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QUALITATIVE CHARACTERISTICS OF BAUXITE „OŠTRELJ“ NEAR BOSANSKA KRUPA

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SUMMARY

Qualitative characteristics of bauxite deposit „Oštrelj“ are defined through extensive laboratory testing of chemical and mineralogical-petrographic composition, and geomechanical characteristics. Chemical composition has shown that it is a relative poor bauxite with low Al/Si module (2,28). Low values of Al/Si module are result of lower Al_2O_3 concentration (48 %), and higher SiO_2 concentration (21 %), what these bauxites define as high silicic or »acidic«. Identified are increased concentrations of larger number of analyzed trace elements (B, Co, Cr, Li, Mn, Ni, Sn, V, Zn) comparing to the medium content in the Earth's crust. Mineralogical composition, structure and texture are uniform.

Holders of Al mineralization are bemite and diaspor (to a lesser extent) as crypto-crystalline phases of rock matrix. Lower Cretaceous age (K_1) of roof layers over bauxite deposit is paleontologicaly documented, while in the bauxite any fossils are not registrated. Values of geomechanical paramers of layers under and over bauxite is uniform. In bauxite value of compressive strength is increased, which is equivalent to chemical and mineralogical composition, and structural and textural characteristics of tested bauxite samples.

Key words: *chemical composition, mineralogical-petrographic composition, geomechanical parameters, bauxites, Oštrelj*

INTRODUCTION

Geological exploration of bauxite on the locality Oštrelj date from 1960. Researched are “Oštrelj 1” (lower deposit) and “Oštrelj 2” (larger deposit). On the smaller deposit exploitation has been performed.

With aim of expanding raw material base for the "Bauxite Mine" Bosanska Krupa, there were performed systematic sampling and testing of chemical, mineralogical and petrographic composition of bauxite, its geomechanical parameters as well as paleontological characteristics of bauxite and associated sediments.

Contribution to the understanding of bauxite geology in the wider area gave more geologists [1,2, 3,4, 5,6,7].

GEOMORPHOLOGICAL AND HYDROLOGICAL CHARACTERISTICS

Exploration area of Oštrelj is located about 17 km southeast of the Bosanska Krupa. Forest road connects this area with Jasenica (11 km), and further with regional road Sanski Most - Bosanska Krupa.

Wider area of Oštrelj belongs to hilly and mountainous terrains with an altitude 330 - 1200 m. Terrain is hilly-mountainous, with numerous of ridges and plateaus that have characteristics of small rocky fields, withe relative numerous number of karst forms (sinkholes), Figure 1. Speaking about geomorphological processes, there are developed karst, proluvial, deluvial and eluvial processes. The intensity of these processes is not large, considering good vegetative cover and slight inclination of slopes. Morphological characteristics of the terrain provide favorable conditions for the exploitation of bauxite deposite using some of the surface mining methods. Hydrographic network in the wider area is poorly developed. Main watercourse is the Una river, which drains the groundwater and surface water from this area into the Sava river.

According to data from Hydrometeorological Institute of Bosnia and Herzegovina, in the area prevails continental climate with humid character.

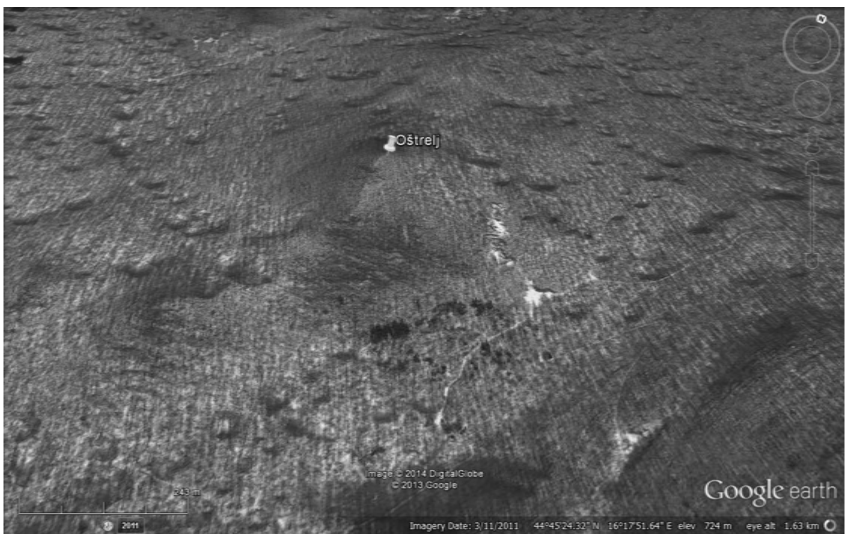

Figure 1. Geomorphology of deposit Oštrelj wider area (Google Earth 2011)

