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Extraclasts from Cretaceous/Tertiary Bauxites of the Transdanubian Central Range and the Northern Calcareous Alps. Preliminary Results and Tentative Geological Interpretation

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With 4 Text-Figures, 1 Table and 13 Plates

Österreich
Ungarn
Kreide
Bauxit
Extraklasten
Herkunft
Mineralogie
Abtragungsgeschichte

IGCP-Project 287
"Tethyan Bauxites"

Contents

Extraklasten aus Kreide-Tertiär-Bauxiten des Transdanubischen Mittelgebirges und der Nördlichen Kalkalpen. Vorläufige Resultate und Versuch einer geologischen Interpretation.

Zusammenfassung

Die Bauxitvorkommen des Transdanubischen Mittelgebirges verdanken ihre Entstehung mehreren Episoden von Trockenlegung und Verkarstung, welche an die altalpidischen Gebirgsbildungs-Phasen der Kreidezeit gebunden sind.

Wir haben die aus den Bauxiten der verschiedenen stratigraphischen Horizonten separierten Extraklasten untersucht, um damit neue Informationen über die Denudations-Geschichte der weiteren Umgebung des Transdanubischen Mittelgebirges zu

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erhalten. Diese Ergebnisse werden mit den wenigen von österreichischen Bauxiten zur Verfügung stehenden Beobachtungen verglichen. Schließlich wird versucht, auf Grund dieser Ergebnisse eine neue Hypothese hinsichtlich der Herkunft der exotischen Schüttungen aufzustellen.

Von jenen klastischen Mineralien, die in allen drei stratigraphischen Horizonten in gleicher Weise vorkommen (vorwiegend Quarz, einige magmatische oder gering-metamorphe Gesteinsfragmente, teilweise auch die Mineralien der „ultrastabilen" Gruppe) nehmen wir an, daß diese schon in den mesozoischen Karbonatgesteinen des Bauxit-Liegenden enthalten waren und als Verwitterungsreste im Zuge der Verkarstung in den Bauxit gerieten.

Von jenen Extraklasten dagegen, die entweder vorwiegend oder allein für einen bauxitführenden Horizont charakteristisch sind, nehmen wir an, daß sie aus nicht-karbonatischen Gesteinen stammen und sich, transportiert durch Wind und/oder Wasser, mit dem Bauxit im Laufe der Sedimentation vermischten. Diese Extraklasten können uns Informationen bezüglich der Paläogeographie der weiteren Umgebung geben.

Ergebnisse

Das Haupt-Schwermineral des Alb-Bauxithorizontes ist der Titanit; daneben sind noch verschiedene Mineralien aus metamorphen Gesteinen (Disthen, Hornblende) und Gesteinsfragmente bezeichnend.

Der Senon-Horizont ist auffallend arm an Extraklasten. Die wenigen identifizierbaren Mikroklasten sind – neben den „ultrastabilen" – Quarz, Feldspat, Glimmer und Fragmente von plutonischen, bzw. gering-metamorphen Gesteinen.

Der Paläozän-Untereozän-Horizont ist auffallend reicher an Extraklasten; sein Schwermineral-Spektrum ist breiter und charakterisiert durch einen hohen Anteil an Mineralien aus hochmetamorphen Gesteinen (Disthen, Sillimanit, Staurolith, Granat, Zirkon, Turmalin, Epidot, Zoisit, u. a.). Auch Gesteinsfragmente sind auffallend häufiger, ebenso idiomorphe Kristalle von Zirkon und Ilmenit. Vereinzelt wurden auch vulkanische Mikroklasten gefunden.

Schlußfolgerungen

1) Subaerische Erosion von metamorphen Gesteinen der kontinentalen Kruste war schon während des Unter-Alb in der weiteren Umgebung des Transdanubischen Mittelgebirges möglich.
2) Ähnlich wie in den Nördlichen Kalkalpen läßt sich auch im Transdanubischen Mittelgebirge die Denudation eines hoch-metamorphen Grundgebirges erst nach dem Campan erkennen.
3) Das Vorkommen von idiomorphem Ilmenit und Zirkon im Eozän-Bauxit-Horizont läßt eine unter-eozäne vulkanische Tätigkeit in der weiteren Umgebung des Transdanubischen Mittelgebirges möglich erscheinen.

Extraklasztok a dunántúli-középhegységi és az északi-mészkő alpi kréta–harmadidőszaki bauxitokból. Előzetes eredmények és földtani értelmezés

Összefoglalás

A Dunántúli-középhegység bauxitelőfordulásai keletkezésüket a kréta időszak óalpi hegységképződési fázisaival kapcsolatos szárazrakerülési és karsztosodási eseményeknek köszönhetik.

A szerzők a különböző rétegtani szintek bauxitjaiból elkülönített extraklasztokat abból a célból vizsgálták meg, hogy így újabb ismeretekre tegyenek szert a Dunántúli-középhegység távolabbi környezetének lepusztulás-történetéről. Észleléseiket összehasonlították az osztrák bauxitokról rendelkezésre álló szórványadatokkal. Ennek alapján az extraklasztok eredetére vonatkozó újabb hipotézis felállítására tesznek kísérletet.

Azon törmelékes ásványokról, amelyek mindhárom rétegtani szintben egyaránt jelen vannak (elsősorban kvarc, néhány magmás, vagy enyhén metamorf kőzettörmelék, valamint az "ultrastabil"csoport ásványai), feltételezik, hogy már a bauxitfekvő mezozóos kőzetekben is megvoltak, s a bauxitba a karsztosodás során "mállási maradék"-ként kerültek. Azokról az extraklasztokról viszont, amelyek vagy túlnyomórészt, vagy kizárólagosan jellemzőek valamelyik bauxit szintre, feltételezik, hogy nem-karbonátos kőzetekből származnak és víz által szállított, vagy szélfújta törmelékként keveredtek el a bauxittal. Ezek azok az extraklasztok, amelyek tájékoztatást nyújthatnak a távolabbi környezet ősföldrajzi viszonyairól.

Eredmények

Az albai bauxitszint jellemző nehézásványa a titanit, amelyet különböző metamorf ásványok (disztén, hornblende), valamint kőzettöredékek kísérnek.

A senon szint feltűnően szegény extraklasztokban. Az "ultrastabil" ásványok mellett, kvarcot, földpátot, csillámot és csupán kevés plutóni, illetve enyhén metamorf kőzettöredékeket tartalmaznak.

A paleocén–alsó-eocén szint feltűnően gazdag extraklasztokban; a törmelékes ásványtársulás feltűnően változatos (disztén, szillimanit, sztaurolit, gránát, cirkon, turmalin, epidot, zoizit stb.). Gyakoriak benne a kőzettöredékek, valamint az idiomorf cirkon és ilmenit. Szórványosan vulkáni eredetű mikroklasztok is előkerültek belőle.

Következtetések

1) Kontinentális kéregeredetű metamorf kőzetek a Dunántúli-középhegység távolabbi körzetében már a kora-albai idején is fel lehettek tárva.
2) Az Északi Mészkőalpokhoz hasonlóan a Dunántúli-középhegységben is – csak a campaniai után észlelhető a finomtörmelékes üledékekben a magas fokú metamorf alaphegység denudációjának hatása.
3) Az idiomorf ilmenitnek és a cirkonnak az eocén bauxitszintben megfigyelhető dúsulása esetleg a Dunántúli-középhegység távolabbi körzetében a kora-eocénben meginduló vulkáni tevékenységet jelezheti.

Abstract

Bauxites of the Transdanubian Central Range are related to subaerial exposure phases apparently synchronous with important orogenetic events in the Periadriatic area. Extraclasts separated from the Albian, Senonian and Eocene bauxite horizons were studied with the aim of contributing to the denudational history of the broader surroundings of the Transdanubian Central Range sector at the time of the subaerial exposure phases. The results are compared to the few available observations made earlier on Cretaceous bauxites of the Northern Calcareous Alps and tentative suggestions regarding the source of the extraclasts are made.

Extraclasts present in all three horizons (mainly quartz, some igneous or low-grade metamorphic rock fragments and part of the "ultrastable" group i.e. zircon, rutile, tourmaline) are considered to be grains already present in the Mesozoic carbonate substrate and left over by karstic dissolution. Those occurring predominantly or exclusively in one or the other of the horizons, are considered as extraclasts admixed to the bauxitic sediments during their accumulation, transported either by wind or by surface waters on to the karstic terrain, and thus giving information about the paleogeography of the surroundings.

