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The origin of early paleogene bauxites of Istria yougoslavia

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The Upper Cretaceous bauxites of Istria occur along the Cretaceous-Paleogene geological border. The bauxite underlying rocks are exclusively made up of Cretaceous limestones, and even in the wider area no rocks with aluminosilicate minerals are found. The content of the insoluble residue of limestones was examined, as well as its mineralogical and chemical composition. On the basis of a comparative study of macro- and microelements, and also of accessory minerals in the insoluble residue of both the limestones and bauxite, it has been determined that it is possible, and probable as well, that the bauxites of Istria owe their existence to the bauxitization of insoluble residue of the footwall limestones.

In the period between World Wars I and II Istria had a significant share in the world production of bauxite. It provided about 10 percent of the world production of bauxite. Over the last few decades the output of Istrian bauxites has gone down and the world production considerably increased, so that Istria's present share in the world output of bauxite is only 0.3 percent. The total output of bauxite since the beginning of bauxite production in Istria in 1915 to the end of 1972 amounted to 8,900,000 tons.

There are two hypotheses on the genesis of Istrian bauxites. Crema (1920) thought that the bauxites were formed through the activity of hydrothermal solutions. According to d'Ambrosi (1943) the formation of bauxite is associated with pedological processes which took place during the continental stage of the Upper Senonian. The source material for bauxite was the insoluble residue of Cretaceous limestones. Istrian bauxites have also been the subject of studies by Ratto (1920), Franchi (1924), Petronio (1929), de Weisse (1948) and Mojsilović (1958).

1. THE GEOLOGY OF BAUXITE BEARING AREA

The geological structure of the bauxite bearing area of Istria is simple. According to Polšak (1965), Polšak and Šikić (1966), ano Šikić and Polšak (1963) the southwestern part of Istria was built from Mesozoic carbonaceous sediments. The earliest layers are situated between Rovinj and Poreč, and belong to the Kimmeridgian. The emergence took place towards the end of the Kimmeridgian, while kaolinitic-boehmitic bauxites were formed on carbonaceous land. After a transgression during the Tithonian, sedimentation continued to the lower part of the Campanian stage of the Senonian. The Upper-Turonian and the

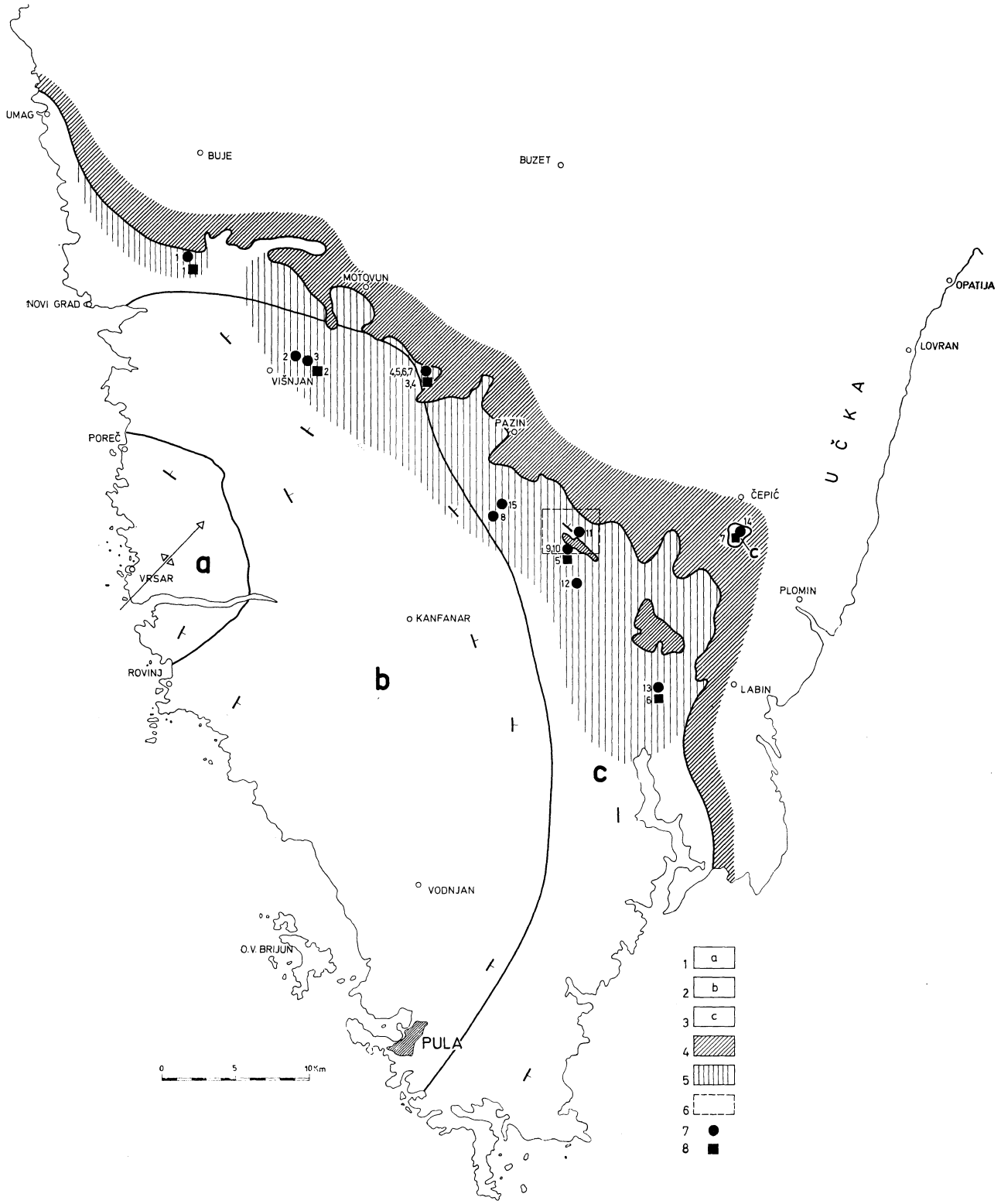


Fig. 1. — Geological sketch of Istria. According to Polšak (1965) and Šikić and Polšak (1963)

1. Malm. — 2. Lower Cretaceous. — 3. Upper Cretaceous. — 4. Eocene. — 5. Bauxite bearing area. — 6. Location of fig. 2. — 7. Sample locations, bauxites. — 8. Sample locations, carbonaceous rocks.

