TRAVAUX, Proceedings of the 3rd International Congress of ICSOBA , Nice, 17 - 21 September 1973

Trace mineral and element investigation in bauxites by electron-probe

Gy. BÁRDOSSY and Gy. PANTÓ

The authors have worked out the method of investigation of bauxites by electron probe X-ray microanalyser. Their first results were published in 1970 and 1971. Here they present the new results of their continued research work on bauxites.

They found that the trace elements in bauxites may be concentrated into single mineral grains or uniformely disseminated in the ore. In the second case the the concentration of the trace elements is near the limit of detectability of the probe. Elements that are not detectable by the bulk analysis because of their low average concentration can be detected by the probe if they are concentrated in trace-minerals. The authors have stated different relationships between the concentration of trace elements and the structural units of the bauxites. Examples are demonstrated referring to these cases.

Finally the authors present occurrences where the trace mineral investigations were useful to throw light on genetic problems.

1. INTRODUCTION

We have worked out a method of investigation of bauxites by the electron probe X-ray microanalyser (1970, 71, 72). These investigations have been concerned with the distribution of the main elements and the micro-textures of the bauxites.

The trace minerals and trace elements of the bauxites have been studied using the same specimen preparation techniques and the same type of instrument (JEOL JXA-5) described previously. For the purpose of finding the trace minerals a combination of using back-scattered electron images and searching by the characteristic wavelength of a given element proved to be the most effective. These investigations were carried out on karst bauxite samples from France, Greece, Hungary, Italy, URSS and Yugoslavia.

2. DISCUSSION

We consider as *trace elements* those elements occurring in concentrations less than 0,5 percent in the bauxites, and *trace minerals* those in which the trace elements are concentrated.

Trace elements are present in the bauxites:
1) Homogeneously distributed over the entire bauxite body;
2) In well defined textural units (oolites, crusts, etc.);
3) In trace minerals.

2.1. **Homogeneous distribution**

The distribution of V and Ga, trace elements generally enriched in the bauxites, was typically homogeneous. We found no concentrations of these elements in trace minerals or textural units surpassing the detection limit of the instrument.

2.2. **Concentration in textural units**

Iron-rich detrital bauxite grains from the deposits of Pas-de-Recoux and Mazaugues (Southern France) were observed to have Cr, concentrated on the rim of the grains and along their fissures. (Figs. 1 and 2.) Co and Ni enrichment was found in an iron-rich detrital bauxite grain (1-2 mm) from a deposit near Dragoni-Monte Maggiore (Central Italy).

This occured as a spherical inclusion having a diameter of 60 microns. Iron-rich detrital bauxite grains from Distomon (Greece) contained an average Ni content of 0,01-0,1 percent whereas it was not detectable in the groundmass.

2.3. **Concentration in trace minerals**

The trace minerals and their trace element contents are shown in Table I.

Among the *detrital minerals* the most abundant was *zircon*. The grain size varied from 5-200 microns and the particles exhibited homogenous internal structure without zonation. All contained Hf. In some samples from Mazaugues (France) and Campo Felice (Central Italy) the zircon contained some Y and Sc in isomorphous substitution. The small P content of the grains can be related to the isostructural relationship of xenotime and zircon.

Monazite generally occured as very small grains below 10 microns in diameter (Fig. 3) and was very rich in rare earth elements: Ce > La > Nd > Pr. However we found in the deposit of Allauch (France) monazite grains containing Y as well and elements characteristic for the xenotime grains: Sm > Ho > Dy > Pm > Er.

In a sample of bauxite from the San Giovanni Rotondo (Central Italy) deposit *cheralite* grains were found. This Ca-rich Th-bearing member of the monazite group contained Ce > Nd > La > Sm, Pr, Gd, Ho, Th. The grain size was less than 10 microns.

The *xenotime* grains are generally also less than 10 microns, but in the Pas-de-Recoux deposit some grains up to 30 microns also occured. Y and Dy are the two most abundant elements; other elements present in lower concentrations included: Er, Yb, Ho, Gd. Sm and Eu were found only in the Allauch deposit; Lu in Pas-de-Recoux and Gánt; Hf, Tb and Tm only in the Gánt deposit. (Figs. 4 and 5.)

It is our general experience that the members of the rare earth group with atomic numbers 57-60 are concentrated mainly in monazite and cheralite, whereas those with atomic numbers 61-71 are concentrated in xenotime. This can be explained by the ionic radii: the elements substituting for Y^{3+} (1,06Å) have ionic radii from 0,92-1,02Å; and those substituting for Ce^{3+} (1,09Å) have ionic radii from 1,06-1,12Å.