Results

Samples originating from the Albian bauxite horizon are rich in titanite, various metamorphic minerals (kyanite, amphibole) and rock fragments. The Senonian horizon is rather poor in extraclasts: in addition to the "ultra-stable" minerals it contains mainly quartz, felspar, mica and low-grade metamorphic rock fragments. The Paleocene–Lower Eocene horizon is characterized by a strikingly higher grade metamorphic association with kyanite, sillimanite, rutile, garnet, zircon, tourmaline, epidote/zoisite, staurolithe, etc. In addition to this – particularly in the youngest deposits – the abundance of euhedral ilmenite and zircon is increased considerably, and – though very rarely – they contain also calc-alkaline volcanic rock-fragments.

Conclusions

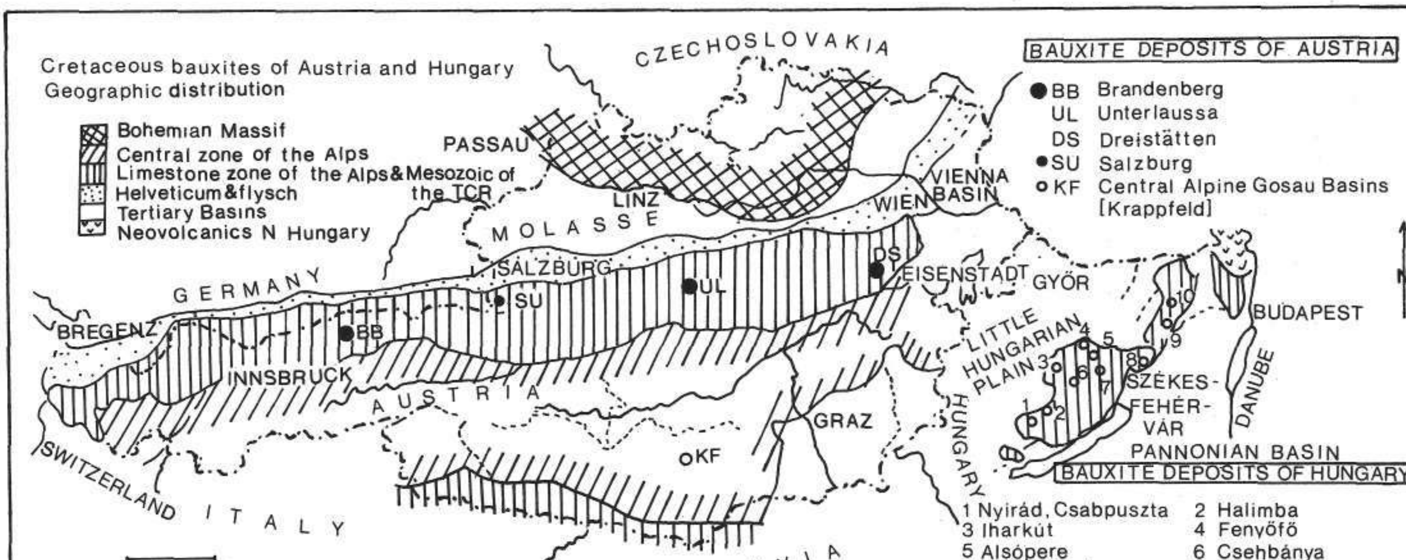
1) Subaerial erosion of continental crust-type material was possible as early as the early Albian already in the broader surroundings of the Transdanubian Central Range section of the Periadriatic area.
2) Similarly to the Eastern Alps also in the Transdanubian Central Range sector, the influence of the higher-grade metamorphic basement, as a "source" of fine-grained mechanical weathering products, became predominant in latest Cretaceous/Early Tertiary times only.
3) Euhedral ilmenite, zircon and the volcanic rock-fragments may be assigned to some hypothetic distant early Eocene volcanic source.

1. Introduction

Being the product of intense chemical weathering bauxites are generally poor in extraclasts. Almost all of them – even those occurring on the surface of carbonate rocks ("karst" bauxites) – do contain, however, at least a few highly resistant mineral grains. Part of the extraclasts in karst bauxites undoubtedly originates from the underlying carbonate substrate as the insoluble residue left over on karstification. Detailed micromineralogical studies, however, often reveal the presence of less resistant minerals and rock fragments as well, which are unlikely to have survived more than one cycle of weathering. Instead they apparently were admixed to the bauxitic sediment during its deposition and are the weathering products of contemporaneously exposed non-carbonatic rocks.

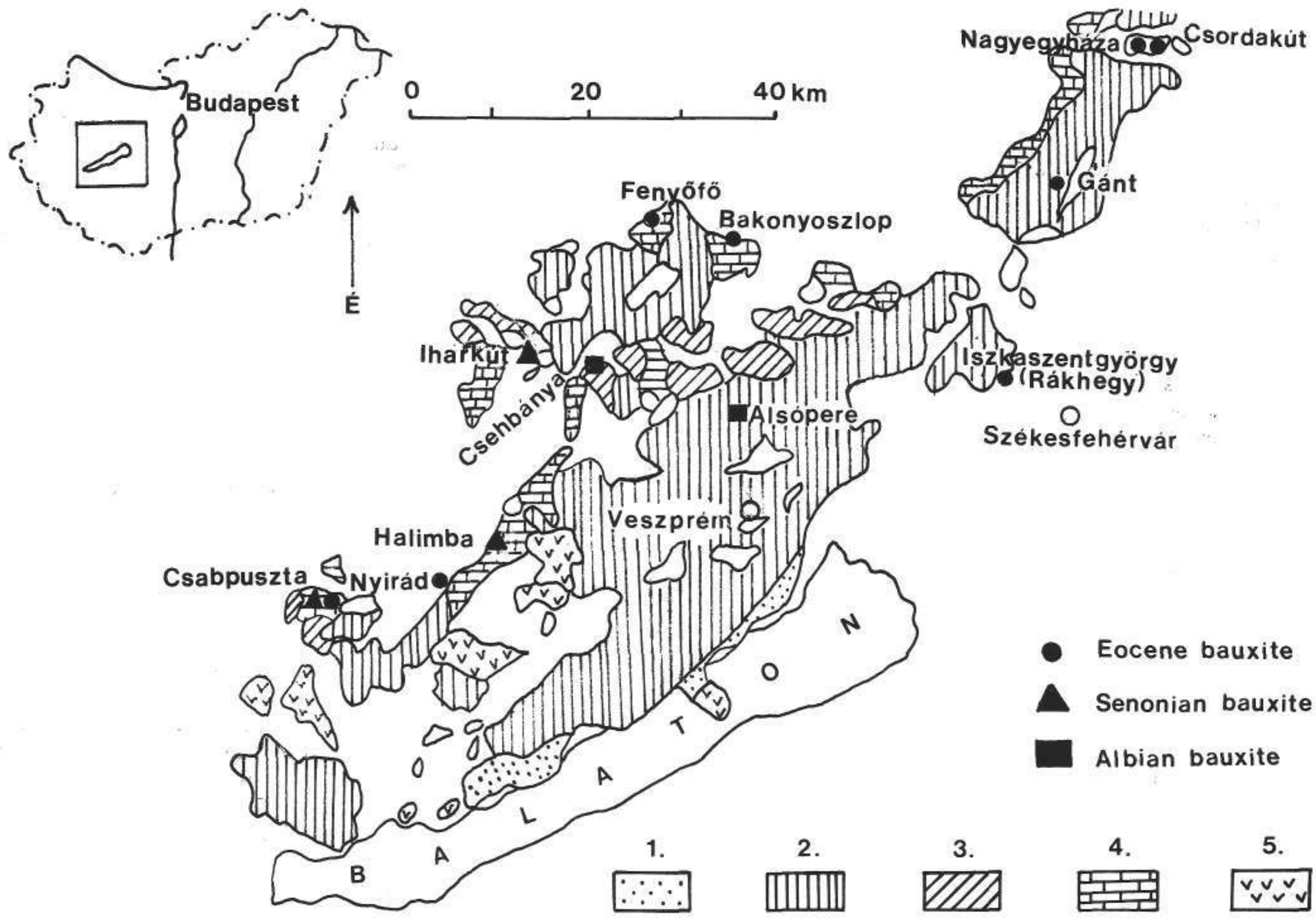
In most cases the size of these extraclasts (silt to fine-sand) suggests eolian transport; there are examples, however, where transportation of extraclasts by sheet-wash or by surface water-flows cannot be excluded either. Their importance lies in the fact that when lacking other more direct information, as is often the case at the time of regional unconformities, they may be the only references regarding the details of paleogeography of subaerially exposed terrains.

