REPUBLIC OF SERBIA
MINISTRY OF MINING AND ENERGY

GEOINSTITUT

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

March 2002
BRGM/RC-51448-FR

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BRGM/RC-51448-FR

BRGM

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:

Monthel J., Vadala P., Leistel J.M., Cottard F., with the collaboration of Ilic M., Strumberger A., Tosovic R., Stepanovic A. (2002) – Mineral deposits and mining districts of Serbia. Compilation map and GIS databases. BRGM/RC-51448-FR, 67 p., 26 Fig., 1 Table, 1 Plate, 2 App., 1 CD-rom.

Abstract

Work for the map and GIS databases of the mineral deposits and mining districts of Serbia was carried out within the context of a French Government aid project for the Republic of Serbia's Ministry of Mining and Energy.

The Minerals map, compiled at 1:750,000 scale, shows the country's principal deposits for energy minerals, base and precious metallic minerals, and industrial minerals, and also the country's main mining districts. The data have been plotted on a topographic and simplified geology base using MapInfo software.

The mineral deposits and mining districts databases have been constructed under Microsoft Access, based on the model developed by BRGM for its scientific research projects.

The "Ore deposit" database contains 199 records that include:
- geographic location,
- geological data (typology, morphology, age and type of mineralization and host rock, mineralogical composition of the ore, gangue and hydrothermal alteration),
- economic data (mine status, type of development, former production, status of resources and reserves),
- data concerning environmental hazards likely to be generated by the deposit,
- bibliographic references.

The same information is also provided in catalogue form as an appendix to this report.

Twelve main mining districts are distinguished. The relevant information concerning these districts is stored in the "District" database and includes:
- a list of the deposits located within the district,
- the main primary and secondary ore minerals (commodities or substances) present, each annotated with an assessment of the contained metal weight so as to enable an evaluation of the district's economic importance,
- the dominant typology or characteristic(s) of the district,
- the age of the mineralization and host rocks,
- a synopsis of the geological and economic data,
- a comment on the potential environmental releases and damage associated with the relevant mining and mineral-processing industry,
- the main bibliographic references.

All this information is also provided in catalogue form as an appendix to this report.

The report introduces these documents and then reviews the country's mineral and mining potential through a series of figures compiled from thematic analyses of Serbia's best-represented mineral commodities.

Serbia's Kosovo-Metohija Pliocene Basin contains the largest exploitable reserves of lignite in Europe. Serbia is also known for its copper mining in the Timoc District and lead-zinc mines in the Kopaonik District —two districts that provide an important economic potential, but where the relaunching and development of the mining industry will require major changes and extensive investment. If one considers the examples of Greece and the Republic of Macedonia, then the Tertiary volcanic exposures of the Serbo-Macedonian Metallogenic Province should be highly favourable for the presence of precious metals. Moreover, in Serbia, this province appears to have been under-explored for gold, particularly with the availability of modern exploration tools and procedures suited to the country's geology and morphology. Among the many industrial minerals present in Serbia, particular attention should be paid to the significant resources in borate, magnesite and raw materials for the ceramics and glass industries (halloysite, wollastonite).

The documents, despite their imperfections, provide a basis for promoting and aiding in the restructuring and development of Serbia's mining sector. Combing mining with environmental data, they provide a "sustainable development" approach.

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CD-ROM containing: (i) the mineral deposits ("Ore deposit") and mining districts ("District") databases (under Access); (ii) the map compilation files in MapInfo 6.5 format; (iii) the map compilation files in ArcView 3.2 format; (iv) the various graphic documents in '**.wmf**' format; (v) the text of this report.

Introduction

Serbia, located in the Balkans and at the heart of Europe, possesses significant mineral resources, particularly where lignite, copper, lead, zinc and industrial minerals are concerned.

Mining and the mining-metallurgical-mechanical complexes in this part of the world were, before the demise of communism, the keystone to the regional economy. The mining and metallurgical sector was at a peak prior to the break-up of the Federal Republic of Yugoslavia in the early 1990s, but declined rapidly due to the 1992 to 1995 embargo and finally became paralysed following the Kosovo conflict and the NATO bombing in 1999.

The Republic of Serbia's new government, following democratic elections in 2000, is fully aware that the rebirth and development of its industry and economy can only be achieved through capital investment, and thus of necessity through privatization. The government has to provide advantageous conditions in order to attract investment to the mining industry.

In the context of its "Fonds d'Etudes et d'Aide au Secteur Privé" (*Private sector study and aid funds*), the French government released the necessary funding and instructed BRGM to provide help to the Republic of Serbia's Ministry of Mining and Energy in relaunching the mining sector, which has a major role to play in the country's economy, and promoting it to private investors.

Two aspects have been approached in context of this cooperation project:

- support for modernizing the mining law,
- construction of a synoptic promotional map and GIS-type databases for the mineral deposits and mining districts of Serbia.

The first aspect was the subject of a specific study that is summarized in BRGM Report BRGM/RC-51453-FR "Institutional support to the Ministry of Mining and Energy of the Republic of Serbia for the improvement of the mining law" by N. Stolojan and M. Lansiart, January 2002.

The present report concerns the second aspect. It introduces the Minerals map, GIS databases and catalogues concerning Serbia's mineral deposits and mining districts. It also provides an opportunity to review the country's mining potential and define priority zones for mineral exploration and development.

BRGM was aided in this work by various bodies involved in the geology and mining economy of Serbia, and in particular by the Faculty of Mines and Geology of the University of Belgrade and by GeoInstitut.

The project has also benefited from the knowledge acquired by BRGM in the context of its scientific research project entitled "GIS Central Europe", as well as from various expert assessment missions to the Balkans during the period 2000-2001, in partnership with the *Société Tec Ingénierie*, for a mining audit of the Trepca mining and metallurgical complex in Kosovo and for a reconnaissance visit to Bor in northeastern Serbia.

The mineral deposits map was compiled using MapInfo 6.5 software. So that it can be reproduced with other GIS software, we also created export files compatible with ArcView 3.2 software and a file in ***.wmf** format that can be accessed with PowerPoint..

The mineral deposits and mining districts databases have been constructed under Microsoft Access, based on the model developed by BRGM for its scientific research projects.

1. Introduction to the Minerals map of the Republic of Serbia

The Minerals map at 1:750,000 scale, produced using MapInfo 6.5 software, shows all the relevant deposits on a very simplified geologic base.

The raw materials extracted from the subsurface classically fall into the following categories:

- fossil fuels (coal *s.l.* and hydrocarbons) also known as "energy minerals",
- metallic minerals,
- industrial minerals,
- precious and semi-precious stones,
- construction materials,
- mineral waters and geothermal energy, relating to deep groundwaters and generally studied under "hydrogeology".

The priority for the Minerals map only concerns the first three groups, for which we have tried to be as exhaustive as possible. We have also plotted the location of a few semi-precious stone sites, as well as the main quarries worked for cement raw materials. However, no data has been plotted for mineral waters or geothermal energy.

1.1. PROJECTION SYSTEM AND TOPOGRAPHIC BASE

The details of the projection system used for the map are:

- Transverse Mercator,
- spheroid NAD 27, ellipsoid Clarke 1866,
- central meridian: 21°,
- reference latitude: 0°,
- scale factor: 1,
- false easting: 1000 km,
- false northing: 0 km.

The data shown on the topographic base have purposely been limited to national borders, the drainage pattern and the main road network. Other than mineral deposits, only the main towns are named.

1.2. GEOLOGICAL BACKGROUND

The geological base was deliberately simplified to show only the major lithostructural units, some of which have played a dominant role in the origin and distribution of the mineralization. Thus, we have emphasized (Fig. 1):

- The ultrabasic rock massifs characterizing Triassic-Jurassic ophiolitic paleo-rifts;

- The Upper Cretaceous volcanic and volcano-plutonic complexes that gave rise to the copper mineralization of the Carpatho-Balkan Metallogenic Province in northeastern Serbia;

- The Tertiary volcano-plutonic complexes that characterize the major Serbo-Macedonian Metallogenic Province, which crosses Serbia from the borders of Macedonia and Bulgaria in the south-southeast to the borders of Bosnia-and-Herzegovina and Croatia in the north-northwest;

- The intrusive granites, of which the oldest have been dated as Permo-Carboniferous and the youngest as Tertiary;

- The Quaternary sediments, mainly represented by the molasse of the Pannonic Basin in the Voivodine.

Finally we have graphically highlighted the main discontinuities (faults and thrusts), and particularly the groups of faults delimiting the Vardar Zone.

The geology is based on the Geological map of Yugoslavia at 1:500,000 scale (Federal Geological Institute, 1970). The changes and additions that have been made derive from the 1:200,000-scale Geological Map of Serbia (Milovanovic and Ciric, 1968) and from different map compilations found in a variety of publications.

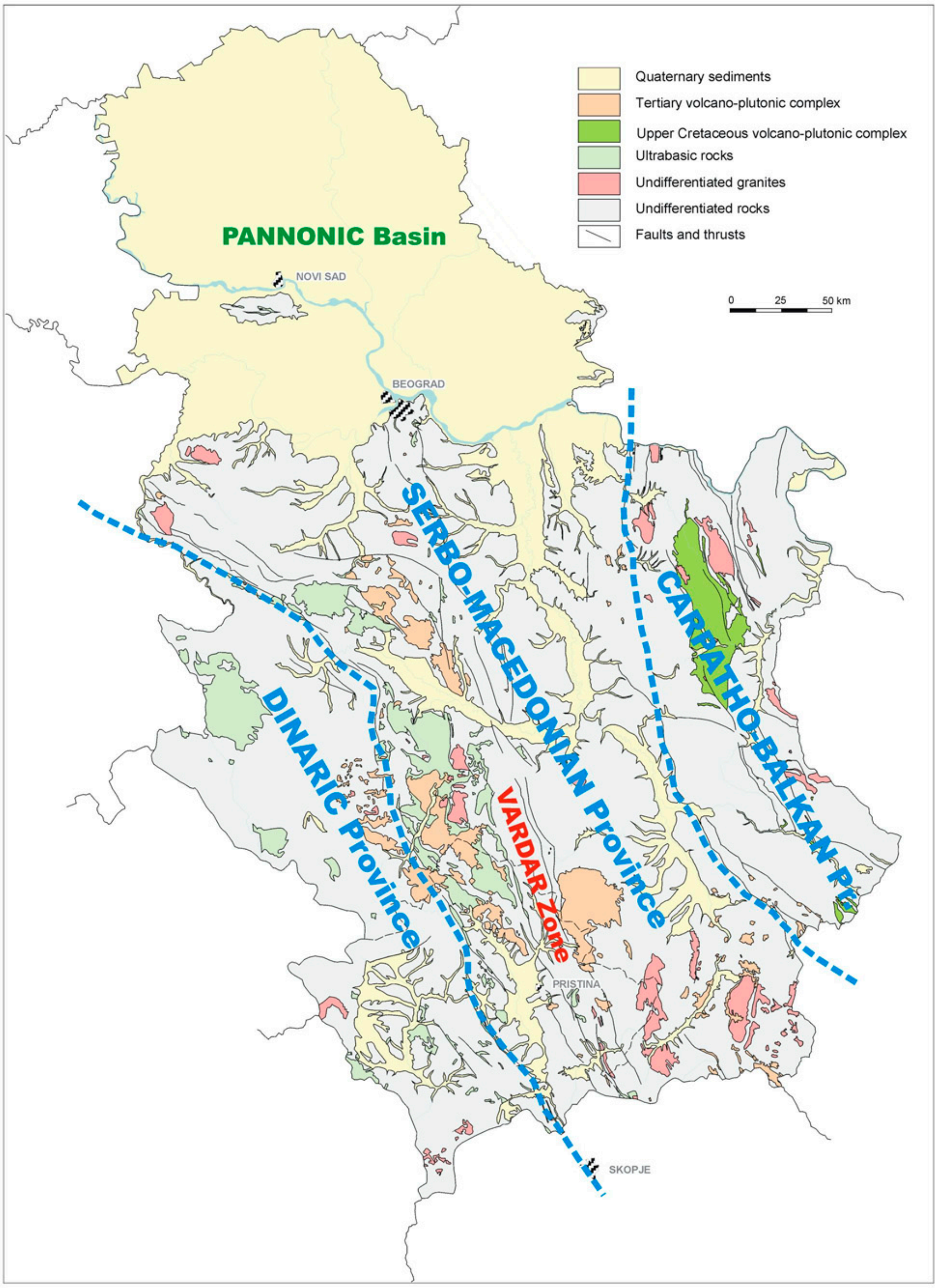

Fig. 1 – Simplified geological map of Serbia showing the main structural and metallogenic provinces.

1.3. MINERAL DEPOSITS

Although sometimes grouped by district, the major metallic-mineral and industrial-mineral mines and quarries are generally well localized and represented as such.

The **symbol shape** used for representing the deposit has allowed us to distinguish:

- fossil fuels, or energy minerals – represented by hexagons,
- metallic minerals – represented by circles coloured according to the dominant commodity(ies),
- industrial minerals – represented by squares coloured according to the dominant commodity(ies).

The **symbol size** and **size of the deposit name** reflect the economic importance of the concentrations. They are proportional to the deposit's cumulative metal weight (mined + reserves) where these figures are known or can be estimated. We restricted ourselves to defining only three classes:

- large size deposit,
- medium size deposit,
- small size deposit and occurrence.

