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CRETACEOUS KARST BAUXITES IN THE APUSENI MTS. IN THE SW CARPATHIANS AND THE VLASENICA AREA IN THE DINARIDES: MINERALOGY AND GEOCHEMISTRY

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The karst bauxite areas of the Northern Apuseni Mts. in the SW Carpathians, and Vlasenica in the Inner Dinarides, are characterized by bauxites of Cretaceous age but vary in bauxite composition. The Vlasenica bauxites consist of boehmite, hematite and kaolinite, and locally are epigenetically kaolinized. The Apuseni Mts. bauxites in the Bihar Mts. and Pădurea Craiului are metamorphosed by banatite intrusions and consist of corundum, diaspore, boehmite, magnetite, hematite and kaolinite and locally some chlorite. The trace element geochemistry, based on studies of B, Ba, Be, Co, Cr, Cu, Ga, La, Mn, Mo, Nb, Ni, Pb, Sc, Sr, V, Y, Zn and Zr, indicate that both Vlasenica and Apuseni Mts. bauxites have been formed by in situ bauxitization but that their diagenesis and later histories differ. The bauxite diagenesis occurred in Vlasenica under oxic, and in Apuseni Mts. under unoxic, conditions. Later, the Vlasenica bauxites were locally epigenetically kaolinized, in geochemically open systems. The Apuseni Mts. bauxites have been metamorphosed due to the thermal influence of banatite intrusions, which produced corundum and magnetite in geochemically closed systems.

Key words: karst bauxite, mineralogy, geochemistry, bauxite alteration, Apuseni Mts., Carpatho-Balkanides, Vlasenica area, Dinarides

INTRODUCTION

The Carpatho-Balkanides (CB) and the Dinarides (DIN) constitute the northeastern parts of the Mediterranean belt of karst bauxites. Both CB and DIN are characterized by numerous karst bauxite deposits and occurrences, varying in age and composition and distributed in several bauxite provinces. However, two of the bauxite areas with bauxites of nearly the same age, one in DIN and the other in CB, are very interesting due to some specific mineralogical features of bauxites. The Vlasenica area in the Inner Dinarides, a karst bauxite province of DIN, is characterized by boehmitic bauxites and some specific epigenetic transformations. The Apuseni Mts. area in the Inner Dacides of CB (SW Carpathians or Western Romanian Carpathians) is characterized by boehmitic-diasporic-corundum bauxites.

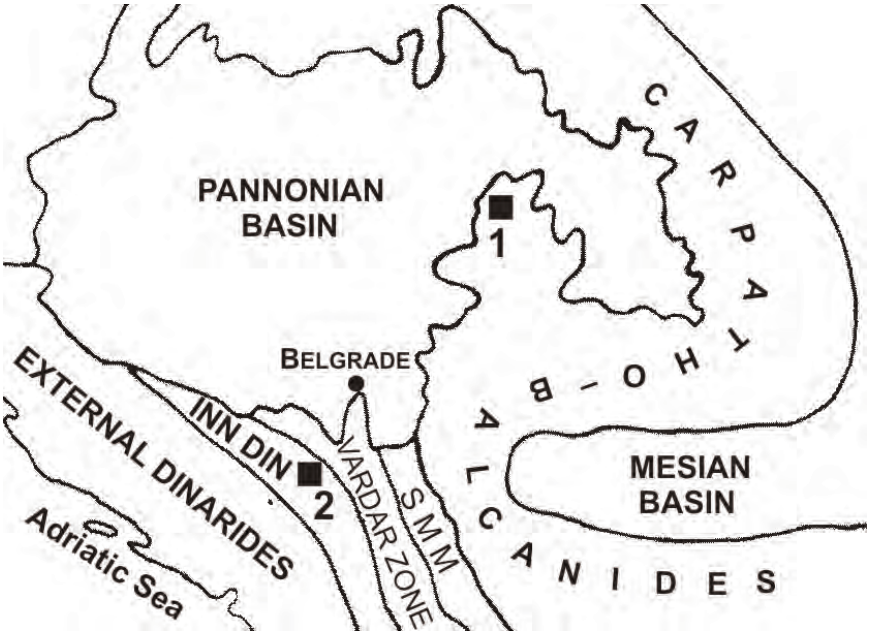
This paper presents main mineralogical and geochemical features of the bauxites in these two areas and discusses and compares their origin and genesis. For the Apuseni Mts., new mineralogical, chemical and trace element data are reported.