Bauxites of the Transdanubian Central Range are related to subaerial exposure phases apparently synchronous with important orogenic events in the Periadriatic area (cf. Figs. 1 and 2). Those occurring at the base of the Albian *Munieria* marls can be correlated with the Austrian phase; the Turonian/Senonian ones with the Pre-Gosau phase and the Paleocene/Eocene bauxites with the Laramian phase (KÁROLY et



Oberhauser 1968 ← | → after Szantner 1979 and Bárdossy 1980

Text-Fig. 1.
Major bauxite deposits in Austria and Hungary.
Geographic distribution.



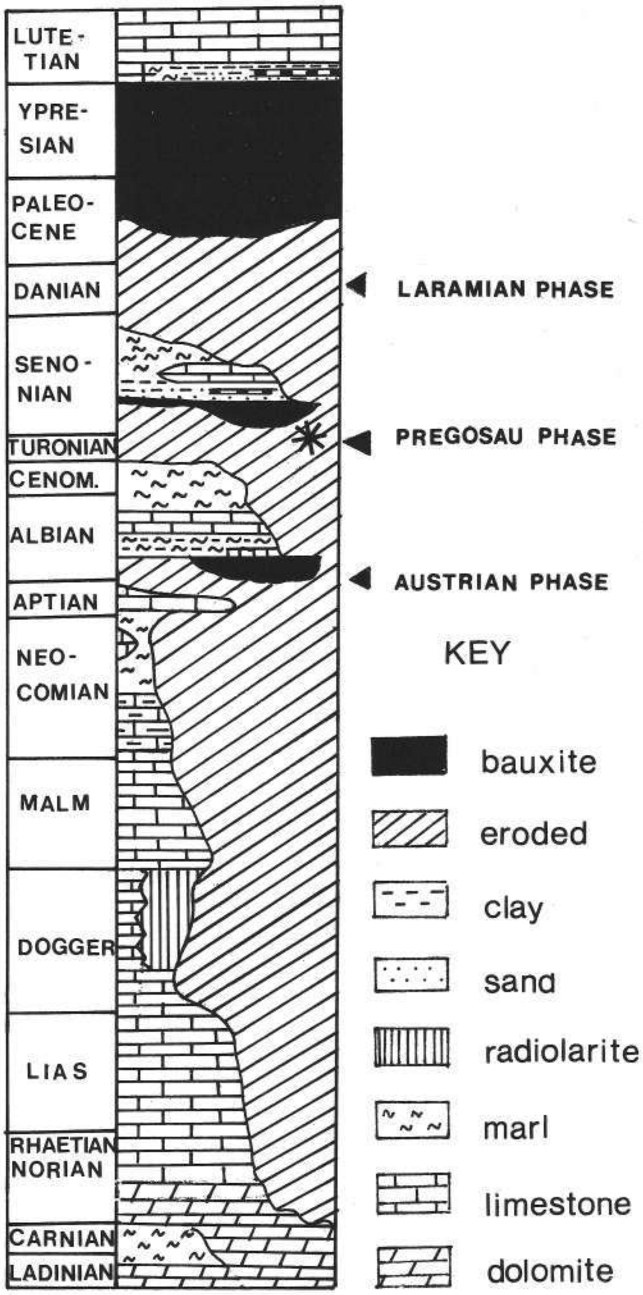
Text-Fig. 2.
Geographic distribution of bauxites in the Transdanubian Central Range.
1 = Palaeozoic, 2 = Triassic–Jurassic–Neocomian, 3 = Upper Cretaceous, 4 = Eocene, 5 = Neovolcanics.

al., 1969; SZANTNER-SZABÓ, 1969; DUDICH-KOMLÓSSY, 1969; MINDSZENTY-D'ARGENIO, 1987). Of the three horizons only the one associated with the Pre-Gosau phase has got its equivalent in Austria (in the Northern Calcareous Alps; RUTTNER, 1969). In connection with the Austrian phase which resulted in erosion and associated clastic sedimentation at many places in Austria no bauxitiferous subaerial exposure-surface was reported as yet (OBERHAUSER, 1980), and also the widespread Paleocene/Eocene bauxite horizon of Hungary is represented only by a thin red argillaceous layer at the base of the Lower Eocene at Krappfeld (Central Alpine Gosau basin, BECK-MANNAGETTA in OBERHAUSER, 1980).

Micromineralogical study of silt- to sand-size extraclasts separated from Hungarian bauxites dates back to the early fifties and resulted in detailed description of the micromineralogical suite of the economically most significant Eocene deposits: Gánt, Iszkaszentgyörgy, Nyirád and Nagyegyháza (KISS, 1955; GECSE-MINDSZENTY, 1968; VÖRÖS, 1971; ANTAL, 1973; VÖRÖS-GECSE, 1976 and GECSE, 1982). The first data regarding the older (Turonian/Senonian and Albian) horizons (based mainly on preliminary micromineralogical assessments and on thin-section information) were mentioned by MINDSZENTY (1984), MINDSZENTY et al. (1987) and MINDSZENTY & GÁL-SOLYMOS (1988) who also called the attention to the apparent micromineralogical differences between the individual bauxite horizons. To prove and partly correct these preliminary findings, systematic re-examination of the micromineralogy of bauxites including those of the older (Turonian/Senonian and Albian) horizons commenced in 1986 supported by the Hungarian Geological Institute and the Bauxite Prospecting Company of HUNGALU.

The only micromineralogical data on Austrian bauxites are those mentioned by SIEGL (1973) from Unterlaussa and by MINDSZENTY et al. (1987) in connection with the Dreistätten occurrence (Turonian/Senonian in age). Detailed information regarding micromineralogy/extraclasts of Albian, Senonian and Lower Tertiary sedimentary formations of the Eastern Alps, contemporaneous with one or the other of the above mentioned bauxitiferous horizons is, however, abundant in the literature (DECKER et al., 1987; DIETRICH-FRANZ, 1976; FAUPL, 1975, 1983; WINKLER-BERNOULLI, 1986; WOLETZ, 1963, 1965, 1967; RUTTNER-WOLETZ, 1957).

The aim of the present paper is to review – horizon by horizon – the available micromineralogical information on Hungarian bauxites (including the first results of the above mentioned systematic re-examination) and thus to contribute to the denudational history of the broader surroundings of the Transdanubian Central Range sector at the time of the subaerial exposure phases. The authors are aware of the fact that the data presented here are by far not sufficient to reach final conclusions. All the same, the results will be compared to the few available observations made earlier on Cre-



Text-Fig. 3.
Stratigraphic column indicating the position of bauxite deposits in the Transdanubian Central Range.
Asterisk marks the horizon equivalent to the bauxite deposits of Austria.

taceous bauxites of Austria, and tentative suggestions regarding the source of the extraclasts will be made in order to provoke further more detailed studies and thus eventually facilitate a regional comparison.

2. Extraclasts in Bauxites of the Transdanubian Central Range

2.1. Methods

Extraclasts identified from in all 11 localities comprising all three bauxitiferous stratigraphic horizons and incorporating all previous published and unpublished data are summarized by Table 1. Most figures stand for representative bulk-samples (500 to 1000 g each) either hand-sampled in active mines or made as composite samples from cores of several boreholes drilled at one and the same locality. Exceptions are those from Alsópere (Albian) and Bakonyoszlop (?Eocene) which were attained at by treating about 200 g of bauxite from one single borehole each.

Sample preparation was undertaken by hydrochloric acid treatment followed by subaqueous mechanical agitation and decantation. Due to cementation by finely distributed sesquioxides desaggregation frequently took several weeks and sometimes had to be combined by repeated steps of washing/freezing/drying/gentle crushing. The silt and sand-size dissolution residue was sieved and then concentrated with an isodynamic magnetic separator. When necessary also hand-picking under the binocular microscope was used to attain an optimum recovery. The size of the extraclasts thus concentrated generally fell between 0.1 and 0.06 mm or was smaller than 0.06 mm, with lesser amounts of grains occurring in the 0.1–0.2 mm fraction (particularly in some of the Eocene bauxites and to a lesser extent also in some of the Cretaceous ones).