This classification is dependent on the commodity(ies) present in the deposit, as shown by Table 1.

Commodity	Large size deposit	Medium size deposit	Small size deposit
Lignite	> 1,000,000 kt	1,000,000 - 5,000 kt	< 5,000 kt
Copper	> 1,000,000 t	1,000,000 - 10,000 t	< 10,000 t
Lead	> 100,000 t	100,000 – 1,000 t	< 1,000 t
Zinc	> 200,000 t	200,000 – 2,000 t	< 2,000 t
Nickel	> 200,000 t	200,000 – 2,000 t	< 2,000 t
Iron	> 100, 000 kt	100,000 – 1,000 kt	< 1,000 kt
Chromite	> 5,000,000 t	5,000,000 – 200,000 t	< 200,000 t
Magnesite	> 10,000,000 t	10,000,000 – 100,000 t	< 100,000 t
Kaolin	> 10,000,000 t	10,000,000 – 500,000 t	< 500,000 t
Gold	> 50 t	50 – 1 t	< 1 t
Silver	> 2,500 t	2,500 – 100 t	< 100 t

Table 1 – Deposit classification for the main commodities according to economic size.

1.4. MINING DISTRICTS

The deposits, and particularly the metalliferous deposits, can be grouped within districts characterized by similar geological and gitological (metallogenic) contexts, identical mineralogical associations, and a contained mineralization derived from commonly contemporaneous metallogenic processes.

The mining districts are represented by envelopes whose colour reflects the dominant commodity(ies). The retained name is usually that used in scientific articles dealing with the metalliferous deposits of Serbia.

1.5. SMELTERS

The map was completed by showing the five main smelters, i.e. the Bor copper smelter, the Zvecan lead smelter, the Kosovo Mitrovica zinc smelter, the Glogovac nickel smelter and the Zajaca tin smelter.

Fig. 2 – Introductory screen to the "Ore deposit" database.

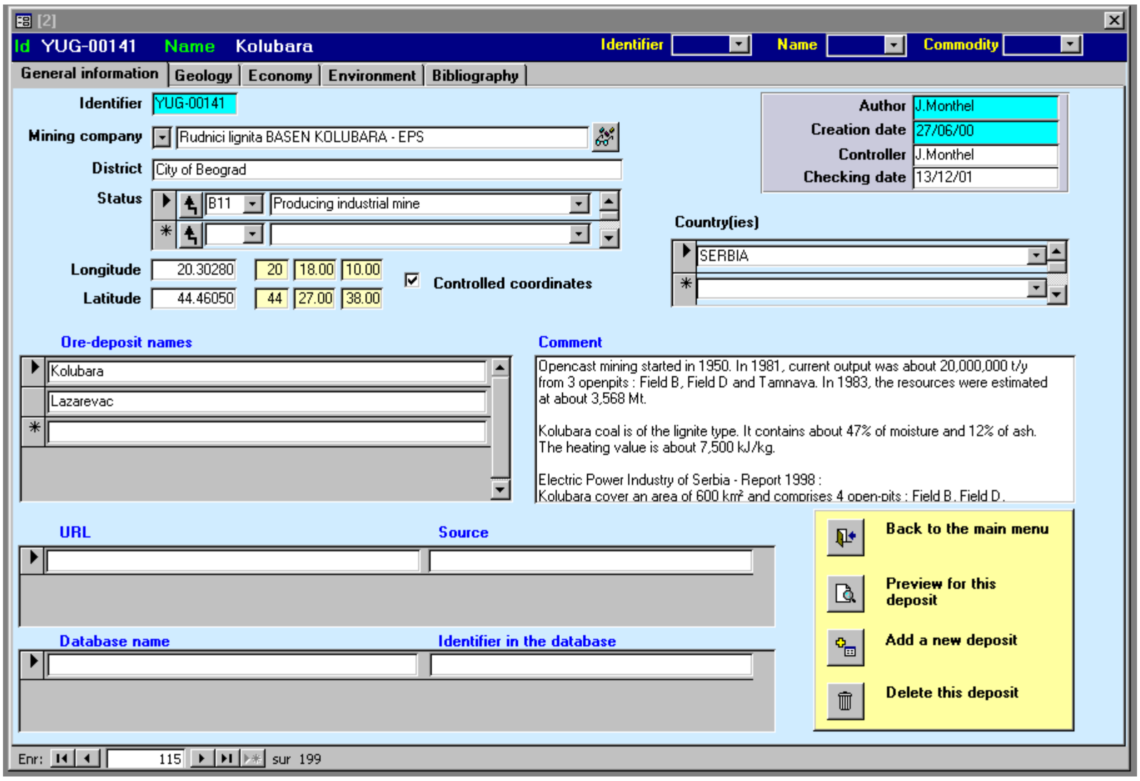

Fig. 3 – "General information" data input screen for deposit location, status, mining company, etc.

2. Mineral deposits database and catalogue

The "Ore deposit" database has been constructed according to the model developed and used by BRGM for its GIS projects on the Andes, Africa and Central Europe. It is an Access database with five main input screens. The contained data for each deposit can be printed at any time in file (or status) format containing the essential information. Here we have printed the files and grouped them into a Catalogue of the Mineral Deposits of Serbia as Appendix 1 to this report.

2.1. THE DATABASE EXPLAINED THROUGH ITS DATA INPUT SCREENS

The "General information" data input screen (Fig. 3) is used for information concerning the identity and location of the deposit (coordinates, administrative province), the name of the mining company, the status of the deposit, references to other databases containing information on the deposit, etc. The "Comments" box allows relevant information to be included that is not requested by any of the database's screen input headings.

The input screen shown in Figure 4 is devoted entirely to the deposit geology. It requests information on the deposit's typology (metallogeny, gitology) and morphology(ies), and also asks for data concerning both the mineralization (age, ore and gangue mineralogy, hydrothermal alteration) and the host rock (age, formation name[s], lithology[ies]).

Information concerning the type of exploitation (mining and processing) and the main commodity(ies) is given under the "Economy" data input screen shown in Figure 5. This screen is also used for entering past (former) production figures and the status of the reserves and resources along with a qualification of the degree of confidence (proven, probable, possible), etc. Due to the confidential character generally associated with data concerning production and reserves, it is generally impossible to provide more than the past production figures.

The environmental factors and main hazards likely to arise from the deposit are given in the "Environment" data input screen.

Note that the "Environmental signature" of a mineral deposit is defined as "the compositions, concentrations and availabilities of chemical elements in waters, soils, sediments and airborne particulate at a site". These chemical elements result from the natural weathering of exposed mineral deposits, as well as from mining, mineral processing and smelting activities. For example, the environmental signature of a mine site may include:

- its metal contents,
- the composition of the mine drainage water,
- the stream sediments and soils,
- the identification of readily soluble secondary salts associated with the mine waste.

Seeing that few data regarding these items were available for the present study, we have based the "environmental signature" of a mineral deposit mainly on geological factors that could have potential environmental effects, i.e.:

- ore and gangue mineralogy (e.g. acid-generating versus acid-consuming minerals),
- secondary mineralogy,
- wall-rock alteration and the alteration products,
- type (e.g. veins, massive, disseminated, etc.) and size of the ore deposit
- lithology of the host rock (e.g. existence of acid-consuming limestone).

Other factors such as climate, hydrology, topography and physiography, as well as mining and milling methods, also play a key role in influencing potential environmental effects, but have not been taken into account due to a lack of available data.

The literature references are given in the "Bibliography" data input screen shown by Figure 6. They are linked to a list of almost 150 published (thus non-confidential) articles, mainly in English or with an English abstract. A specific tab to the right of the reference accesses an additional screen giving details and key words of the article in question.

The bibliographic searches were done from the two databases:

- GeoRef, developed and maintained by the American Geological Institute,
- PASCAL, developed and maintained by the CNRS in France.

Other publications were provided by the Faculty of Mining and Geology of the University of Belgrade.

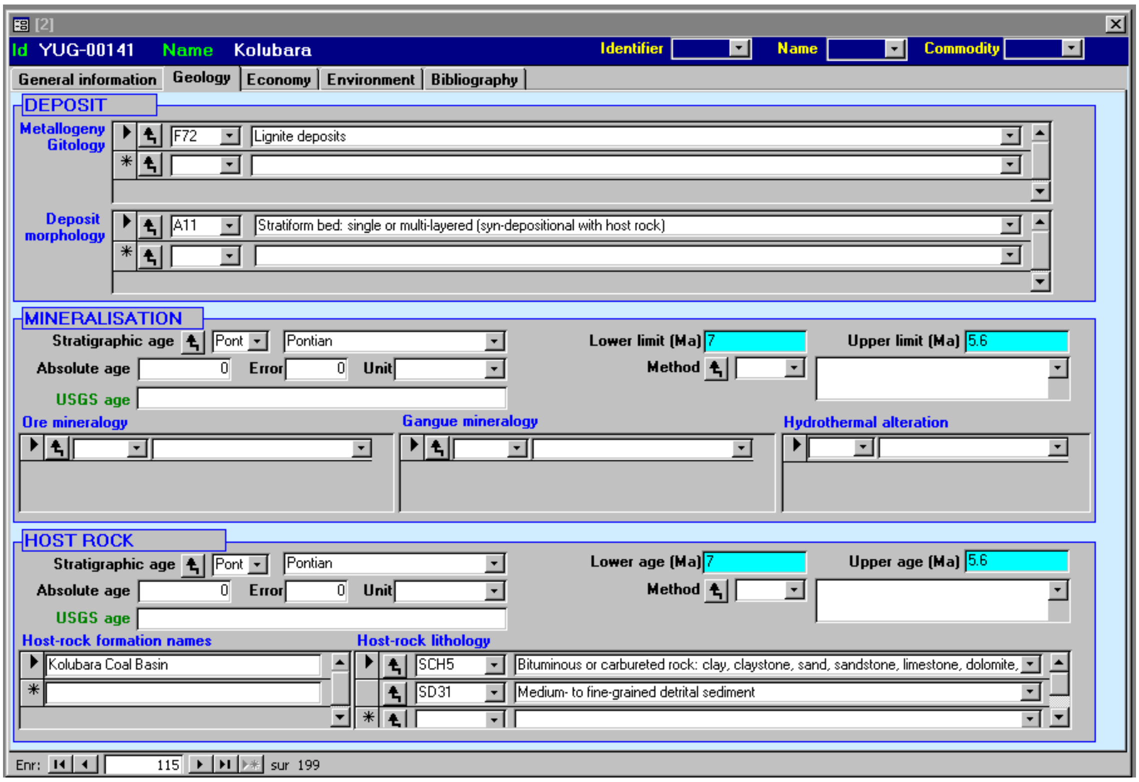

Fig. 4 – "Geology" data input screen.

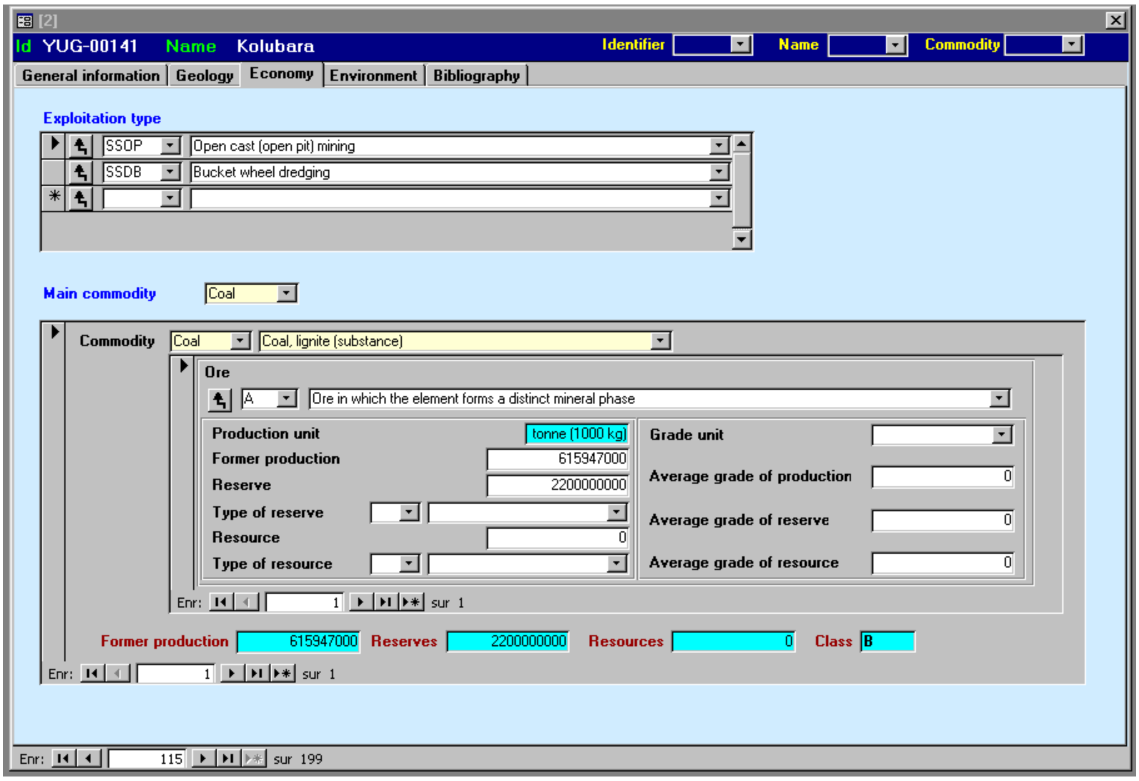

Fig. 5 – "Economy" data input screen.