GEOLOGICAL SETTINGS

The Inner Dinarides (IDIN) and the Inner Dacides (IDAC) are units of DIN and CB adjoining the Pannonian Basin at the south and east, respectively (Map 1). The Apuseni Mts. are units of the IDAC, i.e. part of the Carpatho-Balkanides which adjoin the Pannonian Basin at the south and east, respectively. In IDIN, bauxite deposits are of Cretaceous age and are concentrated mostly in two bauxite areas, Vlasenica and Grebnik, which are characterized by boehmitic and diasporic bauxites, respectively. In the Vlasenica area, bauxites have not been affected by the Tertiary dacitic-andesitic magmatism at the adjacent Srebrenica area. On the other hand, an epigenetic bauxite kaolinization is reported (Dangić 1985; 1988). In the Grebnik area bauxites are diasporic.

In the Northern Apuseni Mts. area (AM) in IDAC, the bauxite deposits are of Cretaceous age and are characterized by a specific and rather complex mineralogical composition. Bauxite deposits appear in two regions, near Remeți in the Bihar Mts. (BM) and the Pădurea Craiului (PC), and have been subject to a thermal metamorphism influenced by

the Laramic magmatism (banatites) (Bárdossy 1982; Бушинский 1975; Cochet 1971; Mantea 1985; 1986/87; Papui & Minzatu 1969). These bauxites are of the boehmitic-diasporic-corundum type and contain also some magnetite and chlorite.



Map. 1. - The geological sketch map of the realm of the Carpatho-Balcanides and the Dinarides with position of the investigated karst bauxitic areas.
INN DIN= Inner Dinarides; SMM= Serbo-Macedonian Mass; The investigated bauxitic areas: 1- The Apuseni Mts. area, 2- The Vlasenica area.

MATERIALS AND METHODS

Bauxites samples from AM have undergone mineralogical, chemical and trace element analyses. In the mineralogical studies, the method of X-ray powder diffraction analyses (XRD) and a Philips PW-1050/25 diffractometer equipped with a PW-1730 generator, $Cu_{K\alpha}$ radiation and a graphite monochromator were applied.

In the chemical analyses, classical methods of wet chemical and spectrophotometric analyses (atomic absorption spectrophotometer PERKIN-ELMER 373) were used. Trace elements have been analyzed using emission spectrometric analyses. Excitation of samples in a

controlled atmosphere (O+Ar), a spectrograph with crossed dispersion (STE-1) and internal standards (Ge and Pd) and a geochemical reference standard (bauxite BX-N) have been applied. The following elements have been analyzed: B, Ba, Be, Co, Cr, Cu, Ga, La, Mn, Mo, Nb, Ni, Pb, Sc, Sr, V, Y, Zn and Zr.

RESULTS AND DISCUSSION

THE VLASENICA AREA BAUXITES

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The Vlasenica area bauxite is characterized by numerous bauxite deposits with bauxite bodies localized in karstic depressions in Middle Triassic limestones covered by Upper Cretaceous limestones and/or sandy/clayey limestones of Upper Cretaceous or Neogene age. The ore bodies appear as discontinuous layers, lenses, and pockets within limestone overlain by partly or completely eroded hanging wall rocks. The deposits range in size from several tens of thousands to more than ten million tons of bauxite. Braćan and Kosturi deposits are among the largest. Bauxite geology, mineralogy and geochemistry of bauxite in the area are studied in detail (Dangić 1985a; 1985b; 1988; 2003; Maksimović & Dangić 1984).

The Vlasenica bauxites are boehmitic, have high iron content and are characterized by a red matrix and reddish-brown oolites/pisolites. Mineralogically, they consist chiefly of boehmite, hematite, kaolinite and TiO_2-minerals (anatase and rutile) (Tab. 1). Boehmite and kaolinite are most abundant in the matrix and hematite is most abundant in oolites/pisolites. Chemically, bauxites are characterized by high iron content and rather low silica content. The chemical composition and trace element contents in bauxites and clayey bauxites are considered based on data from the Kosturi and Braćan deposits.