GEOLOGICAL STRUCTURE OF DEPOSIT „OŠTRELJ“ AND ITS WIDER AREA

In geological structure of the wider area participate Triassic, Jurassic, Cretaceous and Quaternary sediments, Figure 2. Underlayer is built of Upper Jurassic limestones (J_3), and overlayer consist of Lower Cretaceous limestones (K_1) [1]. Considering that bauxites occur ont the contact of Upper (J_3) and Lower Cretaceous limestones (K_1), their detailed description is given.

Upper Jurassic (J_3) mainly consist of massive reef limestones and quite subordinate of dolomites. Upper Jurassic is documented with abundant fauna of *Nerinea*, *Ellipsactinia* and *Sferactinia*.

Superpositioned package of Lower Cretaceous ($^1K_1$) lies concordantly over the Upper Jurassic with *Clypeina*. It is represented with gray, rarely black layered limestone with interlayers of dolomite. Among limestones distinctly are dominant micrite (with fossils and with transition into pelmicrite), while intraspares and oosparites are subordinate. Very rarely encountered are dolomitic pelsparites and dismikrites. Superpositioned package of Lower Cretaceous was separated based on presence of different *Dazicladaceas*.

Superpositioned package of younger Lower Cretaceous ($^2K_1$) was isolated in the areas where is developed older and younger superpositioned package of Lower Cretaceous. Here come in a package layered limestones with interlayers of dolomites. Limestones are represented by different varieties of micrites (pelmicrites, oomikrites and biomicrites) and pelsparites, intrasparites, intramikrosparites and intrasparudites. In tectonic terms, deposit Oštrelj belongs to structurally-facial unit Grmeč mountain, tectonic block Majkići-Lastva [5,6].

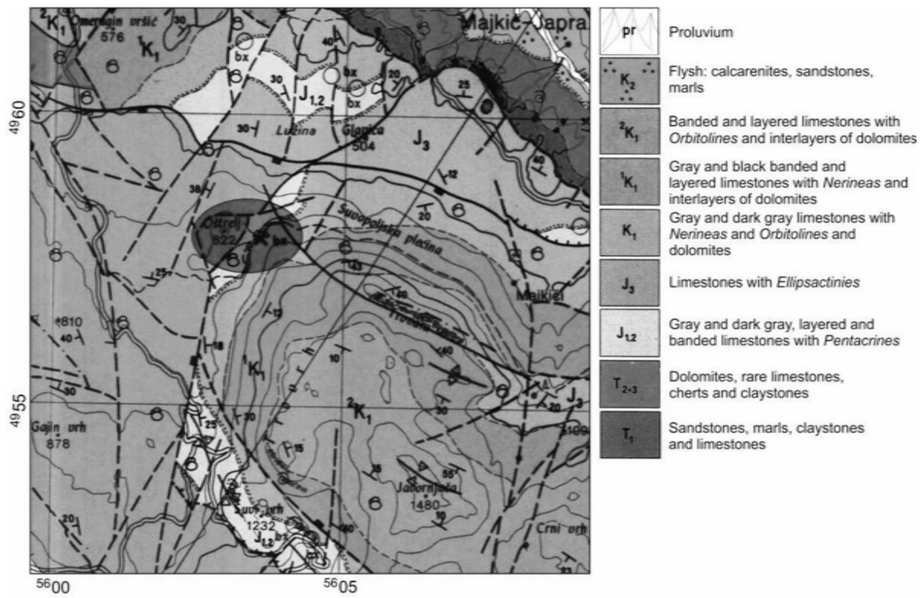

Figure 2. Geological map of deposit Oštrelj wider area (BGM, sheet Bosanska Krupa, scale R – 1 : 100 000)

Burić and Živaljević [4] are defined bauxite of Oštrelja as Upper Jurassic, where are discovered two bauxite deposits (underlying and contact). Underlying deposit covers area of about 8.000 m^2, average thickeness is about 4 m. Undelying stratum of deposit is uneven and presented with massive Upper Jurassic limestones wich contain *Cllipeinas* i *corals*. Average content of Al_2O_3 is 52,26 %, SiO_2 14,28 %, and Al/Si module is 3,7. Bauxite is dark red colored, compact and rare pisolitic. Contact deposit has the same stratigraphic position. Over substratum built by Upper Cretaceaous limestones lie dark red compact oolitic or pisolitic bauxites (thick about 10 m), then greenish grey bauxite (thick up to 1 m), dark red limestones (thick about 1 m), dark red bauxite (thick up to 5 m), and rooflaying Lower Cretaceaous limestones. Average thickeness of deposit is about 12 m. Quality of bauxite show variation. Average content of Al_2O_3 is 47,5 %, SiO_2 19,5 %, and Al/Si module is 2,44. Greenish grey bauxite have poorer quality: average values of Al_2O_3 (48,5 %) and SiO_2 (27,5 %) gave relatively low Al/Si module (1,76).

