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Mineral resources of Serbia

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Abstract: The mineral resources of Serbia were formed by complex processes of metallogenic development and in various geological epochs (Pre-Baikalian to Alpine). Their overview in this paper is supported by the simplified Metallogenic map of Serbia showing virtually selected mineral deposits, as well as by maps of the most important fossil fuel resources. The most important group of metallic mineral resources of Serbia includes Cu, Pb-Zn, Au, Ag, Sn, Mn, U, Mo, Ti, W, Co, Sb and Fe ores. The important group of industrial mineral resources include: bentonite, boron minerals, refractory clay, gypsum and anhydrite, diatomite, dolomite, zeolite, kaoline, quartz sand, cement marl, ceramic clay, limestone, magnesite, phosphates, chrysotile-asbestos, building industry granulates (natural and crushed) and decorative stone. Serbia also has significant resources of fossil fuels, particularly coal and oil shale. The soft brown coal (lignite) is of great economic importance since it represents the main source for the production of electric energy. The remaining petroleum potential of the Pannonian Basin in Serbia indicates that modern exploration may result in the discovery of significant additional reserves of oil and gas. Production of shale-oil also has great potential, but it depends on future detailed valorization of various factors.

Key words: Serbia, potential, reserves, ore, industrial minerals, oil, gas.

Introduction

The geological setting of Serbia is very complex. It is characterized by a large number of rock formations of varied lithological composition, petrochemical features, age and metallogenic specialization.

The mineral resources of Serbia and the metallogenic or tectonic units within which they are located are constituent parts of regional metallogenic and geotectonic units larger than its territory. Accordingly, the position, time and conditions of the formation of the mineral resources of Serbia depended to a large extent on the geotectonic evolution of that broad territory and the accompanying volcanic, sedimentary and metamorphic processes. The importance of the mineral deposits in the above mentioned metallogenic and geotectonic units varies depending on their territorial distribution, their type and environment, the extent of their occurrences, the association of the ore and accompanying elements, and the chronological span of their formation.

The largest geotectonic units in the territory of Serbia are: the Dinarides, the Vardar Zone, the Serbo-Macedonian Massif, the Carpatho-Balkanides and the Pannonian Basin (Dimitrijević 1982, 1997). From the metallogenic point of view, they are all incorporated into the Tethyan-Eurasian Metallogenic Belt (TEMB), or, in the broader scale into the so-called North-Eastern Mediterranean Sector (Janković 1967, 1974, 1990, 1997). A more detailed territorial grouping of these units is based on an analysis of the relationship between the mineral deposits and the geological environment with which they are genetically and territorially associated (Janković 1990; Janković et al. 2003).

The geology of Serbia

The territory of Serbia covers various geological units of composite structure and complex tectonic interrelations. The ideas about its geological subdivision have changed, mostly in relation to prevailing geotectonic concepts — from Kober's orogene (1952) and Stillean magmatic and orogenic phases to several new models of plate tectonic ideas in the early eighties (Aleksić et al. 1971; Dimitrijević & Dimitrijević 1973; Dimitrijević 1974a,b; Grubić 1974; Dimitrijević & Grubić 1977; Dimitrijević & Djoković 1979). Most recently a subdivision of the Serbian territory has been proposed by Karamata et al. (1992, 1997), Karamata & Krstić (1996), based on the terrane-concept.

According to Dimitrijević (1997), the territory of Serbia is subdivided into: the Dinarides, the Vardar Zone, the Serbo-Macedonian Massif, the Carpatho-Balkanides and Neogene sediments which cover the products of the older tectonic events (Fig. 1).

Dinarides — Four main geotectonic units can be distinguished in the Serbian part of Dinarides: The East Bosnian-Durmitor Block, Drina-Ivanjica Element, Studenica Slice and Ophiolite Belt.

The East Bosnian-Durmitor Block lies in the extreme southwestern part of Serbia. It covers a very small portion of Serbia, and extends into Montenegro and Bosnia. It is characterized by a complex nappe structure. The Lower Triassic sediments (mostly sandstones), Anisian dolomites, bioclastic limestone, red Bulog Limestone and volcanics prevail in this unit. The Ladinian mostly begins with chert and tuffs, followed by relatively thin cherty limestone, dolomite and reef

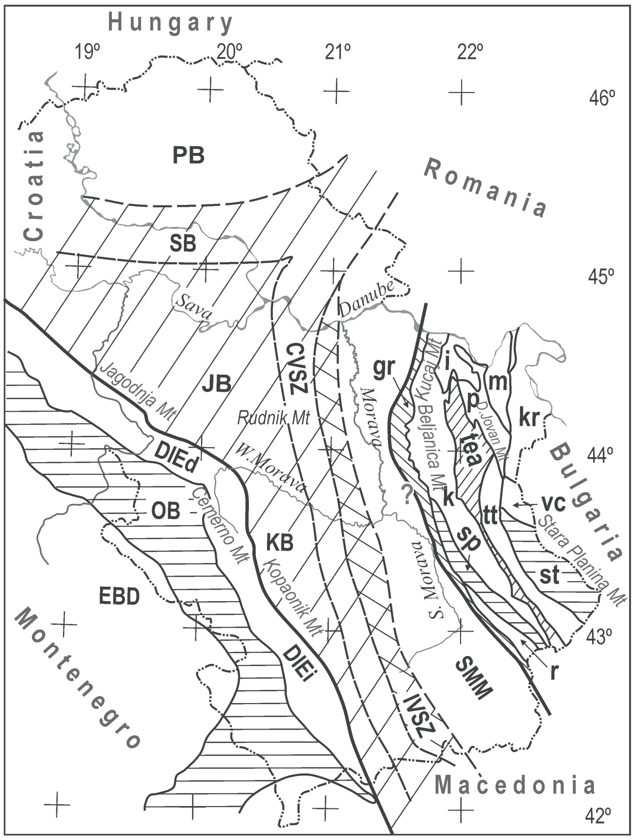

Fig. 1. The main geotectonic units of Serbia (Dimitrijević 1997; modified). *Dinarides*: **EBD** — East Bosnian-Durmitor, **OB** — Ophiolite Belt, **DIE** — Drina Ivanjica Element (d — Drina block, i — Ivanjica block). *Vardar zone:* External Vardar Subzone: **SB** — Srem block, **JB** — Jadar block, **KB** — Kopaonik block; **CVSZ** — Central Vardar Subzone; **IVSZ** — Internal Vardar Subzone; **SMM** — Serbo-Macedonian massif. *Carpatho-Balkanides:* **gr** — Gornjak-Ravanica Zone, **r** — Ruj Zone, **sp** — Stara Planina Zone, **k** — Kučaj Zone, **i** — Liškova (Homolje) metamorphites, **tea** — Timok eruptive area, **tt** — Tupižnica-Tepoš Zone, **p** — Poreč Unit, **m** — Miroč Zone, **st** — Suva Planina, **kr** — Krajina Unit. **PB** — *Pannonian Basin.*

limestone. In the Upper Triassic, a platform with a thick carbonate succession is characteristic for the SW area. The Jurassic is carbonate dominated; Ophiolitic mélange occurs under rather curious conditions. The Cretaceous is mostly absent.

The Drina-Ivanjica Element consists of two intensely tectonized Paleozoic blocks: the Drina block in the northwest and Ivanjica block in the South, overlain by Triassic rocks on the southwestern and eastern margins (Triassic platform). In the western and northwestern parts of the belt some shallow marine Upper Cretaceous sediments occur. The eastern boundary of the element is fringed by products of trough flysch, most probably deposited in the back-arc basin of the boundary toward the Vardar Ocean. Extensive volcanic activity took place in both Drina and Ivanjica blocks during the Miocene, with shallow granodiorite intrusions of Golija.

The Studenica Slice runs from the West Morava over the Čemerno Mountain. Its eastern boundary is mostly covered with allochthonous ultramafics; the western boundary is marked by Senonian ophiolite mélange in contact with Senonian flysh of the Dinarides. The Studenica slice extends to the south across Čemerno, with characteristic metamorphic rocks. They are progressively metamorphosed by Čemerno granitoids, which occur as a swarm of hectometric masses, representing apical parts of conformable granitic intrusions.

The Ophiolite Belt occurs in the Inner Dinarides (Dinarides–Albanides and the Othris Zone in Greece). As the scar of a Middle Triassic to uppermost Jurassic oceanic tract, it has a base of somewhat deeper-water Mesozoic limestones, overlain mostly by oceanic siliceous shales and chert of the continental slope, followed by the Ophiolitic Mélange. Large obducted ultramafic masses, with hot lower contacts and fragments of the whole oceanic crust are characteristic.

The Vardar Zone — This zone is situated between the Serbo-Macedonian Massif (SMM) on the East and the Dinarides on the West. Its eastern boundary is marked by longitudinal reverse dislocations along which the SMM is superposed over the Vardar Zone. Along its western zone with the Dinarides, the boundary of the Vardar Zone is not distinctly outlined like along the SMM. The Vardar Zone is thrust over the Pelagonian Massif/the Dinarides, but to the north the terranes of the Vardar Zone are obducted in the form of the Kopaonik overthrust to the WSW onto the Golija Zone (Resimić et al. 2000).

The geological column of the Vardar Zone consists of small blocks of crystalline schists, Carboniferous Veles Beds, Jurassic ultramafics, hemipelagic and eupelagic Triassic sediments, diabase-chert formations, Jurassic granitoids, Lower and Upper Cretaceous flysch and Tertiary calc-alkaline volcano-intrusive complexes. Signs of three main phases of plication are recognized in the Vardar Zone: Upper Carboniferous, Cimmerian and post-Senonian (Grubić 1980).

According to Dimitrijević (1997), the Vardar Zone is composed of several blocks differing in composition, geological history and origin. In the W-E direction, it can be divided into the External Subzone (Srem, Jadar and Kopaonik blocks), Central Subzone and (conditionally) Internal Subzone.

The Serbo-Macedonian Massif (SMM) — This geotectonic unit consists of two complexes of crystalline schists — the lower and the upper one. The lower complex is composed of rocks pertaining to the amphibolite facies group (mica gneiss, micaceous schists, quartzites, some marble and migmatite), with migmatization and Paleozoic granitoids; it is covered in places by shallow-marine Cretaceous and the Eocene clastics of the Pčinja Group. The complex is ~11 km deep. The upper complex of the SMM (~5 km deep) bears Riphean-Cambrian greenschists, covered by weakly metamorphosed Ordovician to Carboniferous strata. It is intruded by granitoids of Paleozoic (Vlajna) to Tertiary age (Surdulica) (Dimitrijević 1997).

The SMM has a tectonic relation to the Vardar Zone and the Carpatho-Balkanides. Crystalline areas of the SMM are thrust over adjacent tectonic units. They were moved particularly strongly to the west, affecting the western periphery of the SMM that was heavily reworked tectonically and adjusted to the structural features of the Vardar Zone (Grubić 1980).

The Carpatho-Balkanides — Four main groups of geotectonic units can be isolated in the Serbian part of Carpatho-Balkanides: Suprageticum, Geticum, Upper Danubicum (Infrageticum) and Lower Danubicum (Dimitrijević 1997).

The Suprageticum consists of the Gornjak-Ravanica Zone (Silurian and Devonian sediments, Permian red sandstone and Mesozoic with numerous breaks in sedimentation).

The Geticum is made up of the Ruj Zone (Upper Jurassic Flysch), Suva Planina Zone (Devonian–Lower Carboniferous Flysch, Permian sandstone, thick Jurassic and Cretaceous carbonates), Kučaj Zone (clastics from Cambrian to Devonian, flysch, Permian and Triassic clastics, Jurassic-Lower Cretaceous carbonates, thin Upper Cretaceous), Timok Eruptive Area, and the Tupižnica–Tepoš Unit (Mesozoic carbonates with numerous breaks).