The Vlasenica bauxites are characterized by high alumina and iron contents (Al_2O_3 45,35-68,40 %, Fe_2O_3 20,19-36,58 %), low silica content (1,98-9,46 %), and some TiO_2, MgO and CaO (2,50-3,27 %, 0,24-0,85 %, and 0,04-0,12 %, respectively) (Tab. 2). The clayey bauxites contain less alumina, iron and TiO_2 (31,19-40,11 %, 11,54-12,41 % and 1,33-1,83 %, respectively) and more silica (27,12-39,92 %) and MgO (0,98-1,50 %) and CaO (0,24-0,52 %).

Table 1. - Mineralogical composition of bauxites from the Vlasenica and Apuseni Mts. areas.

Mineral	Vlasenica area		Apuseni Mts. Bihar Mts.		PC[1]
	bauxite	kaolinized bauxite	clayey baux.	bauxite	bauxite
Boehmite	+			+	
Neoboehmite		+			
Diaspore		+	+	+	
Corundum			+	+	+
Kaolinite	+		+	±	
Neokaolinite		+			
Chlorite					+
Hematite	+		±	+	+
Magnetite			±		+
Goethite		+	+	±	
Illmenite	+		+	+	+
Calcite			+		

[1] - Padurea Craiului Mts.

Table 2. - Partial chemical composition of bauxites in the Apuseni Mts. and Vlasenica areas (in %).

	Apuseni Mts. Bihor Mts		PCM[2]	Vlasenica[1]		
	clayey baux	bauxite	bauxite	clayey bauxite	bauxite	kaolinized bauxite
n[3]	2	3	1	4	12	1
SiO_2	28.69-39.6	13.82-21.80	10.48	27.12-39.92	1.98-9.46	45.35
TiO_2	2.53-2.87	2.74-2.83	2.77	1.33-1.83	2.50-3.27	0.03
Al_2O_3	35.00-37.30	50.02-70.04	54.06	31.19-40.11	45.35-68.40	39.11
Fe_2O_3	3.60-23.90	4.81-16.03	21.02	11.54-12.41	20.19-36.58	0.12
FeO	0.78-1.15	0.53-1.12	0.86			0.00
MnO	0.03-0.17	0.10-0.28	0.09	0.01-0.06	0.06-0.28	0.00
MgO	0.04-0.60	0.14-0.6	0.29	0.98-1.50	0.24-0.85	1.03
CaO	3.80-3.90	0.05-0.40	0.25	0.24-0.52	0.04-0.12	0.09

[1] - Kosturi and Braćan deposits. [2] - Padurea Craiului Mts. [3] - Number of analyses.

The following trace elements: B, Ba, Be, Co, Cr, Cu, Ga, La, Mn, Ni, Pb, Sc, Sr, V, Y, Zn and Zr have been studied in bauxites and clayey bauxites (Tab. 3). In bauxites, each of these elements appears in both deposits in approximately the same range of concentration. Mn is most abundant, with contents of 450-2200 ppm. It is followed by Zr, Cr, Ni, V and Pb, which appear in contents up to 300-450 ppm (Zr 115-450; Cr 192-420; Ni 55-300; V 100-310; Pb 55-335). Zn, Y, La, Ga and B appear in contents of up to 90-180 ppm (Zn 64-180; Y 37-170; La 32-130; Ga 25-110; B 32-90). Sc, Sr, Cu and Co are low abundant, as low as up to 45-58 ppm (Sc 15-58; Sr 10-55; Cu 6-52; Co 11-45). Be and Ba appear in very low contents, as low as 5.6-15 and <3-14 ppm, respectively.

The clayey bauxites are very similar to the bauxite in trace element contents. However, they contain more Ba (36-105 ppm) and somewhat less Co, Cr, and Ga.

Kaolinized bauxite is locally present to a small extent in several of the deposits, but the process of kaolinization has been studied in detail in the Braćan deposit (Dangić 1985a; 1988). Bauxite kaolinization appears as an epigenetic process around fissures in bauxites. Near the fissure, the bauxite matrix has been fully kaolinized and further into the bauxite (in the transition zone) it was boehmitized. The reducing silica-containing solutions descended through fissures and reacted with bauxite.