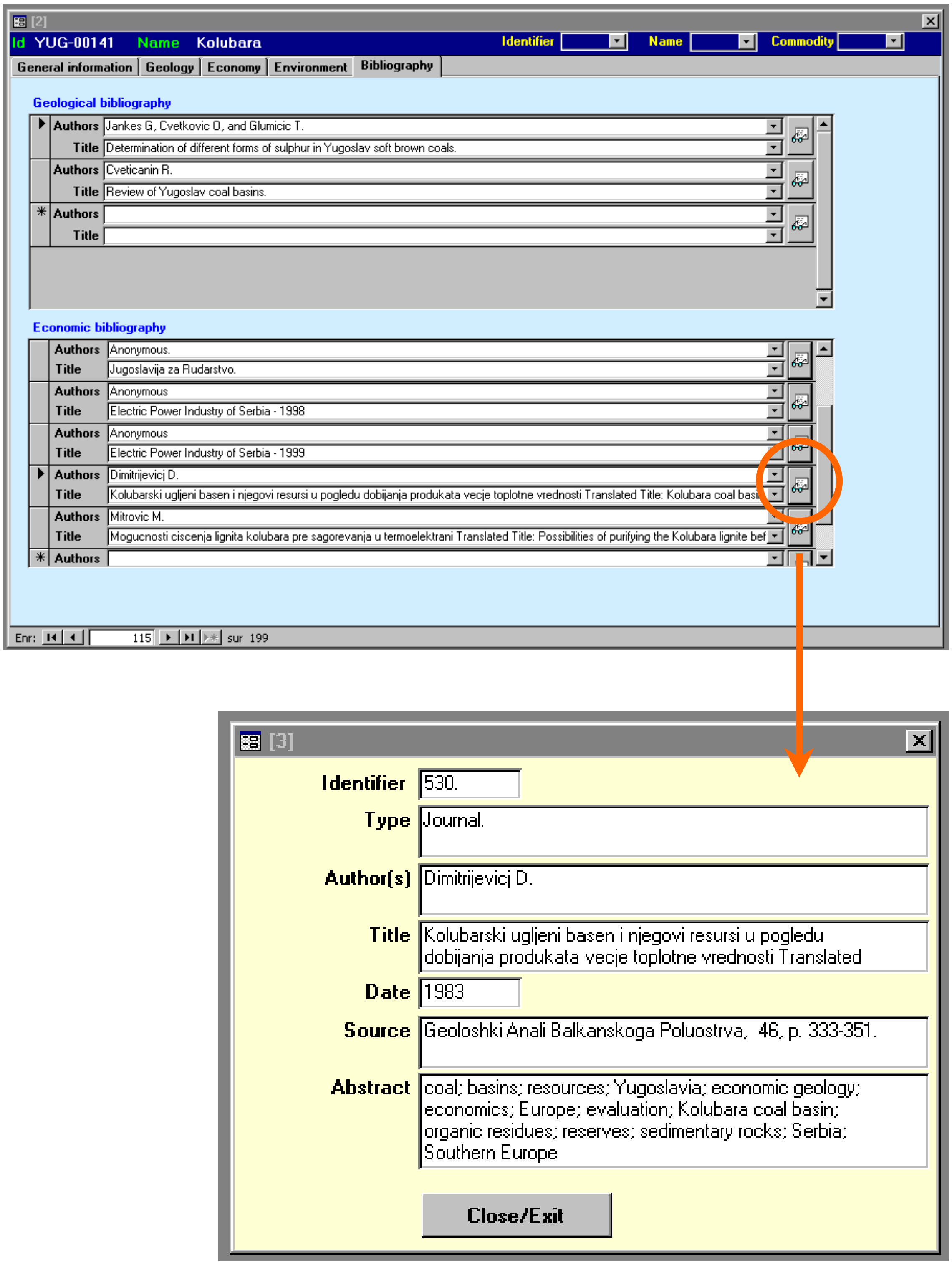

Fig. 6 – "Bibliography" data input screen and article details.

The Introductory screen to the "Ore deposit" database also contains other tabs giving access to database utilities, i.e.:

- "Queries", which can be variably complex like select a given commodity, status, gitological type, etc., within the "Ore deposit" database,
- "Reports" for preparing and printing records contained in the database,
- "Import/Export" for exporting data in Excel format, or importing new data.

These possibilities are illustrated by Figures 7, 8 and 9.

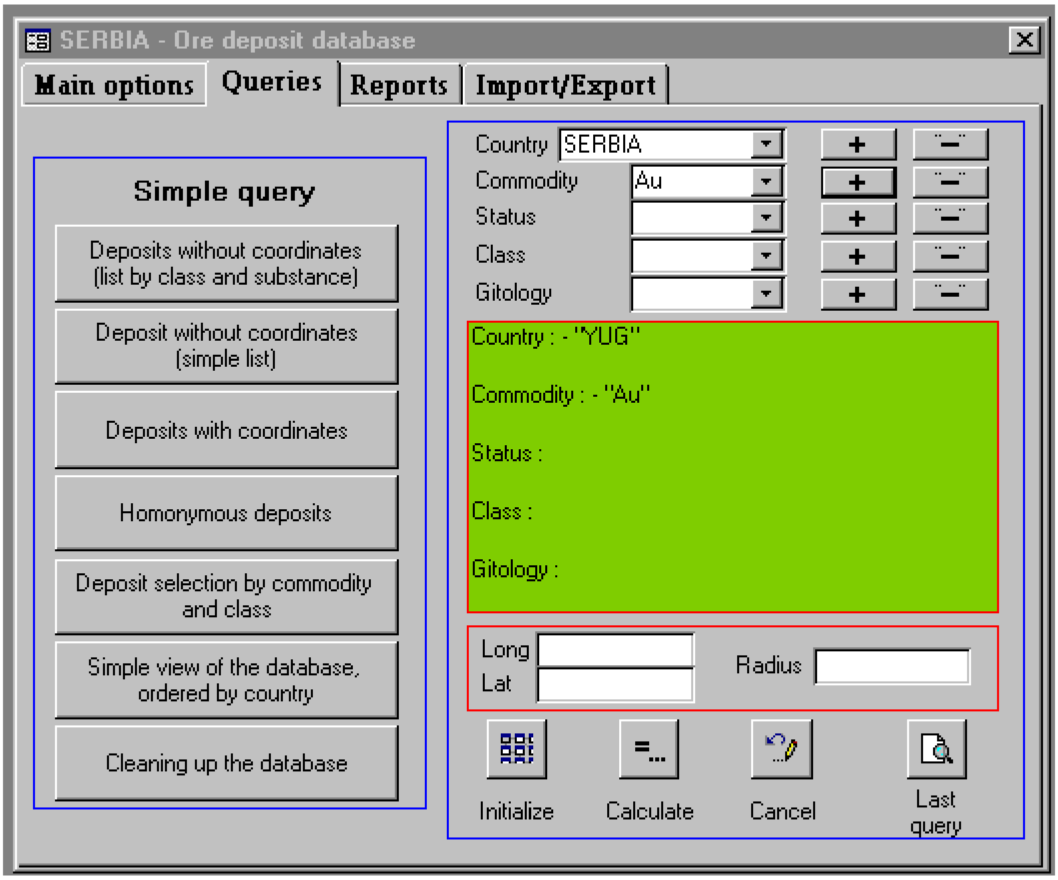

Fig. 7 - Types of query enabled by the "Ore deposit" database.

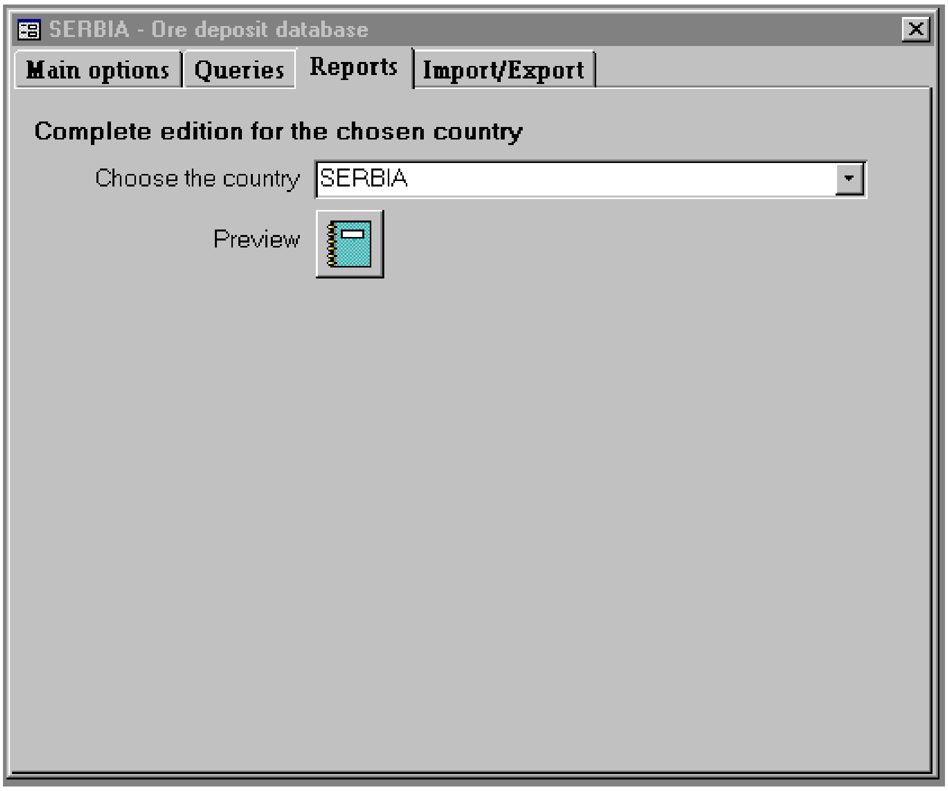

Fig. 8 – Utility for printing records.

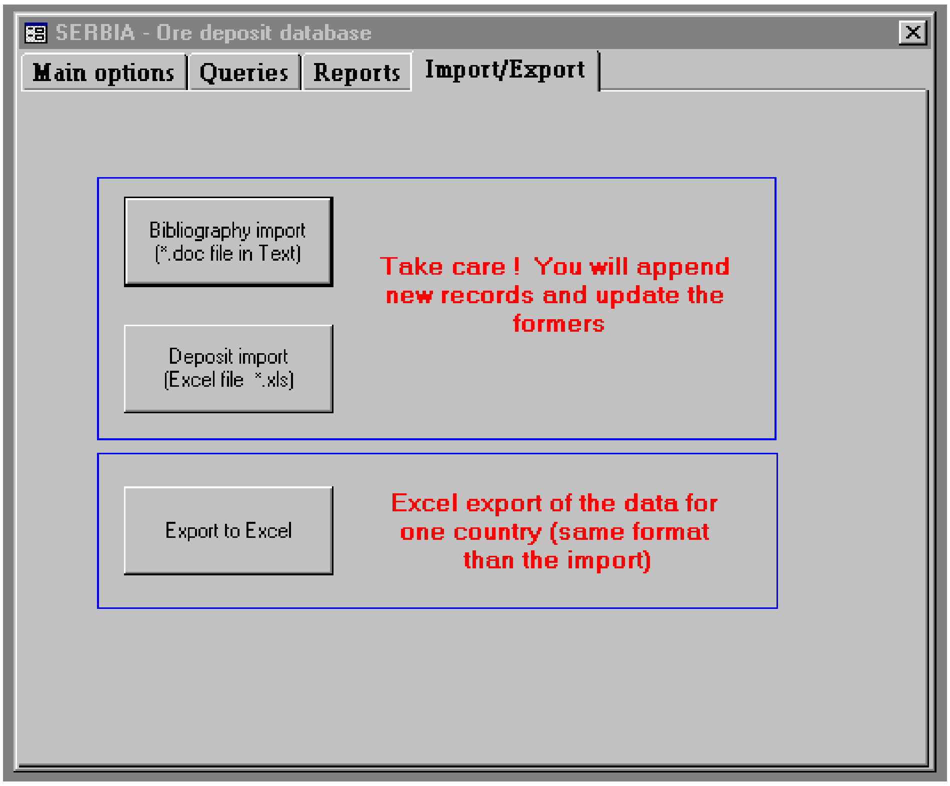

Fig. 9 – Utility for data import/export.

2.2. CATALOGUE OF THE MINERAL DEPOSITS OF SERBIA

Information relating to the recorded 199 deposits and occurrences in the database has been printed as information sheets to make up the catalogue given in Appendix 1.

The deposits in the catalogue are classified according to their identification number, which corresponds to the sequential input number. The catalogue also gives a table linking the deposit name(s) to the deposit identification number —the deposits in the table are in alphabetical order.

Each sheet gives a summary of the:

- General information, including the deposit name(s), identification number, commodities exploited along with their cumulative metal weight (mined + reserves + resources), current mining status (where known), name of the last mining company exploiting the deposit, longitude and latitude (in decimal degrees) and administrative province.

- Geological data, with type of deposit, its morphology(ies), the age and composition of its mineralization, and the age, type and local name of the host rock.

- Economic data, indicating the type of exploitation, the deposit commodity(ies) accompanied by the type of ore, the metal weight and the grade of the former production, reserves and resources.