The Upper Danubicum is composed of the Poreč Zone (highly complex relations of Cambrian to Aptian rocks; Deli Jovan Gabbro), Miroč Zone (in part the whole Paleozoic; Jurassic and Cretaceous varying in thickness, with breaks); Krajina Zone (Sinaia Beds, Mokranje Flysch) and the Stara Planina (semimetamorphic Paleozoic, Permian red sandstone, Mesozoic up to the Cretaceous; Zaglavak Gabbro; granitoids of various ages).

The Lower Danubicum represents the Vrška Čuka Zone (Cambrian? greenschists, very thin Carboniferous and Permian, thin Jurassic and Cretaceous).

The Pannonian Basin — The Pannonian Basin covers the northern part of Serbia. It is filled with lacustrine and marine Tertiary and continental Quaternary sediments. In the southeastern and northern Banat and northern Bačka (part of Tisia) crystalline schists and granitoids build up to basement of the Pannonian Basin. Mesozoic sediments prevail in the greater part of the middle and southern Banat, with the Torda Flysch, and ophiolites along the subzone and block boundaries of the Vardar Zone.

The origin and evolution of mineralization

All mineral deposits and occurrences in Serbia are concentrated into four regional metallogenic units that spatially extend beyond the territorial boundaries of the country: 1 — the Dinaric metallogenic province (DMP) covering western Serbia, 2 — the Carpatho-Balkanian metallogenic province (CBMP) in the north-eastern part of the Serbia, 3 — the Serbo-Macedonian metallogenic province (SMMP) in the central part of the Serbia, covering the terrains of the Vardar Zone, the Serbo-Macedonian Massif and eastern part of Dinarides and 4 — the Dacian metallogenic province (DcMP) that include an extremely small area in the far north-eastern part of Serbia: only small deposits of kaolin in Miocene sediments are known in DcMP (Janković 1977, 1982). The Dinaric, Serbo-Macedonian and Carpatho-Balkanian metallogenic provinces can be subdivided into several metallogenic zones, ore districts and ore fields, some of which have specific features associated with the origin of the ore deposits.

A simplified metallogenic map of Serbia showing the position of the main metallogenic units, mineral deposits and some important metallic and industrial mineral occurrences is presented in Fig. 2.

According to the contemporary knowledge of plate tectonics and of the geotectonic and metallogenic development of the terrain in Serbia, its mineral resources can be classified as: **1** — Deposits related to intracontinental rifting; **2** — Deposits related to ophiolite complexes; **3** — Deposits of subduction related setting and **4** — Deposits of continent-continent collision-related setting (Janković 1990). Apart from magmatogenic ore deposits, some other mineral deposits (magnesite, clays, etc.) hosted by Neogene basins had been identified in the collision-related environments in Serbia.

Deposits related to intracontinental rifting. The processes of rifting, both of the initial and advanced stages, lasted from Early to Late Triassic (Knežević et al. 1997: "*aborted rifts*") have been suggested, but in some sectors of Serbia (Dinarides, Vardar Zone) continued lateral spread of the sea-floor led to the opening of the ocean (Late Triassic–Late Jurassic). Tectonic setting is characterized by elongated and mostly subparallel horst-graben structures (Janković 1987; Janković et al. 1997).

Two principal groups of magmatic rocks, both intrusive and volcanic, are distinguished in relation to intracontinental rifting and opening and oceanic spreading: 1 — quartz-keratophyres, porphyrites and albite-granites (processes of intracontinental rifting) and 2 — diabases and basalts (spilites) — processes of opening and oceanic spreading (Knežević et al. 1997).

The predominant types of ore mineralization in relation to intracontinental rifting are lead-zinc and subordinate copper. From the genetic point of view, they are classified as follows: 1 — hydrothermal volcano-sedimentary, hydrothermal stockwork and vein types (Čadinje and Bobija deposits — hydrothermes related to subcrustal magmas strongly contaminated by crustal material+warmed descending water. Ore elements are mostly leached from the host rocks); 2 — hydrothermal massive sulphide ores and hydrothermal veins in relation to ophiolite mélange (diabase-chert formation — Putnik 1981; Karamata 1986) of Western Serbia (Lajkovača deposit — descending marine water warmed and included into conventional systems. Ore elements are mostly leached from the host rocks).

In relation to processes of intracontinental rifting and opening and oceanic spreading, several other groups of mineral deposits in addition to lead-zinc and copper, are present: *a* — high temperature hydrothermal Fe-veins and lenses; *b* — Fe-Mn oxides and carbonates accompanied by minor Pb-Zn and Fe sulphides; *c* — barite deposits, *d* — mercury deposits and *e* — mineral deposits associated with weathering crust (bauxite deposits developed on the karstified limestone).

Ore deposits related to ophiolite complexes. When the lateral spreading of continental crust continues from the stage of intracontinental rifting, new oceanic crust begins to form. The floor of the ocean has many tectonic elements (the active spreading axes, hot-spot etc.) that are considered to be significant metallotects of ore deposits Jurassic in age (Janković et al. 1997).

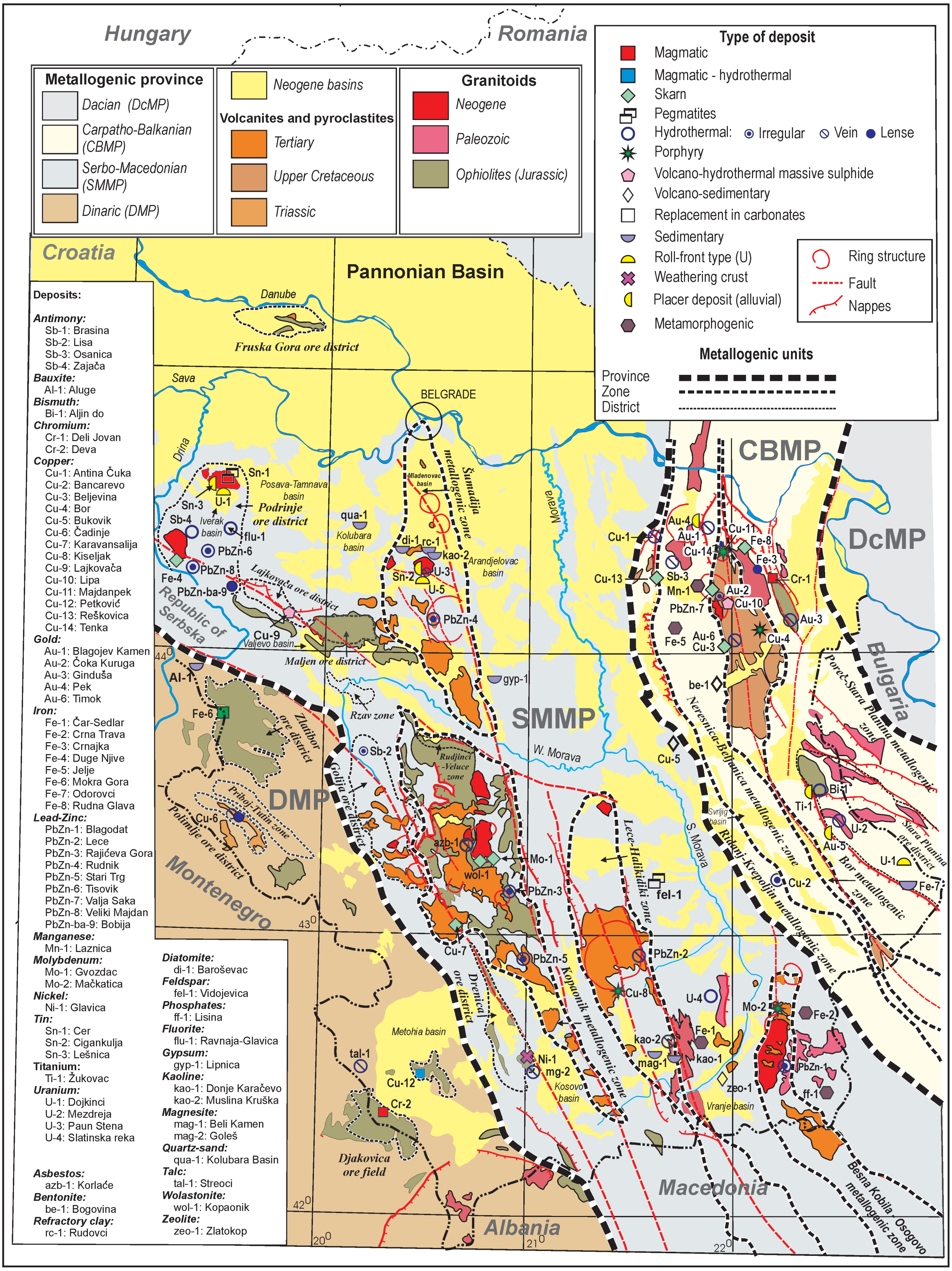

Fig. 2. The main metallogenic units, mineral deposits and some important metallic and industrial mineral occurrences in Serbia. **CPMB** — Carpatho-Balkanian metallogenic province; **DcMP** — Dacian metallogenic province; **SMMP** — Serbo-Macedonian metallogenic province; **DMP** — Dinaric metallogenic province.

The ophiolites form two distinct belts: the Western Belt located in the Inner Dinarides (Dimitrijević 1997), and the Eastern Belt, extends from the Vardar Zone to Asia. The metallogeny of these ophiolitic complexes is closely associated with their petrochemical features and geotectonic settings. The ophiolites of the Western Belt are similar to the present ocean floors. They are characterized by the dominance of lherzolite peridotite, gabbro-pyroxenite and orthopyroxenite (Karamata et al. 1980). Endogenous ore deposits related to these ophiolitic complexes are mostly the Ni-Co-Cu-Fe sulphides, pyritic cupriferous deposits, sporadically magnetite deposits and minor gold mineralization, but without major chromite deposits. The ophiolites of the Eastern Belt consist mainly of Mg-rich peridotite and dunite. Their metallogeny is characterized by major chromite and significant pyritic cupriferous deposits, as well as the major magnezite and chrysotile asbestos deposits, locally nickel silicate and nickeliferous iron deposits.

Deposits from subduction–related settings (subduction beneath the active continental margin; Cretaceous). Many deposits in the eastern Serbian part of the Carpatho-Balkanian metallogenic province are associated with horst-graben structures formed above subducted oceanic lithosphere under the Eurasian plate, following the closure of a Tethyan branch during the Early Cretaceous (Janković 1990).

The most important deposits (Cu, Au, and rare Pb-Zn) related to subduction-related settings are of the porphyry copper, skarn type and volcano-hydrothermal (massive-sulphide): Bor deposit, Majdanpek deposit, Veliki Krivelj deposit (Bor metallogenic zone) and Ridanj-Krepoljin Zone (Reškovica, Antina Čuka etc). The ore elements are mostly leached from the host rock (andesites and analogue plutonites; magmatic arc above the subduction zone or of the rifts over the subduction zone) in the convectional systems by fluids derived from the subducted oceanic plate and partly dehydrated continental crust mixed with descending solution (Knežević et al. 1997).

Deposits from continent-continent collision-related settings (period of closing and intracontinental compression and postcollisional period; Oligocene–Miocene). The closure of a branch of the Tethys Ocean along the Vardar-Izmir-Central Anatolia Zone, starting in the Oligocene, was followed by the collision between Africa and Europe, resulting in magmato-tectonic activity.

Ore deposits formed along the active continental margin are related to intermediate magmatic rocks: dacites, quartz latites, andesites and analogue plutonites of volcano-intrusive complexes. Magmas are derived from the lowest levels of up-domed continental crust, but during upward movement, they can be contaminated by some elements from gabbro-peridotite complexes (Cu, Au), or some lithophile elements from the continental crust (Sn, W, Nb, Ta). In comparison with the volcanic rocks developed in the subduction-related setting of the eastern Serbian part of the Carpatho-Balkanides, the Tertiary volcanic rocks in this tectonic setting are characterized by an increased content of lead and zinc, and by a diminished content of copper.