TEST METODS FOR BAUXITE AND ASSOCIATED SEDIMENTS

Samples of bauxite, systematically sampled from boreholes and exploratory pits, were subjected to chemical analysis, analysis of mineralogical and petrological characteristics, geomechanical parameters and paleontological characteristics. All the mentioned analysis, except mineral-petrographic, were performed in the laboratories of the Faculty of Mining, Geology and Civil Engineering, University of Tuzla. Mineral-petrographic analyzes were done in the lab Ltd. "Geominis" Belgrade.

Silicate chemical analysis of the main elements included 150 samples (from 121 boreholes and 29 from pits), and analyse using ICP OES (Inductively Coupled Plasma Optical Emission Spectrometry) on trace elements included 10 composite samples (six from four boreholes and from pits) . Test results are shown in Tables 1 and 2.

Optical testing of mineralogical and petrographic composition were performed on 10 samples (from 5 wells and 5 from pits). The tests were performed macroscopically and microscopically on the mineral ERC thin-sections in the reflective light using binocular microscope Leica DM 2500P. For the tested samples were taken and the numerous micrographs [8].
Paleontologically has processed 10 samples (from 5 boreholes and 5 from pits). The samples were examined macroscopic and microscopically [9].

Geomechanical analyses included three parameters: specific weight, bulk density (standard B.B8.035) and monoaxial compressive strength (standard EN 1926:2006 IDT) samples from underlayer, bauxite and roof layer [10].

TEST RESULTS OF BAUXITE CHEMICAL COMPOSITION

Test results of bauxite chemical composition are given in table 1. Due to extensiveness of the tests, just average values of major elements concentrations are shown.

Table 1. Major elements test results

Research work	Number of samples	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	LOI	sum	modul Al / Si
OŠ2	6	50,49	20,12	15,31	2,20	0,56	11,31	99,99	2,51
OŠ3	14	50,32	21,29	13,89	2,25	0,48	11,77	99,99	2,36
OŠ4	7	50,44	20,46	14,66	2,19	0,48	11,76	100,00	2,47
OŠ4a	5	49,58	20,76	15,61	2,18	0,52	11,34	99,99	2,39
OŠ5	7	49,29	20,64	15,68	2,24	0,51	11,64	100,00	2,39
OŠ6	8	49,40	20,03	16,06	2,14	0,49	11,88	100,00	2,47
OŠ17	4	47,71	21,35	15,41	2,17	0,75	11,74	99,13	2,23
OŠ18	7	47,29	22,60	15,62	2,23	0,57	11,69	100,00	2,09
OŠ31	8	49,44	20,79	16,53	2,18	0,72	11,96	101,61	2,38
OŠ33	4	48,75	20,81	15,36	2,28	0,48	12,33	100,00	2,34
OŠ37	2	47,41	21,43	16,63	2,18	1,13	11,23	99,99	2,21
OŠ38	2	49,61	20,86	15,08	2,14	0,85	11,47	100,00	2,38
OŠ39	3	50,13	20,51	14,28	2,12	0,48	12,34	99,86	2,44
OŠ40	10	47,45	22,89	14,76	2,19	1,10	11,60	99,99	2,07
OŠ41	8	49,23	20,52	15,76	2,19	0,51	11,79	99,99	2,40
OŠ43	9	48,98	20,98	15,45	2,17	0,71	11,71	100,00	2,34
OŠ44	3	47,90	21,13	16,40	2,19	0,52	11,85	99,99	2,27
average		*49,22*	*21,06*	*15,28*	*2,19*	*0,61*	*11,72*	*100,08*	*2,35*
PK	8	46,55	25,00	14,14	2,16	0,55	11,71	100,12	1,86
R1	1	47,10	21,12	17,03	2,20	1,10	11,45	100,00	2,23
R2	1	43,70	22,10	20,06	2,14	0,62	11,38	100,00	1,98
R3	4	47,27	21,83	16,01	2,23	0,57	12,00	99,92	2,17
R4	3	44,07	19,19	20,81	2,21	0,61	9,07	95,96	2,30
R5	2	48,60	20,98	16,30	2,21	0,70	11,22	100,00	2,32
R6	2	48,68	20,78	15,41	2,12	0,79	12,22	99,98	2,34
R7	1	47,42	22,40	15,24	2,10	1,10	11,74	100,00	2,12
R8	1	46,12	21,60	17,55	2,12	0,92	11,68	99,99	2,14
R9	1	47,40	21,22	16,69	2,15	1,10	11,44	100,00	2,23
R10	1	43,90	19,16	21,29	2,11	0,62	12,90	99,98	2,29
R11	1	51,00	20,52	14,63	2,22	0,49	11,14	100,00	2,49