Senonian sediments however, have been preserved in the eastern and southern parts of Istria, while the youngest Cretaceous sediments in the western and central parts of Istria belong to the Cenomanian and the Lower Turonian.

Cretaceous sediments are represented by limestones exclusively, and to a lesser extent by dolomites. It is only in the Lower Cretaceous that layers of clay and lenses of quartz sand are rarely found. Upper Cretaceous sediments consist of limestones with rudistids and to a lesser extent of bioclastic limestones and dolomites. The overall depth of the Lower Cretaceous déposits is 1,200 to 1,600 m, and that of the Upper cretaceous is 1,700 to 2,500 m.

It was during the Upper Senonian that the regression and Laramide orogenic movements set in. It was then that the large anticline was formed with the axis extending in the direction NE-SW and declining gradually towards NE. The Jurassic Cretaceous sediments dip slightly (most frequently 5° to 10°). The raised carbonaceous region was subjected to intensive erosion and peneplanation. Considerable bauxite deposits were formed at that time (Fig. 1).

The emergence phase lasted until the Early Eocene epoch when transgression set in from the north-east, surpassing considerably the boundaries of present Paleogenic sediments. The regions where bauxite deposits are located on the surface today was subjected to a transgression during the Middle and Upper Cuisian (Drobne, 1971). Freshwater and brackish layers sedimented with coal (Liburnian deposits) in isolated basins at first. They were followed by marine sedimentation of foraminifer limestone and flysch. The sediments of the Lower Eocene lie over Cretaceous strata of different age with pronounced erosion discordance, while the angular discordance is inconspicuous.

2. BAUXITE DEPOSITS

The bauxite bearing area of Istria extends along the geological border of the Cretaceous-Paleogene from Umag in the NW part of Istria to Labin in the SE. This is the stretch, some 60 km long and 4 to 6 km wide, where most of the bauxite deposits are located. A smaller number of bauxite deposits of the same type is to the north of Buje, in the region of the Učka Mountain, and to the north-east of Pula.

The bauxite area of Umag - Labin covers about 220 square km. The deposits of bauxite are found exclusively on Cretaceous carbonaceous rocks. The earliest footwall rocks are situated near Višnjan and belong to the Albian, while the youngest are near Labin and belong to the Turonian.

Microsparites prevail in footwall limestones, but intrasparites, micrites and dismicrites can also be found. Limestones often contain microfossils.

In the majority of bauxite deposits Eocene roofwall sediments were completely eroded so that bauxite is covered by terra rossa. Part of the deposits is covered by Lower Eocene limestones and marls. In the immediate roofwall of certain deposits clay is intercalated with carbon matter. Roofwall sediments are often concavely bent over the deposit, and lowered by some ten metres owing to the postgenetic settlement of bauxite.

Bauxite is always found in small orebodies, conical in shape, which were formed by filling of pits (Fig. 3). The surface of the outcrop most frequently is 100 to 300 square m, the depth being 8 to 30, rarely 45 m. Bauxite reserves are 50 to 25,000 tons, exceptionally 35,000 tons. Deposits without roofwalls are smaller and are estimated at 3 to 4,000 tons at the most. Roofwall deposits i.e. those which have been preserved from partial erosion average 3 to 4,000 tons of bauxite. In respect of the concentration of deposits no regularity has been established, except, which is logical, that their number and size are larger in the vicinity of the Cretaceous - Paleogene border. Ten to ninety bauxite deposits are located on 1 square km. Some 10,000 deposits have been determined so far, one deposit averaging 1,000 tons of bauxite (Fig. 2).

