Mineral deposits and mining districts of Serbia
Compilation map and GIS databases

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March 2002
BRGM/RC-51448-FR
Keywords: Serbia, Former Yugoslavia, ore deposit, mining district, energy minerals, metallic minerals, industrial minerals, smelter, GIS databases, compilation minerals map.

In bibliography, this report should be cited as follows:


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Fig. 12 - Energy-mineral deposits in Serbia.
4. Serbia's mineral deposits and mining potential

Using the "Ore deposit" database, we undertook a thematic analysis for the main commodities; i.e. the energy minerals, metallic minerals and some industrial minerals. The results of this analysis are presented as a set of figures that, more effectively than a long explanatory text, allow one not only to visualize the preferential zones for such or such commodity, but also to determine the overall mining potential of the country and thus define areas that are potentially favourable for mineral exploration and development in Serbia.

4.1. ENERGY MINERALS

Figure 12 shows the locations of the main lignite and hydrocarbon deposits in Serbia.

Lignite represents almost 90% of the country's energy resources, whereas oil and gas represent less than 10%. More than 65% of the electricity is generated by coal-fired power stations with an annual lignite consumption of around 37 Mt. All active coal mines in Serbia operate within the Electric Power Industry of Serbia (EPS).

A public company, the Coal Mining Basin "Kolubara", is Serbia's biggest producer of coal. Its main activity, based in the Miocene lignite basin, covers an area of 600 km² with remaining mineable reserves of 2.2 billion tonnes. Four open-pit mines operate in this basin —Field B, Field D, Tamnava-East and Tamnava-West— all of which are equipped with the most up-to-date continuous mining systems for overburden removal (49.5 Mm³/y capacity) and facilities for a 27.5 Mt annual production of lignite.

The Kostolac Miocene lignite basin, located 90 km east of Belgrade, has remaining reserves of 700 Mt. The lignite is extracted from three open-pit mines —Klenovnik, Cirikovac and Drmno— at an annual rate of 9.2 Mt with 30 Mm³ of overburden.

The largest lignite reserves are in the Kosovo-Metohija Pliocene coal basin near Pristina. The total mineable reserves amount to about 12 billion tonnes of lignite, of which less than 3% has been excavated. The productive part of the basin covers an area of about 250 km². The coal layer has an average thickness of 40 m, although reaching as much as 100 m in the central part of the basin. Before the Kosovo conflict, average annual production of the Dobro Selo and Belacevac open-pit mines was 8.5 Mt of lignite.
Fig. 13 - Pb-Zn deposits in Serbia.
4.2. METALLIC MINERALS

4.2.2. Lead and Zinc

The Pb-Zn mineralization is well positioned in Serbia, being particularly well concentrated in the Kopaonik District where the deposits form the backbone of the famous Trepca Mining and Metallurgical Complex: Stari Trg, Belo Brdo, Novo Brdo, Ajvalija, etc. (Fig. 13).

These deposits contain substitution ores related to Tertiary volcano-plutonic events and are generally hosted by carbonates in contact with andesitic intrusions. The Stari Trg deposit, mined industrially since 1931, has produced at least 2000 t of Pb, 1400 t of Zn and more than 2500 t of Ag. It is a world-class mine in a district where former production was 60.5 Mt of ore grading more than 8% Pb+Zn.

Other deposits of average size, such as Veliki Majdan, Rudnik and Blagodat, are dispersed throughout Serbia (Fig. 13). They are also replacement-type ores and skarn deposits related to Tertiary volcano-plutonic events.

Other than silver, the major by-products from these deposits are copper, bismuth, cadmium and gold.

4.2.3. Copper

Along with Pb-Zn, copper is the main metallic ore mineral mined in Serbia, with most of the production coming from deposits in the Timoc (or Bor) District in northeastern Serbia (Fig. 14).

The "high-sulphidation" type deposits at Bor are now practically exhausted, and currently it is porphyry copper that is mined from the high-tonnage/low-grade (0.3-0.4% Cu) deposits of Majdanpek, Veliki Krivelj, Cerovo, etc. These deposits are inherited from a Late Cretaceous metallogenic episode that also gave rise to many similar deposits in Bulgaria, Romania and Hungary.

The metal potential of the Timoc (or Bor) District is estimated at more than 15 Mt of Cu, 700 t of Au and 4500 t of Ag. This is one of the highest in Europe, although a long way behind Polish Silesia (45 Mt of Cu), and is of the same order of importance as the South Iberian Pyrite Belt. Former production is estimated at almost 6 Mt of copper metal, 300 t of gold and about 1200 t of silver.