Table 3. - Trace element contents in bauxites of the Vlasenica area (in mg/kg=ppm).

	Kosturi deposit		Braćan deposit	
	clayey bauxite	bauxite	bauxite	kaolinized bauxite[1]
n[2]	4	12	18	1
B	26-110	36-85	32-90	44
Ba	36-105	<3-5	<3-14	-
Be	2-5.6	5.6-15	5.6-15	3.5
Co	5-21	11-38	21-45	64
Cr	105-320	192-380	240-420	-
Cu	8-26	15-52	6-32	-
Ga	6-33	41-110	25-60	-
La	27-45	32-83	34-130	-

Mn	74-435	850-1900	430-2200	-
Ni	17-220	120-260	55-300	560
Pb	68-130	130-335	55-210	-
Sc	7-33	25-58	15-34	-
Sr	19-76	10-28	12-55	-
V	72-230	130-310	100-225	-
Y	32-40	37-102	43-170	-
Zn	<30-150	64-180	84-170	70
Zr	200-460	240-520	115-450	15

[1] - Matrix of kaolinized bauxite (from: Dangić, 1985).
[2] - Number of analyses.

In a rather complex geochemical Si-metasomatic process, iron, titanium, and excessive aluminum have been removed from the system (Tab. 2). Additionally, almost all trace elements except B, Be, Co, Ni, Zn and traces of Zr have been removed (Table 3). All these indicate that the process occurred in a geochemically-thermodynamically open system.

THE APUSENI MTS. AREA BAUXITES

Bauxites in AM appear in karstic depressions in Middle Triassic limestones (Cochet 1971; Mantea 1985; 1986/87; Papui & Minzatu 1969). In BM, the bauxite is in the limestones of Upper Tithonian age, and is covered by Barremian-Bedoulian limestones. The ore bodies appear as discontinuous layers and lenses within limestone and are overlain by partly or completely eroded hanging wall rocks. The bauxite is compact and consists of diaspore, hematite, goethite, kaolinite, anatase, chlorite and some pyrite (to 0,2%). In PCM, the bauxite is in the limestones of Oxfordian-Kimmeridgian to Tithonian age, and is covered by Neocomian limestones. The ore bodies appear as discontinuous layers and lenses within limestone and are overlain by partly or completely eroded hanging wall rocks. Unmetamorphosed bauxites consist of diaspore, hematite, kaolinite, anatase and some leptochlorite (to 8%). The black bauxites with corundum appear at/near the contact with the Upper Senonian-Lower Paleogene banatite magmatites. In the PC deposit group, epigene veins of anatase and rutile 30-100 μm wide have been observed by an electron microprobe study (Bárdossy & Panto 1970).

Five samples representing metamorphosed bauxite and clayey bauxite from BM and a sample of metamorphosed bauxite from PCM have been studied and the results are presented in Tables 1, 2 and 4. Mineralogical studies showed that bauxites consist of corundum, magnetite, hematite, and some TiO_2-minerals (illmenite) (Table 1). In addition, the BM bauxite contains diaspore and boehmite and may contain kaolinite and goethite; the PC bauxite contains chlorite. The metamorphosed clayey bauxites (from BM) consist of corundum, diaspore, kaolinite, magnetite and/or hematite, goethite, and contain some calcite.

Chemically, the BM bauxites are characterized by high but variable contents of alumina, silica and iron (Al_2O_3 52,20-70,04 %, SiO_2 13,82-21,80 %, Fe_2O_3 4,81-21,20 %), and some TiO_2, MgO and CaO (2,74-2,83 %, 0,14-0,60 %, and 0,05-0,40 %, respectively) (Table 2).

Table 4. - Trace element contents of bauxites from the Apuseni Mts. (in mg/kg=ppm).

