the selection of new teaching staff was entrusted to eight appointed professors: Jovan Žujović, Sima Lozanić, Jovan Cvijić, Mihajlo Petrović Alas, Andra Stevanović, Dragoljub Pavlović, Milić Radovanović, Ljubomir Jovanović. By the end of 1905, University of Belgrade had 16 full and 18 associate professors and 778 students. Belgrade University was the center of scientific, educational and cultural life.



*The first eight full professors at University of Belgrade, 1905*

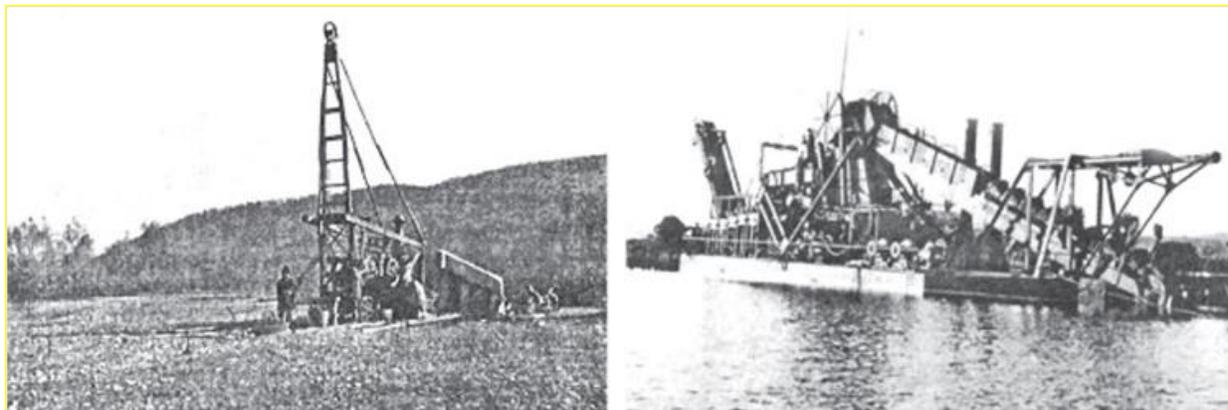
*Sitting from left to right: Jovan Žujović, Sima Lozanić, Jovan Cvijić, Mihajlo Petrović Alas*

*Standing from left to right: Andra Stevanović, Dragoljub Pavlović, Milić Radovanović, Ljubomir Jovanović.*

These events had an impact on scientific courses and higher education in geology and left a positive mark in mining. Studies of geology were on Faculty of Philosophy, in two groups and two corresponding institutions: for geology and paleontology and for mineralogy and petrography. Over time, the managers of the Institute of Geology and Paleontology were Svetolik Radovanović, Vlada Petković and Kosta Petković, and of the Institute of Mineralogy and Petrography Sava Urošević and Jovan Tomić. Since the foundation of Technical Faculty geological courses were taught by Jovan Žujović, Dimitrije Antula and Milan Luković. There was the idea of starting the studies of mining at University of Belgrade. Coincidentally, the realization of the idea had to wait for the end of the Second World War. After World War I, in 1919, Faculty of Medicine, Theology, and Agriculture and Forestry were established and in 1936 Faculty of Veterinary as well. University of Belgrade, from the beginning of the twenties to Second World War II, included Faculty of Law in Subotica, Faculty of Philosophy in Skopje and Faculty of Agroforestry in Sarajevo. All

these changes in the structure of tertiary education were reflected in the education of geologists and mining engineers.

After World War II, all faculties seated in Belgrade, and new Faculty of Pharmacy began to work within the renewed university. Faculty of Philosophy was divided in 1947 into two faculties – Philosophy and Natural Sciences and Mathematics, and Economics Commercial Vocational School became Faculty of Economics. The following year, the university was divided into three independent organizations: University, Great Medical School, and Great Technical School. In the same year, Dental Faculty was founded, and Great Technical School was divided into six faculties: Architecture, Construction, Electrical Engineering, Mechanical Engineering, Technological, and Mining. In 1949 they were joined by newly formed Faculty of Geology, which was in 1956 fused with Faculty of Mining into Faculty of Mining and Geology. Agricultural-forestry Faculty in 1949 was divided into Faculty of Agriculture and Faculty of Forestry. Orthodox Theological Faculty was in 1952 by a Government's act separated from University in Belgrade. Great Medical and Technical School again merged with the University in 1954. Belgrade University spawned University of Skopje (1949), Novi Sad (1960), Niš (1965), Priština (1970), Subotica (1974) and Kragujevac (1976).



Exploratory drilling In the vicinity of Bor and mechanized excavation of gold-bearing sediments In the river Pek by a bucket excavator, early XX century

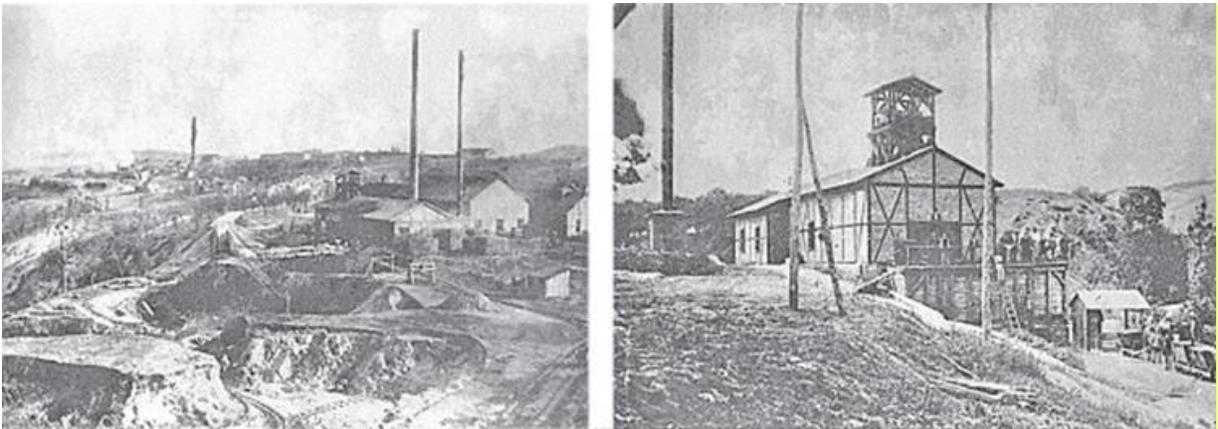
More significant explorations and exploitation of gold from the deposit of Brodica near Majdanpek, with the help of foreign capital, were carried out from 1900 to 1903. The most intensive exploitation exclusively of gold in this deposit took place from 1933 to 1941. When more than 40 excavations and three shafts were done and 55,856 tons of ore excavated, they obtained 585.6 kilograms of gold. For the exploitation of alluvial deposits from Veliki Pek, Georg Waifert in 1902 granted the concession of Blagojev kamen Neresnica. Good revenues enabled further research of gold in the nearby area, which resulted in the opening of the mine of tungsten and gold Sveta Varvara in 1933 with underground exploitation and a modern facility for gravity and flotation concentration of gold-bearing minerals and the amalgamation of gold of a capacity of 100 tons per hour. In the first years, rich ore veins with about 2000 grams of wolframite and gold per ton of ore were mined, about 12 kilograms of gold was produced per month. Realized revenues were so large that in three years they paid off funds invested in geological research, the opening of the mine and the construction of flotation. With short interruptions, mining activities at the site continued until 1966 when the mine of gold and tungsten Blagojev kamen was officially closed due to a drop in the content of useful components in the ore and an increase in mining costs and ore transport from scattered ore veins to the flotation. However, mining works were carried out later under the auspices of geological research.