- Comments on the environmental hazards likely to be generated by the deposit.

- "Free" comments for specific information or details not requested by any of the database's screen input headings.

- Bibliographic references, distinguishing between those that are geologically oriented and those that are economically oriented.

- The deposit reference number in other published databases.

3. Mining districts database and catalogue

Like the "Ore deposit" database, the "District" database has been constructed according to the model developed and used by BRGM for its GIS projects on the Andes, Africa and Central Europe. It is an Access database linked to the "Ore deposit" database. The contained data for each district can be printed at any time in file (or "status") form showing the essential information. Here we have printed the files and grouped them into a Catalogue of the Main Mining Districts of Serbia as Appendix 2 to this report.

3.1. PRESENTATION OF THE DATABASE

The "District" database has a similar form to the "Ore deposit" database (Fig. 10), except that data is entered via a single data input screen (Fig. 11).

The different information that can be input to the database through this screen includes:

- District name,
- List of deposits contained in the district,
- The main and secondary ore minerals or commodities (here termed "substances") present within the district. The link with the "Ore deposit" database gives an automatic update of the cumulative metal weight for each of the indicated commodities,
- The district's dominant typology or characteristic (here entered under "gitology"),
- The age of the mineralization and host rock,
- A free "Comments" box for summarizing the geological and economic data,
- A comment related to potential environmental releases and damage linked to the mining and mineral-processing industry,
- The main bibliographic references.

3.2. CATALOGUE OF THE MAIN MINING DISTRICTS OF SERBIA

We have defined 12 main mining districts. The data concerning these districts are given in catalogue form in Appendix 2 where the districts are classified in alphabetical order. The name adopted for each district is that most commonly found in the literature.

Each District file summarizes the following information:

- the list of deposits included in the district,
- the main and secondary commodities, each accompanied by an estimation of the metal weight from which to ascertain the economic importance of the district,
- the dominant "gitological" type in the district,
- the age of the mineralization,

- a relatively complete comment summarizing the district's geological, gitological and economic factors; it may also define the district's present and potential mining interest where sufficient information is available,
- a comment concerning the likely hazards to be provoked by the mining and the mineral-processing and metallurgical plants within the district,
- a selection of published bibliographic references.

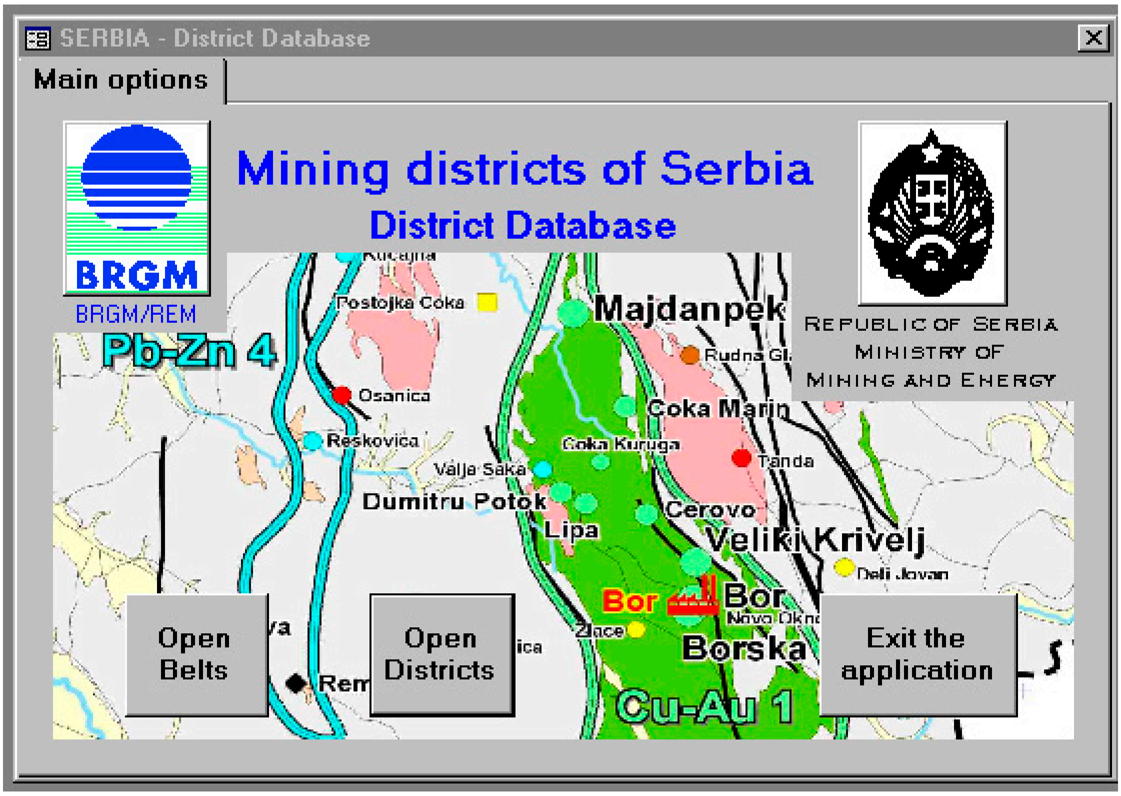

Fig. 10 – Introductory screen to the "District" database.

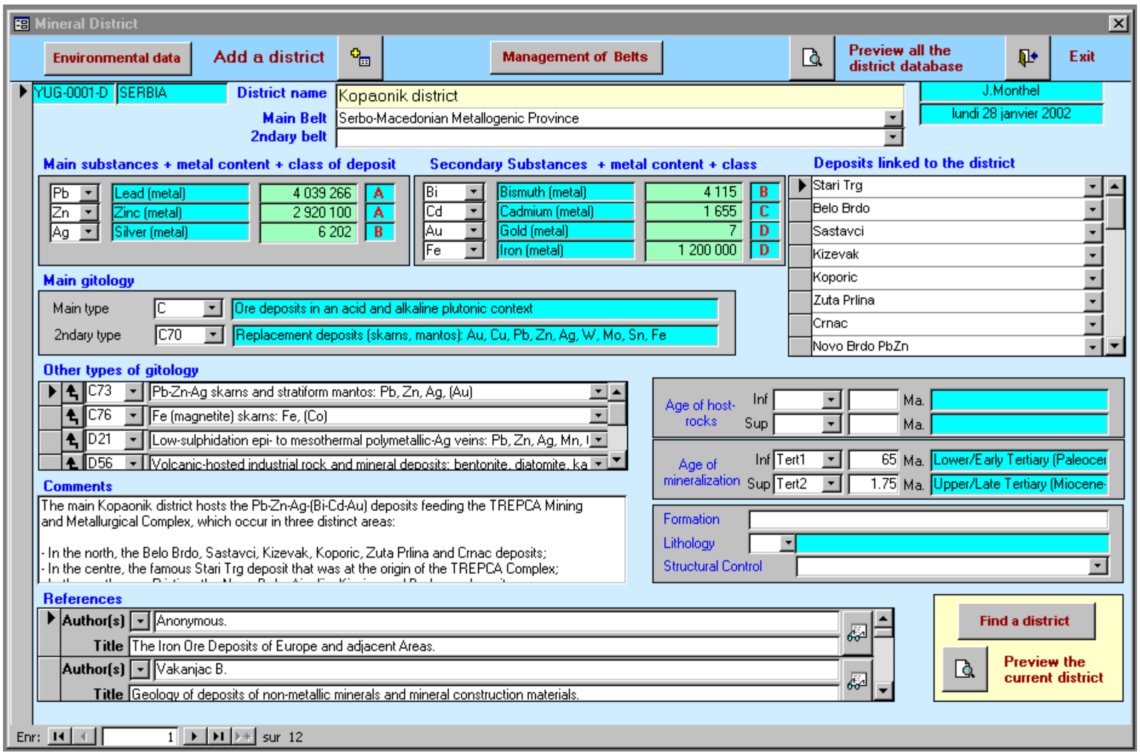

Fig. 11 – Input screen for the "District" database.

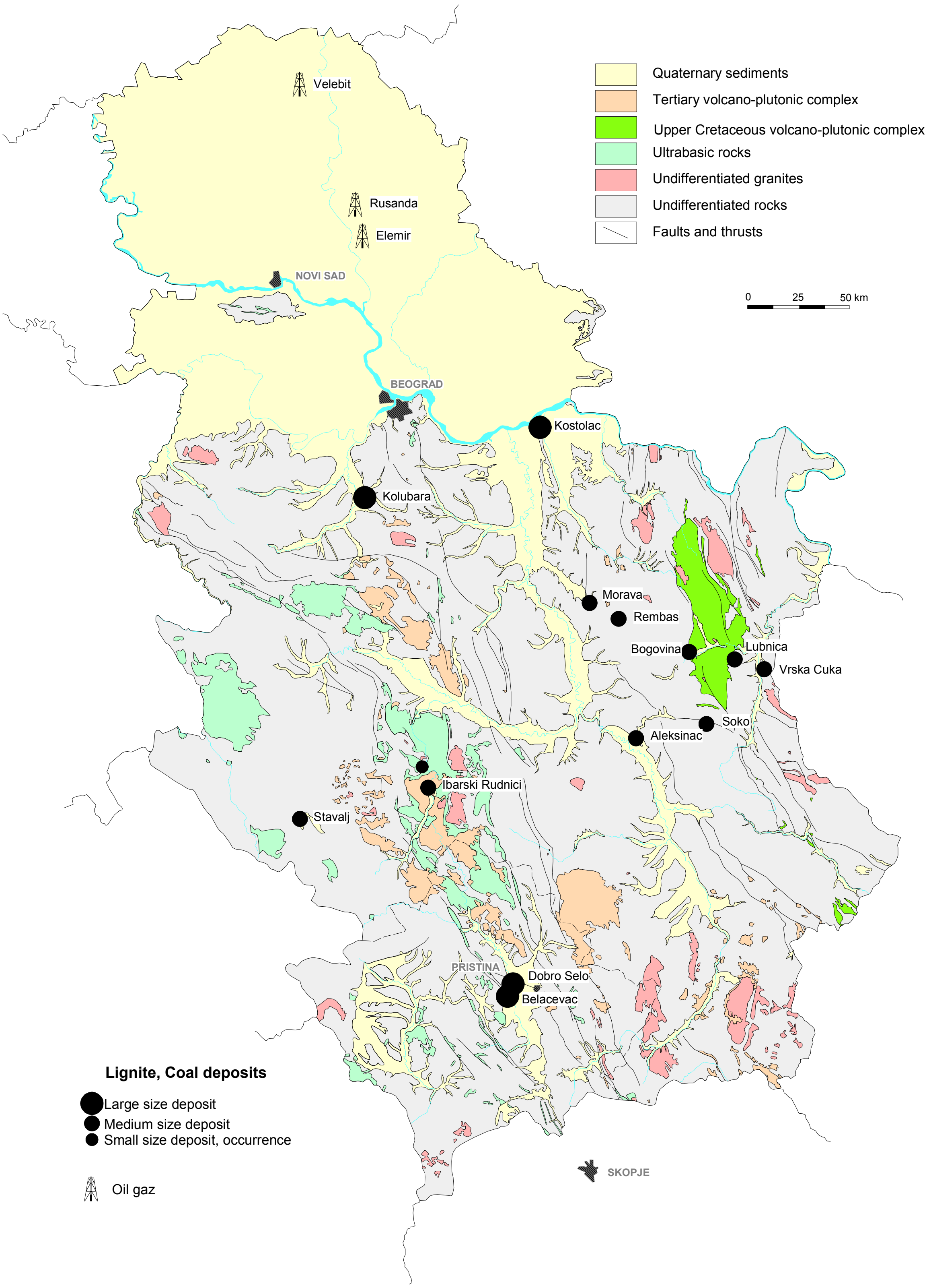

Fig. 12 - Energy-mineral deposits in Serbia.

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 km^2 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 Mm^3/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 Mm^3 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 km^2. 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.