	Bihor Mts.[1]					PCM[2]
No.	1	2	3	4	5	6
B	<1	<1	<1	3	8	25
Ba	<3	<3	<3	<3	18	5
Be	3	4.4	3	2.4	4.5	3
Co	11	18	8	11	24	27
Cr	250	225	330	340	460	250
Cu	5	14	22	12	16	9
Ga	27	32	34	75	90	37
La	95	39	56	32	56	100
Mn	320	1750	2800	1050	2400	900
Ni	68	110	38	30	120	140
Pb	14	11	105	95	95	70
Sc	33	43	40	85	65	70
Sr	<3	<3	<3	<3	74	32
V	195	250	270	475	350	330
Y	37	45	60	48	52	120
Zn	115	210	88	<30	88	110
Zr	600	660	1050	700	510	880

[1] - No.: 1-2 clayey bauxite, 3-5 bauxite. [2] - Padurea Craiului Mts. bauxite.

The PC bauxite is very similar in composition to the high-iron BM bauxites. It contains 54,06 % Al_2O_3, 10,48 % SiO_2, 21,02 % Fe_2O_3, 0,86 % FeO, 2,77 % TiO_2, 0,29 % MgO and 0,25 % CaO.

In comparison to bauxite the BM clayey bauxite contains less alumina (35,70-37,30 %) and more silica (28,69-39,60 %) and CaO (3,80-3,90 %), and nearly the same iron (3,60-23,90 % Fe_2O_3, 0,78-1,15 % FeO), TiO_2 (2,53-2,87 %) and MgO (0,04-0,60 %).

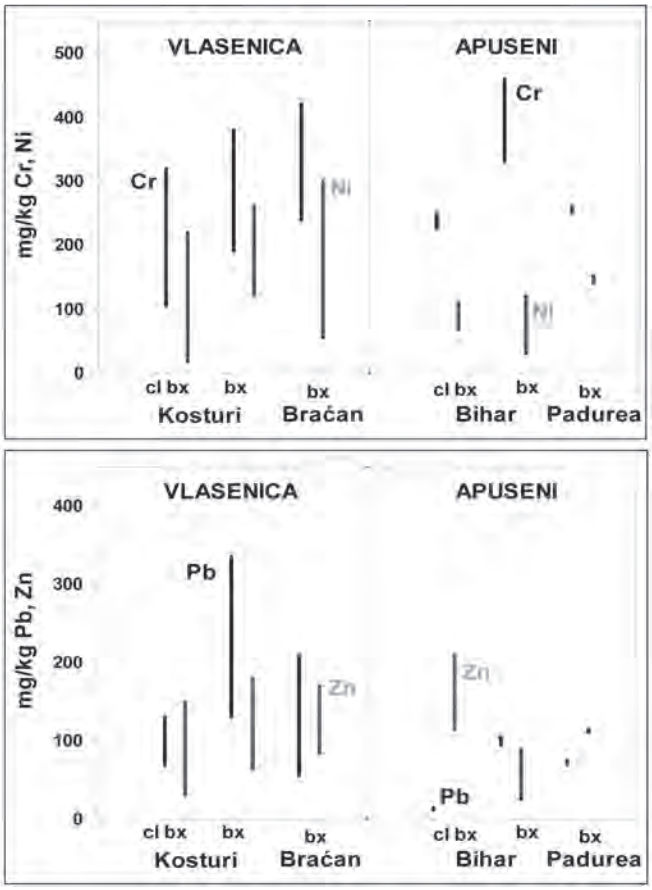

Fig. 1. The geological sketch map of the realm of the Carpatho-Balcanides and the Dinarides with position of the investigated karst bauxitic areas.

INN DIN= Inner Dinarides; SMM= Serbo-Macedonian Mass; The investigated bauxitic areas: 1- The Apuseni Mts. area, 2- The Vlasenica area.

The following trace elements: B, Ba, Be, Co, Cr, Cu, Ga, La, Mn, Ni, Pb, Sc, Sr, V, Y, Zn and Zr have been detected in bauxite and clayey

bauxite (Table 4). Regarding the trace element content, there are no significant differences between the BM and PC bauxites. The only significant difference is the higher contents of B, La and Y in the PC bauxite. Among the analyzed trace elements, Mn, Zr, V and Cr appear to be the most abundant. In bauxites, Mn is as abundant as 900-2800 ppm; Zr is in the range 510-1050 ppm, V ranges from 270 to 475 ppm and Cr from 250-460 ppm.