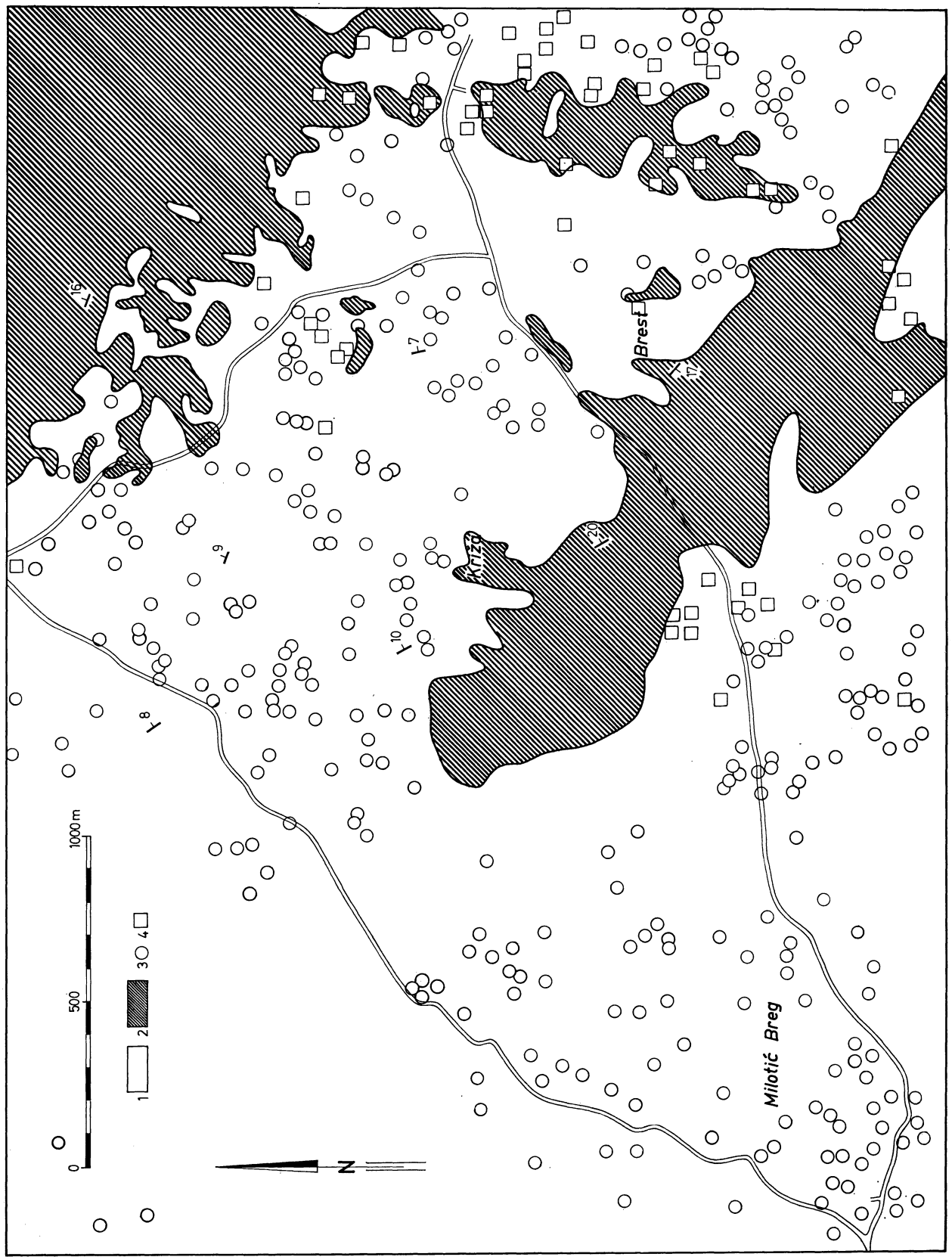


Fig. 2. — Geological map of bauxite bearing area Milotic Breg. Geology according to Šikić and Polšak (1963)
1. Upper Cretaceous. — 2. Eocene. — 3. Bauxite deposits without roofwall. — 4. Bauxite deposits with Eocene sediments in roofwall.

To the south of Pazin and on the western slopes of Učka, deposits of pure, white hydrargillite are rarely found. The shape of a hydrargillite deposit is identical to that of red boehmite bauxite, the only difference being that hydrargillite deposits are considerably smaller and contain 10 to 15 tons of hydrargillite at the most. Hydrargillite deposits are usually located in the vicinity of boehmite bauxite deposits.

Bauxite is mostly red in colour. In the upper and the lower parts of the deposit bauxite is often yellow owing to the transition of hematite into goethite. In some deposits pyrite occurs instead of hematite, and consequently bauxite is grey. Pyritized bauxite never takes up the whole deposit, but is found in the form of irregular bodies in red bauxite. Pyritized bauxite is more common in the SE part of Istria, because intercalations of carbon are often encountered there.

The texture of bauxite is roundgrain, rarely oölite. Oölites and roundgrains (the latter are prevalent) with diametres usually under 0.5 mm are found in the cryptocrystalline matrix. Oölites and roundgrains are in general lighter than the matrix and signs of repeated re-sedimentation can be observed on them.

The chemical and mineral composition of bauxite were determined on samples taken from deposits which are more or less evenly distributed on the bauxite bearing area with varying age of the footwall (from the Albian to the Turonian) (see Fig. 1).

The chemical composition of bauxite is given in Table I and the contents of some of the microelements are shown in Table II (1).

TABLE I

Chemical Composition of Bauxites (%)

Sample	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	H_2O^{105}	H_2O^{180}	*L.O.I.*
1	0.20	60.50	22.16	2.95	0.62	0.32	12.58
2	1.98	56.48	23.10	3.49	0.45	0.30	11.90
3	0.35	57.50	25.80	3.64	0.55	0.01	12.00
4	0.70	49.09	32.00	3.30	1.12	0.33	12.26
4a	0.78	46.54	29.50	3.30	1.87	1.58	14.18
5	1.15	52.85	31.00	3.45	0.70	0.00	11.84
8	0.80	55.78	26.50	3.70	0.27	0.12	11.66
9	0.75	56.67	24.85	3.50	0.52	0.18	11.94
13	1.53	55.34	27.00	3.51	0.85	0.05	11.28
14	11.95	46.79	27.00	2.89	0.75	0.00	11.52