The principal ore deposits in Serbia associated with this geotectonic condition (in the territory of the Vardar Zone and the Serbo-Macedonian Massif) occur as skarn-type to hydrothermal deposits related to volcano-intrusive complexes — hydrothermal metasomatic and veins, locally porphyry-Cu and stockwork-disseminated Mo-types. The dominant metals in these deposits are Pb-Zn, Sb, Bi, Ag, As. Copper and gold occur only occasionally.

Ore elements were leached from host rocks by fluids from the subcrustal magmas of I-type, strongly contaminated by the crustal material and mixed with the heated descending solutions.

Apart from magmatogenic ore deposits, some other mineral deposits have been identified in the collision-related environment in Serbia (Janković et al. 2003). They are hosted by the Miocene basins (magnesite, occurrences of boron, salt, various types of clay, etc.).

The fossil fuels deposits are associated with the regions in which there existed favourable conditions for the accumulation and preservation of organic matter, particularly during the Tertiary. The most important of these are the Pannonian Basin and the smaller Tertiary basins of Serbia, in which petroleum source rocks, oil shale and coal, were deposited during the Miocene.

Mineral deposits

There are more then 2500 metallic and industrial mineral deposits and mineral occurrences in the territory of Serbia (Janković et al. 2003). Brief metallogenic features of the selected deposits are presented in Table 1.

The present state and potential of the mineral resources of Serbia

Many deposits of metallic and industrial mineral resources of Serbia were still exploited until as late as the end of the twentieth century. Today, however, the mining production, particularly that of the metallic ores, has been either abandoned (Fe, Cr, Mn, W, Sb, Ni and others) or greatly reduced (Pb-Zn, Cu, Au, Ag). This is a consequence of the intensive exploitation of the better-quality ore reserves in order to reduce the production costs, of the exhaustion of economic reserves of Cr, Mn, W and other ores, as well as of the considerable reduction of geological exploration. The base metals (Cu, Pb-Zn), partly Al, Ni and some others, have been more thoroughly explored and their total resources have been augmented, so that they still represent, in spite of numerous problems attending their exploitation, developmental potential for Serbia. Many of the industrial mineral resources have shared the fate of the metallic ores, but their ore reserves have been considerably increased and they have gained in importance.

The production of fossil fuels — coal and, particularly oil and gas, has been declining for the past 15–20 years, while the valorization of oil shales as a non-conventional source of oil requires a detailed analysis of the technological, economic and ecological factors involved.

Bearing in mind the above facts, the economically most important mineral deposits of Serbia may be grouped as follows:

Table 1: Brief metallogenic features of the selected metallic and industrial mineral deposits of Serbia. *Continued on next page.*

Geotectonic unit [1]	Metallogenic unit [2]	Metallogenic epoch [3]	Commodity	Type of deposit [4]	Principal minerals	Host rocks	Characteristic deposit	Tonnage / Grade [5]
METALLIC MINERAL RESOURCES								
DINARIC METALLOGENIC PROVINCE								
EBD	Plod	C	Pb-Zn, Cu, Zn	h (l, v, s)	ga, sp, chpy	quartz keratophyres, porphyrites, limestones	Čadinje	1.3 Mt / 1.6% Cu, 0.8% Pb, 4.5% Zn, 33 g/t Ag
OB	Zod	C	Al	kar (l, n)	bx (be, ka, hm)	limestones	Aluge, Poćuta	1.2 Mt / 45% Al_2O_3
OB	Oof	C	Cu-Ni-Co-Fe	m-h (i, d)	pr, pn, chpy	gabbro-peridotites	Petković	n.d. / 2.73% Cu, 0.18% Ni
OB	MGb	A	Fe	sed (b)	hm, mg, li	sandstones, conglomerates, limestones	Mokra Gora	90 Mt / 21% Fe, 0.7% Ni
SERBO-MACEDONIAN METALLOGENIC PROVINCE								
JB	Pod	C	Pb (Zn)	h (l, v, c)	ci	limestones	Tisovik	0.02 Mt / 1.7% Pb
JB	Pod		Zn-Pb, Ba	v-s (b)	sp, ga, ba, py	porphyrites, limestones	Bobija	0.02 Mt / 4% Pb, 6% Zn
JB	Pod	A	Sb	h (n, l, v)	st	limestones, andesites	Brasina	n.d. / 2% Sb
			Pb-Zn	h / (n, l, c)	ga, sp, py, pr, apy	quartzlatites, limestones, schists	Veliki Majdan	0.2 Mt / 6% Pb, 5% Zn
OB	Dod		Ni	w-cr (b)	go, no, pm	peridotites, serpentinites	Glavica	3.7 Mt / 1.47% Ni
DIEi	Lod	C	Cu (Zn)	vms (l, i, s-i)	chy, py	Diabase-Chert Formation	Lajkovača	1 Mt / 1% Cu, 0.1 g/t Au
OB	DMP		Cr	pd (l, n, i)	ch	gabbro-peridotites	Deva	0.08 Mt / 15% Cr
SMMUs	MZ	H	Cu, FeS_2 ± Au	v-s (b, d, vl)	chpy, py, bo, te, mg	albite-muscovite-biotite schists	Bukovik	n.d. / 0.3-4% Cu
	SMMP		Fe	met prim. v-s (d, l)	mg, hm	greenschists, micaschists	Crna Trava	n.d. / 56% Fe
SMMLs	SMMP	H	U	h (v, l, d)	pi, cf, py, mr	granitoides	Slatinska reka	0.6 Mt / 0.45 g/t U_3O_8
		CH	Fe	met (b, l)	mg	amphibolites, chlorite schists	Čar, Sedlar	0.7 Mt /43% Fe
VZ	Kmz	A	Cu (Pb-Zn)	ska (l, i, n)	pr, chpy, apy, pb, zn	skarn, limestones, granitoides	Karavansalija	7 Mt / 1% Cu
VZ	Šmz		Sn	placer	cs	alluvium	Cigankulja	0.53 Mm^3 / 520 g/m^3
JB	Pod		Sn, W, Nb-Ta	peg; gre (vl, s-i)	cs, wo, n-t	pegmatites, granitoides	Cer	n.d.
JB	Pod		Fe (Bi, Cu)	ska (l, i, n)	mg, bi, chpy	skarn, limestones, granitoides	Duge Njive	1.2 Mt / 39% Fe
VZ	Kmz		Mo, W	ska (l, i, n)	mo, bi, chpy, mg	skarn, limestones, granitoides	Gvozdac	n.d.
VZ	Šmz		U	h (v, l, d)	pi, cf, py	granitoides, gneiss, limestones	Paun Stena	3.3 Mt / 350 g/t U_3O_8
SMM	BKmz		Pb, Zn	h-r (b, n, d)	ga, sp, py	granitoides, gneiss, limestones	Blagodat	0.3 Mt / 4% Pb, 4.5% Zn
KB	Kmz	A	Pb-Zn-Ag	h (l, n, i, pl)	ga, sp, py, pr, chpy	limestones, schists, quartzlatites	Stari Trg	7.9 Mt / 5.6% Pb, 4.5% Zn, 114 g/t Ag
VZ	LHmz		Pb-Zn-Au	h (v, d)	ga, sp, py, Au	andesites, quartz-veins	Lece	3.4 Mt / 1.8% Pb, 3.5% Zn, 3.3 g/t Au
VZ	Šmz		Pb-Zn, Bi, Ag	h, ska (r, l, n, v, i)	ga, sh, chpy, cs, bi a.a.	skarn, limest., flysch, qaurtzlatites	Rudnik	3.4 Mt / 2% Pb, 2% Zn, 0.4% Cu, 89 g/t Ag
KB	Kmz		Pb-Zn, Sb	h (i, l, v)	ga, sh, st, py, mr	listweanite, dacite-andesite, flysch	Rajićeva Gora	1.5 Mt / 2.8% Pb, 0.6% Zn, 0.2% Sb
VZ	LHmz		Cu-Au	por (s-d)	chpy, py, mg, ga, sp	andesites	Kiseljak	34 Mt / 0.42% Cu, 0.4 g/t Au, 1 g/t Ag
SMMUs	BKmz		Mo	por (s-d)	mo, py, q	dacites, schists	Mačkatica	25 Mt / 0.09% Mo
JB	Pod		Sb	h (v)	st,	andesites, limestones	Zajača	0.2 Mt / 1.89% Sb
DIEi	God		Sb	h (l, n)	st, va, sn	silicified limestones	Lisa	n.d.
JB	Pod	A	Sn	placer	cs	alluvium	Lešnica	3.36 Mm^3/ 264 g/m^3 SnO_2, 80 g/m^3 Nb/Ta
VZ	Šmz		U	roll-front	pi, at	sandstones, conglomerates	Srednje Brdo	0.59 Mt / 323 g/t U_3O_8
CARPATHO-BALKAN METALLOGENIC PROVINCE								
gr	RKmz	A–C	Cu	ska	chpy, mg, ga, sp	skarn, andesites, limestones	Reškovica	n.d./ 1.9% Cu
			Cu, Pb-Zn	h (r, v)	chpy, ga, sp, py	limestone, schist, dacite	Antina Čuka	n.d. / 0.1% Pb, 0.8% Cu, 5 g/t Au, 20 g/tAg

Table 1: *Continued.*

Geotec-tonic unit [1]	Metallo-genic unit [2]	Metallo-genic epoch [3]	Commodity	Type of deposit [4]	Principal minerals	Host rocks	Characteristic deposit	Tonnage / Grade [5]
				CARPATHO-BALKAN METALLOGENIC PROVINCE				
			Sb-W	h (v)	wo, st	Paleozoic schists	Osanica	0.031 Mt / 2% Sb; 0.1 Mt / 0.39% WO_3
			Cu	h (vl, d)	chs, en, chpy, ma, az	Red Permian sandstones	Bancarevo	n.d.
tea	Bmz	A-C	Cu (Mo), Au, Ag	por (st, i, l, s-d)	chpy, py, bo, en, co, chs	andesites and analogue plutonites; magmatic arcs above the subduction zone or of the rifts over the subduction zone	Bor, Majdanpek etc.	1060 Mt / 0.38% Cu, 0.14 g/t Au
			Cu, Au (Pb-Zn)	vms (st, l, m, v)	en, lu, py, me		Lipa	
			Pb-Zn	hr (l, n, i, v)	sph, ga, chpy, en, lu		Tenka	
			Cu	sk (l, i)	chpy, py, mg	skarn, limestones, andesites	Beljevina	n.d. / 0.44-0.94% Cu
			Pb-Zn, Cu	sk (l, i)	ga, sph, py, chpy	skarn, limestones, andesites	Valja Saka	0.5 Mt / 2.1% Pb, 1.9% Zn, 0.2% Cu
			Au	ep-hs	py, en, chpy, te, tn, sp	hydroquartzites, andesites	Čoka Kuruga	1.1 Mt / 0.5% Cu, 0.3 g/t Au
			Au	ep-ls	py, sph, ga, rare chpy	Q-Au veins	Zlaće	0.03 Mt / 7 g/t Au, 32.5 g/t Ag
k	NBmz	CH	Fe	met/primary v-s (p)/	mg, hm, py	greenschists, keratophyre, diabases	Jelje	25 Mt / 20% Fe
			Mn	met (b, d)	br, ps	schists	Laznica	0.007 Mt / 34% Mn
i		A-C	Au-W	h (v, d)	Au, sh, wo, chpy, ga, sp	greenschists	Blag. Kamen	0.07 Mt / 14.6 g/t Au, 15 g/t Ag
i,k		A	Au	placer	Au	alluvium	Pek	29 Mm^3 / 0.25 g/m^3
p	PSmz	H	Fe	ska (l, m)	mg, chpy, py, mo, sp	crystal, schists, marbles, granites	Rudna glava	0.05 Mt / 50% Fe
p			Fe	h (l)	mg, minor py, pr, chpy	granitoide	Crnajka	0.05 Mt / 44.6% Fe, 1.38% Cu, 0.27 g/t Au
p			Cr	mag (i)	ch	gabbro-peridotite	Deli Jovan	n.d.
p			Au	h (v)	Au	quartz-veins	Ginduša	0.02 Mt / 54.5 g/t Au
st			U	h (v)	pi, chy, mo	schists, granitoides	Mezdreja	0.16 Mt / 346 g/t U_3O_8
st			Bi-Cu	h (v, l, n, i)	apy, pr, chp, sh, py, bi	gabbro-peridotites, granitoides	Aljin do	– / 3.3% Cu, 1.4% Zn, 2.5% Bi, 2.6 g/t Au
tt		A	Fe	sed (b)	he, si, li	limestones	Odorovci	1 Mt / 42% Fe
st			U	roll-front	pi, Au	Red Permian sediments	Dojkinci	0.1 Mt / 640 g/t U_3O_8
st			Au	placer	Au	alluvium	Timok	21 Mm^3 / 0.25 g/m^3
			Ti	placer	Ti	alluvium	Žukovac	0.5 Mm^3 (56000 t ilmenite) / 42% TiO_2
				INDUSTRIAL MINERAL RESOURCES				
JB	DMP	A	barite	v-s	barite	terrigene-carbonate and v-s series	Bobija	0.3 Mt / 72% $BaSO_4$
tt	CBMP	A	bentonite	vsa	bentonite	volcano-sed. series (lake basins)	Bogovina	0.7 Mt
JB	KolB	A	diatomite	sed	diatomite	marine and lake sediments	Baroševac	0.47 Mt
SMMLs	SMM	H	feldspar, mica	peg	feldspar, mica	pegmatites	Vidojevica	2.5 Mt
JB	SMMP	A	fluorite	h (v)	fluorite	terrigene-carbonate series	Ravnaja	n.d.
SMMUs	SMMP	C	phosphates	met	apatite	Paleozoic schists	Lisina	0.09 Mt / 9.1% P_2O_5
VZ	DMP	A-H	gypsum	sed	gypsum, anhydrite	Permian-Triassic evaporites	Lipnica	11.8 Mt
KB	Kmz	A	chrysotile asbestos	h (v)	chrysotile asbestos	gabbro-peridotites	Korlaće	34 Mt
VZ	BujC	A	kaoline	h (v)	kaoline	granites	Muslina Kruška	0.45 Mt
VZ	StrB	A	kaoline	w-cr	kaoline	granites	Karačevo	5.7 Mt
VZ	KolB	A	cermic and refractory clay	sed	kaoline	marine and lake sediments	Rudovci	0.42 Mt