The amount of the HCl-insoluble residue was invariably very low: in the order of magnitude of 0.1 percent in the case of some of the Eocene bauxites and 0.01 or less in the case of the Cretaceous ones. This is why for the time being we refrained from giving an overall quantitative evaluation of the data. Quantitative data from individual occurrences were published by Gecse-Mindszenty (1968), Vörös (1971), Antal (1973), Vörös-Gecse (1976); Gecse (1982).

Identification of the grains was carried out mainly by optical microscopy. In the case of Nagyegyháza, Gánt, Iszka and Nyirád this was supported by the Debye-Scherrer X-ray powder diffraction method applied to hand-picked monomineralic concentrates, whereas more problematic rock fragments and individual grains from Alsópere, Halimba, Iharkút, Fenyöfö and Csabpuszta were identified with the help of the electronmicroprobe or by a combination of the SEM and EDAX.

Instruments applied: JXA 50A microprobe and Superprobe 733 computer controlled microprobe both at 15 kV high voltage and to detect from B^5 to U^{92}; Philips SEM 505 scanning electron microscope with 7 nm resolution power at 25 kV accelerating voltage and an EDAX 711 energy dispersive microanalyser suitable to detect from Na^{11} up to U^{92}.

2.2. Results

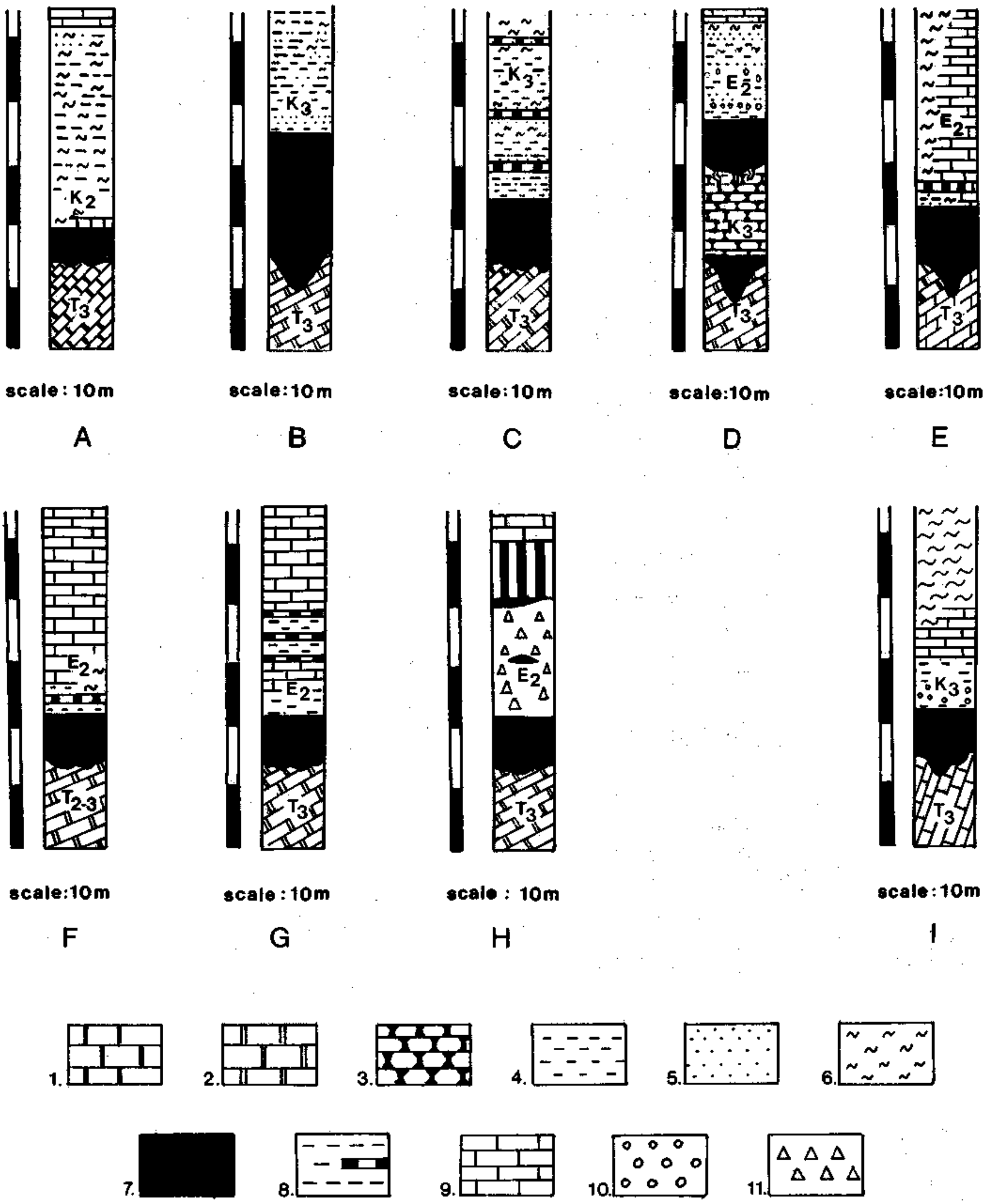
2.2.1. Albian Horizon

(Plates 1–3, Figs. 1–17)

- Type locality: Alsópere.
- Locality studied: Csehbánya, borehole Cseh-27, 410.9–414.9 m.
- Total amount of extraclasts: 0.008–0.004 %.
- Prevalent grain-size: 0.1–0.2 mm.
- Minerals identified: quartz, titanite (with apatite inclusions), K-felspar (cross-hatched twins), K-felspar (perthitic), plagioclase, apatite, kyanite, amphibole, zircon.
- Rock fragments:
  a) Na-rich K-feldspar – amphibole – K-felspar.

Table 1.
Extraclasts identified from Bauxites of the Transdanubian Central Range.
●●● = very abundant; ●● = abundant; ● = present; tr = trace.

	EXTRACLASTS IDENTIFIED FROM BAUXITES OF THE TRANSDANUBIAN CENTRAL RANGE										
AGE OF BAUXITE	C R E T A C E O U S				E O C E N E						
	ALBIAN	S E N O N I A N									
LOCALITY / EXTRA-CLASTS	Csehbánya	Halimba	Iharkút	Csabpuszta lower horiz	Csabpuszta upper horiz	Nyirád	Fenyőfő	Bakony-oszlop	Iszka Bitó/Rákh.	Gánt	Nagyegyháza
quartz	●●	●●	●		●●	●●	●	●	●●	●	●●
felspar (not spec.)				●	●		●				
K-felspar	●●	●●		●		●			●		
plagioclase	●	●									
amphibole	●				●		●		●	●	●
mica/chlorite	●	●		●	●	●			●●	●●	●
titanite	●●●										
apatite	●	●									
tourmaline			●	●	●●	●●	●●	●	●●●	●●	●
rutile			●	tr	●●	●●●	●●	●	●●	●●	●●
zircon (worn)	●	●	●	●	●	●	●	●	●	●	●●
zircon (euhedral)					●	●●	●●	●●	●●	●	●●
garnet					●●		●		●●	●	●
kyanite/sillimanite	●				●	●	●		●●●		●
staurolite					●●●			●	●●		●
corundum					●	●	●		●	●	●
epidote/zoizite					●●				●	●	●
others				●		●	●		●		●●
ilmenite/Ti-hematite			tr		●	●●●	●	●●	●●●	●●●	●●●
chromite/Cr-spinell			tr		●●				●		●●
rock-fragments											
dolomite/limestone	●	●●●									
volcanic					●						●
igneous/low-grade metamorph.	●	●●●			●●●	●●	●		●		●
high-grade metam.									●●●		
total amount of extraclasts (%)	0.008-0.004	0.01-0.001	0.001	0.001	0.06-0.01	0.1	0.03	medium to large	0.1-0.001		0.01-0.05
predominant grain size											
0.2-0.1	●	●			●	●			●	●	
0.1-0.06		●	●	●	●	●	●	●	●	●	●
0.06 >			●				●	●			



Text-Fig. 4.
Selected profiles from the studied localities.
Transdanubian Central Range: A = Alsópere; B = Iharkút; C = Halimba; D = Csabpuszta/Nagytárkány; E = Fenyőfő/Bakonyoszlop; F = Iszkaszentgyörgy/Rákhegy; G = Gánt; H = Nagyegyháza.
Northern Calcareous Alps: I = Dreistätten.
1 = Dachstein limestone; 2 = dolomite; 3 = rudistid limestone; 4 = clay; 5 = sand/silt; 6 = marl; 7 = bauxite; 8 = clay with coal-seams; 9 = limestone; 10 = conglomerate; 11 = fanglomerate.
T = Upper Triassic; K = Upper Cretaceous; E = Middle Eocene.

b) K-felspar – acidic plagioclase – mica – amphibole – apatite – rutile.
c) Limestone (Triassic and Jurassic).