A group of elements involving Ni, Pb, Zn, Ga, Sc, Y, and La appear in contents of up to around 100 ppm. – i.e. in the following ranges: Ni 30-140 ppm; Pb 70-105ppm; Zn <10-110 ppm; Ga 34-90 ppm; Sc 40-85 ppm; Y 48-60 ppm in BM and 120 ppm in PC; La 32-56 ppm in BM and 100 ppm in PC. Less abundant Sr, Ba, Co, Cu, B, and Be appear in the following ranges: Sr <3-74 ppm, Ba <3-18 ppm, Co 8-27 ppm, Cu 9-22 ppm, B <1-8 in BM and 25 ppm in PC, and Be 3-4,5 ppm. The BM clayey bauxites are generally similar in trace element contents to the BM bauxites. The only marked difference is a lower content of lead (95-105 ppm in bauxite and 11-14 in clayey bauxite).

The ranges of contents of selected trace elements: chromium, nickel, lead, zinc, lanthanum, yttrium, vanadium and zirconium, are compared for bauxites of both bauxitic areas in Fig. 1 and 2. The distribution of zinc and lanthanum are rather similar in both areas. The bauxites of the Vlasenica area are generally richer in nickel, lead and yttrium, but bauxites in the Apuseni Mts. area are generally richer in chromium, vanadium and zirconium.

GENESIS AND GEOCHEMICAL EVOLUTION OF BAUXITES

Mineralogical and geochemical features of the Vlasenica bauxites indicate that they have been formed by an *in situ* karst bauxitization. The bauxite diagenesis appeared under oxic conditions. Later, some deposits were locally exposed to an epigenetic silicification, which resulted in the kaolinization of bauxite (Dangić 1983; 1985a; 1988). The process was geochemically rather complex. The epigenetic kaolinite replaced all minerals in the matrix but diaspore, boehmite (neoboehmite) and goethite have been formed in oolites/ooids. During the kaolinization, the excess of alumina and iron and almost all trace elements have been removed from the matrix. The process was metasomatic and appeared

in a geochemically open system. In Tertiary, an intense dacite-andesite magmatism with hydrothermal ore formation appeared in the adjacent Srebrenica area. In the Vlasenica area it produced a deposition of pyroclastics but any metamorphic or hydrothermal effects to bauxites have not been found.

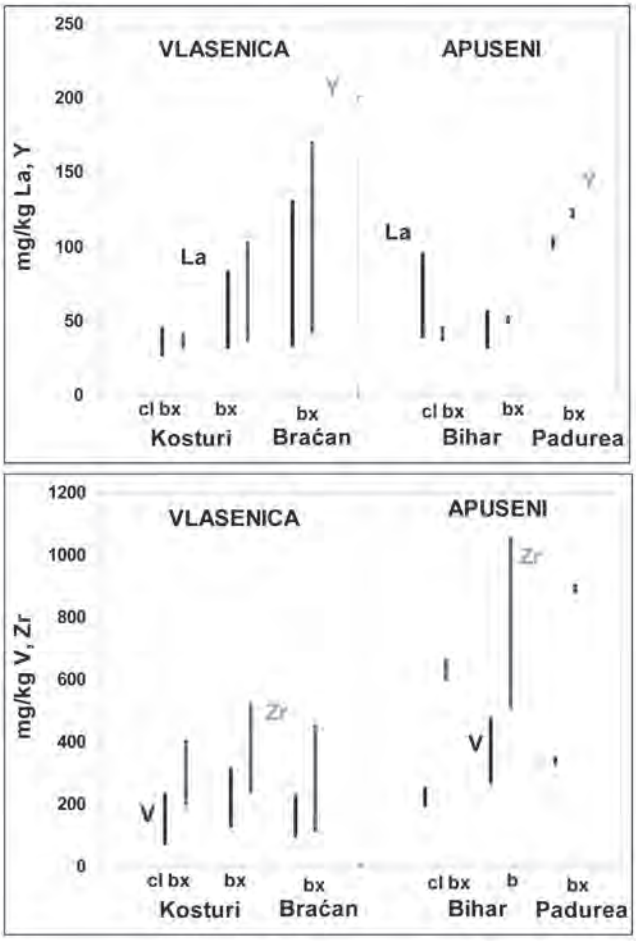

Fig. 2. - The ranges of variation of lantan and yttrium (upper) and vanadium and zinc (lower) in bauxites of the Vlasenica and the Apuseni Mts. bauxitic areas.