Table 1: *Continued from the previous pages.*

Geotectonic unit [1]	Metallogenic unit [2]	Metallogenic epoch [3]	Commodity	Type of deposit [4]	Mineral association	Host rocks	Characteristic deposit	Tonnage: Grade [5]
INDUSTRIAL MINERAL RESOURCES								
tt	CBMP	A	cermic and refractory clay	sed	kaoline	marine and lake sediments	Crne Rovine	0.75 Mt
JB	KolB	A	Q-sand	sed	Q-sand	marine and lake sediments	Kolubara Basin	17 Mt
DIEi	Dod	A	magnesite	h (v)	magnesite	gabbro-peridotite	Goleš	16 Mt / 44% MgO
VZ	SMMP	A	magnesite	sed	magnesite	lake sediments	Beli Kamen	1.7 Mt / 46% MgO
VZ	DMP	H	talc	h - met	talc	Paleozoic schists	Steroci	0.01 Mt
KB	Kmz	A	wolastonite	ska	wolastonite	skarn, limestone, granitoide	Kopaonik	1.36 Mt
VZ	VB	A	zeolite	v-s	zeolites	lake sediments	Zlatokop	0.59 Mt

Abbreviations:

[1]: Geotectonic units (Dimitrijević 1997). [2]: Metallogenic units (Janković 1982; Janković et al. 2003). [3]: Metallogenic epoch (Janković 1967; Janković et al. 2003). [4]: Janković (1967, 1982, 1990), Janković et al. (2003); Vakanjac (1992). [5]: Geozavod, Belgrade; Ministry of Mines and Energy, Republic Serbia.

Geotectonic units: DIEd: Drina-Ivanjica Element — Drina block; **DIEi:** Drina-Ivanjica Element — Ivanjica block; **EBD:** East Bosnian — Durmitor; **gr:** Gornjak-Ravanica Zone; **i:** Homolje metamorphites; **JB:** Jadar block; **k:** Kučaj Zone; **Kmz:** Kopaonik metallogenic zone; **MZ:** Morava Zone; **OB:** Ophiolite Belt; **p:** Poreč Unit; **st:** Stara Planina; **SMM Ls:** Serbo-Macedonian Massif — Lower Series; **SMM Us:** Serbo-Macedonian Massif — Upper Series; **SMM:** Serbo-Macedonian Massif; **tea:** Timok eruptive area; **tt:** Tupižnica-Tepoš Zone.

Metallogenic units (metallogenic province, metallogenic zone, ore district)**: CBMP:** Carpatho-Balkanian metallogenic province; **DMP:** Dinaric metallogenic province; **SMMP:** Serbo-Macedonian metallogenic province; **BKmz:** Besna Kobila metallogenic zone; **Bmz:** Bor metallogenic zone; **Dod:** Drenica ore district; **God:** Golija ore district; **KolB:** Kolubara Basin **LHmz:** Lece-Halkidiki metallogenic zone; **Lod:** Lajkovača ore district **MGb:** Mokra Gora Basin; **NBmz:** Neresnica-Beljanica metallogenic zone; **Plod:** Polimlje ore district; **Pod:** Podrinje ore district; **PSmz:** Poreč-Stara Planina metallogenic zone; **RKmz:** Ridanj-Krepoljin metallogenic zone; **Šmz:** Šumadija metallogenic zone; **VB:** Vranje Basin; **Vz:** Vlasina Zone; **Zod:** Zlatibor ore district.

Metallogenic Epoch (Ma /Janković, Grubić & Romić 1983; Vakanjac 1992/): **A:** Alpine, 0–67 Ma; **C:** Cimmerian, 67–230 Ma; **H:** Hercynian, 230–320 Ma; **CH:** Caledono-Hercynian, 300–530 Ma.

Type of deposit: v-s: volcano-sedimentary; **h:** hydrothermal; **h-r:** hydrothermal-replacement; **h-s:** hydrothermal-sedimentary; **kar:** karst-type; **sed:** sedimentary; **eg:** pegmatite; **met:** metamorhic; **mag:** magmatic; **m-h:** magmatic-hydrothermal; **w-cr:** weathering crusts; **vsa:** volcano-subaqual; **vms:** volcano-hydrothermal massive sulphide; **gre:** greisen; **ska:** skarn; **pl:** pipe-like; **por:** porphyry; **pd:** podiform; **all:** alluvial; **in-s:** infiltration-sedimentry; **ep-hs:** epithermal-high sulphidation; **ep-ls:** epithermal-low sulphidation; **h-qv:** hydrothermal-quartz veins.

Shape and type of ore bodies: b: bed; **c:** column; **i:** irregular; **l:** lense; **n:** nests; **p:** plate; **st:** stock; **v:** vein.

Type of mineralization: d: dissemination; **m:** massive; **ms:** massive sulphide **s:** stockwork; **s-d:** stockwork-dissemination; **vl:** veinlets.

Minerals: ap: apatite; **apy:** arsenopyrite; **at:** autunite; **az:** azurite; **ba:** barite; **be:** boehmite; **bi:** bismuthinite; **bo:** bornite; **br:** braunite; **bx:** bauxite; **cb:** cinnabar; **cf:** coffinite; **ch:** chromite; **chpy:** chalcopyrite; **chs:** chalcosine; **ci:** cerussite; **co:** covellite; **cs:** cassiterite; **en:** enargite; **fd:** feldspar; **ga:** galena; **go:** goethite; **hm:** hematite; **il:** ilmenite; **ka:** kaolinite; **li:** limonite; **lu:** luzonite; **me:** melnikovite; **mg:** magnetite; **mi:** mica; **ml:** malachite; **mo:** molybdenite; **mr:** marcasite; **no:** nontronite; **n-t:** niobo-tantalates; **pi:** pitchblende; **pn:** pentlandite; **pm:** pimelite; **pr:** pyrrhotite; **ps:** psilomelane; **py:** pyrite; **q:** quartz; **qt:** quartzite; **sh:** schellite; **si:** siderite; **sn:** senarmortite; **sp:** sphalerite; **st:** stibnite; **te:** tetrahedrite; **ti:** titanomagnetite; **tn:** tennantite; **va:** valentinite; **wo:** wollframite.

1. *Mineral resources which are already exploited and are already provided with processing capacities (Cu, Pb-Zn), and which continue to be the basis of the industrial development of the country.* This group of metallic mineral resources includes the deposits *of copper* in the Bor Zone, the *deposits of Pb-Zn* in the metallogenic zones of Kopaonik, Šumadija, Lece, Besna Kobila and the Podrinje. The basic characteristics of these deposits are a predominantly low metal content and substantial ore potential. This group also includes industrial mineral resources with a large, unused potential, such as quartz sand, and mineral resources with a significant, partly exploited potential, such as *fluorite*, *dolomite*, *magnesite*, *cement marl*, *building industry granulates* (*natural and crushed*) and various types of clay. The fossil fuels belonging to this group are coal, oil and gas.

2. *Mineral resources with identified, economically interesting, predominantly small reserves which are not already exploited, and mineral resources occurring in small quantities, sufficient for brief periods of production and the supply of domestic requirements. This group includes Sn, Mn, U, Mo and Ti*. The industrial mineral resources belonging to this group are *borates*, *feldspar*, *barite*, *asbestos* and *zeolites*.

3. *Potentially significant mineral resources with partly defined ore reserves, the valorization of which depends on technical and economic parameters, as well as the partly explored mineral resources with favourable prospects for reserve increase*. They include *Ni*, *Co*, *Sb*, *Al*, and mixed Fe-ores. *Au*, *Ag*, *salt*, *phosphorites*, and *wollastonite* also belong to this group. Although most of these resources are only partly explored, the study of the geological setting and metallogenic processes of Serbia show that there are favourable prospects for the discovery of new resources. Oil shales also belong to this group.

4. *Mineral resources likely to be found in the territory of Serbia (Au, Ag, precious and disseminated metals).* The metallogenic analyses carried out so far show that new resources of *gold* are likely to be discovered in the Blagojev Kamen area (hydrothermal quartz-vein type in the Neresnica-Beljanica metallogenic zone), the Timok volcanic complex (porphyry copper-gold and epithermal gold deposits in the Bor metallogenic zone) and Lece volcanic complex (high and low sulphidation epithermal gold mineralization) the Lece-Halkidiki metallogenic zone) and in some other areas. Silver, gold and rare elements are mainly associated with the sulphide deposits of Pb-Zn and Cu.

5. *Mostly exhausted or non-economic mineral resources*. They include *Cr*, *Fe* (*suitable for the technology of blast furnaces*) and W. Prospects for the discovery of new, economically significant resources are small.

Metallic mineral resources

The most important metallic mineral resources of Serbia are non-ferrous metals and precious metals, ferroalloy metals, partly minor and related non-metals and fissionable metals. Especially important, as regards resource potential and economic importance, are the deposits of copper and lead-zinc, with the accompanying elements of association.

The measured, indicated, inferred and potential resources of the main metallic ores are presented in Table 2.

The non-ferrous metals and precious metals are the economically important group of metallic mineral resources of Serbia. The most important are: Cu, Pb-Zn, Au and Ag.

Copper. The most important copper ores are located in: 1 — the Bor metallogenic zone of the Carpatho-Balkanian metallogenic province (porphyry copper deposits Borska Reka, Veliki Krivelj and Majdanpek), 2 — the Lajkovača ore district (hydrothermal volcano-sedimentary massive sulphide deposits) — one of ophiolitic mélange, and, partly, 3 — in the Lece-Halkidiki metallogenic zone (Kiseljak porphyry copper deposit: Mudrinić & Seke 1997). Almost all the economic reserves of copper are associated with the Bor metallogenic zone.