○ Remarks:
1) Acid treatment made on 200 grams of sample only.
2) Limestone-fragments were identified from thin sections of bauxite samples from the type-locality.

2.2.2. Senonian Horizon

(Plates 4–5, Figs. 18–37)

○ Type locality: Halimba.

○ Localities studied:

a) **Halimba**
Total amount of extraclasts: 0.01 – 0.001 %.
Prevalent grain-size: 0.1 – 0.2 mm and 0.1 – 0.06 mm.
Minerals identified: quartz (sometimes with UO_2 inclusions), K-felspar (also with cross-hatched twins), acidic plagioclase, apatite (generally OH-apatite, rarely with 1 % F and Cl), chlorite, zircon (rounded, worn grains).
Rock fragments: a) quartzite; b) K-felspar – biotite – muscovite – (sericite); c) K-felspar – albitic plagioclase with frequent apatite inclusions; d) K-felspar – epidote; e) felspar – garnet; f) mica-schist with rutile needles; g) dolomite; h) low-Mg calcite peloids.
Remark: Bulk sample from underground mine, total weight: 600 g.

b) **Iharkút**
Total amount of extraclasts: 0.001 %.
Prevalent grain-size: 0.06 mm, 0.1 – 0.6 mm.
Minerals identified: quartz, zircon (colorless, yellow, pink), rutile, tourmaline, hematite, very few chromium magnesium-spinell grains.
Rock fragments: None.
Remark: bulk sample from opencast-mine (Nb-XIV, and –XVI), total weight: 900 g.

c) **Csabpuszta**
Lower horizon, borehole Ck-246, 80.1–84.9 m.
Total amount of extraclasts: 0.001 %.
Prevalent grain-size: 0.1–0.06 mm.
Minerals identified: quartz, felspar, tourmaline (brown, green), zircon (worn, isometric), muscovite, few rutile grains and opaque minerals.
Rock fragments: few unidentified grains.
Remarks:
1) composite sample, total weight: 300 g. with very few HCl-insoluble residue;
2) no microprobe or EDAX-work done.

2.2.3. Eocene Horizon

(Plates 6–13, Figs. 38–75)

○ Type locality: Csabpuszta (Upper horizon).

○ Localities studied:

a) **Csabpuszta – Nagytárkánypuszta**
Total amount of extraclasts: 0.06 – 0.01 %.
Prevalent grain-size: 0.1 – 0.06 mm, 0.1 – 0.2 mm.
Minerals identified: quartz, felspar, zircon (worn, rounded or elongate, euhedral, rich in inclusions of which apatite could be identified), tourmaline, rutile (frequent twin-crystals), staurolite, kyanite, sillimanite, garnet (Ca-Fe-Mg or less frequently Mn-), epidote and/or zoisite, ilmenite, chromium-spinell, chromite, corundum, dolomite.
Rock fragments: few quartz-felspar-micaceous grains and one single K-felspar-plagioclase-bearing „trachyte" fragment.
Remark: bulk samples from opencast mine (Kozmatag-I) and composite samples from borehole Nt-1950, 115.4–120.9 m, total weight: 550 g.

b) **Nyirád**
Borehole Nt-732, 72.0–79.0 m.
Total amount of extraclasts: 0.1 %.
Prevalent grain-size: 0.1 – 0.2 mm, 0.1 – 0.06 mm.
Minerals identified: quartz, felspar (perthitic orthoclase), zircon (worn rounded and slender euhedral), tourmaline, rutile, ilmenite, ?beryl, kyanite, corundum, chlorite.
Rock fragments: quartz-felspar-mica.
Remark: Source: GECSE & MINDSZENTY (1968) (no microprobe or EDAX-work done).

c) **Fenyőfő**
Total amount of extraclasts: 0.03 %.
Prevalent grain-size: 0.06–0.1 mm, 0.06 mm.
Minerals identified: Quartz, felspar, zircon (colorless, subrounded or slender euhedral with abundant neddle-form inclusions), rutile, tourmaline, garnet, corundum, amphibole (?anthophyllite), kyanite, brookite, ilmenite, magnetite.
Rock fragments: a) quartzite; b) quartz – K-felspar – albite.
Remark: bulk sample from open-cast mine (Fenyőfő-IV), total weight: 500 g.

d) **Bakonyoszlop**
Total amount of extraclasts: medium to high.
Prevalent grain-size: 0.06 mm, 0.06–0.1 mm.
Minerals identified: quartz, zircon (worn subrounded or slender euhedral with abundant inclusions), tourmaline (green, brown, blue), rutile, staurolite, ilmenite.
Remark: Preliminary results, based on random samples taken from boreholes Bob-660, Bob-600 and Cs-45. No microprobe or EDAX-work done.

e) **Iszka (Bitó, Rákhegy)**
Total amount of extraclasts: 0.1–0.01 %.
Prevalent grain-size: 0.1–0.06 mm, 0.1–0.2 mm.
Minerals identified: quartz, K-felspar (also microcline), plagioclase, zircon, rutile, tourmaline, muscovite, biotite, sericite, chlorite, amphibole, staurolite, epidote, garnet, corundum, kyanite, sillimanite, pseudobrookite, chromite, spinell, hematite, ilmenite, geikielite, magnetite (with ilmenite exsolution).

Rock fragments: a) quartz – felspar – biotite – amphibole (equigranular or schistose); b) muscovite – kyanite (equigranular); c) quartz – rutile; d) "gabbro-diabase" (with magnetite/ilmenite exsolutions); e) basaltic and trachytic volcanic fragments (with K-felspar, plagioclase, glass).
Remark: 1) Rákhegy: composite sample from boreholes Rp-63, –336 and –360, total weight about 200 g; studied in the course of the present work. Additional information was taken over from ANTAL (1973); 2) Bitó: core samples from 11 boreholes. Source of information: VÖRÖS (1958), VÖRÖS & GECSE (1976) (no microprobe or EDAX work done).

f) **Gánt**
Total amount of extraclasts: 0.2–0.01 %.
Prevalent grain size: 0.1–0.06 mm, 0.1–0.2 mm.
Minerals identified: quartz, muscovite, biotite, amphibole, epidote, rutile, garnet (spessartite), tourmaline, zircon, corundum, ilmenite/hematite, dolomite, calcite.
Rock fragments: not reported.
Remark: Source: VÖRÖS (1971), VÖRÖS & GECSE (1976) (identification with X-ray methods).

g) **Nagyegyháza**
Total amount of extraclasts: 0.01–0.05 %.
Prevalent grain size: 0.1–0.06 mm.
Minerals identified: ilmenite, magnetite, maghemite, hematite, chromite, pseudobrookite, tourmaline, zircon (colorless or pink, worn rounded or elongated euhedral) rutile, corundum, garnet (?almandine), kyanite, epidote, zoisite, staurolite, amphibole (hornblende), muscovite, biotite, chlorite, quartz.
Rock fragments: a) few micaceous quartzite grains; b) volcanics.
Remark: Source: GECSE (1982) (detailed study based on 113 core-samples from 14 boreholes).

3. Extraclasts from Cretaceous Bauxites of the Northern Calcareous Alps (Turonian/Senonian Horizon)

(Plate 14, Figs. 76–83)

Dreistätten
Abundance of extraclasts: high.
Prevalent grain-size: 0.1–0.06 mm, occasionally cm-size, white mica-schist fragments.
Minerals identified: mica, chromium-spinell, felspar.
Rock fragments: mica-schists.
Remark: Based on thin-section microscopic study of whole-rock samples, supported by microprobe work on selected grains.