Mechanized excavation of gold-bearing sediments in the Pek by a bucket excavator was initiated in 1903 and during the first day of work 82 grams of gold were obtained. That business was very profitable was confirmed by the fact that near Neresnica in 1906 three bucket excavators were employed. The exploitation of gold was expanded in the

sediments of the Pek, the Mlava, the Timok, the Porečka River and their tributaries. The whole gold-bearing area of the Pek after World War was controlled by the Yugoslav Royal House and the representatives of large foreign capital.

In mid-1903, detected reserves of copper ore in the Bor mine, or Čoka Dulkan deposit, amounted to 255,390 tons, with an average copper content of more than 8%. The same year, Weifert was granted concessions Sveti Djordje for 50 years, of a spatial reach of 240 mining fields. The following year, a joint stock company named Compagnie Françoise des Mines de Bor was formed with a registered seat in Paris. The company was formed by Weifert, bank Mirabeau from Paris, Pierari & Comp. and the French Association for research and taking over works from Paris.

Surface exploitation of ore in deposit Čoka Dulkan began in 1904. Seventy-eight workers dug 5,500 tons of ore with an average content of copper of about 9%. Ore was mined manually and transported by bullock carts to Vražognac, and from there by railway to Radujevac on the Danube, further by water to the buyers. The problem of ore transport, delivery of equipment, consumables, coal and food lasted until 1911 when the construction of railway Bor-Metovnica was completed. The following year, 180 workers dug 12,000 tons. Scarcity of data from the first years of the mine work is explained by the test run, however the real reason was probably the interest of mine owners in concealing real information about the volume of production, the quality of the ore, or the quantity of copper, gold, and silver that was taken away from Serbia, while the government was satisfied with the regular payment of taxes and custom duties.



*Bor, beginning of the exploitation of the copper ore in deposits of Čoka Dulkan, and mine shaft Šistek, early XX century*

The first smelter in Bor was erected in 1905. By 1933 excavated ore did not have to be enriched. Since the production was constantly increasing, parts of the deposit with the poorer content of ore were mined as well, and in 1929 a test flotation was erected. Since the tests were successfully completed, in 1933 the first flotation in Bor was built and put into operation. Ore reserves increased significantly in 1912 by exploring the deposits of Tilva mika. Tilva roš, as a deposit of gold-bearing pyrite with relatively low copper content, was explored during World War II. From 1933 to 1940 Bor annually produced 40,000 tons of blister copper or a million tons of high-quality ore.

During the withdrawal of the Yugoslav army in 1941, mining installations, export facility, compressor station and slope mines in the pit of the Bor mine were demolished. In the second year of the occupation, the Germans, facing great problems, started the production and concluded that it would be more convenient to switch to surface mining. Thus, in 1942 surface mine Tilva mika was opened. During the war, 1.37 million tons of ore were excavated in Bor, from which 55 tons of blister copper, 2.2 tons of gold and a dozen tons of silver were produced.

The Germans used the Bor mine as a concentration camp. It kept about ten thousand camp inmates (Serbs, Jews, Gypsies and Hungarians) who worked in the mine.

In bismuth, copper and gold ore deposit Aljin dol, in 1907 the first explorations were done. During the First World War, the Germans exploited this site underground. After the liberation, the exploitation was suspended. From 1956 to 1958, RTB Bor did geological explorations at the site. About 1,000 meters of undermine and corridors were done. The exploitation was not run because of low reserves.

The production of pyrite in Majdanpek began in 1908 and lasted to the first years after World War II. In XIX century, Majdanpek started its history as an iron mine, then for a short time it was an iron and copper mine, and finally, it became a copper mine.

Copper mine Ljubija was opened in 1916 on Javorik hill near Ljubija, for the war needs of Austro-Hungary. For the transport of ore, narrow gauge railway Ljubija-Prijedor was built in a length of 19 kilometers, a gravel road paved on 12.5 kilometers and a plant for ore transshipment was erected in Prijedor for further transport by standard gauge railway built in 1873. Under inhumane conditions, mining and other heavy physical activities were carried out by several thousands of captured Russians, Italians, and Serbs.

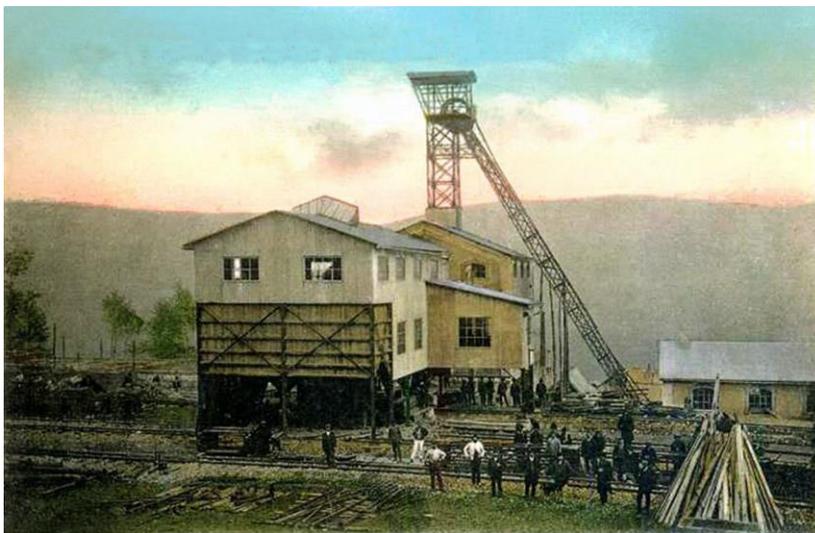
British company Selection Trust in 1924 began to examine the mineral and raw material potentials of polymetallic deposit Trepča (lead, zinc, silver, gold, bismuth, germanium, gallium, indium, selenium, and tellurium). Since the initial results already gave a clear indication of the huge ore potential, the company signed in 1926 a concession contract with Radomir Pašić (son of Nikola Pašić), famous for economic malfeasances. Soon after, in December 1927 Trepča Mines Limited company was founded, headquartered in London, and with the Directorate General in Zvečan, with 2,400 employees, 55 engineers and the initial capital of about 300,000 pounds. The company's leadership consisted of 20 foreigners. At the place of the old Medieval mine, in 1930 Stari trg mine was opened and a flotation was built. During the probation period, they extracted some 500 tons of ore per day, two years later, the production was quadrupled. Until the Second World War, around 5.7 million tons of ore or 625,000 tons of lead concentrate, 685,000 tons of zinc concentrate and 444,000 tons of pyrite concentrate were produced. There are no data on the production of precious metals. The concentrate was exported through the port of Thessaloniki. To rationalize the production, a lead smelter was built in Zvečan in 1940. Trepča, thanks to very favorable concentrations of ores and metals, has developed into the largest zinc and lead mine in Europe. The owners obtained enormous gain from Trepča; for example in 1937 the profit amounted to half a billion dinars. Other mines of lead, zinc and precious metals were being opened. The Lece mine was opened in 1931 by British Pacific and the Bor copper mine. Until the Second World War, about 590,000 tons of ore were produced, of the average content of lead 3.6%; zinc 6.5% and gold 4.7 to 9.4 grams per ton. The production stopped in 1941, and the mine was during the war used as a warehouse.

The Belo Brdo mine (initially named Kopaonik) was opened in 1936, with a high content of metals in ore: lead 9-10%, zinc, 6-7% and silver 80-100 grams per ton. Mining operations were performed at several horizons, 60,000 - 120,000 tons of ore were mined annually. That same year, lead and zinc mine Veliki Majdan was opened, on the slopes of Jagodnja mountain near Ljubovija.