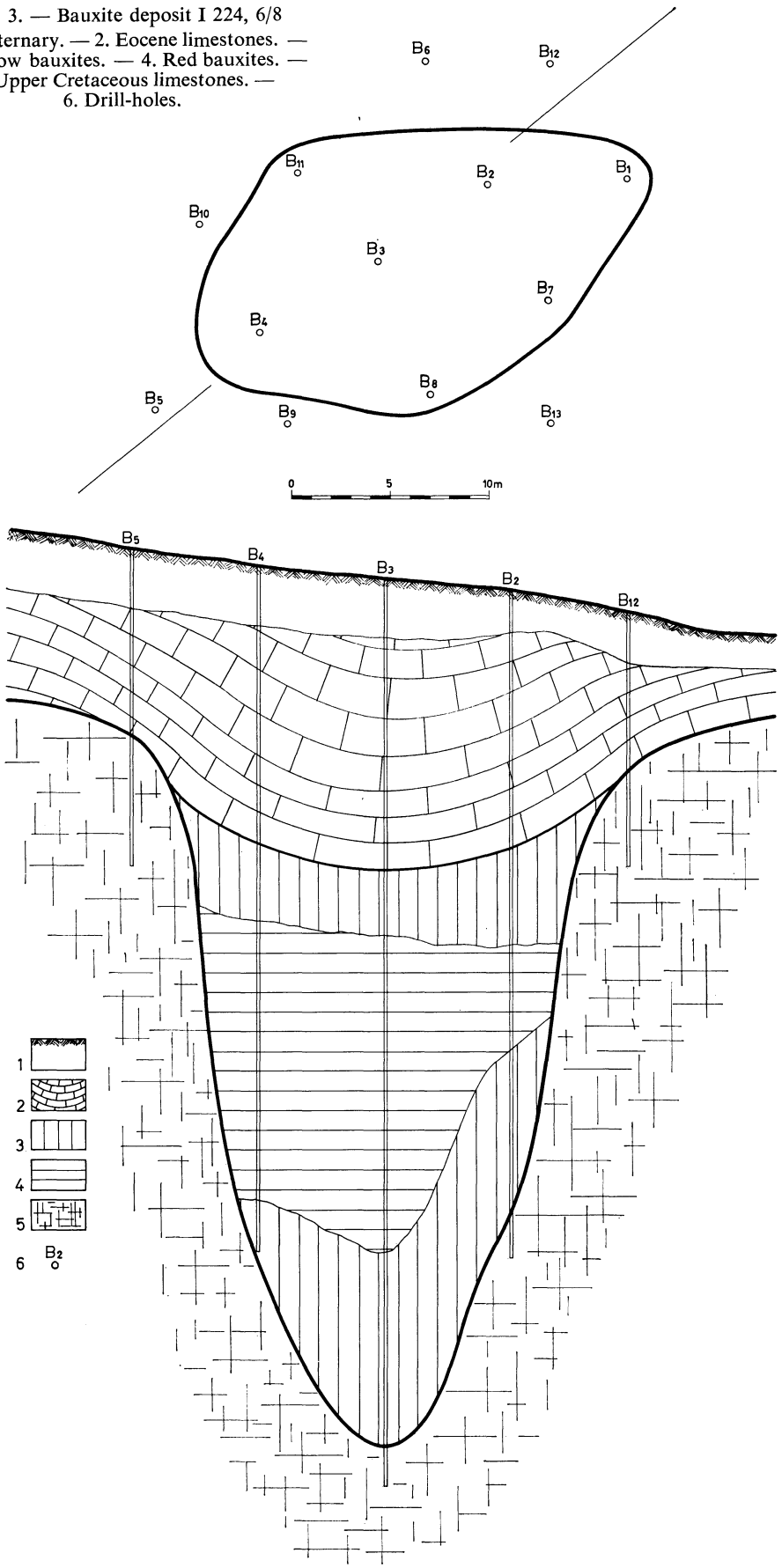
TABLE II

Content of Microelements in Bauxites (in ppm)

Sample	*Ni*	*Co*	*Cu*	*Cr*	*Zr*	*V*
1	145	16	19	560	380	490
2	250	23	53	425	455	220
3	260	22	47	480	560	580
4	240	21	36	450	380	620
4a	255	16	33	460	410	680
4b	55		3	40	40	40
4c	49		5	50	65	130
5	220	24	84	485	510	440
6	200	26	37	590	590	630
7	270	170	112	340	550	410
7a	250	23	37	370	490	550
8	255	21	29	490	510	550
9	120	10	37	565	310	280
10	200	24	26	350	620	410
13	185	12	88	440	350	350
14	810	34	92	610	420	750
15	215	20	55		50	350
Average	210	21	53	480	480	490

(1) Chemical and spectral analyses were carried out by D. Šiftar.

Fig. 3. — Bauxite deposit I 224, 6/8
1. Quaternary. — 2. Eocene limestones. — 3. Yellow bauxites. — 4. Red bauxites. — 5. Upper Cretaceous limestones. — 6. Drill-holes.



1. Serbani
2. Deklevi
3. Sutići
4. I.79,5/6, red bauxite
4a. I.79,5/6, yellow bauxite
4b, 4c. Hydrargillite veinlets in bauxite
5. I.48,5/6
6. I.85,5/6
7. I.46,5/6, bauxite with pyrite
7a. I.46,5/6, red bauxite
8. Pulići
9. I.183,6/7
10. I.194,6/7
13. Labin
14. Cepici
15. Pulići, hydrargillite deposit. (I.79,5/6 = number of deposit)

Mean chemical composition of Istrian bauxites with deposits of high kaolinite content taken into account is: $Al_2O_3 = 54.28\%$, $Fe_2O_3 = 21.88\%$, $SiO_2 = 5.93\%$, $TiO_2 = 3.18\%$, L.O.I. = 14.00%.

Deposits of high quality bauxite are often located in the neighbourhood of bauxite deposits with raised kaolinite content, and no regularity has been noticed in their spatial lay-out. In general, bauxite deposits of the central part of Istria are of higher quality than those situated in the NW and SE parts of Istria.

The mineral composition of bauxite was determined by microscopic, X-ray, and thermic analyses (Table III). Thermic analysis was carried out for all samples listed in Table III, and samples No. 1, 4, 4a, 4b, 9, 13 and 14 were X-rayed as well (1).