R12	1	50,20	20,42	15,69	2,15	0,47	11,07	100,00	2,46
R13	1	47,10	21,41	16,67	2,20	1,10	11,52	100,00	2,20
R14	1	44,16	19,16	20,72	2,15	0,67	13,14	100,00	2,30
average		*46,91*	*21,91*	*16,39*	*2,18*	*0,67*	*11,47*	*99,54*	*2,16*

Chemical composition of bauxite from boreholes and pits is almost identical. Slight deviations were observed at concentrations of Al_2O_3 (49,22% i 46,91%), such as at module Al/Si which is slight higher in the boreholes (2,35) than in the pits (2,16). In correlation with previous research module Al/Si has lower values, comparing to analysis previously shown by Alagić i Lušić (1970) where module Al/Si was 3,81 (Oštrelj 1) and 2,79 (Oštrelj 2). Also, comparing new test results with previous test results of Sakača [3], where module Al/Si = 2,00, we can see a bit higher values in new research. High concentrations of SiO_2 (21,06 – 21,92 %) these bauxite classifie as "acid" or high silicon bauxite.
Trace elements concentrations are given in table 2. Elements B, Co, Cr, Li, Mn, Ni, Sn, V, Zn show increased concentrations compared to the average content in the Earth's crust (Taylor and McLennan, 2001). Low concentrations of Sr are result of low CaO content, where Sr can be isomorfically replaced with Ca.

Table 2. Trace elements chemical analysis results

	boreholes								pits					Taylor& McLennan, 2001.
	OŠ4	OŠ5	OŠ7	0Š33	OŠ39	OŠ41	aver.		R3	R4	R6	R7	aver.	
B	304	550	560	389	404	400	*434*	B	351	360	360	371	*361*	75
Co	424	261	263	281	260	269	*293*	Co	258	253	252	262	*256*	16
Cr	962	920	921	1090	1091	1090	*1012*	Cr	1036	1034	1423	1388	*1220*	74
Cu	335	248	252	242	231	227	*256*	Cu	309	307	281	270	*292*	40
Mn	1530	1204	1207	961	940	942	*1131*	Mn	893	890	717	890	*847*	680
Ni	179	103	109	99	95	94	*113*	Ni	123	124	151	132	*132*	40
V	518	703	701	740	780	796	*706*	V	835	832	815	802	*821*	110
Zn	717	190	195	790	162	167	*370*	Zn	250	243	170	164	*207*	65
Ba	75	69	70	84	88	88	*79*	Ba	59	60	102	104	*81*	480
Sr	39	48	50	50	55	55	*50*	Sr	35	34	38	34	*35*	385
Sn	37	31	35	35	34	34	*34*	Sn	36	37	35	34	*35*	5
Li	945	1620	1596	998	1044	1023	*1204*	Li	1098	1088	1619	1592	*1349*	21
La	370	251	252	352	327	327	*313*	La	138	139	207	204	*172*	28,3

MINERALOGICAL AND PETROGRAPHIC EXAMINATION OF BAUXITE

Macroscopic determination is determined that most samples of bauxite have almost identical mineralogical composition and structural-textural characteristics. Deviations shows a sample PK M7, taken from pit. Structural-textural characteristics and nomenclature of the analyzed samples are shown in Table 3. Microphotographs of typical samples are shown in the Figures 3 and 4.

Samples of bauxite are mainly darkly red colored. On the fractures rounded grains brown to black in color are visible. These grains correspond to pisolites of Fe hydroxide. Also visible are and some recesses from which pisolites during mechanical destruction were turned out. Along the fracture surfaces are observed gray to black manganese coatings. On the fresh fractures are visible fragments with partly rounded edges, which are identical in composition with pelitic ferruginuos matrix that binds them. In the fracture spaces nested to irregular accumulation of limonite are noticed.