Before the Second World War Serbia was producing 40% of the European antimony. The bulk of this production was from Drina mines Krupanj, Zajača, Stolica and Dobro potok. The management of Drina mines formed for the purpose of exploitation of lead proposed to the State as the owner in 1889 to try to assimilate antimony ore, as the price of antimony - metal was much more favorable than the price of lead. Preparations in the mines and the smelter were quickly completed, and already in January 1890 antimony production began. The results were excellent: rich oxide ore was put directly into the flash smelting furnace. Krupanj antimony mine and smelter worked intermittently until 1944. The Stolice mine was opened in 1916 during the Austrian occupation and yielded more than 90% of ore for the Krupanj smelter. The excavated ore in Zajača mines until 1901 was directly sold and exported. Since 1901 the situation had changed by commissioning the smelter which consisted of three furnaces for the oxidation and two flash furnaces for the reduction of ore. The smelting plant in Zajača and Krupanj worked intermittently. After World

War I the smelter in Zajača was out of operation until 1936, when the preparations for the war of the concession for the production of antimony were taken over by German capital Montanija A.D. Two years later the most modern antimony smelter in Europe was put into operation in Zajača.

Industrial consumption of coal gradually increased. In early XX century, the Senje mine was the greatest and the most important coal mine. Engineer M. Blagojević, the Chief of the then Mining Department, told for the Senje mine that it was "the only state company that works with success and that has brought the country great benefits..." Due to coal transport, narrow gauge railway Čuprija-the Senje mine was extended in 1907 by 10 kilometers to the Ravna reka. The following year, the exploitation of coal in Ravna reka mine began. The mine is built to the highest technical standards of the time. From the power plant in Ravna reka, the Senje mine got electricity for lighting in 1908. The opening of the Ravna reka mine significantly increased coal production. On the eve of the Balkan War in 1912, it amounted to over 136,000 tons. During World War I, the Senje mine and the Ravna reka mine were under Bulgarian occupation, mines management was in the hands of the Germans.



*Coal mine  
Ravna reka, 1908.*

Thanks to the investments of Nikola Jocić, a merchant from Čuprija, between 1904 and 1907 coal mines were discovered and opened in the districts of the villages of Stenjevac, Strmosten and Židilje. The Resava mines went into a financial crisis in 1910, so Jocić transferred his concession right to Otto von Steinbeis, a German industrialist. A year later, Jocić was granted concession for surface coal exploitation of a newly discovered deposit of Bare and from 1912 to 1914 constructed cable car Bare – Ravna reka. The cable car was built on wooden pillars, used rope was purchased from the Aleksinac mine, it was driven by a locomotive of 50 hp.

After World War I, receiving a large amount in the name of war reparation, Jocić launched the production in the Resava mines, Stenjevac, Strmosten, Panjevac, and Resavica. In Čuprija in 1929, a power plant, a separation, and a briquette plant were built, and the Resavica mine was connected with a cable car to the railway station in the Senje mine. Thanks to the modernization Resava mines reached a production of 190,000 tons of coal before World War II.

Kostolac mining entered XX century with significant technological advancements. For the purpose of lighting the town and the mine, for starting the fan and the engine in the pit of Stari Kostolac in 1903 they built a power plant of 45 kW. Thanks to the electrical energy, coal production in a short time increased by 250%, in 1909 the mine produced 52.581 tons. Near the mine, a glass factory was built in 1906, which speaks of an effort to rationally manage the available mineral resources. The factory was destroyed by the Austrians in 1915 with an artillery fire. On the eve of World War I, the mine was equipped with two steam boilers of the heating area of 120 m<sup>2</sup>, a steam

engine of 60 hp, with two pumps, a 40 kW generator, two electric engines of 2 kW each and two excavation hammers.

In order to expand production by opening three more pits, Weifert in November 1913 brought together the existing privileges. The war, however, disabled the realization of this idea. With the announcement of the war, miners, *komordžije* (ones that go with horses or vehicles loaded in a chamber), blacksmiths and other skilled workers were mobilized from the mine, which caused great problems in production. With the subsequent mobilization of all men, the mine ceased to work on 11 May 1914. By the occupation of Serbia in 1915 the Bulgarians managed the mine first, then the Austrians, who increased annual production to 24,000 tons of coal by daily shipment of the workforce from the camp in Kovin and Bela Crkva.



*Antimony mine Zajača, mid-twentieth century.*

After World War I, with the construction of power plants and industrial plants in major towns along the Danube, Kostolac coal as an energy source gained in importance, so the annual coal production in 1922 amounted to 107,500 tons. Often fires and huge pressures in the pit, or heavy exploitation conditions, influenced the 1928 decision on the opening of a new undermine (started production in 1930) and the suspension of work in 1933 in Sveti Djordje pit, which was the symbol of Kostolac mining.

Commissioning of 30,000 kW plant power "Snaga i svetlost" in 1930 in Belgrade influenced the construction of 2.5 kilometers of a narrow gauge railway between the mine and the port on the Danube for coal delivery safety.

One of the most important moments between the two wars in Kostolac coal basin was the construction of a transmission line between the "City Central" in Požarevac and Klenovnik in 1934. In addition to providing electricity supply, the same year welcomed a cable car for the transport of Klenovnik coal to Požarevac, with a capacity of 25 tons per hour.

To open the Ćirikovac mine in Kostolac coal basin in 1928 of a joint stock company for electricity, transport and industrial enterprises from Zemun was given the privilege. The mine was put into operation the following year, but could not withstand the competition of Kostolac and Klenovnik, and in 1935 suspended its production.

Instantly upon the capitulation of Yugoslavia, the occupying forces invaded and started the production in the Kostolac and Klenovnik mines. The German plan was for the Kostolac to become one of the powerful energy centers

in the Danube region. Electricity, resulting from this coal, would power the mine in Bor and industrial facilities in Belgrade. In accordance with the plans, to intensify production in early 1942, they brought in Kostolac five steam excavators and started works on detecting coal or opening the surface mine. After almost two years of work on exploration, coal mining started in late 1943. Along with the opening of surface mine Novi Kostolac, in mid-1942 they began the construction of thermal power plant and power line Kostolac-Bor and Kostolac-Belgrade.

The production at the mines of Kostolac was followed by the bloody terror: a special unit for the armed control of work in the mines was brought. The workforce was brought daily, in 1943 there were 2,500-3,000 workers, forcibly brought people, internees and mobilized youth.

Manual excavation of small amounts of coal in Kolubara basin is connected to the end of XIX and the beginning of XX century, or for 1896 when the Zvizdar pit was opened. In addition to the Zvizdar pit, coal was dug in numerous other pits: Sokolovac, Prkosava-Rudovci, Skobalj, Kolubara, Veliki Crljeni, Kosmaj, Baroševac, Junkovac, Šopići, Radljevo, and others. The construction of the 14 MW power plant in Vreoci in 1937, divided and poorly organized production grew into a serious underground exploitation of lignite, which was the beginning of the birth of the mining basin of Kolubara which after World War II grew into the largest mining and energy system of Yugoslavia. The construction of the plant and its demand for coal resulted in the opening of Junkovac pit in 1936, of a daily capacity of 400 t of coal. The mine was well equipped, had cutters, electric drills, and a 5 km cable car for shipping of coal to the thermal power plant. Work in the pit was suspended in 1943.

In the Kosovo coal basin, with over 12 billion tons of geological reserves of lignite, manual excavation of coal shoots at the site of Dobro selo began in 1922. In the thirties of XX century, Kosovo pit was opened and a cable car was built to transport coal to railway station Obilić. After World War II, two new pits Kruševac and Sibovac were opened. Mining excavation of coal in Boljevac began in early XX century. The concession for coal exploitation in 1903 was granted to Mihajlo Čebinac, a stonemason from Kraljevo.