TABLE III

Mineral Composition of Bauxites

Sample	
1.	boehmite > hematite > anatase, hydrargillite > kaolinite
2.	boehmite > hematite > anatase, hydrargillite, kaolinite
3.	boehmite > hematite > anatase > kaolinite, hydrargillite
4.	boehmite > hematite > hydrargillite > goethite, anatase > kaolinite
4a.	boehmite > goethite > hydrargillite > anatase > kaolinite > rutile
4b.	hydrargillite
5.	boehmite > hematite > anatase > goethite, kaolinite
8.	boehmite > hematite > anatase > goethite, kaolinite
9.	boehmite > hematite > anatase > kaolinite
13.	boehmite > hematite > anatase, kaolinite
14.	boehmite > hematite > kaolinite > anatase
15.	hydrargillite

Boehmite is the chief mineral of bauxite, and it is followed by hematite. The amounts of kaolinite vary to a great extent: from below 1% to over 20% in certain deposits, and sometimes in the lower parts of the deposits. Of titanium minerals anatase appears to be more frequent than rutile. Hydrargillite is present in some deposits only and in inconsiderable quantities. Pyrite and marchasite are found in pyritized bauxite only, and while pyrite abounds marchasite is much rarer. In some samples small flakes of hydromica (?) were noticed. Accessory detrital minerals, zircon, apatite, tourmaline and garnet are very rare. Goethite was formed by surface exchange of hematite and pyrite.

Bauxite minerals are mainly cryptocrystalline or fine grained, with the exception of pyrite and marchasite which are partly coarse-grained. Hydrargillite is of secondary or of detrital formation. Secondary hydrargillite is much more frequent and it appears in the form of irregular white veinlets. This type of hydrargillite is fine-grained with frequent platy mineral aggregates of hydrargillite, which are in places radially situated. Detrital hydrargillite is rare and has been found only in the bauxite deposit of Serbani. Detrital hydrargillite is coarsegrained, the crystals reaching a length of 0.6 mm and usually twinned.

(1) X-ray analyses were performed by D. Slovenac.

Hydrargillite grains are fragments of larger crystals and some of the grains are rounded up, which indicates clearly that this hydrargillite was re-sedimented. Single grains served as the core of boehmite oölite, and partial boehmitization of hydrargillite has also been noticed.

3. THE GENESIS OF ISTRIAN BAUXITES

The lithological composition and geological structure of Istrian bauxite bearing area are rather simple, which greatly facilitates the explanation of the genesis of Istrian bauxites. The footwall of bauxite deposits consists exclusively of Cretaceous limestones and dolomites, and alumosilicate rocks are not found in the wider environment.

During the Senonian — Early Paleogene emergence phase the present bauxite region consisted of carbonaceous rocks whose surface was mostly flat or only slightly sloping towards north-east. Judging by the contact line of the Cretaceous - Eocene, the Cretaceous paleorelief had minor elevations.

Owing to such circumstances the source material of bauxite cannot be supposed to have been transported from a remote area of some hypothetic mass of alumosilicate rocks. Source material can only be sought in the Cretaceous - carbonaceous footwall rocks, or, perhaps, in the Eolean transport of this material.

In order to determine the chemical and mineral composition and the amount of insoluble residue in the carbonaceous footwall rocks, 7 samples of these rocks of various age, collected in various places in the bauxite bearing area were analysed (fig. 1).

A 200 g sample was dissolved in weak HCl (at pH 3), and the insoluble residue obtained was submitted to chemical, spectral and X-ray analyses. Because of the small quantity of insoluble residue in samples 1 and 6, macroelements were also analysed by spectral method. The chemical composition of insoluble residue is given in Table IV and the mineral composition of some of the samples is presented in Table V.

TABLE IV

Chemical Composition of Insoluble Residue (%)

Sample	*1*	*2*	*3*	*4*	*5*	*6*	*7*
SiO_2	32	32.80	31.44	46.70	22.05	48	28.40
Al_2O_3	25	20.82	26.50	22.35	19.90	14	31.48
Fe_2O_3	18	15.90	15.32	7.94	3.58	22	14.02
TiO_2	1.9	1.40	1.97	1.47	1.05	1.4	1.81
H_2O^{105}	2.74	3.90	2.00	2.66	1.20	1.15	1.47
H_2O^{180}	1.37	1.20	0.37	1.07	6.47	0.77	0.40
L.O.I.	18.62	16.76	16.88	11.36	28.85	10.70	18.90
Cao	n.d.	n.d.	n.d.	n.d.	8.20	n.d.	n.d.
% Insol. Res.	0.17	0.29	0.28	0.61	1.62	0.19	0.57

1. Serbani (Cenomanian) 2. Sutići (Albian) 3. I.79,5/6 (Cenomanian)
4. I.85,5/6 (Cenomanian) 5. I.183,6/7 (Turonian) 6. Labin (Turonian)
7. Capići (Turonian)

TABLE V

Mineral Composition of Insoluble Residue

Sample	
2.	kaolinite > goethite > quartz, anatase, 14-15 Å material
3.	kaolinite > goethite > anatase, hydrargillite, boehmite (?)
5.	kaolinite > weddellite > whewellite > boehmite, anatase, quartz, rutile
7.	kaolinite > goethite > boehmite > anatase, quartz, halloysite

Table V shows that the chief mineral of the insoluble residue of carbonaceous rocks is kaolinite, and goethite is dominant among iron minerals. Boehmite and hydrargillite in traces or in insignificant quantities were found in a few samples. These minerals were probably brought to the carbonaceous rocks subsequently, because the samples were taken in the vicinity of bauxite deposits. An interesting finding was the occurrence of rare minerals weddellite ($CaC_2O_4 . 2H_2O$) and whewellite ($CaC_2O_4 . H_2O$) which were 20 % of the insoluble residue of sample No. 5. The limestone from which this insoluble residue was obtained contains carbon matter in the form of fibers 3 to 6 micr. thick, which probably represent plant relics.

The contents of Al_2O_3, Fe_2O_3 and TiO_2 in carbonaceous rocks were calculated from the data in Table IV, while the contents of microelements were examined on carbonaceous rocks direct (Table VI). This was done because in the course of dissolution of carbonaceous rocks in HCl microelements can pass to the solution, which diminishes their content in the insoluble residue.