Copper is also recovered as a by-product from the Veliki Majdan, Rudnik and Blagodat Pb-Zn deposits.

Other, smaller, occurrences, such as Lajkovaca, are related to the Jurassic ophiolites located in the west of Serbia. They are of the volcanogenic massive sulphide (VMS) type.
4.2.4. Antimony and Mercury

Antimony deposits are characteristic of the Drina (or Podrinje) District in western Serbia, close to the border with Bosnia and Herzegovina (Fig. 15). They are distributed concentrically around the Boranja Tertiary granite intrusion, with the most important being the Zajaca, Rujevac and Stolice deposits. The orebodies form stratoid lenses and irregular pipes in Carboniferous siliceous limestone. For many years this area was the main centre of Sb production in Yugoslavia, with about 90,000 t of Sb metal having been extracted from its mines between 1890 and 1990.

Mercury is also closely associated with the Tertiary volcano-plutonic events. It was mined from the small Suplja Stena deposit, south of Belgrade.

4.2.5. Nickel-Cobalt and Chromite

Supergene weathering of the ultrabasic rock exposures has given rise to nickeliferous concentrations, the largest of which are the Cikatovo and Glavica deposits in Kosovo (Fig. 16). They correspond to surficial, largely tabular, concentrations between 10 and 30 m thick and several hundred metres long immediately overlying harzburgite massifs. The ore is mainly clayey, with nontronite (a clay mineral of the montmorillonite family) being the main Ni carrier—it is associated with other clay minerals, Fe hydroxides and silicates (chalcedony, opal). Before the mines came online, the reserves at Cikatovo and Glavica were evaluated at about 20 Mt @ 1.3% Ni. Such reserves justified the construction of the Glogovac smelter.

Similar deposits are described at Rudjinci and Veluce in the upper valley of the Morava with "possible" reserves assessed at 17 Mt @ 1.15-1.20% Ni. In the west of the country, the Mokra Gora lateritic deposit has a large Fe-Ni accumulation, but with a subeconmic grade (1 billion tonnes @ 26.5% Fe and 0.7% Ni).

Chromite has been mined from a number of small mines in southwestern Serbia, close to the borders with Albania and Macedonia (Fig. 17). There doubtless exists a not insignificant potential for this ore overlying the many ultrabasic massifs dispersed throughout Serbia.

4.2.6. Tin, Tungsten and Molybdenum

The tin, tungsten and molybdenum deposits are generally linked to granite intrusions in which the three elements are associated.

The Sn occurrences in Serbia, such as Cigankulja and Iverak, are located in the northwest of the country (Fig. 18) and correspond to alluvial deposits resulting from the erosion of granite cupolas.

Tungsten production is anecdotal and limited to the scheelite- and gold-bearing quartz veins of the Blagojev Kamen deposit in northeastern Serbia.
Molybdenite is a known by-product in the Veliki Krivelj and Majdanpek porphyry copper mines in the Timoc (or Bor) District, but has never been recovered. In southeastern Serbia, the Mackatica deposit is dormant because of its sub-economic grade (181 Mt @ 0.078% Mo).
Fig. 14 - Cu deposits in Serbia.
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Fig. 15 - Sb-Hg deposits in Serbia.
Fig. 16 - Ni-Co deposits in Serbia.
Fig. 17 – Cr deposits in Serbia.
Fig. 18 - Sn-W-Mo deposits in Serbia.
Fig. 19 - Au deposits in Serbia.
4.3. PRECIOUS METALS

4.3.1. Gold

Gold is present in many deposits in Serbia (Fig. 19), as shown by several recent publications. It is recovered as a by-product from the deposits in the Timoc (or Bor) District where it provides added value to the copper concentrates. For example, gold grades as high as 5 g/t can occur in the high-sulphidation type ores at Bor where the surficial oxidized part of the deposit included a highly silicified cap of 8.2 Mt with an average gold grade of 2.3 g/t and values ranging from 1.8 to 18.9 g/t. Average gold grades in the porphyry copper at Majdanpek and Borska Reka are 0.6 and 0.3 g/t respectively. The district also contains epithermal vein deposits of the adularia-sericite type in which the gold is either free in the quartz or is associated with pyrite (Zlace).

Most of the Pb-Zn deposits of the Kopaonik District contain gold, but statistics are rare. Between 1950 and 1985 Trepca would have produced 8.7 t of gold, or an average of 250 kg per year. The main deposits reputed to be gold bearing are Belo Brdo, Novo Brdo and Ajvalija.