The first exploration and mining operations in Bogovina coal basin were carried out at the beginning of XX century. The development of the Bor copper mine affected the intensification of production in the Bogovina coal mine so that in 1920 an annual rate of 76,000 tons of brown coal was achieved. At that time Bogovina participated with 43% in the production of brown coal in Serbia.

To ensure easier transportation of coal from Ugljevik, in 1916-1918 narrow gauge railway Ugljevik - Bijeljina – Bosanska Rača was constructed. Austria-Hungary hired Russian and Serbian prisoners and the local population under duress on the construction of the railroad. After World War I the country invested heavily in the coal mine in Ugljevik.

Mine directorate building was built in 1921, the construction of a mining village was encouraged and supported in 1929. On the Sava near Bosanska Rača, in 1934 a bridge was built, coal was until then transported across the river by a cable car, which was functioning until World War II. Due to the needs of the mine, in 1939, the narrow gauge railway was extended to Mezgraja, where a new pit was opened.

The first half of XX century faced a growing importance and the expansion of the exploitation of non-metallic mineral raw materials. Intensive research of magnesite ore in the territory of Čačak and Gornji Milanovac was conducted in 1927, and at the same time, Italian stock companies Salvar and Emilka started mining this ore. Large-scale exploitation of clay and industrial production of bricks and roof tiles Kanjiža began in 1903, in Novi Bečej in 1904, and near Šabac in 1938.

The exploitation of trachyte in the Rakovac quarry started in 1937 Rodin. On Fruška Gora, even before the opening of this surface pit, the stone was mined on several smaller quarries owned by individuals or joint-stock companies (Bazalt and Paragovo). As the needs for technical stone grew and realizing the economic importance of the quarry on Fruška Gora, the Technical Department of the Governor's Administration of Danube Banovina started the action

of dropping high prices of stone by opening a state quarry near Rakovac that would be competitive in relation to private quarries.

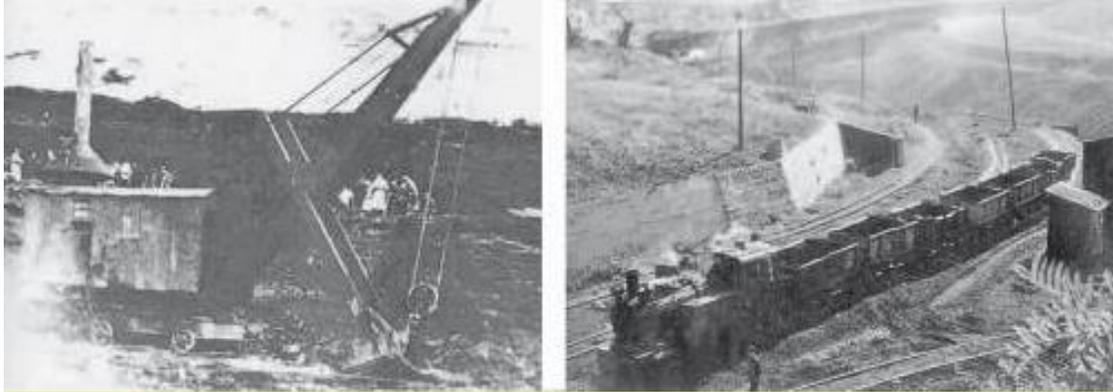


*Ugljevik, open pit coal mine, the administration building of the mine and the loading station, 1921*

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Based on the geological map of A. Koch, geological exploration was carried out at sites Gradac, Lišajev vrh, Kišnjeva glava, Sedam izvora and Buškina ugljara on Fruška Gora. Obtained results were reviewed in January 1931 by the Commission comprised of the eminent geologists of University in Belgrade, M. Luković, J. Tomić and K. Petković, which gave a positive finding of the presence of large quantities of high-quality volcanic stone. They also tested technical properties of trachyte which confirmed the excellent quality of the stone.

Based on these findings, Ban Administration prepared project documentation for opening a quarry, facilities, and equipment. From 1932 to 1935 Ban Administration gathered foreign firms' offers for the delivery of required equipment and its installation (for mining operations, for milling plant and an air cable car to transport stone from the quarry of Kišnjeva glava to the coast of the Danube in Novi Ledinci). 57 companies from Europe and America applied. Agreements were made with Ingersol-Rand from New York for a compressor plant and rotary hammers, with Humboldt from Cologne for a crushing plant and screening, AEG from Berlin for electrical running, with Blajhert from Leipzig for the cable car, and so on. Preliminary works on opening a surface mine at the site of Kišnjeva glava near Stari Rakovac started in 1934 with the construction of access roads, warehouses, and related facilities. The construction of the crushing plant started in 1936, the test run was initiated in September 1937, and after four months regular production began. So by investing the capital of Danube Banovina, the exploitation of trachyte began at the site of Kišnjeva glava. The production was quickly raised so that in 1939 it reached an annual level of 200,000 t of stone. The construction of the 5,900 m cable car was a brave technical and financial undertaking. The port on the Danube near Novi Ledinci proved to be very convenient for loading stone in barges and an inexpensive transport by water. They built a large capacity hopper for loading stone into wagons and trucks, enabling transport by trucks and railway (railroad Beočin - Petrovaradin). This is a textbook example of deliberate and excellent professional management of a process from geological research to opening and exploitation of deposits.



*Kostolac, steam shovel working in a open pit coal mine and railway transport of coal, 1945*

At the beginning of XX century continued the modernization of the cement factory in Beočin, in 1904 a workers' housing colony was build, railway Beočin-Petrovaradin was put into operation in 1908 for shipping cement, two years later, with the construction of the cable car, the delivery of limestone from surface mine Transylvania was modernized. The facilities of old cement factory Filijala suspended the work in 1915. By 1941 the production was repeatedly modernized, in 1920 the factory was nationalized and named *Beočinska fabrika cementa* (Beočin Cement factory), in 1922 the majority of shares was taken over by Cementia Holding from Zurich. During World War II, some plants were mined so the cement factory was not working.

The exploitation of marl and the production of cement in Popovac (launched in 1869 by Lazar Popović, baked clinker in a pit furnace 2 m in diameter, and ground into cement in a spring mill) reached an annual rate of 700 tons of cement on 1903.

With the takeover of the cement plant, Beogradska trgovačka banka (Belgrade Trade Bank) began production modernization, put into operation two vertical furnaces and new mills driven by a 450 hp steam engine, and raised the production to 25 tons of Roman and Portland cement daily. Before the First World War, a newly established joint stock company *Francusko-srpska industrija cementa a.d.* became the new owner of the cement plant in Popovac with the capital of French and Czech origin. The new owners continued the modernization of the cement plant, in 1913 they put into operation a rotary furnace and raised the production to 60 tons of cement per day. For the transport of cement, they built a narrow gauge railway to Paraćin and a cable car for the delivery of coal from the mine in Sisevac. During World War II, the cement plant worked, after the war (1956) a new factory was built which was named Novi Popovac, as a symbol of time.

The development of mining industry could not be possible without the appropriate geological support. An important function in this regard belonged to the Geological Institute of the Kingdom of Yugoslavia, founded on 29 December 1930, with a clearly defined task in Article 1 of the Law on Establishment, which states: "... according to the determined plan and modern scientific methods, research of soil (topsoil) and deeper layers the Earth, mineral resources and groundwater is carried out..." The advisory body of the Geological Institute was the Geological Committee, whose first president was Vladimir Petković. Since the establishment to the beginning of World War II, the Geological Institute published 11 sheets of a geological map in 1: 100,000 and 14 sheets in 1: 75.000. Eight numbers of *Vesnik Geološkog Instituta Kraljevine Jugoslavije* (Geological Institute of the Kingdom of Yugoslavia Journal), five discussions, and two numbers of *Godišnjak* (Yearbook) were published. During World War II, under the administration of the German occupiers, the Geological Institute had no publishing activity.