The metallogenic analyses carried out so far in Serbia have indicated the areas with geological features which show that they are likely to contain new Cu-deposits, predominantly of a porphyry type (the Bor metallogenic zone), and, to a lesser extent, of a volcanogenic massive sulphide ore types (Lajkovača ore district). Gold and other elements of ore association occur either together with copper or separately. The potentials of gold are great. The potential ore-bearing areas have been defined (Bor metallogenic zone and Lece-Halkidiki metallogenic zone); the control factors of the spatial position and the conditions of origin of individual deposits of gold have been established (Jelenković 1998).

Lead and zinc. The Pb-Zn deposits of Serbia are numerous and economically significant. The greatest number of them are in Kosovo. The potential resources are also substantial and are located in the vicinity of known deposits — Blagodat, Lece, Veliki Majdan, Stari Trg, and in environments with favourable metallogenic conditions — predominantly in the region of calc-alkaline, volcano-intrusive complexes

Table 2: Metallic mineral resources of Serbia (source: Ministry of Mines and Energy of Serbia; modified). **MI** — Measured+Indicated resources including Ore Reserves; **I** — Inferred resources; **P** — Potential resources; **n.d.** — no data. (JORC 2004.)

	MI		I	P
	ore [Mt]	metal [t]	ore [Mt]	ore [Mt]
Cu	1090	Cu 4,145,000 Au 153 Ag 1120 Mo 11,900	1.377	2200
Pb+Zn	37.33	Pb 650,920 Zn 488,200 Ag 2940	59.50	Pb 117.5 Zn 128.2
Fe	3.98	1,498,100	15.40	5.00
Fe+Ni	n.d.	n.d.	100.02	52.62
Mn	n.d.	n.d.	1.359	3.72
Cr	0.089	13,800	90.00	0.10
Ni	38.79	262,997	117.00	10.08
Co	38.79	11,954	n.d.	30
Sb	0.778	11,903	3.15	1.96
Al	2.69	688,800	1.20	13.49
Sn	n.d.	n.d.	n.d.	3.450
Mo	n.d.	n.d.	25.16	120.00
W	n.d.	n.d.	n.d.	0.35
Hg	82.998	273.9	n.d.	150.5
U	2.15	727.4	1.50	2.96

of Neogene age in the Serbo-Macedonian metallogenic province (Janković et al. 2003).

The conversion of measured, indicated and inferred lead-zinc mineral resources (or a part of them), into proven and probable ore reserves requires time and preliminary explorations. An important problem in the valorization of these ores is connected with the high mining loss during excavation and low flotation recovery.

Tin. The resources of tin are small and cannot meet domestic demand over a longer period. Tin is found in greissen and alluvial deposits. The primary Sn-occurrences are not economically interesting because of the small resources and low content, while the placer deposits are on the verge of profitability. It should be pointed out, however, that not much attention has been devoted to the prospecting of the Sn-deposits in the past.

Aluminium. The deposits of bauxite are of small economic significance. They are of limited extent and poor quality.

The resources of iron and ferroalloy metals (Fe, Mn, Cr, Ni, Co, Mo, and W) are rather limited and do not meet the requirements of the domestic metallurgy.

Iron. The economically most important iron ores are: 1 — The easy meltable limonitic ores from Majdanpek deposit. 2 — The magnetite ores from: *a* — skarn deposits, *b* — metamorphic deposits and *c* — magnetite in porphyry cooper deposits. 3 — The complex oxide-carbonate-silicate ores of the volcano-sedimentary type. 4 — Lateritic and redeposited lateritic Fe-Ni-Cr ores. The mineral potential of the redeposited Fe-Ni-Cr ores is great, but they have not been sufficiently explored from the metallurgically point of view.

Manganese. The most important manganese ores in Serbia are: 1 — the oxide and silico-manganese ores from the volcanogenic-sedimentary deposits which originated in association with ophiolitic mélange or, less frequently, porphyrite-chert formation of Middle Triassic age, and 2 — the Fe-Mn carbonate ores. The former type was exploited in the past, but at present there are no known ore reserves any more. The potential environments for the discovery of new deposits of silica-manganese ores are the Priboj-Tutin Zone and the Rzav Zone. Another area is Šumadija, with ores whose technological characteristics have not been fully explored yet, and which are supposed to contain ~0.1 Mt Mn. The determination of the mineral potential of manganese in Serbia requires systematic geological explorations and technological analyses.

The Fe-Mn carbonate ores of manganese in Serbia originated in association with the sulphide Pb-Zn deposits in the Kopaonik metallogenic zone: Stari Trg deposits etc. They have not been much exploited in domestic metallurgy in the past, although they contain iron in addition to carbonates.

Nickel and cobalt. The Ni-Co deposits of Serbia are associated with the lateritic zones of serpentinites of Kosovo and within the Rudjinci-Veluće Zone. More thorough explorations are necessary, however, for a valorization of the ore.

Molybdenum. The largest hydrothermal stockwork-disseminated molybdenum deposit in Serbia is Mačkatica (Simić 1997). Several occurrences of molybdenum have been found in the Besna Kobila metallogenic zone, but no full geological and economic estimate of them has been made so far. Only preliminary explorations have been made in the case of the other occurrences (the contact zones of the granitoides of the Podrinje ore district, Kopaonik metallogenic zone, and the Mo-mineralization in the Majdanpek porphyry copper deposit).

Tungsten. The resources of tungsten are small. It is mainly concentrated in quartz veins (shellite). The areas of potential interest for the prospecting of tungsten are the zones of Blagojev Kamen, Golija and Kopaonik. It is possible that future explorations will lead to the discovery of occurrences of shellites in skarns, the economic significance of which is impossible to predict.

The resources of minor metals and related non-metals (Sb, As, Be, Bi, Cd, Hg, REE, Se, Ta, Te, Ti, Zr etc.) are not of economic importance is Serbia. The most important of them are antimony deposits.

Antimony. In addition to several mines, Serbia has considerable facilities for ore processing at Zajača with an installed capacity of up to 4000 t Sb per year. More than 100,000 t of Sb ore was excavated in this area between 1880 and 1991. Conversion of antimony mineral resources to the ore reserves requires heavy investments in exploration (Janković & Jelenković 1997).

Fissionable metals. The most significant concentrations of uranium in the territory of Serbia are associated with the granitoide complexes of Hercynian age (Mezdreja deposit), Tertiary age (Paun Stena deposit), sedimentary series of Permian age (Dojkinci deposit) and Neogene basins in the fringe zones of granitoides. Uranium deposits associated with granitoid complexes belong to the group of hydrothermal vein and stockwork deposits located in the fault zones, while uranium deposits related to sedimentary series belong to the group of ore of roll-front type of mineralization (Jelenković et al. 1997). The further exploration of the uranium resources will depend on the strategic decision of the state to use them as the raw material for the production of energy.

Industrial mineral resources

There are more than 2000 deposits and occurrences of industrial minerals in Serbia. Several of them are already exploited (predominantly raw materials for the production of construction materials). Seen from the economic point of view, they can be classed as follows: 1 — Industrial minerals and rocks already exploited (*building construction industry granulates and decorative stone*, *barite*, *dolomite*, *kaoline*, *common clay*, *feldspars*, *white bauxite*, *zeolites*, *bentonite*, *cement marl*, *ceramic and refractory clay*, *natural mineral pigments*, *expanding clay*, *limestone*, *gypsum*, *diatomite*, *petrurgical rocks, magnesite*, *siliceous rocks/quartz sand*, *quartzite*, *opal*, *fluorite*); 2 — Industrial minerals whose resources and quality are determined, but which were not exploited in the past (boron minerals); 3 — Industrial minerals and rocks with conditionally economic reserves (*phosphates*, *wollastonite*, *alunite*, *alumosilicates*, *vermiculite*, *garnets*, *pyrophylite*); and 4 — minerals likely to be found in Serbia (*salt and mica*).

The most important industrial minerals of Serbia are: bentonite, boron minerals, refractory clay, gypsum, diatomite, dolomite, zeolite, kaoline, quartz sand, cement marl, ceramic clay, limestone, magnesite, phosphates, chrysotile-asbestos, building industry granulates and decorative stone.

The measured, indicated, inferred and potential resources of the industrial minerals of Serbia are presented in Table 3.

Bentonite. Large resources of high-quality bentonite clays are located in several Neogene basins, but the mining production of this mineral is below its natural potentials. A large share of the resources has been classed as inferred because of the unfavourable conditions of exploitation, poor quality of the ore, problems of the processing technology or undefined technical and economic conditions of exploitation.

Boron. The deposits of boron are located in the Ibar Neogene Basin. The areas with potential new deposits are the Vranje, Valjevo and other Neogene basins of Serbia.

Clays. A number of deposits of refractory, kaolinite and ceramic clay are known in Serbia. Most of the deposits of the best-quality refractory clay are either exhausted or nearing the end of exploitation. The other refractory clays are of a poor to medium quality, while the high-quality clays (with >40 % Al_2O_3 and SK>34) are imported. The deposits are predominantly of an allochthonous-sedimentary type, formed in environments rich in humus in the fringe areas of Neogene basins. The areas likely to contain deposits of clay are the basins of Arandjelovac, Mladenovac and the Kolubara, as well as the Liassic basins in south-eastern Serbia.

The available resources of kaoline are not of a particularly good quality, but they are sufficient to meet the requirements of the country.

The deposits of ceramic clay are mostly situated in the Neogene basins of central Serbia and in the Liassic sediments of eastern Serbia. They belong to the high-quality clay deposits of the illite-kaolinite type. Ceramic clay is exploited from the deposits of the Posavina-Tamnava, Mladenovac and Arandjelovac Basins. The available resources of ceramic clay are sufficient to meet the requirements of the domestic industry.

Table 3: Industrial mineral resources of Serbia (source: Ministry of Mines and Energy of Serbia; modified). **MI** — Measured+Indicated resources including Ore Reserves; **I** — Inferred resources; **P** — Potential resources. (JORC 2004.)

	MI [Mt]	**I [Mt]**	**P [Mt]**
Magnesite	5.76	2.00	8.00
Crysotile-asbestos	101.00	3.00	6.00
Cement marl	250.00	120.00	250.00
Dolomite	15.00	42.00	163.00
Limestone	77.50	25.00	250.00
Fire clay	23.00	3.00	15.00
Ceramic clay	29.49	11.00	35.5
Gypsum and anhydrite	11.89	1.00	1.00
Qartz sand and siliceous rocks	65.63	157.00	1.160
Barite	0.99	0.20	0.50
Bentonite	30.23	2.00	5.50
Diatomite	0.47	0.40	25.00
Zeolite	0.62	0.25	12.50
Fluorite	0.71	0.25	0.30
Phosphates	93.15	55.00	245.00
Feldspar	13.00	2.00	2.00
Boron	1.10	3.00	30.00
Wolastonite	1.34	0.30	1.00

Gypsum. One sedimentary deposit of gypsum is known in Serbia (Lipnica in Gruža). Gypsum is used only in the production of cement. The present production is not sufficient to meet the requirements of the other branches of the economy.

Diatomite. The deposits of diatomite are located in the Neogene basins of Serbia. The most important of them are in the Kolubara Basin and in the Metohija Basin. The proven reserves of diatomite are 0.48 Mt with 60–77 % SiO_2 and 8–12 % Al_2O_3. Generally speaking, the mineral resources of diatomite in Serbia are considerable, but only partly explored (particularly those in the Metohija Basin).

Dolomite. Serbia has significant resources of dolomite as well as numerous dolomitic formations, which probably contain still undiscovered deposits. Not counting the dolomite used as building stone, the most important sources of this mineral raw material are used in the glass industry, the production of Mg-metal, refractory industry, metallurgy, etc.

Zeolites. The explorations of zeolites in the Neogene basins of Serbia have been in progress for more that twenty years (Vranje and other basins). It is considered that new deposits may be discovered in many basins with volcano-sedimentary series with laminated tuff, particularly if they are of dacite composition.