The Lece (or Radan Mountain) District in central Serbia is without doubt one of the most promising for precious metals. It is centred on a Tertiary volcanic complex, with several nested volcanic cones and calderas. The gold mineralization at Lece, Djavolija Varos, Tulare and Sijarinska Banja is found in veins and silicified breccia of the adularia-sericite type, developed in hydrothermally altered andesite and pyroclastic rock. Jankovic et al. (1992) described a vertical zoning at Lece that is typical of epithermal mineralization; gold predominates over base metals in the upper part, but this ratio is reversed in the median and deep parts of the mineralized structures. The mineral paragenesis comprises pyrite, sphalerite, galena and native gold, accompanied by chalcopyrite, enargite and grey copper, in a quartz-siderite gangue. Between 1953 and 1959, the deposit produced about 470 kt of ore at 1.95% Pb, 4.5% Zn, 6 g/t Au and 19 g/t Ag.

In general, the various districts within the Serbo-Macedonian Metallogenic Province, characterized by Tertiary volcanic outcrops, are potentially favourable for precious metals, with a high chance of discovering "epithermal" gold deposits. This metallogenic province in Serbia appears to have been under-explored for gold, particularly with the availability of modern tools and procedures suited to the country's geomorphological context.

4.3.2. Silver

Most of the Pb-Zn deposits derived from the Tertiary metallogenic events are largely endowed with silver, associated with galena and Pb sulphosalts (Fig. 20). In the past, the deposits of the Trepca Complex produced more than 4500 t of silver. It was recovered mainly from lead concentrates in which it assayed between 1000 and 1100 g/t. At Rudnik, the silver grades of the lead concentrates are between 2400 and 4500 g/t.
Silver also provides added value to the copper concentrates from the deposits of the Timoc (Bor) District from which an estimated metal weight of 1200 t has been produced.

4.3.3. Platinium Group metals

Elements of the Pt-Pd family have been described from certain deposits, such as Majdanpek and Bor, in the Timoc District. This is not surprising because platinoids are known at Elatsite in Bulgaria, which is a Late Cretaceous porphyry copper deposit within the same metallogenic province.

The presence of platinoids is also reported in the Veluce Ni-oxide deposit and the Rudnik Pb-Zn skarn deposit, but we have no details.
Fig. 20 - Ag deposits in Serbia.
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Fig. 21 - Magnesite and talc deposits in Serbia.
4.4. INDUSTRIAL MINERALS

Serbia produces various industrial minerals for internal consumption, and in certain cases for export. Unfortunately, the available data are often old and insufficiently detailed. Consequently, we can provide little more than an inventory of the industrial minerals, dealing first with those that are most abundant and those in which further interest could rapidly lead to new developments.

4.4.1. Magnesite and Borate

Magnesite in Serbia (Fig. 21) is associated with the ultrabasic massifs where two main types of deposit are known:

- Lodes (Magura or Goles) in the north and stockworks (Liska) in the west with more-or-less dense veins forming horizontally elongate bodies of several hundred metres over a depth commonly in excess of 100 m. Magnesite is the main mineral of the veins and veinlets, associated with small amounts of dolomite, quartz, chalcedony and calcite. These deposits, hosted by serpentine, are fracture fills deposited by CO₂-rich hydrothermal fluids.

- Stratiform bodies of sedimentary-lacustrine origin that formed within varved clay-carbonate sediments close to exposed ultrabasic rocks during the Tertiary. The mineralization is basically magnesian and boron carbonates: magnesite, hydromagnesite, huntite (Mg₃Ca(CO₃)₄), colemanite and howlite (2SiO₂.4CaO.5B₂O₃.5H₂O), associated with dolomite, aragonite and calcite. This is the case with the Bela Stena deposit (more than 4 Mt of high-grade magnesite), which is now exhausted. Close to Bela Stena, new extensions with dominant boron have recently been developed at the Piskanja and Pobrdjski Potok sites (7 Mt @ 35-39% B₂O₃).

4.4.2. Asbestos and Basalt fibres

Chrysotile occurs principally as cross-fibres occupying open fractures in serpentinized ultrabasic rocks.

Mining of the Stragari deposit, south of Belgrade (Fig. 22), has ceased. However, the Korlace deposit in the Kopaonik District is still active, although we have no accurate economic data concerning production.