TABLE VI

Content of Al_2O_3, Fe_2O_3, TiO_2 and Microelements in Carbonaceous Rocks (in ppm)

Sample	*Al_2O_3*	*Fe_2O_3*	*TiO_2*	*Ni*	*Co*	*Cu*	*Cr*	*Zr*	*V*
1.	425	306	32	3.0	0.3	1.0	0.8	0.4	4.0
2.	604	461	41	2.9	0.3	2.2	1.3	0.3	2.2
3.	742	429	55	3.3	0.3	1.6	1.4	0.4	1.4
4.	1363	484	90	8.0	0.5	8.0	1.7	1.1	6.0
5.	3224	580	203	4.5	0.2	1.6	5.5	0.9	1.8
6.	266	418	27	3.3	0.2	1.0	3.4	0.2	0.9
7.	1794	800	103	5.0	0.3	1.5	1.3	1.2	5.5
Average	1203	497	79	4.3	0.3	1.5	2.2	0.6	3.1

During the Senonian — Early Paleogene emergence phase considerable quantities of carbonaceous rocks were worn away. Since the relief of that land was low, chemogenic effect of erosion was strong. Dissolution of carbonaceous rocks was very intensive, so that the Upper Cretaceous layers in the present bauxite bearing area were eroded down to the Turonian (region of Ćepići), or to the Upper Albian (west of Pazin). The thickness of the carbonaceous rocks which were worn away was at least 500 m in the former and at least 1,500, (Polšak, 1965) in the latter region.

In view of the type of bauxite deposits in Istria it is clear that no considerable transport of bauxitic material was effected at the time of deposit formation. It may therefore be assumed that bauxite was formed from the insoluble residue of carbonaceous rocks which overlay the present bauxite bearing area.

In order to prove this assumption the amount of Al_2O_3, Fe_2O_3, TiO_2 and of some of the elements contained in the bauxite on an area of 1 square km (Table VII, Column 1) was calculated, as well as the amounts of the same compounds and microelements existing in the 50 m thick layer of Cretaceous carbonaceous rocks, on an area of 1 square km (Column 2). Maximal amounts of bauxite found in Istria, i.e. 90 deposits with an average of 3,000 tons of bauxite per deposit, which makes 270,000 tons of bauxite per 1 square km, were taken for the calculation of the first column.

TABLE VII

	1	*2*	*2/1*
	(t)	*(t)*	
Al_2O_3	147,000	150,400	1.02
Fe_2O_3	59,000	62,100	1.05
TiO_2	8,600	9,900	1.15
Ni	57	625	10.96
Co	5.7	37	6.49
Cu	14.3	187	13.08
Cr	130	275	2.12
Zr	130	75	0.58
V	132	387	2.93

The date in Table VII show that the dissolution of a 50 m thick layer of carbonaceous rocks was sufficient for the formation of Istrian bauxites. Since considerably larger amounts of carbonaceous rocks were dissolved, the question arises of why the bauxite reserves in Istria are not larger. This can be explained by the specific paleorelief. The almost flat ground, which was not exposed to any significant tectonic movements, and probably the warm humid climate prompted the formation of karst forms such as are rarely found today. The only karst phenomena were narrow and deep pits, while closed larger depressions where greater masses of bauxite could accumulate, did not exist. Bauxite material filled the pits to the brim, and the remaining material was carried away to remoter places by surface currents and probably reached the sea. Part of the material certainly sank underground through cracks. In this way we can explain why in the regions where more carbonaceous rocks were eroded (e.g. west of Pazin) no significant reserves of bauxite can be found.

Column 3 in Table VII presents the ratio of Al_2O_3, Fe_2O_3, TiO_2 and the microelement contents from columns 2 and 1. It can be seen that this ratio for Al_2O_3, Fe_2O_3 and TiO_2 comes near 1, which means that their way from carbonaceous rocks to bauxite and the degree of concentration are roughly the same. The greatest loss, or rather migration in the process of dissolution of carbonaceous rocks and bauxitization was found for copper, followed by nickel and cobalt in that order, while vanadium and chromium showed a lower degree of migration. Zirconium appears to be highest in concentration. This can be explained by the fact that zirconium is contained in the accessory mineral of zircon which, of course, is less movable than the compounds and elements which in the process of bauxite formation occasionally were dissolved.

The ratios of the main components of bauxite approach the ratios of these components in Cretaceous carbonaceous rocks (Table VIII). This also supports the assumption that the source material of Istrian bauxites should be sought in Cretaceous carbonaceous rocks.

TABLE VIII

	Al_2O_3/Fe_2O_3	Al_2O_3/TiO_2	Fe_2O_3/TiO_2
Bauxites	2.48	17.1	6.88
Carbonaceous rocks	2.42	15.2	6.29

If we attempt a "theoretical bauxitization" of the insoluble residue of Cretaceous carbonaceous rocks (Table IX, line 1) by taking for SiO_2 and L.O.I. the values which the Istrian bauxite possesses (line 2), we shall find that the contents of Al_2O_3, Fe_2O_3 and TiO_2 are similar to the amounts of these compounds in bauxite (line 3).

TABLE IX

	Al_2O_3	Fe_2O_3	TiO_2	SiO_2	$L.O.I. + H_2O^{180}$
1.	22.86	13.82	1.60	34.48	21.26
2.	54.28	21.88	3.18	5.93	14.00
3.	47.82	28.90	3.35	5.93	14.00

It follows from the above that it is possible and even probable that the source material derived from the insoluble residue of Cretaceous carbonaceous rocks dissolved during the Cretaceous — Early Paleogene regression phase.