Unterlaussa
Abundance of extraclasts: medium.
Prevalent grain-size: 0.1–0.06 mm.
Minerals identified: chromite, zircon, tourmaline, rutile, ?epidote.
Rock fragments: mica-schists and other obscure fragments (mainly weathered to kaolinite and/or boehmite).
Remark: Source of information: SIEGL (1973) and thin-section study of whole-rock samples by the present authors.

Brandenberg
Abundance of extraclasts: very few.
Prevalent grain size: 0.06 mm.
Minerals identified: mica, tourmaline.
Rock fragments: micaceous quartzite.
Remark: based on thin section study of whole-rock samples.

4. Discussion

4.1. Extraclasts in Bauxites of the Transdanubian Central Range

Minerals of the "ultrastable" group (zircon, rutile, tourmaline) and quartz are present in the HCl-insoluble residue of almost all the studied samples. Other minerals and rock fragments seem to be characteristic of one occurrence rather than of the other.

When neglecting the ultrastables, characteristic assemblages of the three horizons are as follows:

- **Albian**
  Titanite (accompanied by kyanite and amphibole).
- **Senonian**
  Quartz, felspar, low-grade metamorphic- and calc-alkaline ?igneous rock fragments.
- **Eocene**
  Staurolithe, epidote, kyanite, sillimanite, garnet, euhedral ilmenite, elongate euhedral zircon, anomalously abundant tourmaline and rutile, chromite, medium-grade metamorphic and volcanic rock fragments.

We think that the ultrastables may have been present already in the Mesozoic carbonate substrate and, being extremely resistant to weathering, were left over on karstic dissolution and became relatively enriched in the bauxite (their worn and rounded morphology apparently supports the idea of recycling from older sediments).

Those minerals and rock fragments, however, which occur predominantly or exclusively in one or the other of the three bauxite horizons may have originated in adjoining non-carbonatic areas and been admixed to the bauxitic sediment during its deposition. If so, their variation necessarily reflects paleogeographic changes (stages of denudation) on the surface of adjoining contemporaneously exposed non-carbonatic areas.

The fact that euhedral ilmenite and euhedral zircon occur almost exclusively in bauxites of the Eocene horizon points to their possible association with some contemporaneous volcanic episode. Though there is no evidence of middle Eocene volcanism in Hungary as yet, the few volcanic rock-fragments observed in the Eocene bauxite of Csabpuszta and Nagyegyháza seem to support our hypothesis and so do recent fission-track measurements by DUNKL according to which the majority of the zircon grains separated from the upper bauxite horizon proved to be of Eocene age (DUNKL, 1989 and pers. comm.).

In addition to these essentially qualitative variations, there is a rather distinct quantitative variation, too. The total amount of extraclasts is smallest in the case of the Senonian bauxite horizon (0.001 % at Iharkút) and largest in the case of the Eocene one (with 0.2 % at Gánt).

Also there are variations within the individual horizons: both Iharkút and Csabpuszta (lower horizon) are anomalously poor in extraclasts and also the diversity of the detrital mineral assemblage is low, whereas in Halimba, though the abundance of extraclasts is only slightly higher than at the other two Senonian localities, the diversity is definitely greater.

In the case of the Eocene deposits an increase of both the diversity and the abundance of the extraclasts can be observed from the SW to the NE and also – in many cases – from the bottom to the top of the investigated profiles. At Csabpuszta, where the bauxitiferous stratigraphic gap is smallest (bedrock: Senonian; cover: lowermost Lutetian), extraclasts are most abundant in the topmost few meters of the bauxite, and they are not particularly rich in euhedral ilmenite. Further to the North, at Bakonyoszlop where the stratigraphic gap is much wider (bedrock: Upper Triassic, cover: Upper Lutetian [Bartonian]) the situation is similar; however, here on the top of the bauxite there is a sudden increase of the amount of euhedral ilmenite. All the other deposits to the NE of Bakonyoszlop are characterized by a highly diverse extraclast assemblage invariably rich in euhedral ilmenite generally right throughout the profiles. Since the age of the Eocene cover-beds is appreciably younger in the NE than in the SW (lowermost Lutetian in the South and Bartonian in the North as pointed out by BÁLDI & BÁLDI-BEKE, 1985; BIGNOT et al., 1987; DUDICH-KOPEK, 1980) this spatial variation at the same time means a temporal variation, too.

Grain-size variations in space and time – though apparent, both in the inter- and the intra-horizontal sense – would require more detailed quantitative studies to interpret, so they will not be discussed here.

To find the actual "source" area for the extraclasts of each one of the individual horizons is difficult. First of all because in the immediate vicinity of the TCR there are no medium-grade metamorphic rocks the weathering of which might have produced the extraclast assemblage found in either the Albian or the Eocene bauxites.

As to the Senonian horizon, its low-grade metamorphic assemblage does not exclude the Paleozoic of the TCR as a source, but it is not significant enough to prove this either. The other problem which we necessarily face when searching for the source is that the grain-size of the extraclasts is very small (silt to fine sand) in fact, in most cases so small that in addition to overland waterflows they might have been transported by the wind as well, and in this case we anyway have to look for some more distant sources.

The possible maximum distance of these sources, however, may be estimated when using the data of TOMADIN et al. (1984) as an analogy. Based on recent observations they have shown that the amount of atmospheric dust (silty clay with very low sand content) originating from the Sahara is of the order of magnitude of 0.X microgramms per cubic meter in the Central Mediterranean. They concluded that windborn particles greater than 16 micrometers are deposited during the first 1000 kms of transport. By analogy we can say therefore, that even if our extraclasts were partly of eolian origin, their source area must have been situated within a range of less than a 1000 kms to the Transdanubian Central Range at the time of the accumulation of the bauxites. In other words, this is the maximum size of the area the denudational history of which is recorded in the changing extraclast suite of the bauxites.

This, though, certainly restricting the value of the interpretation in the sense of local geology, may increase it in the regional sense.

We think that the above described differences between the three bauxite horizons of the Transdanubian Central Range do indeed record important stages of the Cretaceous-Tertiary denudation history of a larger segment of the Periadriatic area.

What we see is, that the most characteristic signal, namely the sudden increase of the higher-grade metamorphic micro-extraclasts in the Tertiary bauxites as compared to the Senonian ones, seems to correlate quite well with the heavy-mineral change recorded in the Gosau Basins of Austria. According to WOLETZ (1963, 1967) in the lower part of the Gosau, including the underlying bauxite, chromite is the leading heavy mineral, accompanied by zircon, whereas from the Upper Campanian on, along with zircon also garnet, rutile and other higher-grade metamorphic minerals etc. suddenly become abundant and chromite disappears. Chromite was found by SIEGL (1973) in the Unterlaussa bauxite and in the Dreistätten bauxite together with abundant tiny mica-flakes and low-grade metamorphic rock fragments by MINDSZENTY et al. (1987) (see Plate 14, Figs. 76–83). The latter were very similar to those we found in deposits of the Senonian horizon of Hungary (though with only occasional chromite grains there). Interestingly enough the increased abundance of chromite and chromium spinell in Hungarian bauxites coincides with the increased abundance of the higher-grade metamorphic assemblage in the Eocene horizon (see Plate 11–13). Despite this "anomaly" we think that the change of the extraclast suite observable between the Senonian and the Eocene horizons is significant enough to support the idea put forward by MINDSZENTY et al. in 1987. They proposed that while in Austria the intra-Senonian heavy-mineral "switch" to the higher-grade metamorphic assemblage was recorded in the Gosau series, in Hungary it would have been recorded in the Upper Cretaceous and Lower Tertiary bauxites.

Unfortunately the lack of micromineralogical data on paleontologically datable Campanian–Maestrichtian marine formations of the Transdanubian Central Range spanning the gap between the Turonian–Senonian and the Lower to Middle Eocene bauxites does not allow to judge whether the "switch" is exactly synchronous with the one in Austria, or takes place perhaps somewhat later.

In any case we think that our data clearly point to the Alpine provenance of the extraclast suite of both the Senonian and the Early Tertiary bauxites of Hungary, and that with some slight along-strike lithological variations, by and large, they record the denudation of the same distant backgrounds as the Austrian bauxites (and Gosau sediments) do.