Quartz sand and siliceous rocks. The deposits of industrial quartz sand are numerous in the sediments of Serbia. They are of varying quality and granulometry. It is possible to improve the quality of the concentrate by the application of modern methods of ore processing, which means that a substantial portion of resources can transferred to the ore reserves. Viewed as a whole, the geological resources of quartz sand exceed the requirements of domestic consumers.

There are other mineral resources in Serbia, apart from quartz sand, with silica as their basic component: vein quartz, quartzite, cherts, or opal silica and quartz sandstone. Serbia's geological and economic potential as regards the quartz minerals has not been defined yet from the point of view of the processing technology. The extent and quality of the identified masses of quartz minerals show that there are reasons for the construction of new industrial capacities, or the expansion of old ones, for the production of ferrosilica, Si-metals and other products.

Limestone and marble are found in extensive deposits in Serbia. They mostly form deposits of sedimentary (limestone) and metamorphic (marble) types, and sporadic vein deposits of calcite also occur. Although limestone forms large geological formations, its deposits are defined as specific parts of these masses. The reserves of carbonate rocks for the requirements of metallurgy, chemical industry, production of sugar, glass, paper, rubber, dyes, agrarian complex, etc. (not counting the limestone used as building industry granulates) amount to about 100 Mt.

Magnesite is a mineral with an important use in the refractory industry of Serbia. It is associated with the weathered peridotite complexes and Neogene basins of the Serbo-Macedonian province. The ore is of a good quality, represented by crypto- to microcrystal magnesites with a high MgO content, relatively low SiO_2, CaO and good physico-mechanical characteristics. Deposits of crystalline magnesite, which are of great economic importance in the world, are not known in Serbia.

The most important deposits are in the area of Šumadija, Beli Kamen and Goleš. About 80 % of the resources are in vein deposits and 20 % are in sedimentary deposits.

Phosphates. One deposit of phosphates is known in Serbia–Lisina. Although it is not being exploited because of technical and economic reasons, it represents an important potential source for the production of phosphorite concentrates.

Chrysotile-asbestos. The deposits of chrysotile-asbestos of the fibrous ore type are located in the region of the Kopaonik Zone.

Deposits of building construction industry granulates (magmatic, sedimentary and metamorphic rocks) are very numerous in Serbia (several hundred). As regards their quantity and quality, they completely meet the requirements of the domestic economy.

Fossil fuels resources

Serbia has significant resources of fossil fuels, particularly coal and oil shale. Oil and gas reserves have been considerably exhausted, but the calculated remaining potential shows that modern exploration could lead to substantial new discoveries.

Coal resources

There are 13 bituminous coal basins and 33 brown coal basins in Serbia. At present coal is exploited in 13 basins (2 bituminous coal and 11 brown coal basins). Some of the others are exhausted, some are under exploration, and some have been abandoned because of mining accidents. The geological resources of brown coal in Serbia amount to 22.6 Gt, and the economic reserves are 8.9 Gt. The geological resources of bituminous coal amount to about 65 Mt, and the reserves are 8.3 Mt. The greatest resources of coal (lignite) are in the Kosovo, Kolubara, Kostolac and Metohija Basins, and in the Kovin deposit (Fig. 3).

The brown coals of Serbia vary in their quality and degree of carbonification (Ercegovac et al. 2006). They developed in various clastic and terrigene lithostratigraphic units (from the Lower to the Upper Miocene). Almost all the basins belong to the intramontane lacustrine type. The only exceptions are the coals of the Despotovac and, probably, Bogovina basin–Istočno polje, which belong to the paralic type. Their rank has been defined on the basis of the mean reflection of huminite/vitrinite (0.26–0.50%), the total moisture content (13.18–49.11%) and the net calorific value (21.2–28.1 MJ/kg, dry, ash-free basis). Three groups of brown coals have been defined on the basis of these parameters:

◆ **Soft brown coals** (lignite, Low-Rank C; ECE-UN, 1998, 1999, 2000) are characterized by the huminite/vitrinite reflection of 0.26–0.30 % R_r; high content of total moisture (43.41–49.11%); ash content, as-received basis of 17.40–20.53 %; ash content of 31.6–42.91% (dry basis); total sulphur content of 1.06–3.98 % (dry basis); net calorific value of 5.43–8.37 MJ/kg (as-received basis); net calorific value (dry, ash-free basis) of 21.22–24.68 MJ/kg. These coals have mildly acid to very acid ashes, with the melting point values of 1261–1366 °C. The soft brown coals are pale brown to dark brown in colour, and are of heterogeneous composition with a predominance of matrix and xylitic lithotypes. The mineral-rich lithotype and doplerite coal appear in very thin layers. The most common macerals are textinite, ulminite, densinite and atrinite. Their vegetal structure is well preserved, sometimes only slightly altered, and visible. The liptinite and inertinite content is low.

◆ **Dull brown coals** (Low-Rank B), are characterized by the huminite/vitrinite reflection of 0.31–0.4% R_r; total moisture content of 17.05–37.59 %; ash content, as-received basis of 12.87–25.74 %; ash content, dry basis, of 18.82–34.57 %; total sulphur content 1.44–4.06 % (dry basis); net calorific value of 10.51–16.97 MJ/kg (as-received basis); net calorific value, dry, ash-free, of 24.3–26.6 MJ/kg. These coals have mildly base to acid ashes, and the melting point varies from 1246 to 1318 °C. Dull brown coals are dark brown and often with banded structure. The most common macerals of the coals of this group are ulminite, textinite, densinite and atrinite. The

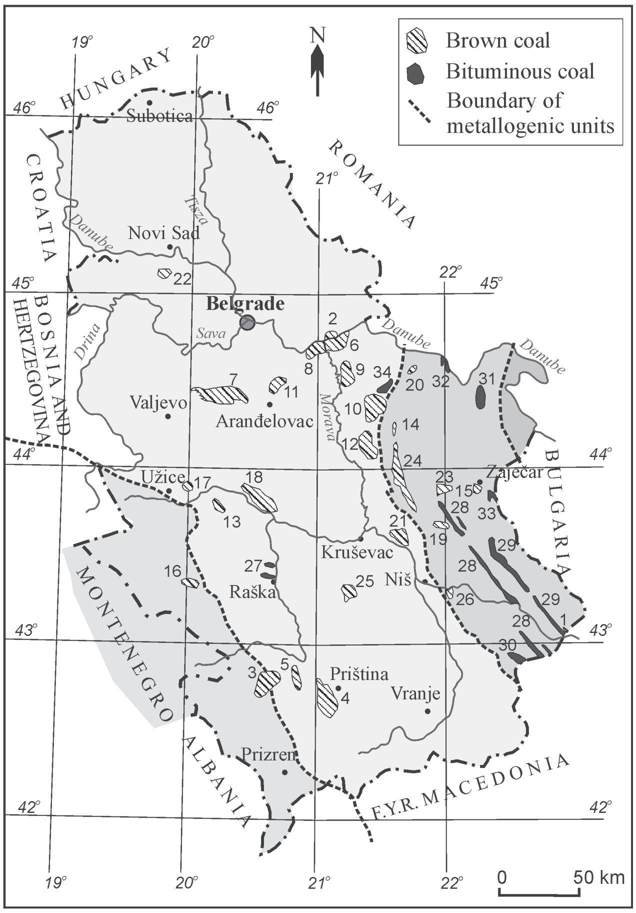

Fig. 3. Coal basins and deposits of Serbia. *Brown coal:* **1** — Mazgoš, **2** — Kovin, **3** — Metohija, **4** — Kosovo, **5** — Drenica, **6** — Kostolac, **7** — Kolubara, **8** — Smederevsko Pomoravlje, **9** — Poljana, **10** — Mlava, **11** — Mladenovac, **12** — Despotovac, **13** — Dragačevo, **14** — Krepoljin, **15** — Lubnica, **16** — Sjenica, **17** — Požega, **18** — Zapadna Morava, **19** — Soko Banja, **20** — Zvižd, **21** — Aleksinac, **22** — Vrdnik, **23** — Bogovina, **24** — Senje-Resavica, **25** — Jankova Klisura, **26** — Jelašnica. *Bituminous coal:* **27** — Ibar, **28** — Senonski rov, **29** — Stara Planina, **30** — Jerma, **31** — Miroč, **32** — Dobra, **33** — Vrška Čuka, **3** — Mlava-Peč.

liptinite content is comparatively low, except in some basins, where it ranges from 10 % to 15 % (Lubnica Basin). The resources of dull brown coals are comparatively large, but they are of secondary economic significant because of their complex tectonic and lithological composition and difficult conditions for exploitation.

◆ **Bright brown coals** (sub-bituminous, Low-Rank A), are characterized by black colour, banded structure and highly gelified tissue, with huminite/vitrinite reflectance between 0.41 and 0.47 % R_r. They have total moisture content of 13.18–27.55 %; ash content, as-received basis of 12.54–22.53 %; ash content, dry basis of 14.70–26.71%; total sulphur content of 1.35–6.54% (dry basis); net calorific value of 13.35–19.45 MJ/kg (as-received basis); net calorific value (ash-free, dry basis) of 25.26–28.05 MJ/kg; and mildly acid ashes. The melting point varies from 1220 to 1393 °C. Most common macerals are densinite, ulminite and gelinite. The liptinite and inertinite content is low, except in the case of the coal in the Aleksinac Basin, which has a high liptinite content, and Bogovina-Istočno polje, which has a comparatively high inertinite content.

The bituminous coals of Serbia played an important role in former Yugoslavia until the 1970s, but numerous mines have been closed and abandoned. There are many explored, exhausted and abandoned deposits of Carboniferous, Jurassic, Cretaceous and Neogene basins. At present, bituminous coal is mined only in the Ibar Basin and at Vrška Čuka. The bituminous coals are divided into the following groups according to the degree of carbonification:

• **Low-rank bituminous coals**, with vitrinite reflection of 0.51–2.20 % R_r, total moisture content below 10 %, volatile matter content below 42 % (ash-free, dry basis), carbon content of over 75 % (ash-free, dry basis) and net calorific value of 26–35 MJ/kg (ash-free, dry basis). The deposits belonging to this group, which are being exploited, are located in the Ibar Basin.

• **High-rank bituminous coals,** anthracite, with mean vitrinite reflection of over 2.20 % R_r, total moisture content below 5 %, volatile matter content below 10 %, carbon content of over 80 % (ash-free, dry basis) and net calorific value of over 35 MJ/kg (ash-free, dry basis). The most important deposit belonging to this group, and the only one being exploited, is at Vrška Čuka.

The future explorations of coal in Serbia will be aimed primarily at the augmentation of the present reserves and a more thorough analysis of their quality. It is also necessary to carry out detailed geochemical analyses of the coal, coal ashes and flying ashes in order to forecast and estimate the harmful and potentially toxic elements. Only a comparatively small part of the complex geological explorations will be devoted to the exploration of areas with prospective new coal deposits.

Oil and gas resources

The petroleum exploration carried out so far in Serbia have resulted in the discovery of commercial accumulations of oil and gas in the Pannonian Basin (the Banat Depression) only. Minor occurrences of hydrocarbons have also been found in some small Tertiary basins in Serbia.

Most of the hydrocarbon deposits are located in Miocene clastic sediments, at depths of 400–3500 m. As many as two-thirds of Serbian deposits are in the sands and sandstones of the lower and upper Pontian, and a third are associated with the earlier Miocene sediments and the basement (Paleozoic schist and Mesozoic sediments). From the point of view of proven reserves, the most important are the basal Miocene sandstones and their basement (mainly fractured Paleozoic schist).