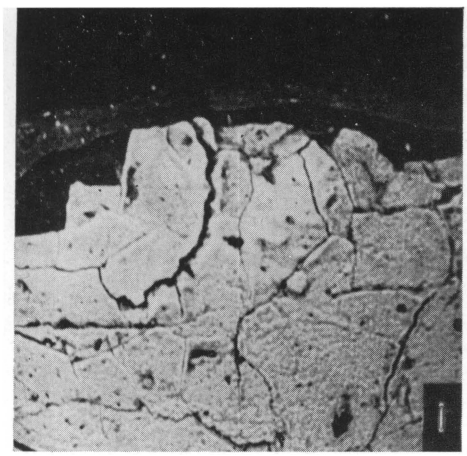
Only in the deposit of Pas-de-Recoux did we find some pure *chromite* grains (3-12 microns in diameter). They occur only in the iron-rich detrital bauxite grains (1-2 mm).

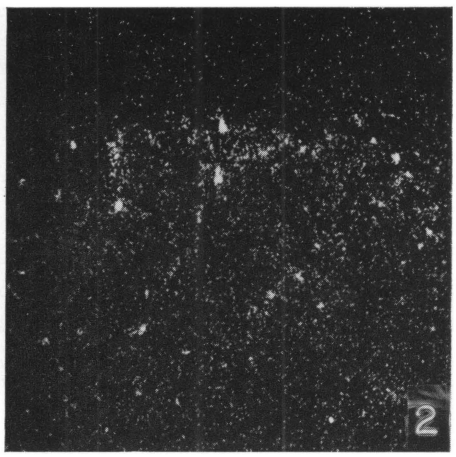
For the *secondary minerals* the grains belonging to the *bastnäsite* group generally occured fissure fillings (Figs. 6 and 7) (300 × 3 microns) and micro-pore fillings (Figs. 8 and 9) of maximum diameter of 100 microns. In some cases these patches had no sharp boundaries. In the San Giovanni Rotondo deposit the bastnäsite minerals were found only in the lower part of the bauxite profile. In the upper part of the deposit the monazite

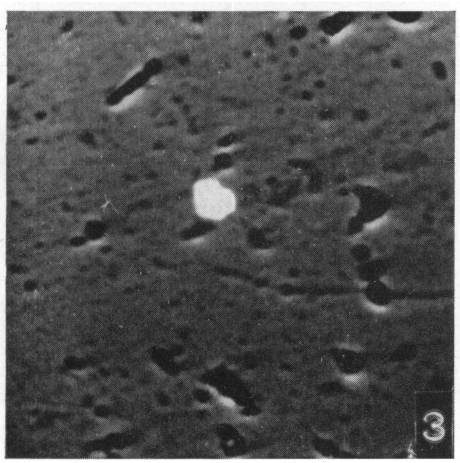
TABLE I

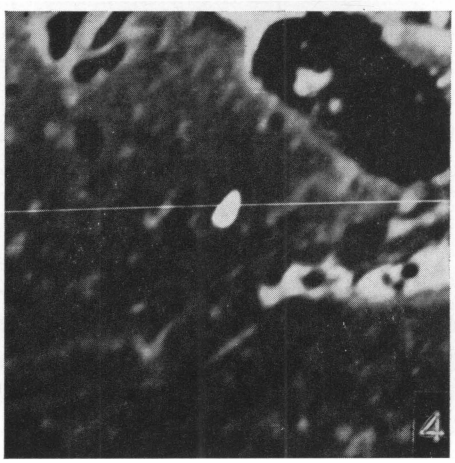
Minerals	*France*			*Italy*			*Yugosl.*	*Greece*	*Hungary*	*USSR*
	Allauch	*Pas de Rec.*	*Mazaug.*	*Dragoni*	*Campo Fel.*	*S. Giov. R.*	*Podlipa*	*Distom.*	*Gánt*	*N. Ural*
Detrital										
Chromite	—	*Cr*	—	—	—	—	x	x	—	x
Zircon	Zr, Hf	Zr, Hf	Zr, (Sc, Y) * Hf	Zr, Hf	(Sc, Y) * Zr, Hf	Zr, Hf	x	x	Zr, Hf	x
Monazite	Ce > La > Nd > Pr > Sm > Ho > Dy > Pm > Er, Y	—	Ce > Nd > La	—	Ce > La > Nd > Pr, Th	Ce > La > Nd > Pr	x	x	Ce > La > Nd	x
Cheralite	—	—	—	—	—	Ce > Nd > La > Sm, Pr, Gd, Ho, Th	x	x	—	x
Xenotime	Y > Dy > Sm > Gd > Yb > Ho > Er > Eu > Nd	Y > Dy > Er > Yb > Ho > Lu > Gd	Y > Dy > Gd > Ho, Er > Yb Tb > Lu > Sm	—	Y	Y	x	x	Y, Dy > Er > Ho > Yb > Gd > Tb > Tm > Hf > Lu	x
Secondary										
Pyrite	—	—	—	—	—	—	Ni	—	—	—
Bravoite	—	—	—	—	—	—	—	Ni, Co	—	—
Chalcop	—	—	Cu	—	—	—	—	—	—	Cu
Sphaler.	—	—	—	—	—	—	—	—	Zn	x
Galena	—	—	—	—	—	Pb	—	—	Pb	x
Baryte	—	Ba	—	—	—	—	x	x	—	x
Bastnäs. group	Ce > La > Nd	—	—	—	—	Ce > La > Pm	x	x	—	x
NiP mineral	—	Ni	—	—	—	—	x	x	—	x