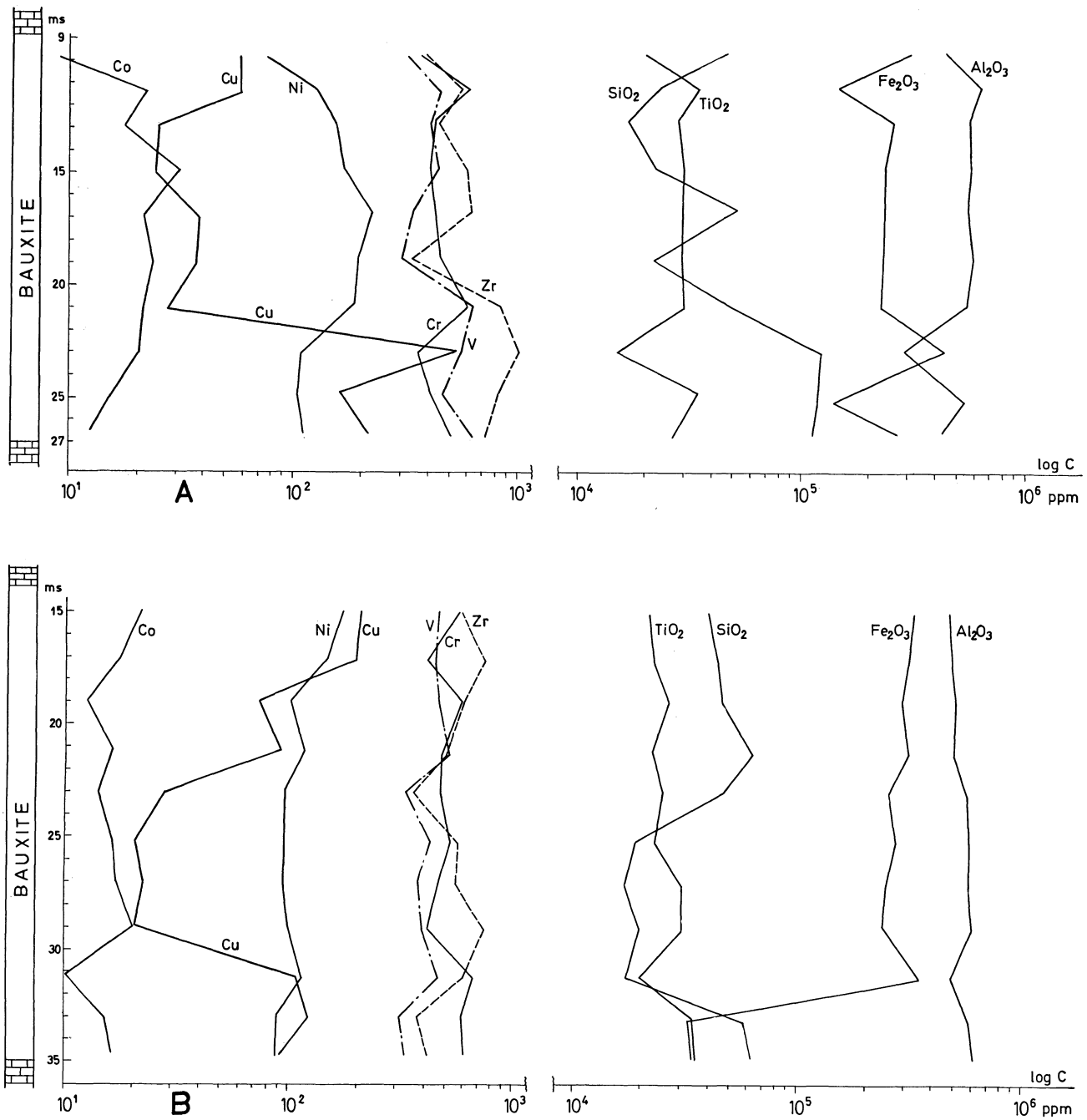


Fig. 4. — Variations of chemical composition of I 272, 6/7 (A) and I 224, 6/8 (B) bauxite deposits

Eolean origin should also be considered as possible for the source material of bauxites. It is not likely, however, that Eolean material had any significant bearing on the formation of Istrian bauxites. The Eolean sediments usually contain larger amounts of accessory minerals which are resistant to surface weathering and which would remain in the bauxite. Istrian bauxites however, are poor both in the amounts and kinds of accessory minerals.

After regression in the Later Senonian surface weathering of carbonaceous rocks began and with it the process of bauxite formation. Those processes continued throughout the Paleocene and into the beginning of Early Eocene. Since Istrian bauxites were mainly formed during the Early Paleogene, they are of Early Paleogene age.

Chemical dissolution of carbonaceous rocks released the insoluble residue. Occasional water streams accumulated the insoluble residue in the neighbouring pits. Warm and humid climate caused the bauxitization of the insoluble residue in the pits. The residue was mainly composed of fine-grained kaolinite. Further erosion and lowering of the level of the ground involved bauxite deposits in the pits, and the bauxite re-sedimented in the neighbouring newly formed pits. The process of destruction of older deposits and the re-sedimentation into younger pits proceded throughout the Cretaceous — Paleogene emergence phase, and further bauxitization of bauxite material went on simultaneously. This is reflected in the texture of the bauxites, where roundgrains prevail with distinct marks of re-sedimentation, while true oölites are rather rare.

In the central part of the bauxite bearing area, where bauxite is found in lower horizons of Cretaceous sediments, re-sedimentation of bauxite was more intensive than in the NW and SE parts of the region. This influenced the quality of the bauxites which are on the average higher in the central part. Nevertheless, deposits with a higher kaolinite content are also found together with high quality bauxite on the whole bauxite bearing area. The bauxite from those deposits re-sedimented to a lesser extent probably, or the drainage might have been poorer in those deposits.