Mineralogical and geochemical features of the AM bauxites indicate that they have been formed as boehmitic/diasporic bauxites, in the same way as bauxites in the Vlasenica area. However, diaspore may be either of singenetic mineral (like in the Grebnik bauxites of IDIN) or produced during metamorphic events. During bauxite diagenesis some chlorite and

pyrite have been formed in some deposits. After the bauxite diagenesis, bauxite deposits have been exposed to thermal metamorphism caused by magmatic (banatite) intrusions.

The metamorphism resulted in the formation of corundum and magnetite in the bauxite, according to the following reactions:

$2AlOOH \rightarrow Al_2O_3 + H_2O$ …...…….....(1)

boehmite corundum

$3Fe_2O_3 + H_2O \rightarrow 2FeO{\cdot}Fe_2O_3 + 2OH$ .....(2)

hematite magnetite

Metamorphism did not change the bulk chemical composition and trace element geochemistry of bauxite. In other words, it was an isochemical process. This indicates that it was a thermal metamorphism without influence of hydrothermal solutions as was proposed by some former models. The micro-veins of rutile/anatase indicate that some micro-scale transport in the system occurred during the metamorphism. It was enabled by a restricted amount of water in the system which was liberated from the Al-monohydrates during corundum formation.

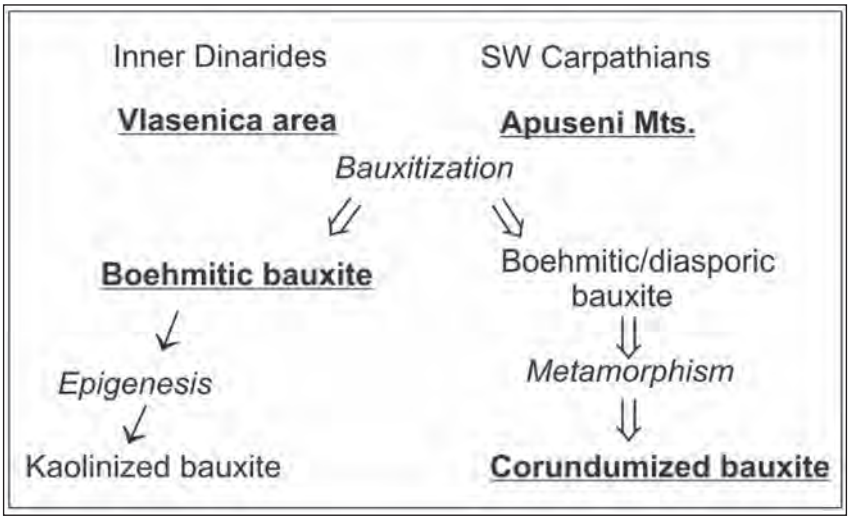

Fig. 3. - Karst bauxite formation and evolution in the Vlasenica area (Dinarides) and the Apuseni Mts. (SW Carpathians).

Taking everything into account, it may be concluded that the Vlasenica bauxites and the Apuseni Mts. bauxites were formed in the

same way but that their later histories differ (Fig. 2). They were formed by an *in situ* bauxitization of aluminosilicates in karst depressions, as boehmite-hematite bauxites. However, they may have undergone the diagenesis under diverse conditions - in the Vlasenica area under oxic, and in the Apuseni Mts. area under unoxic conditions. As a result, in the Apuseni area bauxites may contain some chlorite and magnetite and/or less iron.

In their post-diagenetic geological history, bauxites in the Vlasenica area have been locally exposed to a process of the epigenetic kaolinization, i.e. resilification, in a geochemically open system (Dangić 1985a; 1988). It appeared around fissures in bauxite deposits and resulted in a total kaolinization of the bauxite matrix which is associated with the removal of almost all trace elements.

On the other hand, in their post-diagenetic geological history, bauxites in the Apuseni Mts. area were thermally metamorphosed by banatite intrusions. This resulted in the corundumization/magnetitization of bauxite. As the metamorphism appeared in a geochemically closed system, in the corundumized/magnetitized bauxites the previous chemical and trace element composition has been preserved. Some fluid phase enabling micro-scale transport in the system was water-liberated from Al-monohydrate during corundum formation.