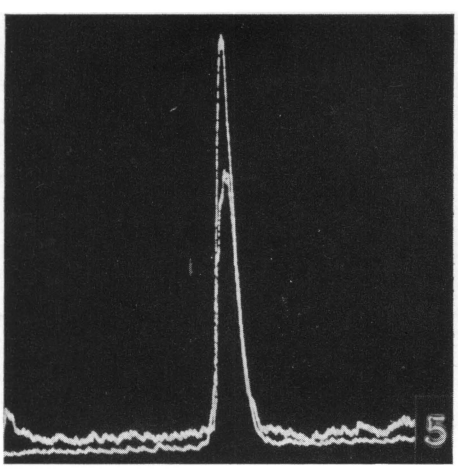
* = in some zircons only x = uninvestigated











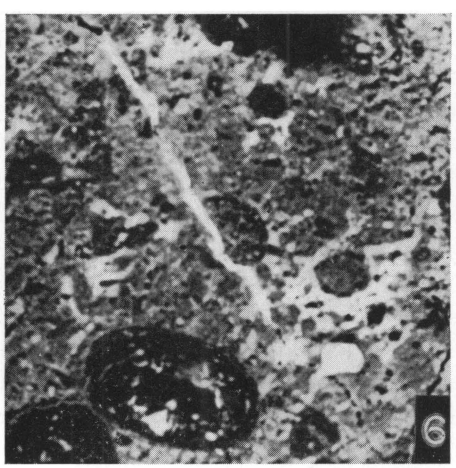


Fig. 1. — Iron-rich detrital bauxite grain with Cr enrichment. Pas de Recoux, France. Electron picture 1 mm = 5,5 μ

Fig. 2. — $Cr_K\alpha$ X-ray picture of Figure 1

Fig. 3. — Detrital monazite grain. Campo Felice, Italy. Electron picture. 1 mm = 1,4 μ

Fig. 4. — Detrital xenotime grain. Gant, Hungary. Electron picture. 1 mm = 1,4 μ

Fig. 5. — $Y_L\alpha$(lower peak) and $P_K\alpha$ X-ray profile along the line on Figure 4

Fig. 6. — Bastnäsite fissure fillings. San Giovanni Rotondo, Italy. Electron picture. 1 mm = 2,8 μ

grains were common. We suppose that the Ce content necessary for the bastnäsite formation came from the dissolution of the monazite grains of the upper part of the deposit. Compared with the rare element content of the monazite, the bastnäsite contains predominantly Ce (appr. 70-75 percent) accompanied by very small amounts of La and Pm. Based on the Ca content found in some grains it can be concluded that Ca-bearing members of the bastnäsite group are also present (parisite, röntgenite, synchisite).

The sulphide minerals can also represent trace element enrichment in the bauxite. The *pyrites* found in many deposits did not contain trace elements, but in almost all pyrite grains found in the Podlipa deposit (Yugoslavia, Slovenia) Ni enrichment was detected. A relationship was established between the morphology and the Ni content: the irregularly shaped grains contain only about 0,1 percent Ni. The more euhedral the grains are the more Ni they contain. The maximum Ni content was 2 percent.

In the Distomon deposit (Greece) a particularly high Ni enrichment was observed in *bravoite* grains. Based on our quantitative analysis the average Ni content of the bravoite was 6 percent. The mineral also contained 0,2 percent Co and 0,9 percent As.

The only copper enrichment in bauxite was found in the form of pore filling *chalcopyrite* in a bauxite sample from the Northern Ural Mountains and in a Mazaugues deposit (France). The grains were irregularly shaped with a size of 3-40 microns.