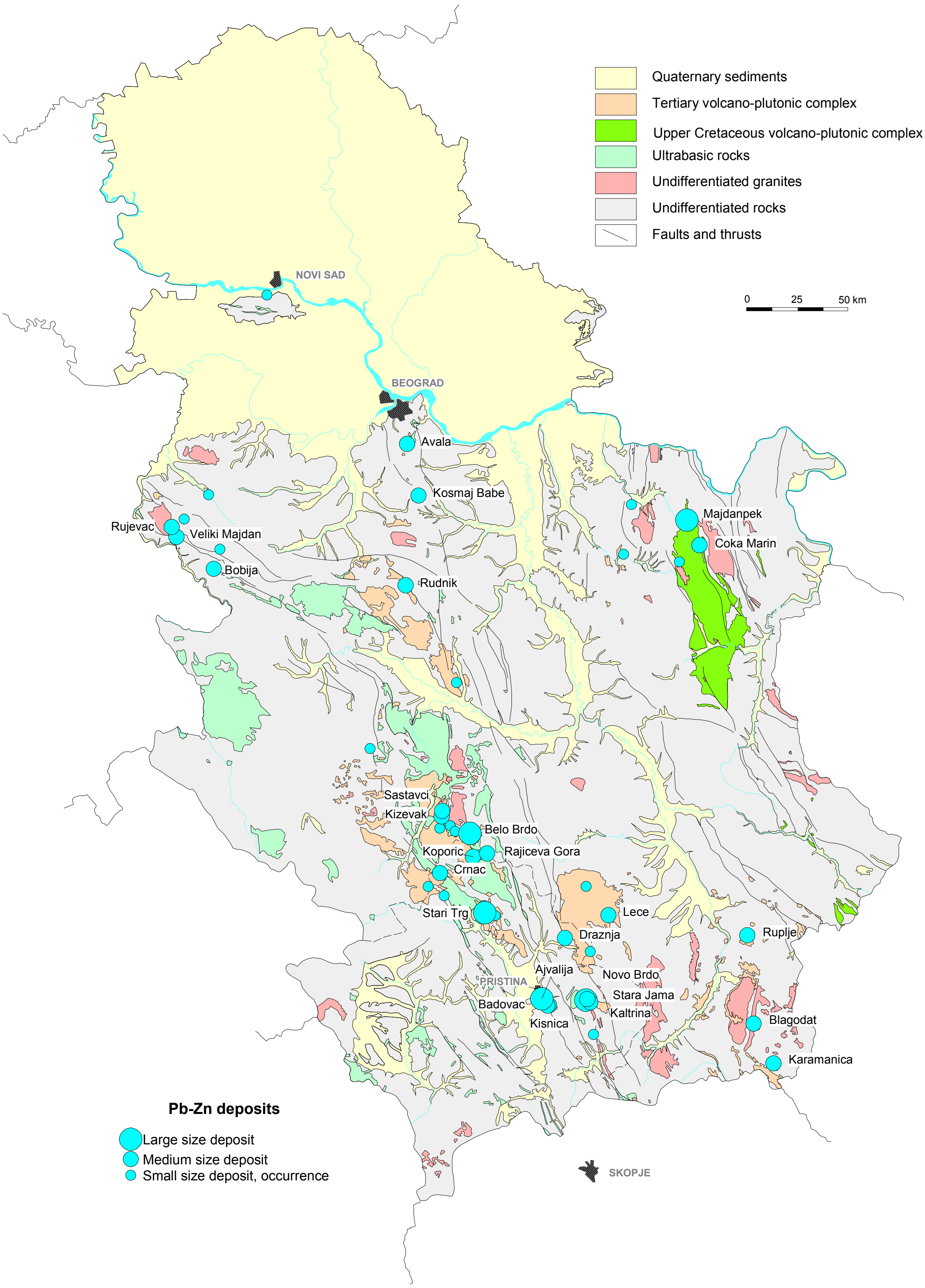

Fig. 13 - Pb-Zn deposits in Serbia.

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 subeconomic 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).

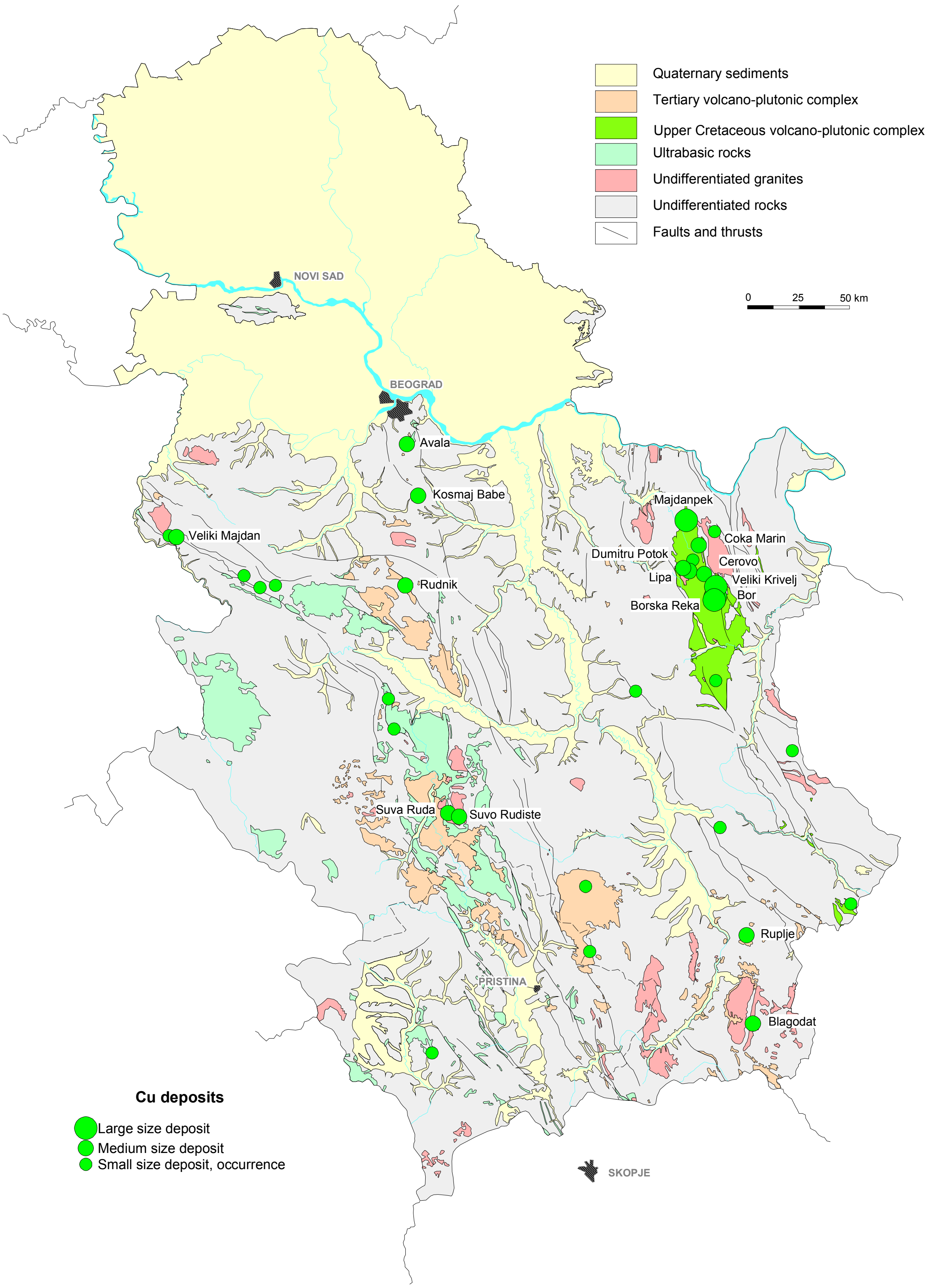

Fig. 14 - Cu deposits in Serbia.

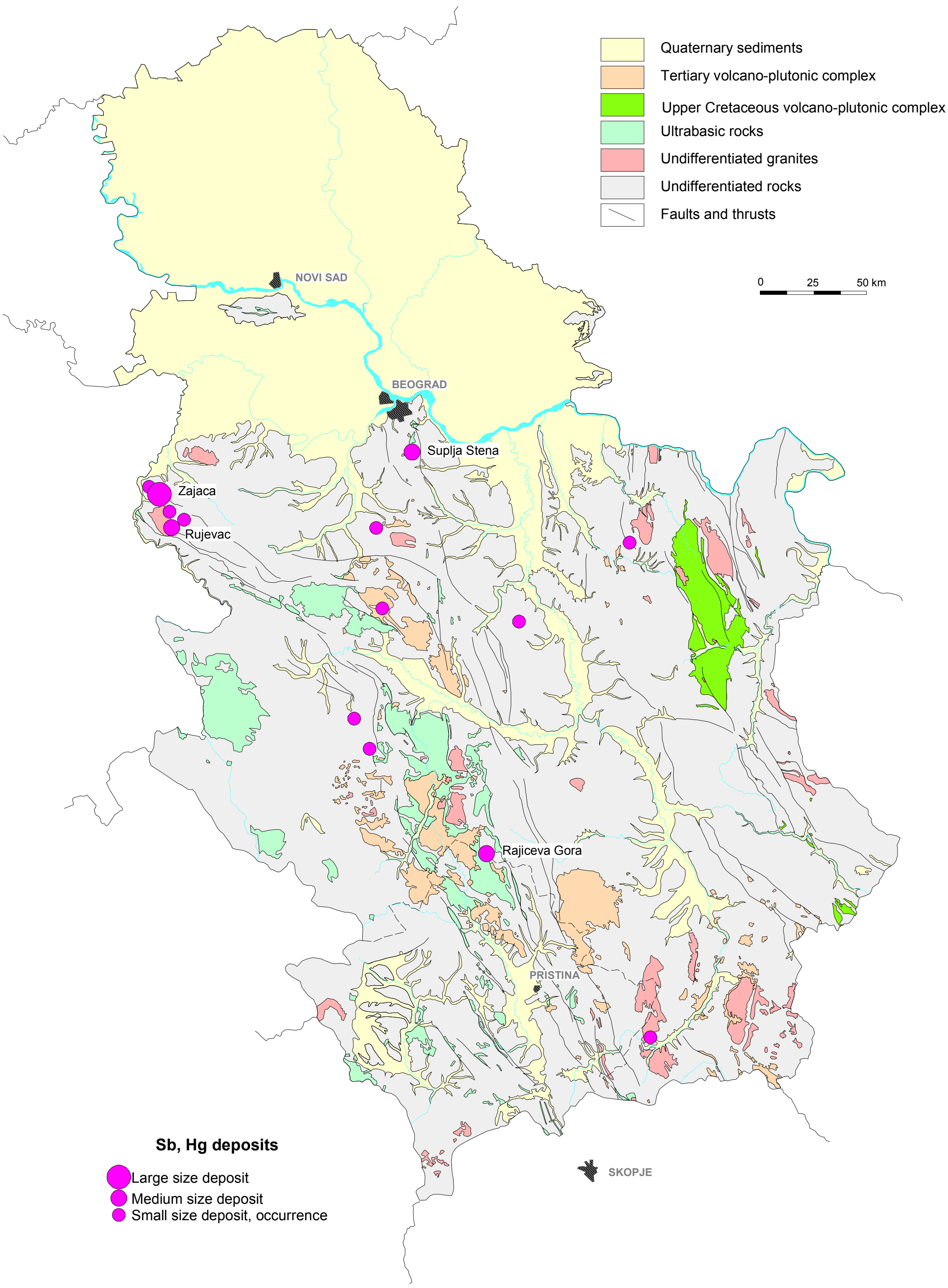

Fig. 15 - Sb-Hg deposits in Serbia.

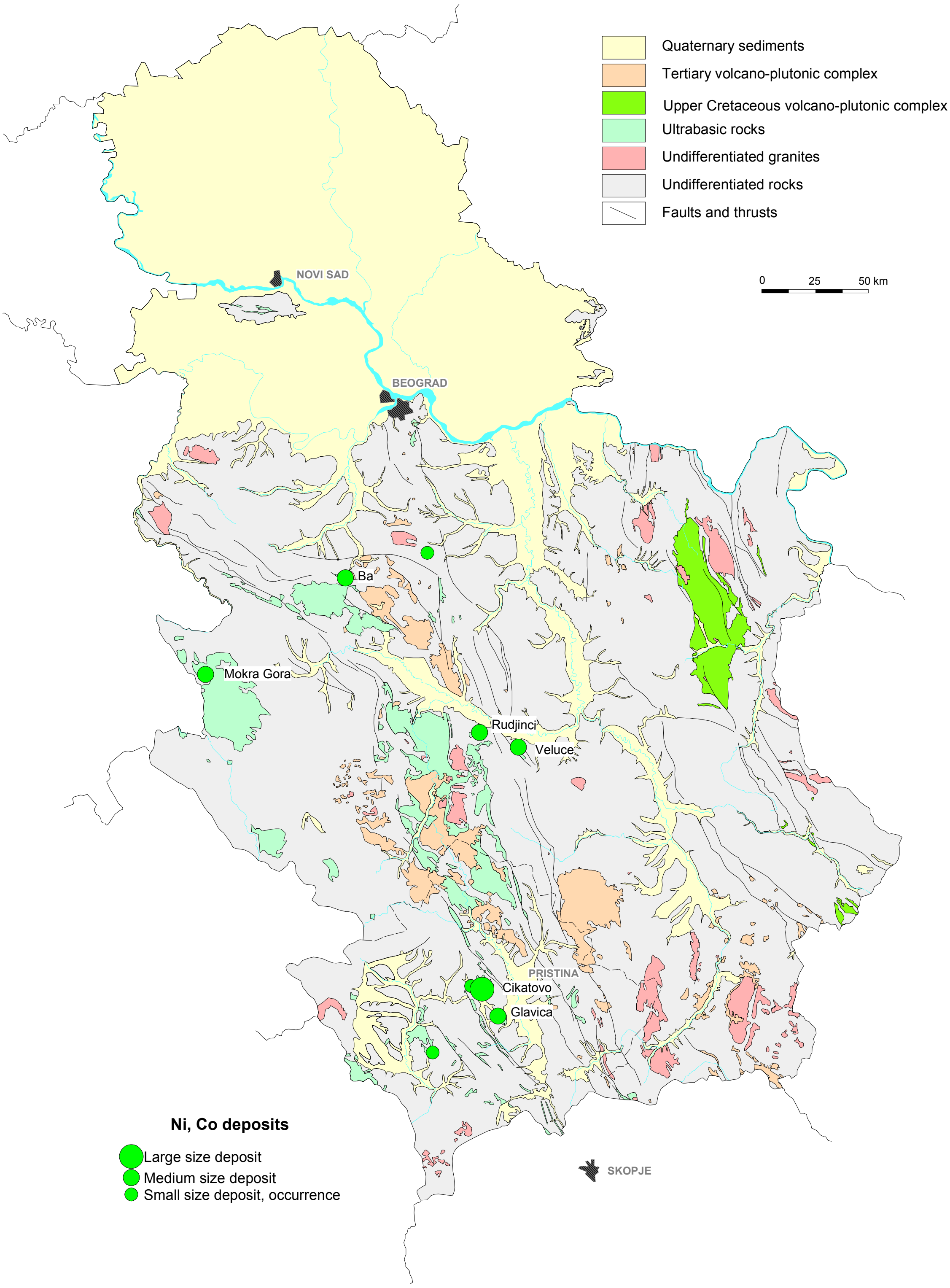

Fig. 16 - Ni-Co deposits in Serbia.