CONCLUSIONS

In the karst bauxite areas of Vlasenica in the Dinarides and the Apuseni Mts. in the Carpatho-Balkanides, bauxites are of Cretaceous age and appear as fillings of karst depressions but differ in mineralogy. In the Vlasenica area, bauxites are boehmic-hematitic and are to a small extent epigenetically kaolinized. In the Apuseni Mts. area, bauxites consist of diaspore, corundum and magnetite but some also contain some chlorite.

The trace element geochemistry indicates that bauxites in both areas have been formed by an *in situ* bauxitization in karst depressions. In Vlasenica, the bauxite diagenesis appeared under oxic conditions but afterwards the bauxite was kaolinized locally due to a process of silicification. The later process was metasomatic, i.e. it appeared in a geochemically open system.

In the Apuseni Mts., the bauxite diagenesis appeared partly under unoxic conditions and afterwards a thermal metamorphism connected with banatite intrusions caused corundumization and magnetitization of bauxite. The trace element geochemistry indicates that in the later process, contrary to some former models, the process of bauxite corundumization/magnetitization was not caused by hydrothermal solutions. In fact, it occurred in a geochemically closed system. Some fluid phase enabling micro-scale transport in the system was water-liberated from Al-monohydrate during corundum formation.

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КРЕДНИ КАРСНИ БОКСИТИ У АПУСЕНИ ПЛАНИНАМА У СЗ КАРПАТИМА И У ПОДРУЧЈУ ВЛАСЕНИЦЕ У ДИНАРИДИМА: МИНЕРАЛОГИЈА И ГЕОХЕМИЈА

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Р Е З И М Е

У раду су приказани резултати геолошких, минералошких и геохемијских истраживања карстних боксита у подручју северних Апусенских планина (Румунија), у Карпато-балканидима и у подручју Власенице (Босна и Херцеговина) у Динаридима (бокситоносна провинција Унутрашњих Динарида).

У оба бокситоносна подручја, боксити су кредне старости и сличног начина појављивања, у виду запуњења карстних депресија, али су заступљене и извесне значајне разлике у минералошким особинама боксита. У подручју Апусена, у рејонима Бихар планине и Pădurea Craiului, боксити су метаморфисани интрузијама банатита и изграђују их дијаспор, корунд и магметит а локално и нешто хлорита. У подручју Власенице, боксити су бемитско-хематитски а локално су, у мањој мери, епигенетски каолинисани.

Геохемија микроелемената, која је обухватила проучавања B, Ba, Be, Co, Cr, Cu, Ga, La, Mn, Mo, Nb, Ni, Pb, Sc, Sr, V, Y, Zn и Zrp, указује да су у оба бокситоносна подручја, Власеници и у Апусенима, лежишта боксита образована *in situ* бокситизацијом а да су разлике у њиховој минералогији везане за процесе дијагензе

и касниј геолошку историју. У подручју Власенице дијагенеза боксита одвијала се у геохемијским условима оксичне средине а у подручју Апусена у условима аноксичне средине.

У Власеници, у пост-дијагенетском периоду, локално, уз разломе у лежиштима боксита, дошло је до епигенетске алтерације боксита која се манифестовала као каолинизација боксита. Из кровине боксита богате силицијом, подземне воде кретале су се наниже кроз раседне зоне вршећи Si-метасоматозу (ресилификацију) боксита. Процес је имао зонарни карактер и поред епигенетског каолинита формирани су и необемит и дијаспор. У зони највеће алтерације, основа боксита потпуно је каолинисана што је праћено и одношењем скоро свих микроелемената.

У подручју Апусена, у пост-дијагенетском периоду, боксити су били изложени термалном метаморфизму, везаном за интрузије банатита, који је проузроковао корундизацију и магнетитизацију боксита. Геохемија микроелемената указује да се процес корундизације/магнетитизације боксита одвијао у геохемијски затвореном систему, што значи да се није одвијао под дејством хидротермалних раствора како се објашњавало у неким генетским моделима ранијих истраживача. По нашем моделу, у метаморфном систему могло је да буде нешто флуидне фазе - то је заправо била вода ослобођена из Al-монохидрата током образовања корунда, која је могла да омогући транспорт компоненти само у микро-скали.