More than 90 oil and gas discoveries, with more than 260 deposits, have been discovered in the Banat Depression, which is still the most promising exploration area in Serbia. There are 40 fields being exploited, and some are already exhausted. The most important oil fields are “Velebit”, “Kikinda”, “Kikinda-varoš”, “Mokrin”, “Elemir” and “Turija sever” (Fig. 4). About one third of oil is still produced in the field “Velebit”, and “Kikinda-varoš” and “Kikinda” yield about 17 % each. “Turija sever” contributes about 14 % of the annual production. As regards gas, the gas-oil field “Mokrin” gives nearly a third of the annual production. The gas fields “Srpska Crnja”, “Itebej” and “Srbobran” are also of considerable importance.

The production of oil in Serbia began in 1956, and a total of about 41 Mt has been produced so far. The quantities produced meet only 20–30 % of the domestic requirements. The peak oil production was in 1982, when it amounted to over 1.3 Mt. That was followed by a general decline of production. The production of gas began earlier, in 1952, and so far about 28 billion m^3 have been produced. The greatest production was in 1979, when it reached 1.1 billion m^3.

The deposits of oil and gas in the Banat Depression are primarily associated, as in most parts of the Pannonian Basin, with the elevated basement structures, so that the main fields are in compaction anticlines and buried hills. The traps are predominantly structural (convex and fault traps), less frequently stratigraphic (pinch-outs and lances). Most deposits of the Banat Depression have paraffinic oil, but about 30 % of the reserves and production consist of biodegraded naphthenic oil (“Velebit”, “Kelebija” and others with shallow reservoirs — at lower temperatures).

As regards the locations of petroleum deposits, it should be pointed out that all accumulations discovered so far are spatially closely related to the local depressions in which the sediments are more than 2500–3000 m thick. The lateral migrations of hydrocarbons are practically in all cases rather short — 10 to 20 km. The structural geometry of depressions strongly controls migration paths and hydrocarbon accumulations in the Pannonian Basin, so most of them could be accurately predicted (Kostić & Ercegovac 2002). The directions of lateral migration paths are perpendicular to the step-like normal faults, and, to a large extent, it took place along the contact between the fractured basement and the Tertiary clastites. The lateral migrations through later formations were also controlled by the faults and geometry of the paleorelief.

The main oil source-rocks in the Banat Depression are Pannonian and Sarmatian marly limestones and marls, then Badenian shales and siltstone, and to a less extent Ottnangian-Carpathian shale (Kostić 2000a). The sediments of the

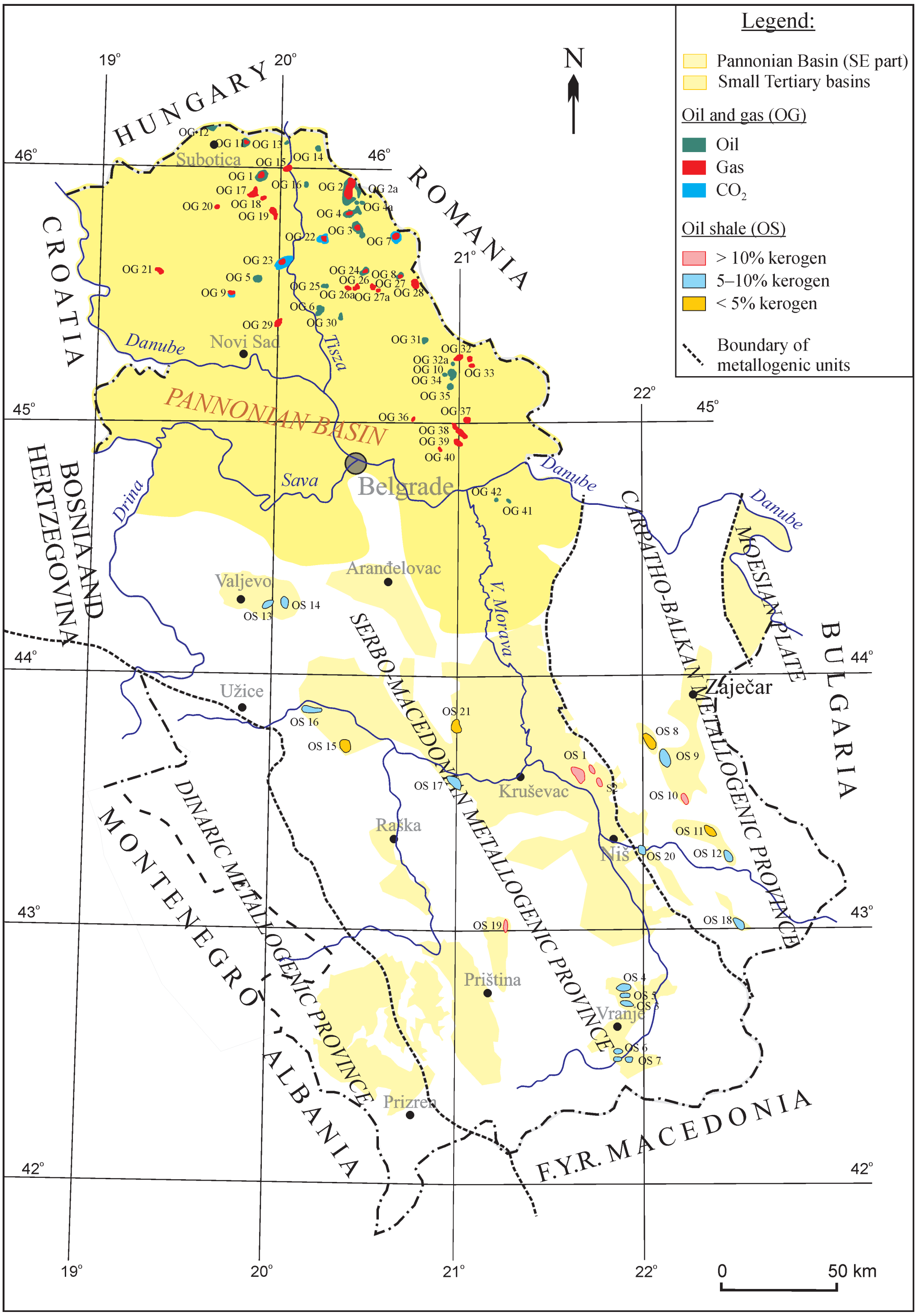

Fig. 4. Oil and gas fields and oil shales in Serbia. OG 1 — Velebit; OG 2 — Mokrin; OG 2a — Mokrin jug; OG 3 — Kikinda; OG 4 — Kikinda-varoš; OG 4a — Kikinda-varoš sever; OG 5 — Turija sever; OG 6 — Elemir; OG 7 — Srpska Crnja; OG 8 — Itebej; OG 9 — Srbobran; OG 10 — Jermenovci; OG 11 — Palić; OG 12 — Kelebija; OG 13 — Martoneš; OG 14 — Majdan; OG 15 — Novi Kneževac; OG 16 — Čoka; OG 17 — Čantavir; OG 18 — Gornji Breg; OG 19 — Ada; OG 20 — Bačka Topola; OG 21 — Ruski Krstur; OG 22 —Miloševo; OG 23 — Bečej; OG 24 — Karađorđevo; OG 25 — Rusanda; OG 26 — Banatski Dvor; OG 26a — Banatski Dvor zapad; OG 27 — Begejci; OG 28 — Međa; OG 29 — Gospođinci; OG 30 — Zrenjanin; OG 31 — Boka; OG 32 — Velika greda; OG 32a — Velika Greda Jug; OG 33 —Banatsko Plandište; OG 34 — Janošik; OG 35 — Lokve; OG 36 — Banatsko Novo Selo; OG 37 — Nikolinci; OG 38 — Tilva; OG 39 —Mramorak; OG 40 — Mramorak selo; OG 41 — Sirakovo; OG 42 — Bradarac-Maljurevac. OS 1 — Aleksinac deposit; OS 2 — Bovan-Prugovac; OS — Goč-Devotin deposit; OS 4 — Vlase-G.Selo; OS 5 — Stance; OS 6 — Buštrenje; OS 7 — Klenike; OS 8 — Vlaško polje-Rujište; OS 9 — Vina-Zubetinac; OS 10 — Podvis-G. Karaula; OS 11 — Manojlica-Okolište; OS 12 — Mirinovac-Orlja; OS 13 — Šušuoke-Klašnić; OS 14 — Radobićka strana-Svetlak; OS 15 — Pekčanica-Lazac; OS 16 — Parmenac-Lazac; OS 17 — Odžaci; OS 18 —Raljin; OS 19 — Rača; OS 20 — Paljina; OS 21 — Komarane-Kaludra.

"lower Pontian" (local stratigraphic division), which contain an unfavourable type of kerogen, represent source-rocks only for gas, mostly in central and northern Banat, where they are sufficiently matured.

As regards the further outlook of petroleum exploration in the Serbian part of the Pannonian Basin, the application of modern methods of exploration may be expected to lead to new discoveries of oil and gas in the majority of the depressions, although they are not likely to be very large fields. Recent studies of the petroleum potential of the Banat Depression show that highly rational and targeted exploration may result in the discovery of an additional 20 % of the initial reserves of oil and gas in Serbia (Kostić 2000b). There are also good prospects for the condensate, small quantities of which have been discovered so far, but which might be expected at greater depths and in the deepest local depressions. The most promising of the other areas for the exploration of oil and gas in Serbia are the Srem Depression and the small Tertiary basins of Serbia, although what is known of them at present does not seem to indicate that substantial reserves may be expected.

Oil shale resources

Serbia has a considerable number of rather rich deposits of oil shales, but not all of them have been thoroughly explored (Ercegovac et al. 2003).

The genesis of oil shales in Serbia is associated with the lacustrine depositional environments, which existed from the end of the Late Cretaceous era, in the Paleogene and Miocene. The major deposits of oil shales (Fig. 4) are in the Tertiary basins of Serbia and in a part of the Senonian tectonic trench in eastern Serbia.

The oil shales of Serbia are typically lamosite, of Tertiary origin, with the domination of kerogen types I and II. Generally they have kerogen content below 5 %, maturity levels that correspond to huminite/vitrinite reflection up to 0.45 % R_r and oil yield below 5 %. The total estimated oil shales resources of Serbia amount to about 5 billion tons.

The largest and most important deposit of oil shales in Serbia–Aleksinac — has considerably better characteristics than the average deposits. It covers an area of 20 km^2 and it has two thick productive sequences. The upper sequence of oil shale is 75 m thick and yields 10 mas. % of oil, on average. Lower sequence of oil shale is 26 m thick and yields 12.5 mas. % of oil, on average. The potential reserves of oil shales in the Aleksinac deposit are estimated at about 2.1 billion tons. Test production of oil from Aleksinac shale yielded 80–90 l/t; 400 m^3 of gas/t, and the potential in-place shale oil of this deposit are estimated at about 210 Mt (Ercegovac et al. 2003).

The current study of the use of oil shales for the production of synthetic oil will take into consideration all the relevant technological, economic and ecological factors.

Conclusion

The end of the twentieth century and the beginning of the twenty-first century marked a period of substantial decline of mining production in many deposits of metallic and industrial mineral resources of Serbia. This is a consequence of several factors, the most important being: 1 — intense exploitation of higher-quality ores: 2 — substantial reduction of geological exploration; and 3 — inadequate investments in the development of new technologies for the preparation and processing of mineral resources which would enable the valorization of lower quality ores as well.

The further development of the mineral resources of Serbia depends on the mineral policy of the country, the strategic decisions concerning future investment of domestic and foreign capital into systematic geological exploration of deposits and prospective terrains, the development and introduction of new technological methods of ore processing, the adaptation of the existing procedures of ore processing to the newly discovered deposits of mineral resources and the increased profitability of exploitation.

The most important group of metallic mineral resources of Serbia includes Cu, Pb-Zn, Au, Ag, and, to a considerably lesser extent, Sn, Mn, U, Mo, Ti, W, Co, Sb and Fe ores. In future explorations greater attention should be given to the Cu and Au deposits in the region of the Bor metallogenic zone; to the Pb-Zn deposits (Au-Ag with the accompanying elements) in the region of the Serbo-Macedonian province; and to the deposits of alloyed metals. The exploration of uranium ores will depend on the strategy of the state concerning the utilization of energy resources.