It would be interesting to see whether the euhedral ilmenite and euhedral zircon "signal" (supposed to be of volcanic affiliation) does have its equivalent in the lower Tertiary formations somewhere in the Periadriatic area?

The question of the source for the extraclasts of the Albian horizon is even more problematic. Of these sectors of the Periadriatic area which had been tectonically affected (thrusted, folded) during the Cretaceous, the Transdanubian Central Range is apparently the only one where tectonic uplift resulted in large-scale subaerial exposure and bauxite-type weathering already as early as the Early Albian. From within Hungary we do not have any evidence of kyanite- or titanite-bearing rocks exposed by the Austrian phase, so here again we must hypothesize some distant source (though within a range of 1000 kms to the Cretaceous karst terrain of the Transdanubian Central Range), most probably somewhere at the northern extremes of the "African Promontory" (sensu D'ARGENIO et al., 1980), where early thrusting produced high enough tectonic relief to expose crystalline basement rocks as early as that.

4.2. The Bauxites of the Northern Calcareous Alps

Apart from the few preliminary data presented here, provenance studies in the Eastern Alps are confined to the sedimentology of the cover beds – and to general speculations so far. Detailed comparative studies on the extraclasts of the bauxite are still awaiting for realization.

At Unterlaussa ("Weyerer Bögen", Upper Austria) the bauxite bodies are clearly basal parts of the Lower Gosau sub-group (Coniacian, Santonian, Lower Campanian): they interfinger with the basal dolostone-breccia and are conformably overlain by black limnic shale and limestone of Late Turonian age, according to their pollen content (Á. SIEGL-FARKAS, pers. comm.). So, the provenance of the bauxite is closely linked there to that of the sandstones and conglomerates of the Lower Gosau sub-group. The predominance of chromite in the heavy mineral assemblage of those sandstones points to the possible exposure of ophiolitic rocks in the source area (WOLETZ in RUTTNER & WOLETZ, 1957), in addition to phyllites, Q-phyllites, Q-porphyry and green-schists described from the conglomerates (ERKAN, 1970, 1973, in TOLLMANN, 1976). Tiny relics of chromite being present also in the bauxite (SIEGL, 1973) along with fine mica and quartz support the idea of a common source. As to the cover, FAUPL postulates a northern to western position of the source area on the basis of paleocurrent data (FAUPL, 1983; FAUPL et al., 1987). According to his opinion "the coarse clastic sediments were deposited on stream-dominated alluvial fans transitional to a braidplain environment" (FAUPL et al., 1987).

The bauxite deposits at Untersberg (situated to the North of that mountain, SW of the town of Salzburg) and Brandenberg (north of Rattenberg, Tirol) are also covered by beds of the Lower Gosau sub-group; Coniacian age of these coverbeds is proved at both sites. At Brandenberg, heavy mineral spectra of sandstones in these coverbeds are extremely rich in chromite and some of the green-coloured sandstone layers were named "serpentine sands" (SCHULZ, 1952; HERM et al., 1979).

At Dreistätten (easternmost part of the NCA, NW of the town of Wiener Neustadt), however, the bauxite bodies are unconformably overlain by the "Dreistätten Conglomerate" and by the "Orbitolina Sandstone" being of Early and Late Campanian age respectively (PLÖCHINGER in BRIX et al., 1982). Though beds of the Lower Gosau sub-group are missing here, the abundance of chromite grains in the bauxite of Dreistätten suggests that this bauxite, too, belongs to the same bauxite horizon as the three deposits mentioned above.

Until recently, a ridge extending to the North and along the front of the northward movig NCA-nappes was thought to have been the source area for the clastic sediments of the Lower Gosau sub-group (TOLLMANN's "Ultrapienidic ridge"; FAUPL's and GRAUPP's "Rumunic ridge"; OBERHAUSER's "Stauwulst"). The considerable longitudinal distance covered by the bauxite deposits along the strike of the NCA seems to match well with this concept. Yet, this model seems to be too simple to be suitable for all bauxite deposits of the NCA. In the case of Brandenberg, the discovery of a narrow trough situated to the North of the Gosau deposits, but still within the same tectonic unit (Lechtal nappe), and filled with deep water sediments of Cenomanian to Santonian (Early Campanian) age (Branderfleck Formation), forbids to derive the Gosau sediments of Brandenberg (Coniacian, Santonian) and also the detrital ingredients of the underlying bauxite, from an area still farther to the North (WEIDICH, 1984).

Nevertheless, very recently O. LEISS (1989) postulated a northerly source area for these Lower Gosau Beds of Brandenberg, and also for those of Muttekopf (Tyrol) and Gaisberg (Salzburg). This source area might have been an obduction zone ("Eoalpine Cordilleras") situated immediately to the North of the Eastalpine Thrust Mass at Cretaceous times. In its position it corresponds roughly with the "Rumunic Ridge" etc. mentioned above.

Another possible source area is assumed to have been somewhere to the South of Brandenberg ("Tethys suture zone" [DECKER et al., 1987; FAUPL et al., 1987]; "Vardar-Suture" [FAUPL & POBER, this vol.]).

Based on the chemistry of detrital chromian spinels (and on paleocurrent data) POBER & FAUPL (1988) distinguish both a northern and a southern provenance area of the clastic sediments of the Gosau Group. According to that, most of the Lower Gosau complex occurrences (Coniacian – Lower Campanian) – among them also that of Brandenberg – are of northern provenance, whereas the Upper Gosau Complex (and a few occurrences of the Lower Gosau complex) belong to the "southern provenance group". Ironically, the spinels of the above mentioned Branderfleck Formation (situated to the North of the Brandenberg Gosau) "shows more conformity with the 'southern provenance group' of spinels (Upper Gosau Complex) than with the northern one" (POBER & FAUPL, 1988; see also FAUPL & POBER, this vol.).

As a matter of fact serpentinite, more than 500 m in thickness has been penetrated by the borehole Grünau-1 (Upper Austria) right below the thrust pile of the NCA and closely attached to rocks of the Klippen zone (WESSELY, 1988). However, this body of serpentinite is rather a northward displaced part of the "Rumunic Ridge" than that of a hypothetic southerly "Vardar-Suture".

It should be mentioned that both the serpentine rich sand and the bauxite are confined to the northern part of the Gosau basin of Brandenberg.

RUTTNER (1987) discusses this problem and suggests a transport from the NE. But this seems to be not very satisfactory either, because of the likewise long way of transport it would involve. However, O. LEISS (1989) actually found indications of a long history of sedimentation as far as the bauxite and the overlying sandstones of Brandenberg are concerned.

A third potential source of lateritic material are inliers of basic volcanic rocks on Permian evaporites ("Haselgebirge") to be found within the NCA. LEISS considers them to be the source of lateritic Lower Gosau sediments resting on the southern tectonic units of the NCA.

So, like in Hungary also in Austria the provenance of the Upper Cretaceous bauxites is still obscure. The paleogeographic situation has changed in late Campanian times already, and post-Cretaceous deformations have concealed former source areas to such an extent that a reconstruction is hardly possible now. An extension of comparative studies in extraclasts in bauxites from the TCR to the NCA, combined with further studies on the sedimentology of the coverbeds, will perhaps shed some light into the puzzle.

5. Conclusions

❶ The presence of kyanite, amphibole and titanite in the Albian bauxite indicates that subaerial erosion of igneous?-metamorphic continental-crust type material was possible already as early as the Early Albian in the broader surroundings of the Transdanubian Central Range sector of the Periadriatic area.

❷ The extraclast assemblage of the Senonian bauxite horizon likewise reflects the denudation of continental crust-type material, this time, however, with the predominance of definitely low-grade metamorphic rocks, occasionally (in Austria, particularly at Dreistätten) accompanied by chromite-bearing ultramafics.

❸ The Eocene horizon records a sudden increase of the influence of the medium pressure type higher-grade metamorphic basement (of amphibolite-facies) as a "source" of fine-grained mechanical weathering products and probably also some distant volcanic episode. The abundance of chromite and chromium-spinell in the Eocene bauxites of the Transdanubian Central Range suggests that in addition to this, the possibility of oceanic crust type (ophiolitc) material having been subject to erosion at the same time, even though locally, must also be counted with.