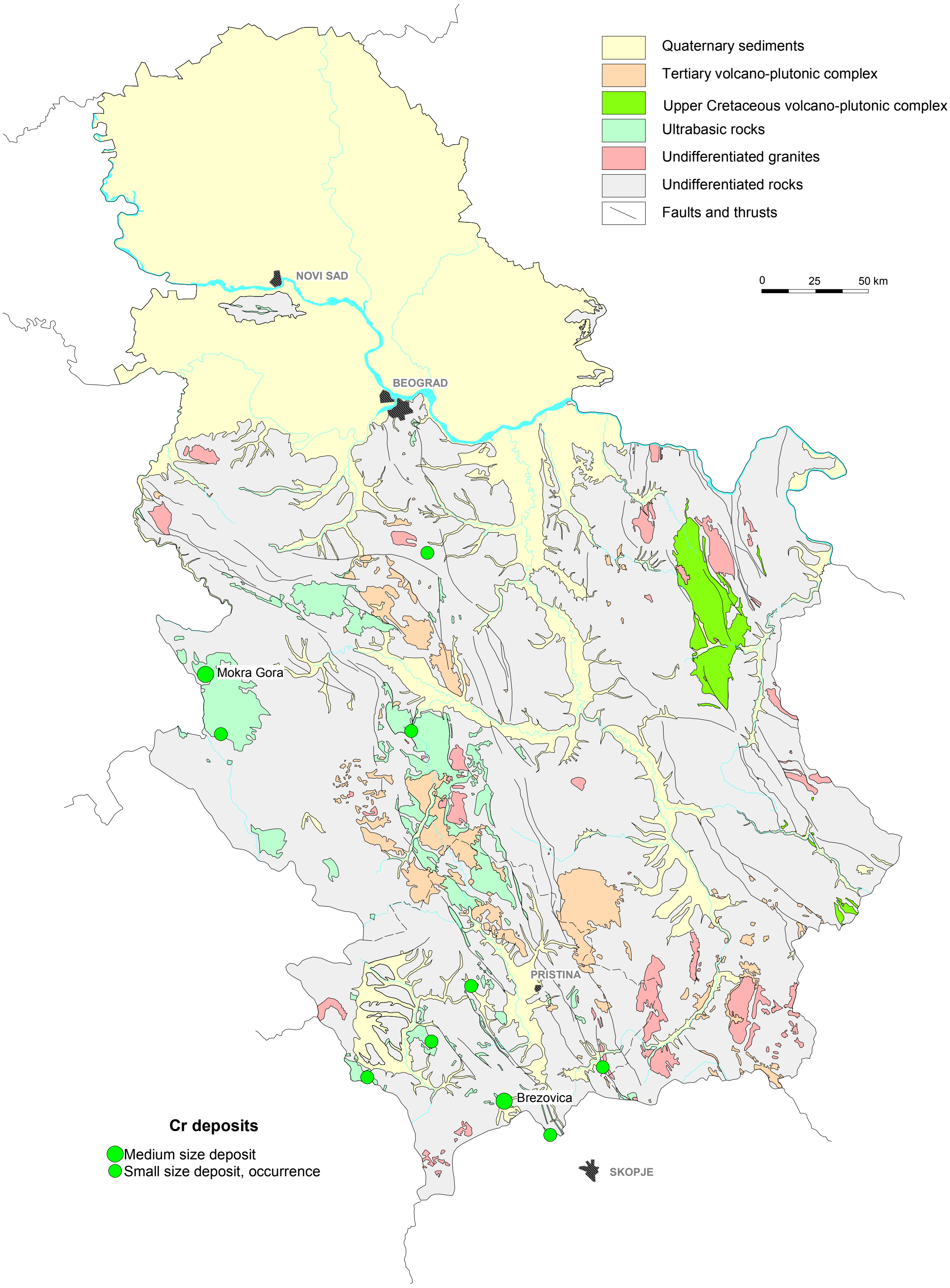

Fig. 17 – Cr deposits in Serbia.

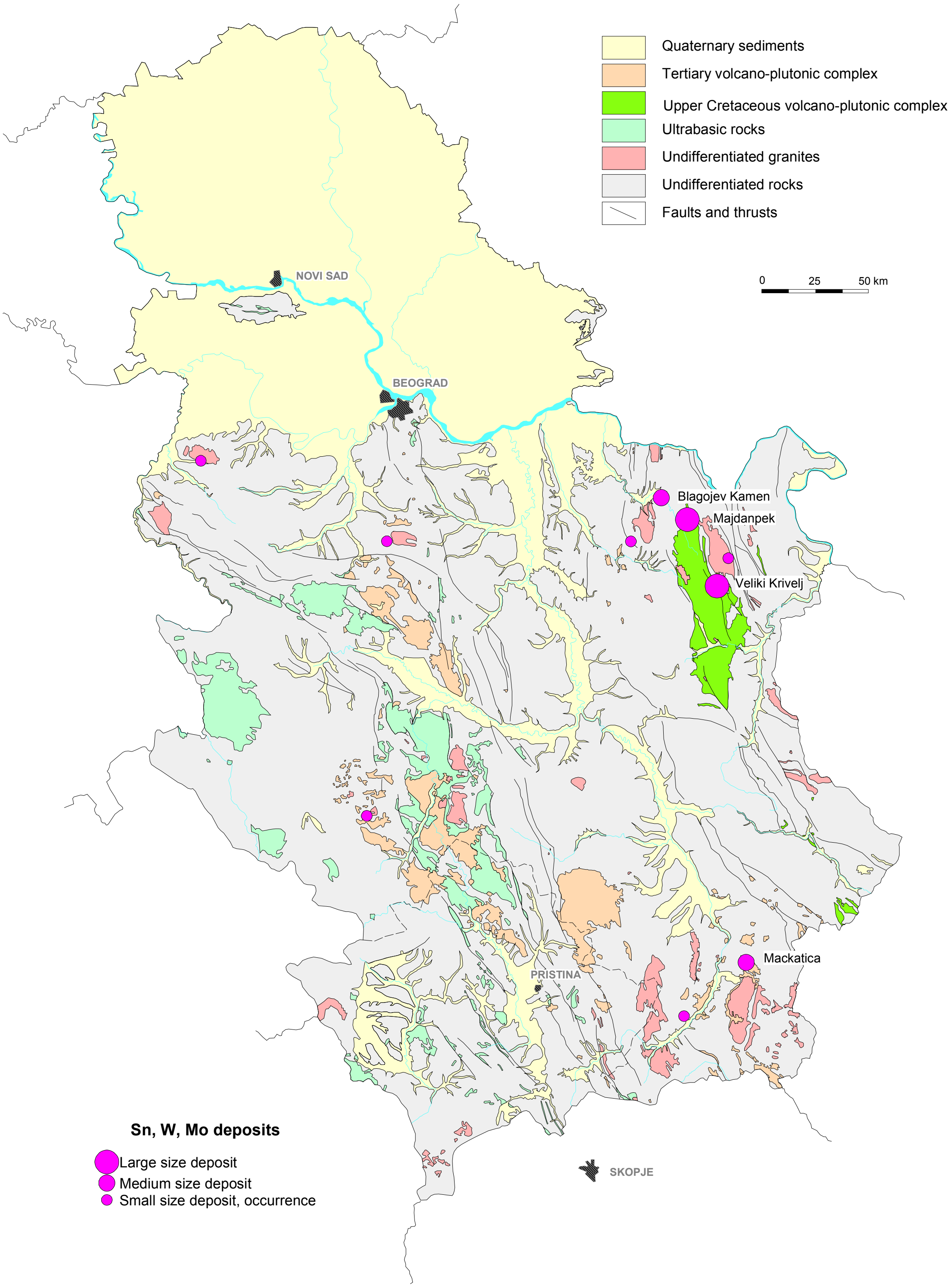

Fig. 18 - Sn-W-Mo deposits in Serbia.

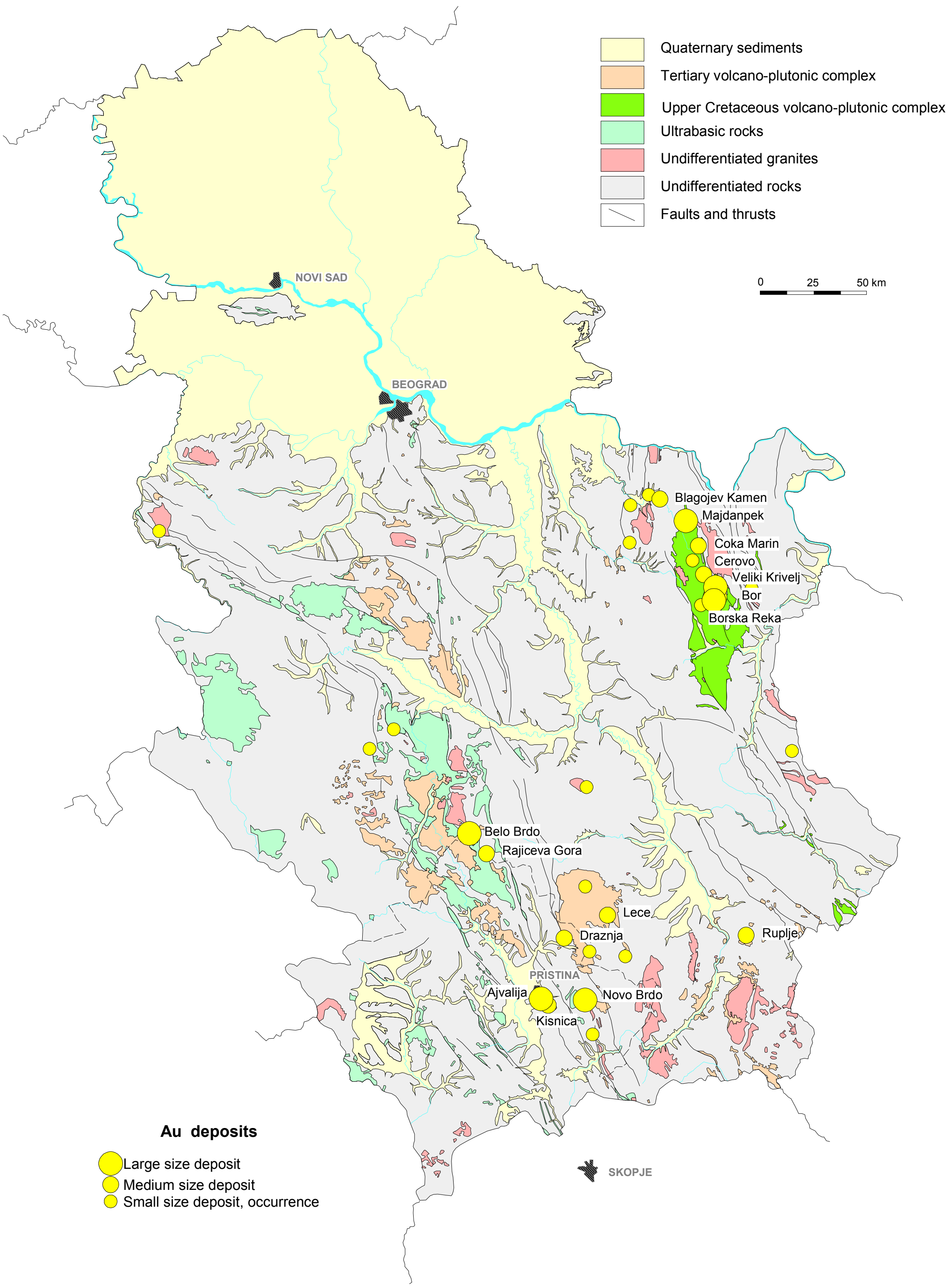

Fig. 19 - Au deposits in Serbia.

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 19g/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.