As regards the industrial minerals, of particular interest are the deposits of bentonite, borate, refractory and ceramic clays, gypsum, anhydrite, diatomite, industrial carbonates, zeolites, quartz and quartz sands, magnesite, feldspars and phosphates. Of the sporadically exploited or not exploited industrial minerals particularly important are dunite and rock for pottery and glass.

The soft brown coals represent the main source for the production of electric energy, and they are therefore of great economic importance. They will represent the mineral base for the existing thermoelectric plants in the future, too, provided the prospective parts of the basins are additionally explored. There are considerable resources of bright brown coals, but, owing to the complex tectonic features of their basins and the difficulties involved in their production, they are used only for general consumption and, occasionally, as supplementary fuel in thermoelectric plants.

As regards oil and gas, recent studies show that more rational exploration may lead to the discovery of additional reserves of oil and gas in Serbia, particularly in the Pannonian Basin. As regards the remaining oil potential, the most promising are certain local depressions in the Banat Depression. Oil shales also have a considerable potential, particularly the Aleksinac deposit, but the exploitation of these non-conventional oil sources depends on various technological, economic and ecological factors.

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References

Aleksić V., Pantić N. & Kalenić M. 1971: The observations of some tectonic processes in Serbia in connection with the plate tectonic or with the new global tectonic. *Glasnik Prirodnjačkog muzeja, Beograd* (A), 26–83–102 (in Serbian, English summary).

Dimitrijević M.D. 1974a: Dinarides: An outline of the tectonics. In: Dimitrijević M.D. & Sikošek B. (Eds.): Evolution and metallogeny of the Dinarides. *Earth Evolution Sci.* 1, 4–23.

Dimitrijević M. 1974b: The Dinarides: A model based on the new global tectonics. In: Janković S. (Ed.): Metallogeny and concepts of the geotectonic development of Yugoslavia. *Faculty of Mining and Geology*, Belgrade, 141–178.

Dimitrijević M.D. 1982: Dinarides: An outline of the tectonics. *Earth Evolution Sci*. 1, 4–23.

Dimitrijević M.D. 1997: Geology of Yugoslavia. *Geological Institute — GEMINI, Belgrade, Spec. Publ., Monograph*, 1–197.

Dimitrijević M.D. & Dimitrijević M.N. 1973: Olistrome melange in the Yugoslavian Dinarides and late Mesozoic plate tectonics. *J. Geol. Chicago* 81, 328–340.

Dimitrijević M.D. & Djoković I. 1979: Pre-Triassic position of the Eastern Dinarides: Evidence from Paleozoic Deposits. *6. Ann, Meeting EGS, Abstracts*, Vienna.

Dimitrijević M.D. & Grubić A. 1977: Models of geotectonic development of the northestern Mediterranean. In: Janković S. (Ed.): Metallogeny nad plate tectonics in the northeastern Mediterranean. *IGCP Project No. 3, Faculty of Mining and Geology*, Belgrade, 21–103.

ECE-UN 1998: Economic Commission for Europe, Committee on Sustainable Energy — United Nations: International Classification of in-Seam Coals. *Energy* 19, 1–41.

ECE-UN 1999: Economic Commission for Europe, Committee on Sustainable Energy — United Nations: International Codification System for Low-Rank Coals. *Energy* 9, 1–19.

ECE-UN 2000: Economic Commission for Europe, Committee on Sustainable Energy — United Nations: International Classification for Low-Rank Coals. *Energy* 12, 1–21.

Ercegovac M., Grgurović D., Bajc S. & Vitorović D. 2003: Oil shales in Serbia: geological and chemical-technological investigations, actual problems of exploration and feasibility studies. In: Vujić S. (Ed.): Mineral material complex of Serbia and Montenegro at the crossings of two millenniums. *Margo-Art*, Belgrade, 368–378 (in Serbian, with a summary in English).

Ercegovac M., Životić D. & Kostić A. 2006: Genetic-industrial classification of brown coals in Serbia. *Int. J. Coal Geol.* 68, 39–56.

Grubić A. 1974: Eastern Serbia, new global tectonic and influence on tectonic of the north branch of the Alpides. In: Janković S. (Ed.): Metallogeny and concepts of the geotectonic evolution of Yugoslavia. *Faculty of Mining and Geology*, Belgrade, 153–182 (in Serbian).

Grubić A. 1980: Yugoslavia: Outline of Yugoslavian geology. *26th Int. Geol. Congr.*, Paris–Belgrade, *Guide-Book: Excursions* 201A, 5–49.

Janković S. 1967: Metallogenic epoch and ore areas of Yugoslavia. *Faculty of Mining and Geology*, Belgrade, 1–151 (in Serbian).

Janković S. 1974: Metallogenic provinces of Yugoslavia in time and space. In: Janković S. (Ed.): Metallogeny and concepts of the geotectonic evolution of Yugoslavia. *Faculty of Mining and Geology*, Belgrade, 37–63 (in Serbian).

Janković S. 1977: Major Alpine deposits and metallogenic units in the NE Mediterranean and concepts of plate tectonics. In: Janković S. (Ed.): Metallogeny and plate tectonics in the NE Mediiterranean. *UNESCO/IGCP No. 3. Faculty of Mining and Geology*, Belgrade, 105–172.

Janković S. 1982: Yugoslavia. In: Dunning F.W., Mykura W. & Slater D. (Eds.): Mineral deposits of Europe. Vol. 2. Southeast Europe. *Mineral. Soc. Inst. of Mining and Metallogeny*, 143–198.

Janković S. 1987: Genetic types and major Triassic deposits of the Dinarides, Yugoslavia. In: Janković S. (Ed.): Mineral deposits of the Tethyan Eurasian metallogenic belt between the Alps and the Pamirs. *Faculty of Mining and Geology*, Belgrade, 11–33.

Janković S. 1990: The ore deposits of Serbia: Regional metallogenic settings, environments of deposition, and types. *Faculty of Mining and Geology*, Belgrade, 760 (in Serbian, with a summary in English).

Janković S. 1997: The Carpatho-Balkanides and adjacent area: a sector of the Tethyan Eurasian metallogenic belt. *Mineralium Deposita* 32, 5, 426–433.

Janković S. & Jelenković R. 1997: Tertiary antimony deposits in SE Europe and Central Anatolia: Mineral associations and types of mineralization. In: Piskin O., Ergun M., Savascin M.Y. & Tarcan G. (Eds.): International Earth Sciences Colloquium on the Aegean Region (ISCA) 1995, Vol.-II, 549–565.

Janković S., Grubić A. & Romić K. 1983: Metallogenetic map of Yugoslavia 1 : 500,000. *Federal Geol. Inst.*, Belgrade.

Janković S., Serafimovski T., Jelenković R. & Čifliganec V. 1997: Metallogeny of the Vardar zone and Serbo-Macedonian Mass. In: Boev B. & Serafimovski T. (Eds.): Magmatism, metamorphism and metallogeny of the Vardar zone and Serbo-Macedonian Mass. *IGCP* 356, *Faculty of Mining and Geology*, Štip, 29–67.

Janković S., Jelenković R. & Vujić S. 2003: Mineral resources and potential prognosis of metallic and non-metallic mineral raw materials in Serbia and Montenegro at the end of the XXth century. *Monograph. Engineering Academy of Serbia and Montenegro, Margo-Art*, Belgrade, 1–875 (in Serbian).

Jelenković R. 1998: Gold mineralizations in the western part of the Bor metallogenic zone (East Serbian sector of the Carpatho-Balkan metallogenic province). *XVI Congress of the Carpathian-Balkan Geological Association, Viena, August 30th to September 2nd*, 1–250.

Jelenković R., Serafimovski T. & Lazarov P. 1997: Uranium Mineralization in the Serbo-Macedonian Massif and the Vardar zone: Types and distribution pattern. In: Boev B. & Serafimovski T. (Eds.): Magmatism, metamorphism and metallogeny of the Vardar zone and Serbo-Macedonian Mass. *IGCP* 356, *Faculty of Mining and Geology*, Štip, 149–159.

JORC 2004: Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves. Prepared by the Joint Ore Reserves Committee of the Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia.

Karamata S. 1986: "The Diabase-chert Formation" — some genetic aspects. *Guide-book for the Third International Conf. of Siliceous deposits. IGCP* 187, *Yug. Comm.*, Belgrade, 31–41.

Karamata S. & Krstić B. 1996: Terranes of Serbia and neighbouring areas. In: Knežević-Đorđević V. & Krstić B. (Eds.): Terranes of Serbia. The formation of the geologic framework of Serbia and the adjacent region. *Faculty of Mining and Geology, Comm. Geodynamics Serb. Acad. Sci. Arts*, 25–40.

Karamata S., Majer V. & Pamić J. 1980: Ophiolites of Yugoslavia. *Ophiolite, Spec. Iss. Tethyan Ophiolites* 1, 105–125.

Karamata S., Krstić B. & Stojnov R. 1992: Terranes from Adriatic to the Moesian Massif in the Central Part of the Balkan Peninsula. *Terra Nova,* 4, *Abstract suppl.* 2, *Alcapa Symp., Gray*, Graz 1992, 1–36.

Karamata S., Krstić B., Dimitrijević D.M., Dimitrijević M.N., Knežević V., Stojanov R. & Filipović I. 1997: Terranes between the Moesian plate and the Adriatic sea. *IGCP No. 276: Terranes maps and terrane description. Ann. Géol. Pays Hellén*. 37, 429–477.

Knežević V., Cvetković V., Resimić K., Memović E. & Živković P. 1997: Wall-rock alterations and their significance for the Pb, Zn and Cu ore deposits investigation in Serbia. In: Romić K. & Kondžulović R. (Eds.): Ore deposits exploration. *Faculty of Mining and Geology*, Belgrade, 28–32 (in Serbian).

Kober L. 1952: Leitlinien der Tektonik Jugoslawiens. *Serb. Akad. Wiss., Sonderausgabe, CLXXXIX, Geol. Inst.*, Belgrade 3, 1–64.

Kostić A. 2000a: The generative petroleum potential of the Tertiary sediments in the Banat Depression (Pannonian Basin). *AAPG Bull.* 84, 11, 1866.

Kostić A. 2000b: The generative petroleum potential of the Tertiary sediments in the Banat Depression. *Ph.D. Thesis, University of Belgrade, Faculty of Mining and Geology*, 318 (in Serbian).

Kostić A. & Ercegovac M. 2002: Modeling of petroleum generation in the Banat Depression (Pannonian Basin). *Geol. Carpathica* Spec. Issue, 53, 110–113.

Mudrinić Č. & Seke L. 1997: Copper deposits in Tulare ore field, South Serbia. In: Romić K. & Kondžulović R. (Eds.): Ore deposits exploration. *Faculty of Mining and Geology*, Belgrade, 347–356 (in Serbian).

Putnik S. 1981: Metallogeny of copper deposits related to the Jurassic Diabase-Chert Formation and its comparision to the Triassic spilite-keratophyre-porphyrite formation of the Podrinje-Polimlje district. *Monograph, Spec. Publ. Geoinst.*, Belgrade, 1–190 (in Serbian).

Resimić K., Karamata S., Popević A. & Balogh K. 2000: The Eastern branch of the Vardar zone — the scar of the main Vardar ocean. In: Karamata S. & Janković S. (Eds.): Proceedings of the Int. Symp. Geology and metallogeny of the Dinarides and the Vardar zone. *Academy of Scienes and Arts of the Rep. Srpska*, Banja Luka–Srpsko, Sarajevo, 81–85.

Simić M. 1997: Geological structural features of the Besna Kobila zone in SE Serbia. In: Boev B. & Serafimovski T. (Eds.): Magmatism, metamorphism and metallogeny of the Vardar zone and Serbo-Macedonian Mass. *IGCP* 356, *Faculty of Mining and Geology*, Štip, 185–195.

Vakanjac B. 1992: Geology of non-metallic mineral deposits. *Faculty of Mining and Geology*, Belgrade, 1–250 (in Serbian).

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