The microelement content in the vertical cross-section of the deposits No. 1.272,6/7 and 1.224,6/8 (Nos. 11 and 12 in Fig. 1) is also indicative of re-sedimentation of bauxite material (Fig. 4). These elements are on the whole evenly distributed in the deposit with the

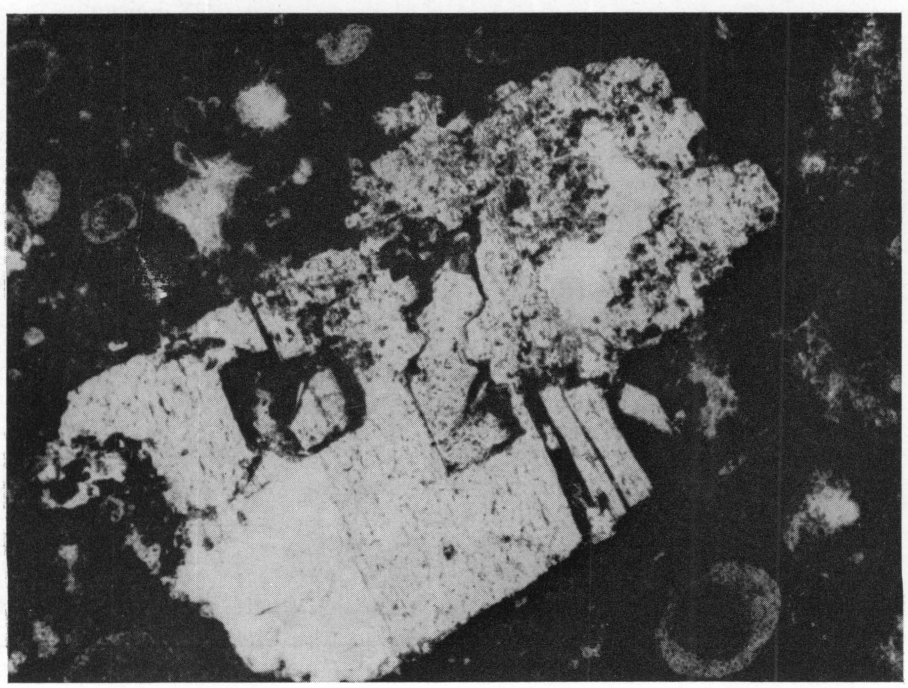


Fig. 5. — Detrital coarse-grained hydrargillite (white) in boehmitic bauxite (black), 180 ×

exception of copper, and to a certain extent zirconium, whose content is higher in the lower clayey part of the deposit. It is possible that copper as the most movable among the elements examined migrated from the upper part of the deposit to the lower part.

During the bauxitization of the insoluble residue of carbonaceous rocks, hydrargillite was probably formed, and when the deposits were covered by Eocene sediments it passed into boehmite. This is suggested by detrital fragments of coarse hydrargillite crystals in boehmite bauxite (Fig. 5), the crystals being preserved due to their size. Some of them were partly boehmitized on the rims (Fig. 6).

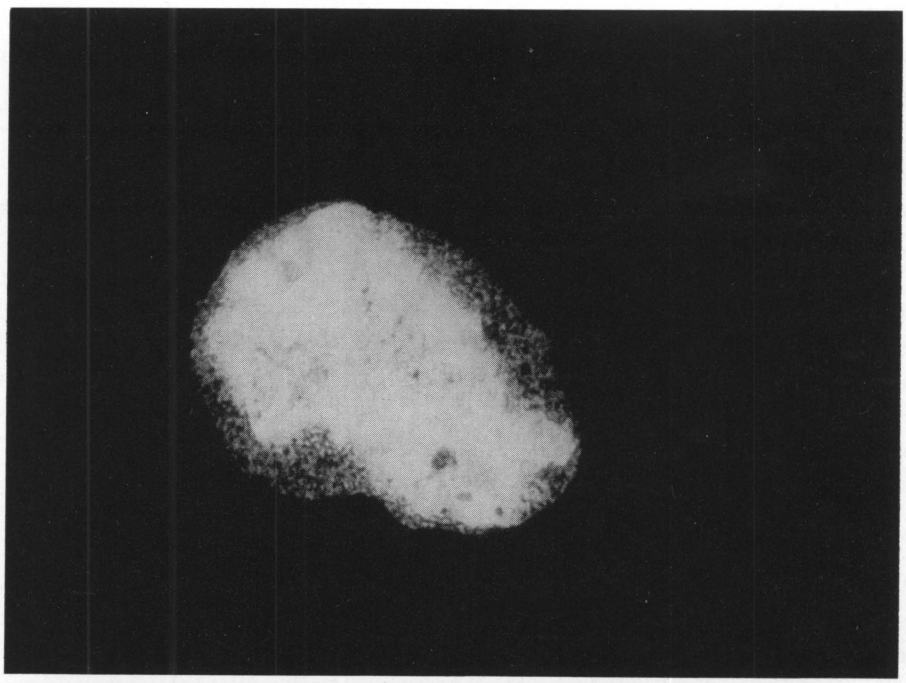


Fig. 6. — Rounded grain of hydrargillite boehmitized on its rims (grey) in boehmitic bauxite (black), 230 ×

The origin of small deposits of pure hydrargillite has not been explained yet. The contents of Ni, Co, Cu and V in hydrargillite deposits are identical to the contents of these elements in red boehmite bauxite; their content in hydrargillite veinlets which are found in boehmite bauxite and were formed from solutions, is much lower (Table II). Those data indicate that the deposits of hydrargillite probably represent erosion remains of deferrified deposits of bauxite which did not convert into boehmite. On the other hand the fluid structure of hydrargillite in hydrargillite deposits and the very low TiO_2 content (below 0.1 %) suggests that this hydrargillite crystallized from solution i.e. it is of secondary origin.

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