*Kanjiža, up - works on excavation  
and loading of clay, down - brick  
drive slipway*

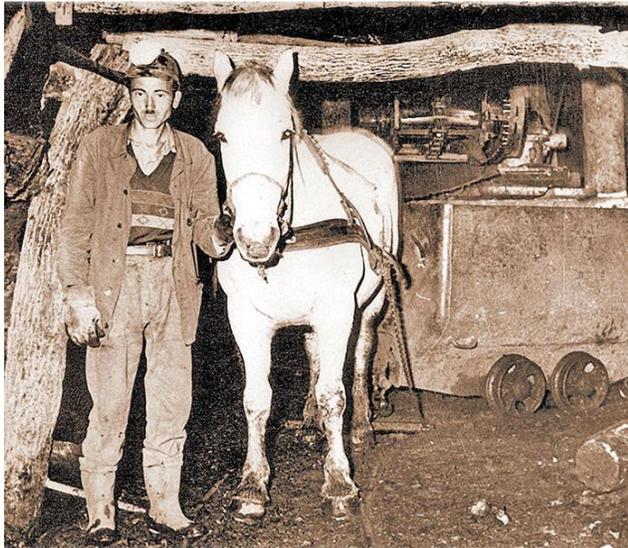
With the beginning of World War II and the German occupation, the phase of economic free development of Serbian mining ended. During World War II, the Germans exploited and irrationally used all significant deposits of coal, copper, lead, zinc, antimony, silver and gold. The Blagojev kamen mine is a typical example of this ruthless plundering. Mines were turned into concentration camps, people were interned and forcibly brought to work, and all that was followed by the bloody terror.

## 7. THE SECOND HALF OF XX CENTURY

After World War II, in the devastated and ravaged country, mines were nationalized. In such an environment, large investment and professional efforts were made to revitalize and revive mining production. The lack of experts was highly pronounced. Aware of this fact, the state responded quickly and wisely set off to create educational and scientific institutions, with a mission to provide engineering and scientific support to the development. Scientific-Research Institute was established on 1 December 1994 in the Mining Department of the National Committee of Liberation of Yugoslavia; Geological-Research Institute was formed in 1946 in Ministry of Mines of NR Serbia. That same year, Ministry of Education of the Republic of Serbia decided on beginning the study of mining and opening the Mining Department at Technical Faculty in Belgrade, where in addition to mining, geological experts would be educated as well. Mining segment would soon turn into Faculty of Mining and Geology, and then into a single Faculty of Mining-Geology in Belgrade. Details about the development of scientific, educational and other institutions of importance for our mining and geology in the second half of the twentieth century are given in section 2.2.1. Monographs „Serbian mining and geology in the second half of the XX century“ (Academy of Engineering Sciences of Serbia, Matica Srpska, Mining Institute Belgrade, Belgrade, 2014).

As this Monograph contains detailed factography, for the purpose of rationality and chronological continuity, this section covers only the key events in the Serbian mining and geology in the second half of XX century, or since the Second World War to the early years of the second decade of XXI century.

In Kostolac, as mining basin with the longest tradition, after the liberation, it was impossible to continue the construction of the thermal power plant started by the Germans. They took with them or destroyed technical documentation and part of the equipment. Therefore, in 1948 it was decided to dismantle and transfer to Kostolac the equipment of the first thermal power plant in Belgrade, and build 8 MW thermal power plant Mali Kostolac. A year later, the first of the four turbo generators of Veliki Kostolac power plant of the total power of 44 MW was put into operation.



*Mining combine Kolubara,  
underground coal mine Junkovac,  
wagons were horse-drawn*

The future of coal exploitation in Kostolac basin was not in the underground exploitation, so Klenovnik pit was closed in 1959, Stari Kostolac in 1966 and pit Ćirikovac worked only from 1955 to 1957. Surface pit Klenovnik was opened in 1968, and surface pit Ćirikovac in 1973, and continuous technology of mining was applied. Thermal power

plant Kostolac A1, of the power of 100MW, was put into operation in 1967, and thermal power plant Kostolac 2, 210 Mw in power, was launched in 1980. Both power plants are still working.

On surface pit Kostolac, the production was suspended in 1980, and surface pits Klenovnik and Ćirikovac in 2009.

The decision to open pit mine Drmno and thermal power plant Kostolac B (publicly known as thermal power plant Drmno) was made in 1976. Preservation and conservation of parts of the archaeological site of Viminacium and emerged financial problems slowed the preparatory mining works and the construction of the thermal power plant. In October 1977 the opening of surface pit Drmno began and it was ready for the production of coal mine after sixth years (1983).

The abundance of investors and the diversity of equipment on which they insisted during the construction of thermal power plant Kostolac B caused constant changes in design solutions.

The first test of the installation was carried out on 15 September 1985 when technical issues reappeared but were not discussed publicly, so the block B1 of the thermal power plant, of the power of 348.5 MW, was commissioned on 30 December 1987. The second block B2, of the same power, started working in January, only to face damage to the turbine a few months later. Soon an accident occurred on the block B1, pipe system exploded, and one worker was killed. It was estimated that repairs to the piping system would last long, and it was decided that move the turbo generator of the block B1 to block B2. Due to certain circumstances, but primarily due to mistakes in the choice of investors and equipment suppliers, the construction of thermal power plant Kostolac B was burdened with numerous problems and took a long time.

From 1870 and produced 15,050 charcoal cents (752.5 tons) of coal, more than 212 million tons of coal were excavated Kostolac basin to date, 93% by surface and 7% by underground mining. The annual volume of coal production was increased about 12 thousand times. Energy and technologically, Kostolac has made an enormous contribution to the industrial development of Serbia.



*Mining combine Kolubara,  
the opening of surface coal  
mine Field D, 1961*

After World War II, Kolubara coal basin grew into the largest mining and energy system of Yugoslavia. Expensive and low productive underground coal exploitation was replaced by surface mining. Surface excavation of lignite began in 1952 with the opening of surface pit Polje A in the eastern part of the basin. In the same part of the basin, surface mines Polje B and Polje D were opened in 1952 and 1961, respectively. In the western part of Kolubara basin grew surface mines: Tamnava Istočno polje in 1979, Tamnava Zapadno polje in 1994 and Veliki Crljeni in 2008. Coal

cleaning plant with wet separation was put into operation in 1956, coal drying plant started operating in 1957, the first phase of dry coal separation was completed in 1969, a new dryer was put into operation in 1986.

Coal was transported from the crusher plant by railway to thermal power plants Nikola Tesla (A and B) in Obrenovac, Kolubara in Veliki Crljeni and Morava in Svilajnac. Fewer amounts of coal (about 10%) were intended for the consumer market.



*Electric power industry of Serbia, details from open pits coal mines in Kolubara and Kostolac, today*

Since the beginning of coal mining in 1896 until today, in Kolubara mines around a billion tons of coal, and about two billion cubic meters of tailings have been excavated. In surface mines, 98.33 %, and in pits 1.67% of coal was excavated. Today, mining basin Kolubara annually produces about 30 million tons of coal, digs out 80 million cubic meters of tailings, achieves 70% of coal production in Serbia and from coal energy produces 52% of electricity in the country. It annually produces about 450,000 tons of raw coal pieces and about 600,000 tons of dried coal for industry and the consumer market.

In the Kosovo coal basin after World War II, pits Kruševac and Sibovac were opened. Underground exploitation was suspended in 1966 by closing the Kosovo pit. Surface pit Dobro selo was opened in 1956, and in 1968 people obtained the first quantities of coal from surface min Belačevac. Surface pits supplied with lignite thermal power plants Kosovo A and B, of the total installed power of 1,478 MW.