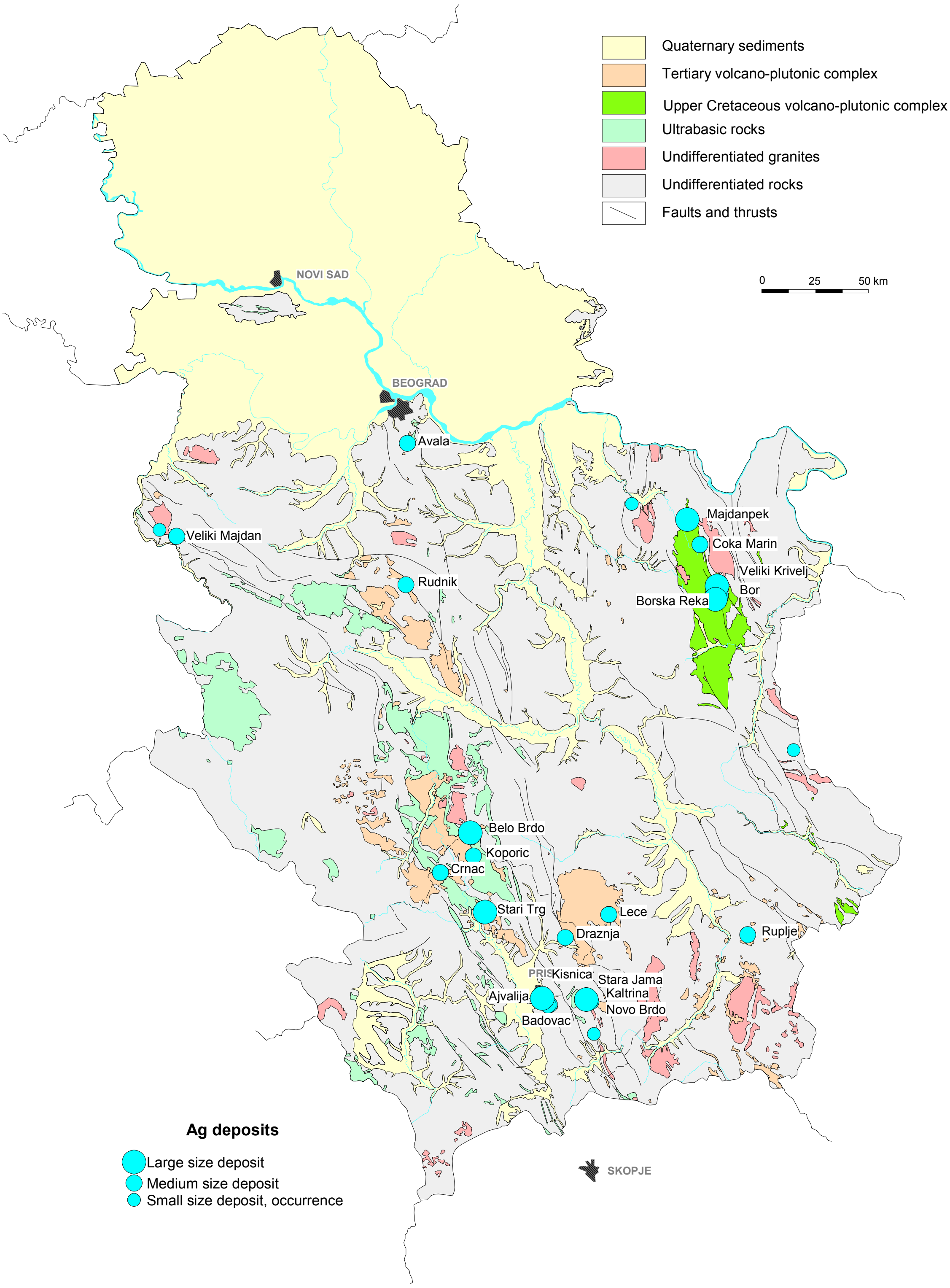

Fig. 20 - Ag deposits in Serbia.

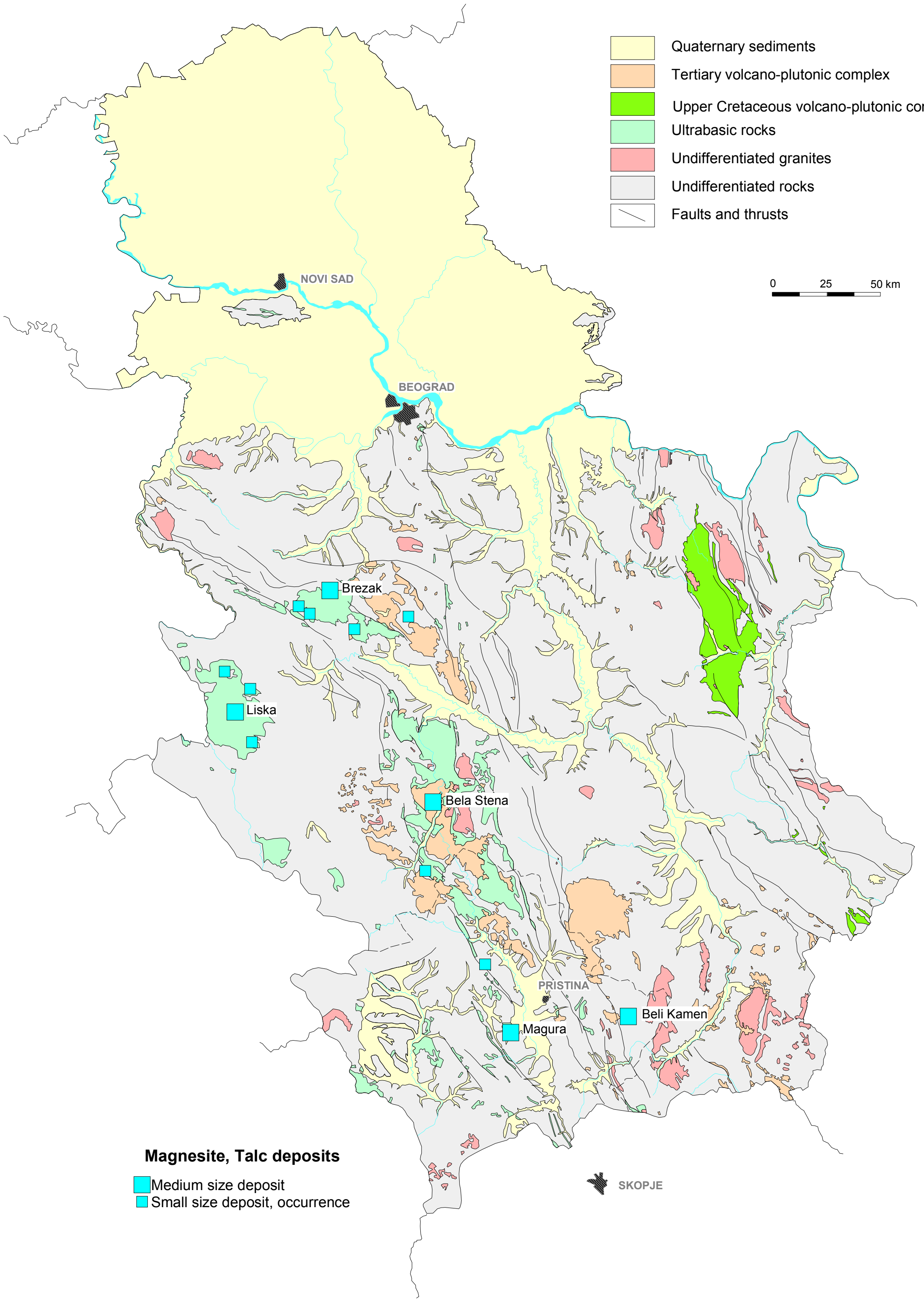

Fig. 21 - Magnesite and talc deposits in Serbia.

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 serpentinite, are fracture fills deposited by CO_2-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 ($Mg_3Ca(CO_3)_4$), colemanite and howlite ($2SiO_2.4CaO.5B_2O_3.5H_2O$), 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% B_2O_3).

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.

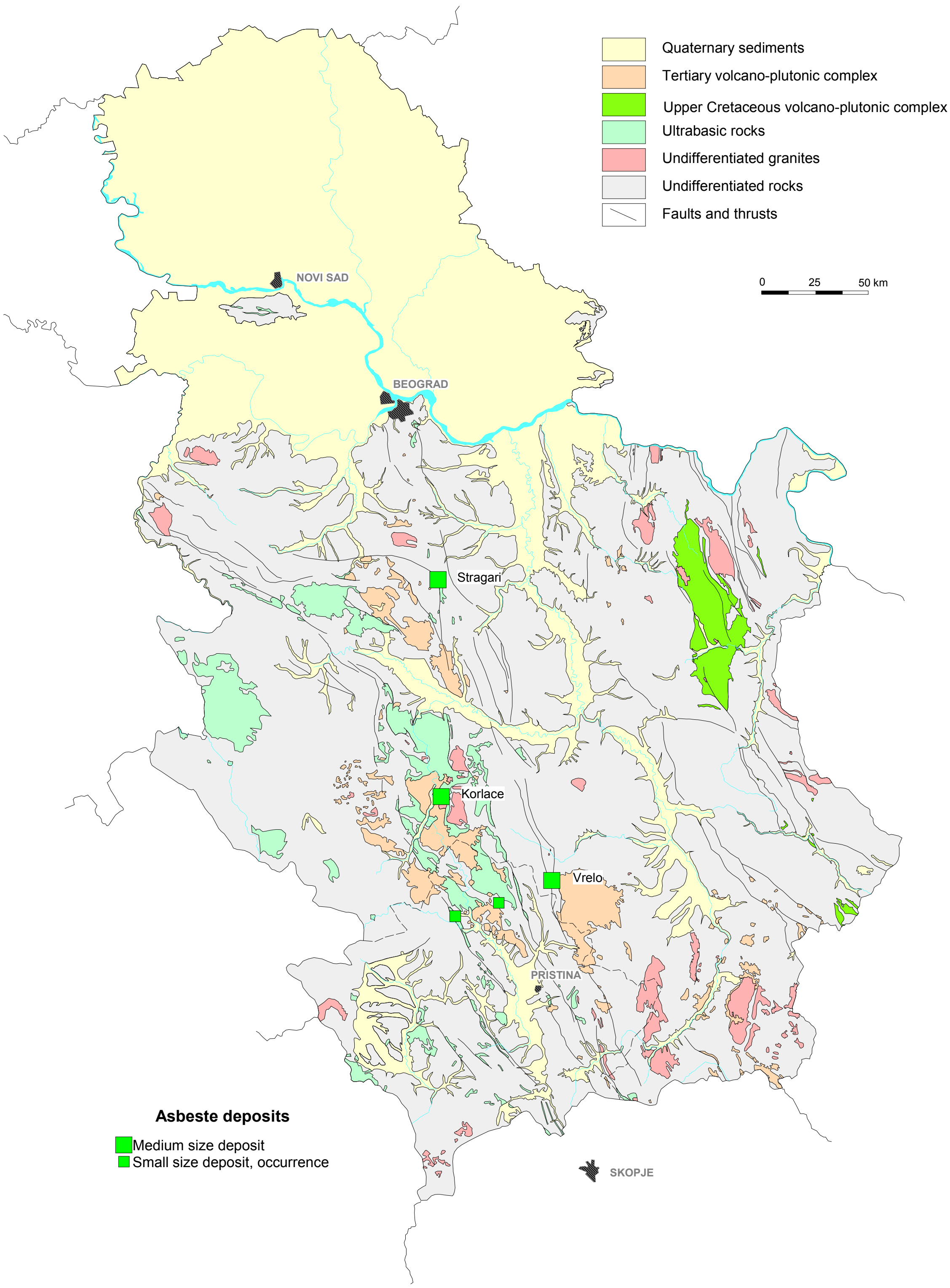

Fig. 22 - Asbestos and Basalt fibres deposits in Serbia.

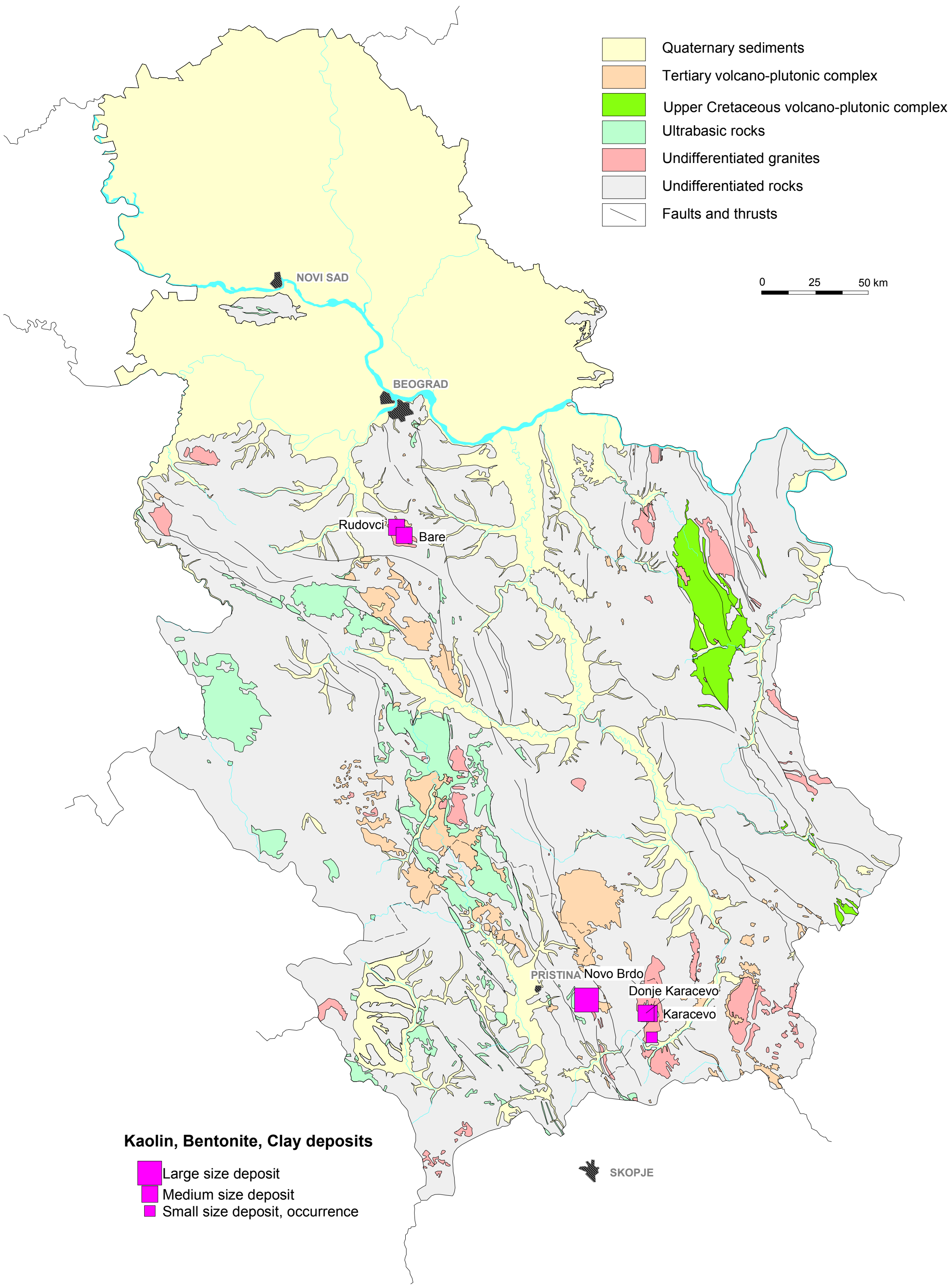

Fig. 23 - Kaolin and clay deposits in Serbia.