Bauxites are made of cryptocrystalline ground mass with bemite-diaspor-pelitic(caolinite?) composition, or of matrix that binds many Fe oxides oolites and pisolites, as well as clasts of primary bauxite (Figure 3). Most of oolites and pisolites have terigenous embryo in the center.

Ferreous component mostly matches to the magnetite. At some grains is visible process of martitisation and transformation into hematite-martite. Process starts from the edge of the grain, and concentrically spreds to the the central part of oolite and pisolite. In this way is formed hematite-martite. In some grains this process is complete, and grains are transformed into hematite. At the grains of hematite allocations (hematoilmenite etc.) was not observed. Pyrite was identified, but just as sporadic.

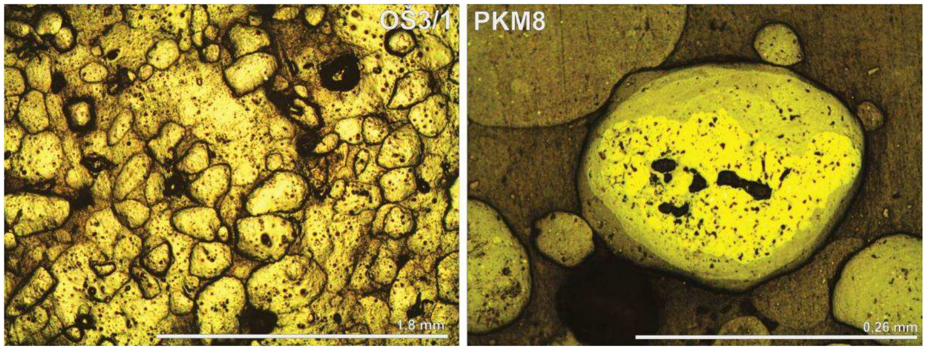

Figure 3. Microphoto of samples OŠ3/1 and PKM8 in the reflected light

Bauxite mineralization matches to the cryptocrystalline bemite and the diaspor (probable with caolinite), who build "pelitic"rock matrix.

Sample PK M7

The sample represents contact between red to brown bauxite and brecciated bauxite of the weathering zone's lower levels. Probably it belongs to peripheral facies where bauxite decomposition products are in contact with metamorphic rocks of lower metamorphism degree.

At the intersection of rock it is visible encroachment on thefoliation, where red pigmented phase of bauxite impinge in slated and brecciaed gray yellow rock. As part of it, oolite and pisolites with an infill of bright yellow clay are distinctive. Observed also are and the rectangular form of millimeter sizes, which correspond caolinized relics of basic or intermediate feldspar (?). Along the cracks of cleavage and foliation it is abundant Fe oxides and hydroxides mineralization, with oolites and pizolites in the main mass of rock.

Bauxite from lower part of weathering zone (which is tectonically disrupted - brecciaed and schisted) is optically tested. Clasts are composed of cryptocrystalline material with pelitic-carbonate composition. Rock matrix is composed of cryptocrystalline bemite and diaspor with pelite (caolinite?). A smaller part of the clasts fits to the matrix – bemite and diaspor mineralization, what illustrates multiphase succession of sedimentation within the bauxite depositional environment. Clasts have expressed foliated (directed) arrangement. Along the lines of foliation and cleavage, observed are linear groupings of psilomelan and goethite with limonite.

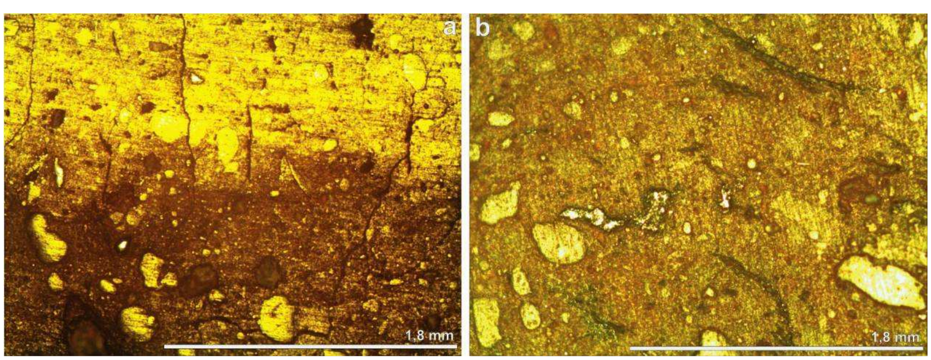

Figure 4. Microphoto of sample PK M7 in reflected light

Sporadically, and to a lesser extent than in the red bauxite, identified are relics of hematite grains in the form of corrosion tapes, as well as hematite-martite oolitic form, Figure 4.