After the liberation, the underground exploitation of brown and stone coals in the Ibar mines Baljevac, Rembas - Resavica, Aleksinac, Bogovina, Soko, etc. was revived and increased.

In the early seventies, energy policy of the country and the price of oil on the world market, on the one hand, and low productivity of underground coal mining, on the other hand, affected the suspension of production and the closure of many pits. In Vrdnik, in the oldest coal mine in Serbia, exploitation works were suspended in 1968, in the brown coal mine in Aleksinac in 1989 after a great accident etc.



*Bor, open pit copper mine, 1952*

During the withdrawal, the Germans dismantled and destroyed or brought the equipment with them, which complicated and aggravated the revitalization of mines and the start of the production in Bor. The Bor copper mine was nationalized in 1950. In early 1953, it was decided, and in 1957 began the first phase of the construction and reconstruction of the mine, including the smelter, the production of sulfuric acid and the construction of railway Vražogrnac - Bor, by which is connected to the railway network of the country. The second phase of development of RTB Bor, which included the Majdanpek copper mine, started in 1965.

The capacities of RTB Bor, mining facilities and underground exploitations, flotation and a smelting plant were built and expanded in stages. From 1958 to 1967 deposit Lipe near Crni Vrh was excavated on the surface. Near the village of Mali Krivelj, from 1960 to 1969, rich ore was mined in a pit. In the vicinity of metallurgical plants and mine flotation, ore body H was discovered and excavated on the surface from 1978 to 1984. Near the mining shaft, ore body Novo okno was discovered, which was also excavated in a pit. Surface mine with flotation Veliki Krivelj was opened in 1982, with the annual production of about 12 million tons of ore, and in 1993 smaller surface pit Cerovo I was opened.

The Bor copper mine has so far produced about 2 million tons of copper of the market value (at today's prices) of about \$ 16 billion, 137 tons of gold, worth about \$ 6.3 billion, 410 t of silver worth about \$ 304 million. There is data on produced quantities and values of other useful components.

After the liberation, the construction of the Majdanpek copper mine was launched by the decision of the Federal Government in 1954 and granting the initial funding in 1957. The construction of the mine lasted less than four years, from 1957 to 1961. Works on the opening of surface pit Južni revir started in 1958. The first tons of copper ore concentrate were sent to the smelter on June 25, 1961, and this year passed in the adjustment of the production. Regular production was established in 1962 by an ambitious plan to excavate six million tons of tailings and three million tons of ore or to obtain 100 thousand tons of concentrate with a copper content of 20%. The plan was exceeded by 400,000 tons of excavation. In those years, ore production was stabilized at 3.5-3.6 million tons annually, and in 1967 excavated rock stripping volumes increased from 6.5 to 22 million tons. That year, 140,000 tons of concentrate were produced.



*Panorama of town mine Majdanpek and open pits: South (in the center of the picture) and Northern Field (right).  
Electronic Journal, 2014;  
Photo Stock.*

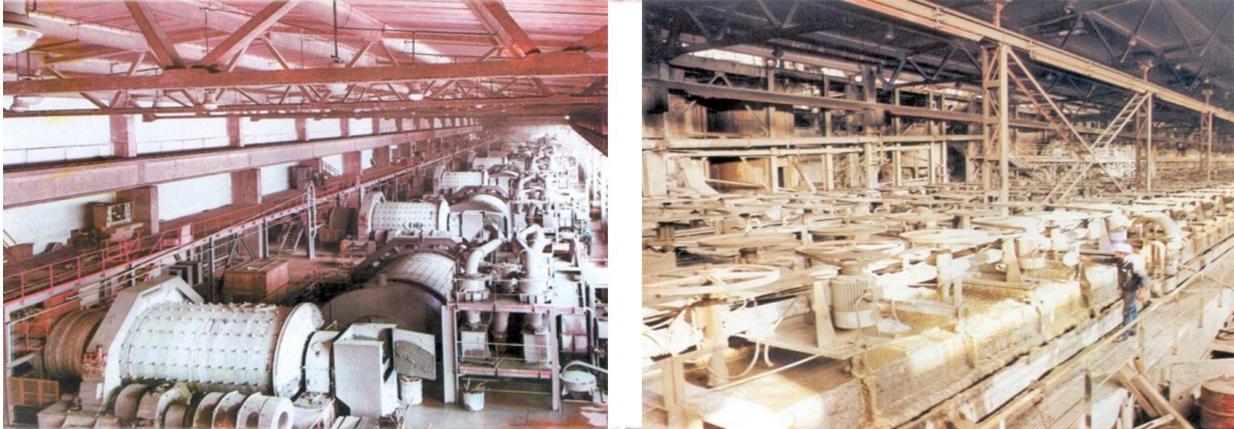
One of the basic principles of mining that only constant development and modernization can provide the cost-effectiveness of production and the survival of the Majdanpek copper mine was well accepted, so already with the completion of the first construction phase they were seeking opportunities to further modernize the mine. Material base of this approach in planning consisted of 220 million tons of determined ore reserves with the average copper content of 0.75%. The most significant achievements of the second phase of the development were: an increase in the annual volume of ore production to 2.7 million tons and the construction of a new flotation - the largest facility of this kind in Europe. With numerous flotation equipment and installations, four mills were mounted in a capacity of 170 tons per hour, 260 flotation cells 48 pumps.

Along with the mine, Majdanpek was being built and developed. For example, during the second phase of the development, about one thousand apartments, numerous infrastructure and other facilities necessary for the function of the town were built. At the end of the second developmental phase, in 1971 began the construction of a jewelry workshop and copper pipes factory.

Non-ferrous metal price fluctuations on the world market that almost always occur periodically, deterioration in exploitation conditions with operations at greater depths and fall of copper content in the ore of the Majdanpek copper mine was successfully overcome by constant technological improvements, increasing the production and productivity, better use of resources and reducing operating costs. Average annual production was stabilized at

about 12 million tons of ore; in 1984, a transport system with belts was introduced, a new generation of capital mining machinery, excavators of buckets volume of 18 m<sup>3</sup>, dump trucks of carrying capacity of over 200 tons were used, a closed system of fragmentation was constructed and similarly. Along with the development of surface pit Južni revir, in 1986, a new surface pit named Severni revir was opened.

The Majdanpek Copper Mine was among the largest mines of its kind in the world, has produced approximately 1.8 million tons of copper of the market value (at today's prices) of about \$ 14.4 billion, 168 tons of gold of a value of \$7.73 billion, 780 tons of silver of a value of \$578 million.



*Flotation of the Copper Mine Majdanpek, 1986*

The youngest area of Serbian mineral-raw material complex is oil mining. The first steps in this field of mining are related to the creation and the history of the development of Naftna industrija Srbije (Petroleum Industry of Serbia). Looking for oil and gas in Vojvodina, structural drilling began in 1947 and gravimetric tests in 1948.



*Mining and smelting combine Bor, Flotation of the Copper Mine Veliki Krivelj, today*



*Mining and smelting combine Bor, open pit mine Veliki Krivelj and underground copper mine Bor, today*

The embryo of Petroleum Industry of Serbia is the company for the research of oil and gas, established by the Government's decision in Zrenjanin FNRJ in 1949. At the establishing, the company's task was to begin the exploration and produce oil and gas in the northeastern part of Serbia. The company in 1953 received new name Naftagas.

The first stage of development lasted from 1949 to 1956 on the area of Banat. The first gas field was found on July 13, 1949, by the eruption on borehole Vg-2 at Velika Greda. The following year in Bečej a new gas field with the presence of carbon dioxide was discovered.