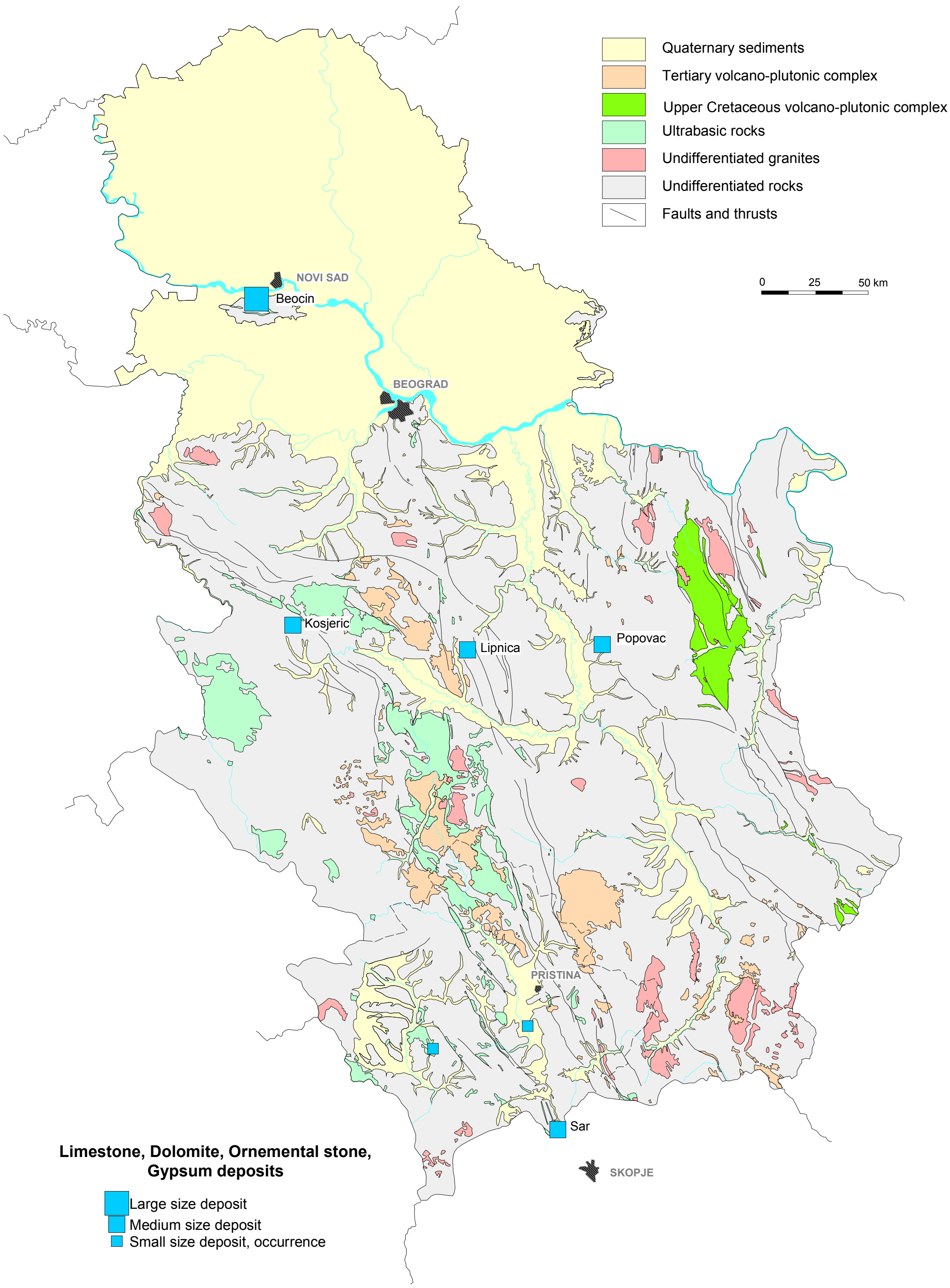

Fig. 24 – Cement raw materials deposits in Serbia.

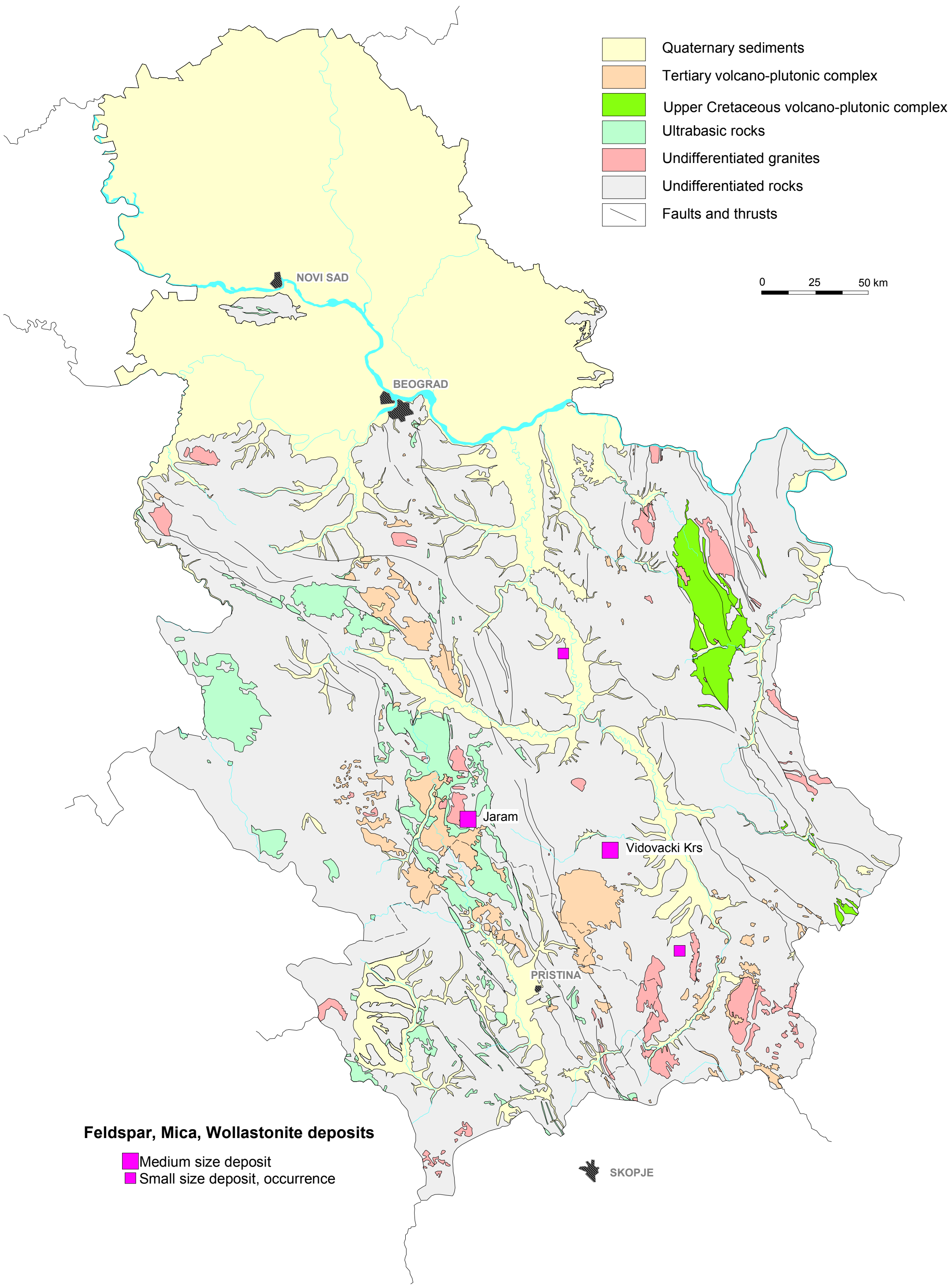

Fig. 25 - Feldspar, mica and wollastonite deposits in Serbia.

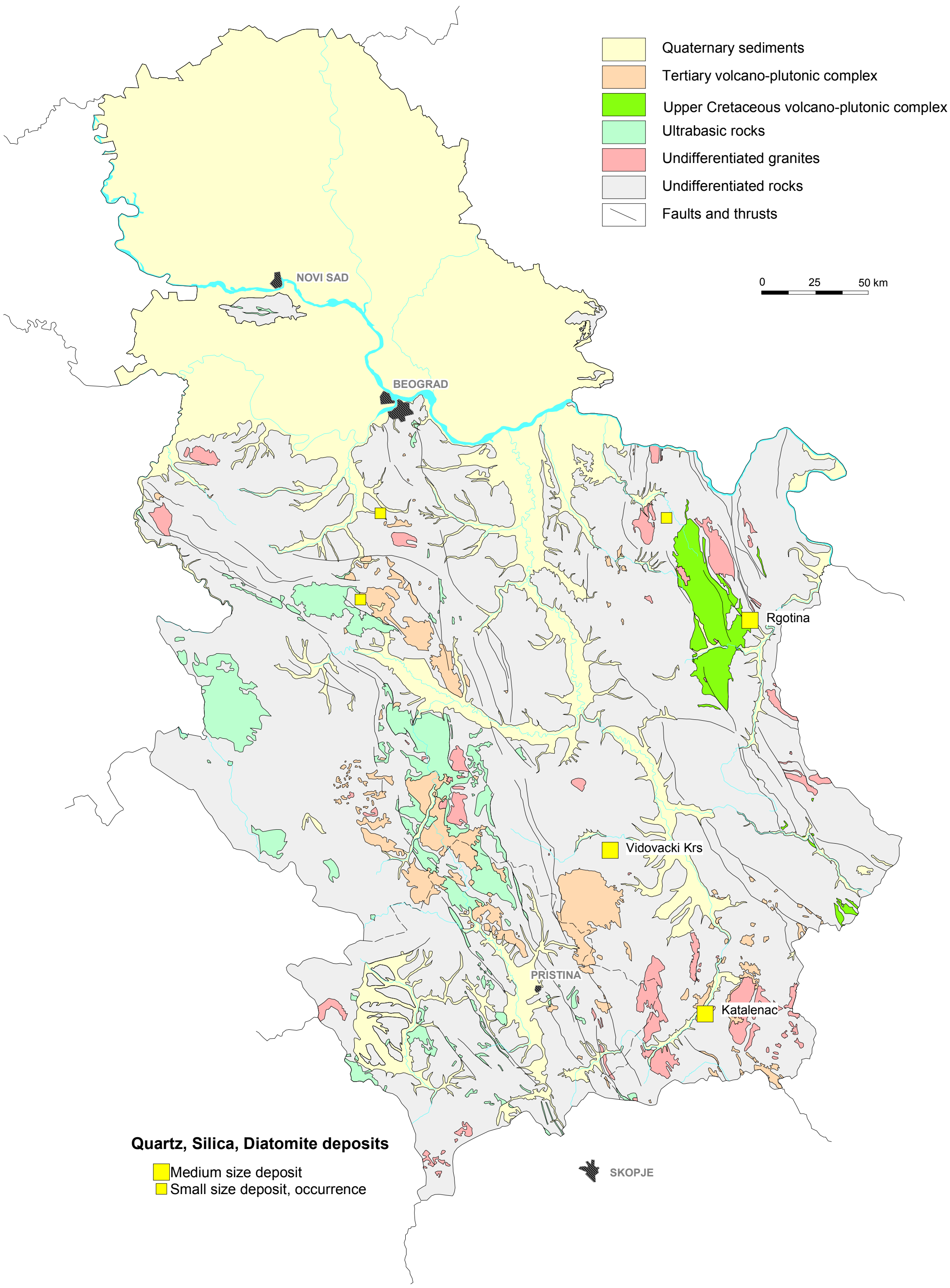

Fig. 26 - Quartz and silica deposits in Serbia.

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.

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