Also of note is a new project for mining basalt at the Vrelo site, in the vicinity of Kursumlija. Transformed to rock fibres (basalt fibres), this product will replace asbestos with its well-known harmful effects. The project is at the feasibility stage with an annual production target of 2700 t of continuous basalt fibres.
4.4.3. **Kaolin, Bentonite and Clay**

Figure 23 shows all the clay mineral deposits.

Kaolin and kaolinic clays are worked at the Bare and Rudovci sites in the north and at the Karacevo site in the south. These deposits are derived from supergene weathering of granite massifs.

Large resources of halloysite, a top-quality fibrous clay used in ceramics, are reported at the Novo Brdo Pb-Zn deposit in Kosovo. Depending on the authors, the resources vary between 1.5 and 3.0 Mt of halloysite assaying 39-42% Al_2O_3, 39-43% SiO_2 and less than 1% Fe_2O_3. The halloysite at this deposit was derived from an intense argillic alteration associated with the hydrothermal activity that accompanied the Tertiary volcano-plutonic event.

4.4.4. **Cement raw materials**

Cement production in Serbia is dominated by manufacture of the Portland variety, with four operating Portland cement plants (Fig. 24) - Beocin (1.2 Mt/y), Popovac (0.8 Mt/y), Kosjeric (0.5 Mt/y) and Sar (0.3 Mt/y). The raw materials, marlstone and limestone, are extracted close to the plants.

The Lipnica gypsum-anhydrite deposit is also worked for the cement industry.

4.4.5. **Other industrial minerals**

The main feldspar, mica, and wollastonite deposits and the main quartz and silica deposits are shown in Figures 25 and 26, respectively.

Feldspar, mica and quartz are obtained from the Vidovacki Krs pegmatite deposit near Prokuplje. They are processed by flotation with an annual yield of 50,000 t of feldspar concentrate, 36,000 t of quartz and 14,000 t of muscovite concentrate.

The Rgotina quartz sand deposit is mined in two open-pits. The grade of the raw run sand is usually 93-98% SiO_2, 0.5-2.0% Al_2O_3 and <0.4% Fe_2O_3.

Neogene vitroclastic tuff and opal breccia at Katalenac are mainly used as hydraulic admixtures in the cement industry.

The Jaram (or Duboka) wollastonite deposit is located on the eastern edge of the Kopaonik granodiorite massif. The ore contains 60-70% wollastonite, 2-16% carbonates and 4-12% quartz. Although still not in commercial production, processing tests have produced satisfactory market-grade wollastonite concentrates.
Fig. 22 - Asbestos and Basalt fibres deposits in Serbia.
Fig. 23 - Kaolin and clay deposits in Serbia.
Quaternary sediments
Tertiary volcano-plutonic complex
Upper Cretaceous volcano-plutonic complex
Ultrabasic rocks
Undifferentiated granites
Undifferentiated rocks
Faults and thrusts

Limestone, Dolomite, Ornamental stone, Gypsum deposits

Fig. 24 – Cement raw materials deposits in Serbia.
Fig. 25 - Feldspar, mica and wollastonite deposits in Serbia.
Fig. 26 - Quartz and silica deposits in Serbia.
Conclusions and recommendations

Production of the mineral deposits map and GIS databases for Serbia necessitated a large amount of research, selection and compilation. The grouped information, which does not pretend to be either exhaustive or completely up-to-date, is vast and is now in a form that is readily accessible by a large public.

These documents, despite their imperfections, will form a basis for promoting and helping to restructure and develop Serbia's mining sector. By combining mining and environmental factors, they provide a "sustainable development" type approach.

They show the diversity and location of Serbia's mineral resources and can thus usefully support discussions with investors interested by the country's mineral and mining potential. The answers to some of the questions that possible investors are bound to ask can be found on the map and/or in the databases.

These documents will also be useful to those responsible both for regional planning and development and for environmental protection. The Minerals map enables one to localize the main mining and metallurgical districts where "past mining" has generated environmental problems that now have to be taken into consideration for any regional planning. The databases contain descriptive, and in places statistical, data required to determine certain environmental problems.

The elements provided for this project by Serbia's Ministry of Mining and Energy need to be completed and periodically updated so that it maintains its credibility for the different users. Certain aspects, particularly as regards the environment, need to be enhanced with the addition of statistical data and so gradually comply with the standards recognized by the European Union in the context of "mining waste" inventories.

The work constitutes an important component in the computerization, currently being carried out by the Ministry of Mining and Energy, of Serbia's Mine Register and past exploration data.