The initial phase of the first stage was completed in 1952, by the discovery of the first oil field near the village of Jermenovci, near Vršac. The field was not large, but it was very important from a professional point of view, its discovery denied the opinion that in the eastern part of the Pannonian Basin there is no oil. From 1952-1956, efforts were made and all available resources concentrated in order to commission the first oil field. The field was to be fully explored, project documentation to be compiled and exploitation wells to be made, installations were to be built in order to enable the exploitation of the deposit. This was all completed in 1956 when the field of Jermenovci produced 6,500 tons of oil.



*Oil Industry of Serbia Naftagas, drilling and exploitation of oil, 1989*

In the following years, research of oil and gas was intensified and improved and newly discovered oil, oil and gas and gas fields were activated: Lokve (1957), Elemir (1959), Plandište (1962), Kikinda (1963), Mokrin (1963), Kikinda - Varoš (1965), Janošik (1966), Velebit (1968), Gospodjinci (1969), Tilva (1969), Mramorak (1970), Begejci (1971), all the way to the field of Martonoš (1987). Oil field Turija Sever, one of our greatest oil deposits, was put into operation in 1991. Oil and gas explorations were performed in other regions in Serbia: in the Morava region, the

Danube area, the Danube key, the Timok region, the Kruševac basin, the Vranje basin and at the stretch of Čačak-Kraljevo. From 1949 to 1987, in Serbia, about 1,700 wells were drilled, or about 2 million and 700 thousand meters of exploitation boreholes. Since 1969, along with oil and gas exploration, Naftagas began systematic research on thermal mineral water. Between 1969 and 1979, 17 wells were drilled and tested to obtain thermal mineral water and geo-thermal energy. The first system to use underground geothermal water started to work in 1978 in Bačko Karadjordjevo, followed by Junaković spa near Apatin, Kanjiža spa, geothermal systems in Kikinda and Srbobran etc. At the turn of XX century, the average annual production of NIS Naftagas was about 750 thousand tons of oil and 450 billion (normal) of cubic meters of gas.

Reflection upon the duration of mining on the territory of Serbia leads us to prehistoric mining of copper ore on Rudna glava, but thinking about the original collection of quartz, pigments, obsidian and use of clay takes us to even more distant past. After World War II, with the construction and industrialization of the country, the long tradition of exploitation and use of non-metallic minerals was revived by the improvement of the existing and the construction of numerous new capacities for the production of cement, bricks, tiles, ceramics, glass, lime, plaster, technical and architectural stone etc. The cement factory in Beočin, Novi Popovac Kosjerić, and Djeneral Janković upgraded the technology and raised production capacities to the total annual level close to the four million tons of cement.

On the exploitation of clay, bricks, tiles, and ceramics industry was expanded and built, with greatest plants in Kikinda, Kanjiža, Novi Bečej, Leskovac, Šabac, Mladenovac and Vlasotince. Production potential of this industry reached two billion pieces of brick, ceiling and wall blocks, about 270 million pieces of tile and equivalently around one million tons of ceramic tiles, sanitary and decorative ceramics. The scope and quality of production of mineral non-metal industry opened the international markets and ensured the placement of a part of the production.

In the middle of the second half of XX century, the world faced a breakthrough of major research and discovery of new scientific areas in geology and mining, in which our experts actively participated. Scientific results in sprang areas of mathematical modeling, simulations, system sciences and operations research, applied computer science and computer integrated technology y mining and geology realized the contributions that ranked our scientists in the world's top. This had a direct impact on innovation in the education of mining and geological experts, the improvement of engineering thought, the introduction of new courses and study programs at undergraduate and postgraduate studies, and encouraged the interest of foreign students and experts to come for education and improvement.

In a long time walk through history, Serbian mining and geology achieved their greatest economic and scientific climb in the second half of XX century. Historical rule that mining with geology as a substructure of all civilizations shares the fate of mankind and has its ups and downs is confirmed by the events in our mining and geology in the last decade of the XX century and the first decade of XXI century.

Before the breakup of Yugoslavia in the early nineties of the past century, Serbia as its largest republic had developed the mineral economy. This claim is based on reserves of mineral resources, the achieved level of exploitation of the most important mineral resources, the share of the mineral economy in foreign trade, the participation of the mineral-raw material complex in the country's industry and the economic-value assessment of the mineral wealth of the country. Annually, about 100 million tons of various ores were exploited, which is, in proportion to the size of Serbia, relatively large-scale production. Non-ferrous, precious metals and concentrates of non-ferrous metals occupied a high position in the foreign trade balance of the country. By the end of the eighties of the last century, investment in geological exploration, the development, and the improvement of production of the existing and the opening of new mines faced an upward trend.



*Potisje Kanjiža, open pit Majdan III and command center of the computer-supported system with satellite GPS technology for monitoring and managing clay exploitation and transport, 2000*

With the breakup of Yugoslavia and the introduction of economic sanctions imposed by Western countries it came to a stagnation, decline and numerous problems in the country's economy, and consequently mineral economy. The production of many mines was reduced or suspended, investment in geological exploration decreased ten-fold, investments in the construction and opening of new capacities were suspended, investments in the modernization of existing mining technologies and new equipment and machinery disappeared.

In terms of sanctions and discontinued payment transactions with foreign countries, the supply of spare parts for imported machinery was very aggravated and only possible through a number of intermediaries, which increased costs associated with the business several times.

Insufficient quantities of domestic and lack of imported oil, as the main energy source in mines with cyclic exploitation technologies, caused delays, reduction in production and losses, and the oil from the "black" market considerably made mining production expensive.

War conflicts caused in former Yugoslavia oriented the domestic industry for the production of commercial explosives to the production for military purposes, leading to a lack of explosives for mining, to the impediment of production, losses in the multi-fold increase in costs.

Social turmoil, economic hardship in the country and outside, constantly encouraged political turbulence complicated social relations and adversely affect the staff structure of many mines. A large drop in earnings in the mines caused a brain drain, especially of highly educated experienced professionals. This additionally complicated the existing problems, younger, unprepared and technologically insufficiently coordinated staff assumed the leadership positions in production and often caused serious failures, mistakes, and damage.

In these conditions, weakened mining industry, in the attempt to maintain production functions, ceased to invest in development, and lost absorption capacity to accept new scientific and technical achievements, which was reflected in the decline in the need for research and engineering designing services. Lack of research and designing tasks and collapsed general economic situation in the country caused the depletion of the material base, reduction of earnings and staff leaving the universities, institutes and designing houses. The consequences were improvisations in designing, low quality of projects and loss of scientific and professional youth.

The problems caused by the economic and political blockade grew by "merciful" NATO bombing of the country in 1999 whose strategic goals were taking over a part of the territory of the Republic of Serbia - Kosovo and Metohija, the destruction of infrastructure and the creation of conditions for privatization by which the country will become dependent.