Zu in the form of *sphalerite* was found only in the Gánt deposit (Hungary). It was associated with galena with a size of 40 microns (Figs. 10, 11 and 12). The irregular shape of the grains suggests their secondary origin.

Galena was found, as mentioned above, in the Gánt deposit and in San Giovanni Rotondo (Italy). It was generally of 4-8 microns in size without other measurable trace element content. In the San Giovanni Rotondo deposit the galena grains were detected throughout the entire profile from the top to the bottom but in a very low quantity.

Ba was found in the form of *baryte* in the deposit of Pas-de-Recoux (France). The grain size was 4 microns. It was very rare. In the same deposit we found a mineral *consisting only of Ni and P which occurs in an iron-rich detrital bauxite grain in the form of micro*-fissure and micro-pore fillings occupying an area of 300 microns in diameter. The size of the individual minerals is 3-30 microns.

The mineral cannot be a hydrate because it was found to be very stable under electron bombardment. Because of the very small grain size the exact identification of the mineral was not possible.

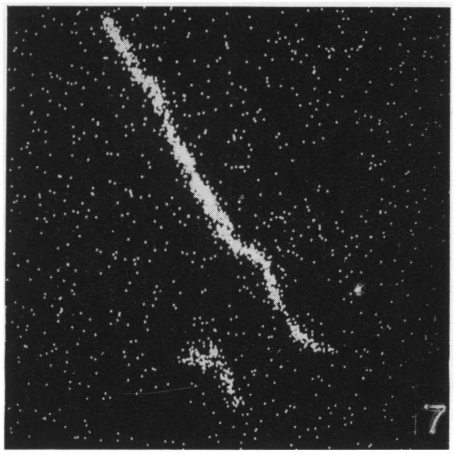
3. GEOLOGICAL IMPLICATIONS OF THE RESULTS

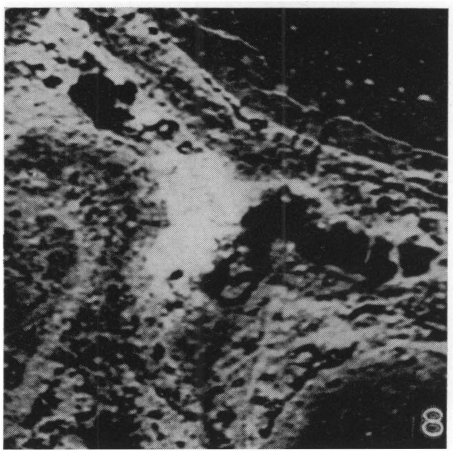
These trace mineral and trace element determinations can be used effectively as a key in the search for the source rocks of bauxite deposits.

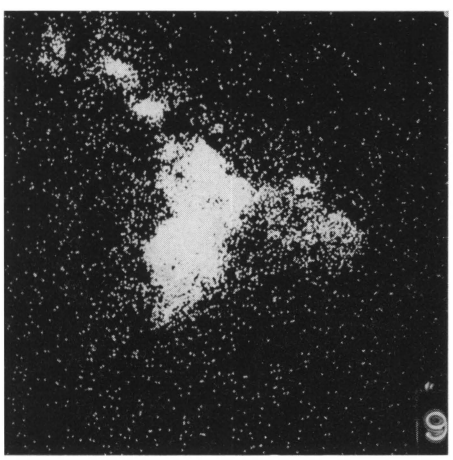
For example in the case of the *Distomon deposit* (Greece) the presence of the Ni and Co in the form of bravoite confirms the theory according to which the bauxites of this region have been derived from the laterites of the Lokris territory, these laterites being considerably enriched in Ni.

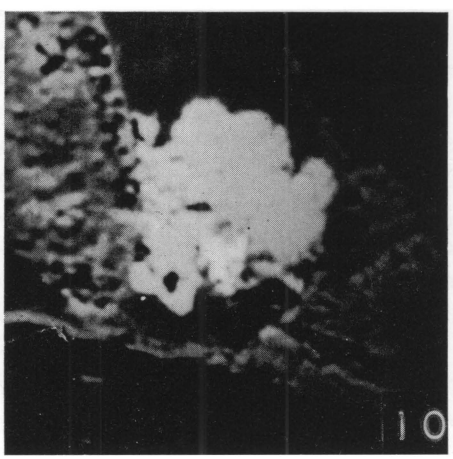
In Hungary the trace minerals found in the *Gánt deposit* were also detected in the granites of the Velence Mountains, occuring 15 km to the SE of the given bauxite deposit. The sphalerite and galena mineralizations occuring in these granites make it easy to explain the Zn and Pb content (sphalerite, galena) of this bauxite. The zircon, monazite and xenotime are common accessories of these granites.