Table 3. Nomenclature of analyzed samples

sample	texture	structure	nomenclature
PK M6	cryptocrystalline, clastic	massive, breccia-like,conglomeratic	Bauxite microbreccia with oolites of Fe oxides and hydroxides
PK M7	cryptocrystalline, clastic	breccia-like, schisty	Contact of red bauxite with bauxite of weathering zone's lower part
PK M8	cryptocrystalline	massive, breccia-like	Redeposited bauxite microbreccia with oolites of Fe oxides and hydroxides
R6 M9	cryptocrystalline	massive, breccia-like	Bauxite oolitic microbreccia
R8 M10	cryptocrystalline	massive	Cryptocrystalline bauxite
OŠ3/1	cryptocrystalline, clastic	breccia-like	Bemitic-diaspor microbreccia with Fe oolites
OŠ3/2	cryptocrystalline, clactic	breccia-like	Bemitic-diaspor microbreccia with Fe oolites
OŠ3/5	cryptocrystalline, clactic	breccia-like	Bemitic-diaspor microbreccia with Fe oolites
OŠ31/4	cryptocrystalline, clastic	breccia-like, massive	Redeposited bauxite oolitic microbreccia
OŠ40/5	cryptocrystalline, clastic	breccia-like, masive	Bauxite oolitic microbreccia

GEOMECHANICAL TESTING OF BAUXITE AND ASSOCIATED SEDIMENTS

These tests were performed on the bauxite samples, as well as on the samples from under layers and roof layers. (table 4). The highest values of compressive strength are obtained in the bauxite, and also the highest values of bulk density and specific weight. Values were used for the purpose of bauxite ore reserves calculation.

Table 4. Average values of exemined geomechanical parameters

	Number of probes	Bulk density $\square_w$ (kN/m^3)	Specific weight $\square_s$ (kN/m^3)	Compressive strength σ_p (MPa)
Under layer	4	26,53	27,64	116,72
bauxite	4	30,09	31,23	133,89
roof layer	6	26,90	27,67	108,04

CONCLUSION

In order to define qualitative characteristics of bauxite deposit "Oštrelj" there were performed extensive laboratory testing of samples from boreholes and pits.

Chemical analyzes show that it is a relatively poor bauxite with an average content of Al_2O_3 (about 48 %), and high content of SiO_2 (oko 21%), which resulted in low Al/Si module (2,28). High values of SiO_2 concentration represent an undesirable component of bauxite, because in the process of alumina production SiO_2 consumes expensive sodium base and valuable aluminum hydroxide.

A larger number of analyzed trace elements have higher concentrations compared to average content in the Earth's crust. Considering that it is about of composite samples, these results represent a realistic basis for further research of concentration in individual probes, by depth and laterally.

Almost all optically tested samples match to bauxite micro breccias with abundant oolitic and posolitic Fe oxide mineralization. Structural - textural characteristics are uniform in almost all samples (except for PK M7) and refer to cryptocrystalline-clastic and massive-brecciaed.

Redeposited grains of primary bauxite are with slightly rounded edges indicating sedimentation within identical depositional environments. Based on poorly rounded clasts of primary bauxite, it can be assumed that these clasts match to an identical kinematic stage of basin bauxitisation.

Sample PK M7 differs from other samples and fits to the contact of two stages or levels of bauxite basin weathering zone. Based on the optical determination and literature data holders of Al mineralization are bemite and diaspor as crypto crystalline phases of rock matrix.Considering the grain sizes of examined mineralization, in order to give final determination of mineral phases, it will be necessary to do X-ray (XRD),differential-thermal (DTA) and thermo-gravimetric recording (TGA).

Paleontological tests in bauxites are not ascertained microfossils. Paleontological content is documented only in dark gray limestone sample from borehole OS3. Microscopic were ascertained smooth remains of ostracodes (*Ostracoda gen. et sp. Indet.)*, indicating Lower Cretaceous age. Based on paleontological findings, it is concluded that the tested sample belongs to the overlying sediments.

Bauxite's underlayer and roof layer geomechanical parameters values are uniform and correlate with literature data. Bauxites are characterized by a higher compressive strengths values, what is in accordance with the mineral composition and structural-textural characteristics.

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