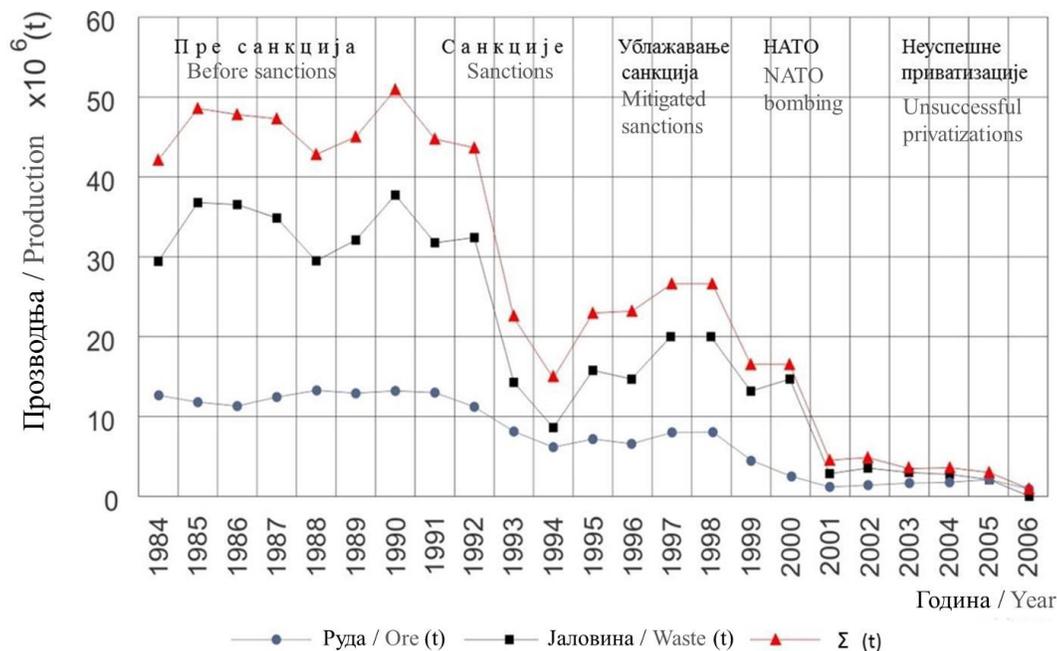
The collapse of the economy of the country and mining with the privatization by the model licensed and imposed from the West, whose objective is not to modernize and translate the economy into a more efficient and productive state but primarily to grab resources, get rich quickly and destroy the production in order to gain market, has negative effects, the hardest of which are the closing of industrial production, a large increase in the unemployment and huge indebtedness of the country.

This is a brief picture of the devastating consequences for Serbian mining, generated by economic blockade, bestial NATO bombing (24 March to 10 June 1999) shamelessly participated by 19 Western countries led by the USA, and then transition and privatization.

RTB Bor shared the fate of these events, so for factographic reasons we present specific data from this period, and the image provided by the data for RTB Bor is similar to the overall picture of events in the economy and mining of the country.

Before the introduction of economic sanctions against Serbia, RTB Bor was one of the major world producers of copper and precious metals famous in the world for the high quality of cathode copper. For Serbian economy, RTB Bor is an especially important company, it annually brings the country hundreds of millions of dollars. The company with its production and mineral-raw material resources is strategically important for the development of Serbian economy, but play an important role also for the economic prosperity of neighboring countries.

Changes in the economic conditions with the introduction of the economic blockage had a powerful effect on working conditions and productions outputs. In the Majdanpek copper mine operating in the system of RTB Bor ore production was decreased by 51%, tailings production by 71% or total excavated mass by 65%, the number of employees was decreased by 16%, and the production by an employed worker by 58%. Annual ore production dropped from 23 to 15.7 millions of tons. In the following figure shows the trends of production in Majdanpek copper mine, similar in trends to the production of mining economy in Serbia.



*Majdanpek copper mine, production in the period of 1984-2006*

Disproportionate ratio of downsizing employees and production per employee is explained by the drop in production due to difficulties in the supply of oil as a fuel for trucks and utility machines, the reduction of machine availability due to lack of spare parts, the impossibility of buying new machines and to some extent due to staff turnover. To illustrate, Majdanpek copper mine in 1991 disposed of 14 bulldozers ready to work, and in 1994 there were only eight of them. Or another example, between 1984 and 1991, Majdanpek copper mine averagely had 38-47 trucks with the capacity of 150, 170, 190 and 200 tons, in 1992 there were 32 trucks, in 1993 19, and in 1994 only 13 trucks ready to work. Machinery was maintained by dismantling the parts from one machine and installing them on another. Lack of spare parts, maintenance of so established machines and mechanization renewal inability resulted in misaligning the execution of works on surface pits, lagging with tailings excavation, intensifying the excavation in depth and on surface pit Južni revir in drainage suspension - which created an accumulation of about 15 million cubic meters of water. Despite this kind of works execution, copper content in the ore was not significantly disrupted, which speaks of the effort to achieve a positive economic balance of production by excavating smaller quantities but richer ore, or ore with higher copper content. For example, in surface pit Južni revir, the greatest surface pit in RTB Bor, by the end of 1994, according to the planned dynamics, the works should have gone down to the level of +215 m. However, they went down significantly lower, to the level of +140 m. By this method of work, being the struggle for survival, the surface pits of RTB Bor were brought into a state that further development was impossible without significant investments into equipment, works on tailings excavation, and especially on the surface pit of Southern field in Majdanpek, on the removal of large quantities of accumulated water.

The financial situation in this period is characterized by the erosion of material substance, liquidity problem, limited crediting and development opportunities. To raise and normalize the production after the blockage it took around 160 million dollars. And in such conditions the company found the strength to invest around 55 million dollars during the sanctions in the opening of new surface pit Cerovo, in the expansion and reconstruction of Jama (underground exploitation) and surface pit Veliki Krivelj.

NATO bombing amplified further destruction of production. In Bor, they destroyed a transformer station, which caused the suspension of production at the smelter, and oil tanks, which interfered with the production in open pits and in Jama.

Turmoil in the transition after 2000 with two failed privatizations led to a drop in production to only two million tons of ore, which is production lower by 21 million tons compared to the nominal production before the introduction of economic blockade in 1991. This is the result of the exhaustion of all company's resources and the misguided privatization policy. Changing the strategic relationship of the state towards RTB Bor, in 2008, an investment cycle of system revitalization, normalization and technical and technological stabilization of production was initiated, and by building a new smelter environmental problems created by the technologically obsolete plant in Bor were eliminated.

In this brief sequential view of the history of Serbian mining and geology, from perhaps the greatest human discovery that a piece of rock turns to metal in fire to contemporary computer-integrated mining technologies, it is evident that mining and geology together represented and represent not only a support to economic, cultural, scientific, technological and overall social development, but also laid the foundations and spawned classical engineering disciplines, metallurgy, mechanical engineering, civil engineering, mining measurements-geodesy, organization and system engineering, mechanics, material engineering, and have significantly contributed to the birth and affirmation of electrical engineering.

Many facts confirm this, the key is that the first technological faculties, academies, and universities established hundreds of years ago (in Petrograd, Freiberg, Chemnitz, Aachen, Pribram ...) educated mining engineers with the integrated knowledge of mining, geology, chemistry, mechanics, mechanical engineering, civil engineering, mining measurements - geodesy, organization and protection.

A little-known fact supporting the above is that our great scientist **Mihajlo Pupin** graduated with honors (as the



best) in 1883 from School of Mines at Columbia University (founded in 1754) in America. He then spent several years at Cambridge University in England and four years in Berlin where with Helmholtz he obtained a doctoral degree in mathematical physics, more specifically in the field of physical chemistry, the science that was in its infancy then, on the topic of Osmotic pressures and free energy. In 1899 he returned to School of Mines at Columbia University as a physics teacher. Then Columbia University, at the suggestion of Thomas Edison, founded two-year post-graduate studies of electrical engineering for students who have previously completed fourth years of School of Mines. There were two teachers: Francis Bacon Crocker, one of the first Presidents of the American Institute of Electrical and Electronic Engineers, IEEE today, and Mihajlo Pupin, who was also the President of this association. The school in 1896 changed its name to School of

Mines, Engineering and Chemistry and to date twice changed the name, first to School of Engineering and Applied Science, as it is often called today, although the official name is Fu Foundation School of Engineering and Applied Science in the honor of Chinese Z. U. Fu who donated the university \$ 24 million.

There is a resemblance to Ljubomir Klerić, who as a mining engineer at University of Belgrade founded the teaching of Mechanics and Science of Machines.

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