The *Central Italy* bauxites have been assumed to be formed exclusively from the footwall limestones. The recent detection of zircon, monazite, cheralite and xenotime can not be explained by this theory. Our results suggest the possibility of an igneous source rock, at least in part.









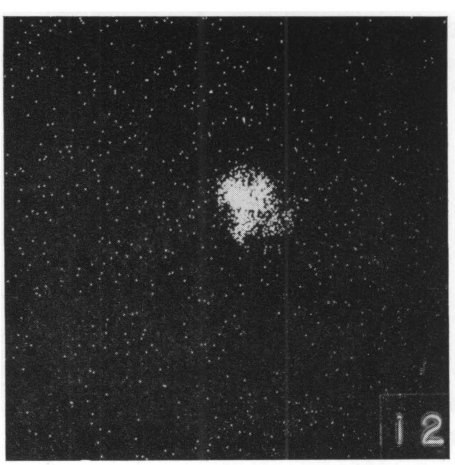


Fig. 7. — $Ce_L\alpha$ X-ray picture of Figure 6

Fig. 8. — Bastnäsite micro-pore fillings. San Giovanni Rotondo, Italy. Electron picture. 1 mm = 2,8 μ

Fig. 9. — $Ce_L\alpha$ X-ray picture of Figure 8

Fig. 10. — Galena and sphalerite. Gánt, Hungary. Electron picture. 1 mm = 1,4 μ

Fig. 11. — $Zn_K\alpha$ X-ray picture of Figure 10

Fig. 12. — $Pb_M\alpha$ X-ray picture of Figure 10

In Provence (France) some authors supposed that the bauxite originated exclusively from the footwall carbonate rocks. On the contrary, others belive that their source was the igneous rock of the nearby Maures Massive. Our results confirm this latter theory. The deposits which we studied are situated on a WSW-ENE line. Their distance from the granites and granite-gneisses at Pas-de-Recoux was 10-12 km, at Mazaugues 30-35 km and at Allauch an estimated 25-30 km. On the nearly 2 cm^2 surface of the specimens we determined the following data:

TABLE II

Minerals		*Allauch*	*Mazaugues*	*Pas de Recoux*
Monazite	number of grains	6	5	—
	most frequent grain size	8×6 μ	4×3 μ	—
	maximal grain size	20×10 μ	8×4 μ	—
Xenotime	number of grains	3	5	5
	most frequent grain size	3×2 μ	4×3 μ	6×4 μ
	maximal grain size	4×3 μ	20×20 μ	30×22 μ
Zircon	number of grains	50	20	30
	most frequent grain size	20×10 μ	10×8 μ	15×10 μ
	maximal grain size	110×60 μ	30×30 μ	50×30 μ
Chromite	number of grains	—	—	10
	most frequent grain size	—	—	5×5 μ
	maximal grain size	—	—	25×15 μ
Cr-bearing detrital bauxite grains	number of grains	—	10	30
	most frequent grain size	—	80×50 μ	500×300 μ
	maximal grain size	—	100×100 μ	2 000×1 500 μ

The Cr-bearing iron-rich detrital bauxite grains were detected in the greatest number and with the largest grain size in Pas-de-Recoux; chromite and the above described Ni-P mineral were found only in this deposit. The number of the monazite grains and their grain size increased from the ENE to the WSW; on the other hand, these values for the xenotime grains increased in the opposite direction. These general trends point out differences in the composition of the source rock and a clear dependence of distance from them.

The above examples show that a careful trace element and trace mineral study of the bauxites can considerably enlarge our knowledge of this ore and can serve as a useful genetic key.

REFERENCES

[1] BÁRDOSSY (Gy), PANTÓ (Gy), 1970. — Bauxitok vizsgálata elektron-mikroszondával. *Bányászati és Kohászati Lapok, Bányászat, 103*, p. 825-837, Budapest.

[2] BÁRDOSSY (Gy), PANTÓ (Gy), 1971. — Investigation of bauxites with the help of electron-probe. *Tschermaks Min. Petr. Mitteilungen, 15*, p. 165-184, Wien.

[3] BÁRDOSSY (Gy), PANTÓ (Gy), 1972. — On the pyrite types in bauxites. *Acta Geologica Acad. Sci. Hung., 16*, p. 3-11, Budapest.

Académie des Sciences de Hongrie
Kossuth ter 18, 1055 Budapest V (Hongrie)