❹ The intra- to post-Campanian exposure of the higher-grade metamorphic basement observed in the clastic successions of the Gosau basins of Austria is recorded as a characteristic extraclast "signal" also in the TCR, possibly indicating a common regional source area for the two in late Cretaceous–early Tertiary times.

❺ The grain-size of the extraclasts suggests that the maximum extension of the area, the denudation history of which is recorded in the changing extraclast suite of the bauxites, was around a 1000 kms.

❻ To refine our understanding of the details of subaerial denudation in the eastern sector of the Austro-Alpine during the Upper Cretaceous and Lower Tertiary, an extension of similarly detailed extraclast studies on the bauxites of the Northern Calcareous Alps and on Upper Cretaceous and Lower Tertiary non-bauxitic sediments in the Transdanubian Central Range is highly desirable.

❼ An important practical outcome of the present study was that – having recognized the micromineralogical differences between the individual bauxite horizons in the Transdanubian Central Range – we could offer an analogy-based stratigraphic correlation method for the exploration companies working in the area. By micromineralogical analysis now also the age of those bauxite deposits may be established, which – because of the erosional lack of their primary cover – could not have been dated previously.

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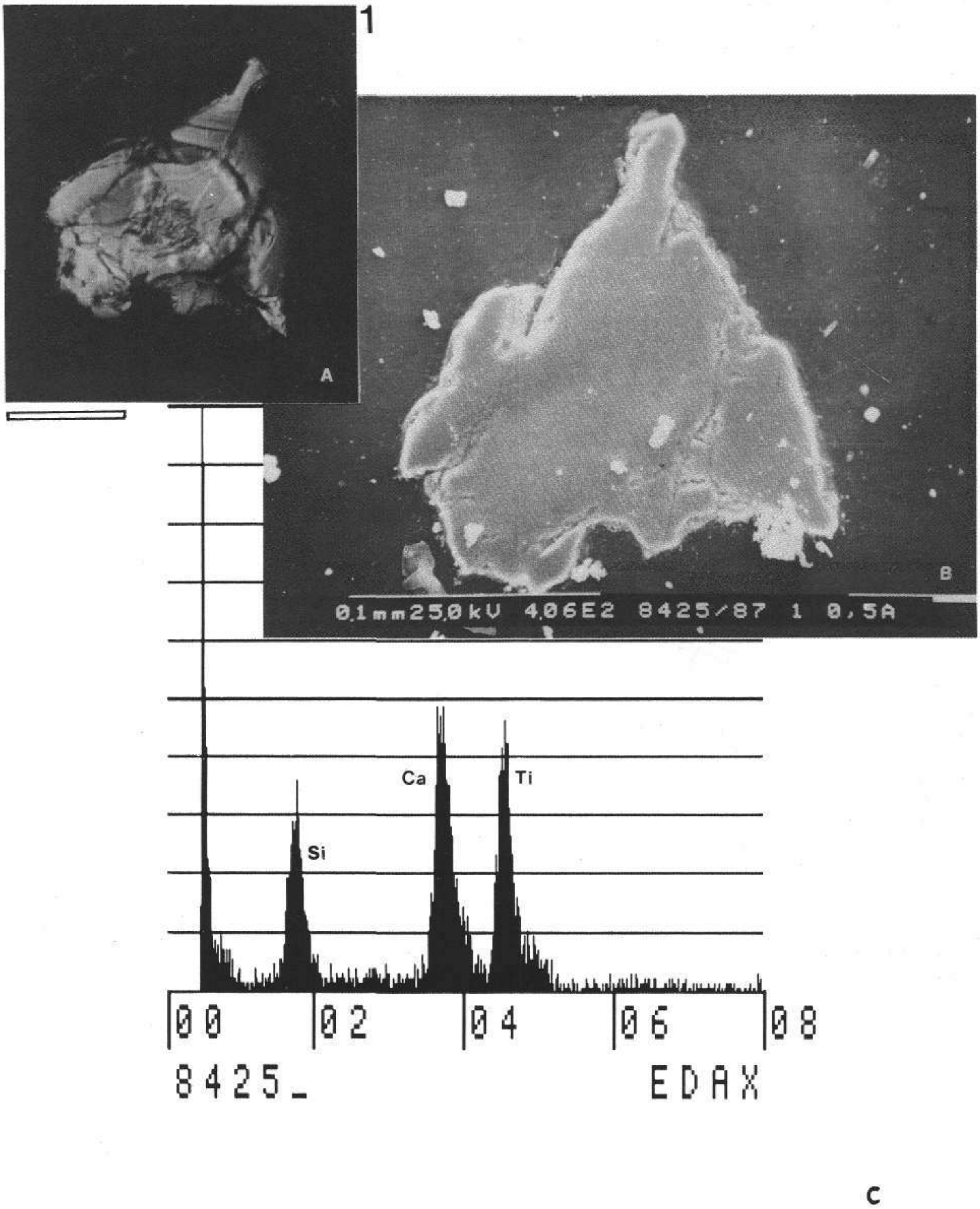
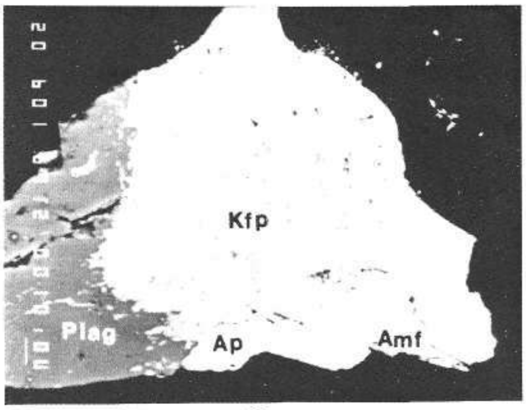


Fig. 1: **Titanite in Albian bauxite (Csehbánya).**
A: Optical microscopic photograph. Crossed polars. bar scale: 100μm.
B: SEM-photograph of the grain shown by Fig. 1A.

Plate 2

Fig. 2: **Rock-fragment from the Albian bauxite of Csehbánya.**
Back scattered electron image (BEI).
Kfp = K-felspar, Plag = plagioclase, Ap = apatite, Amf = amphibole.

Figs. 3–9: **X-ray images of the grain shown by photo 2.**



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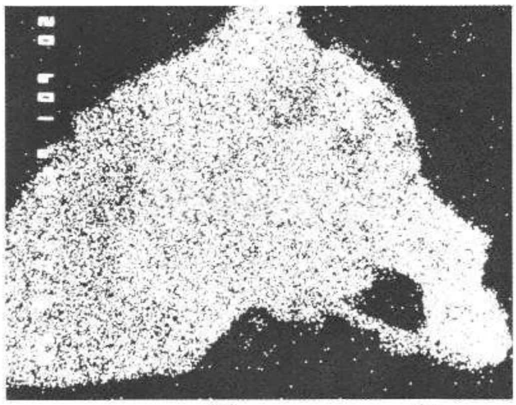
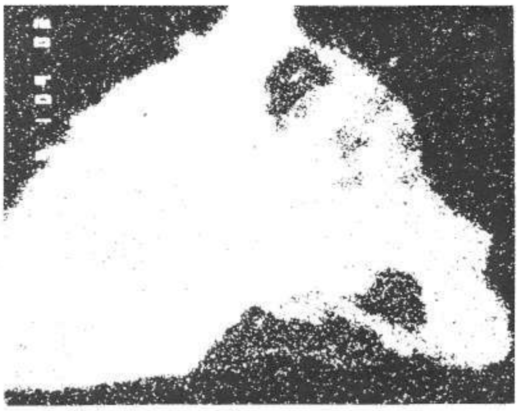
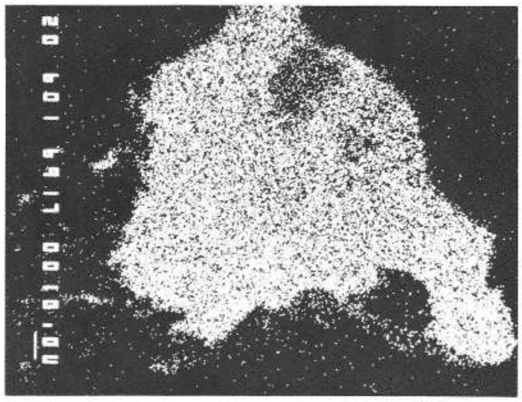


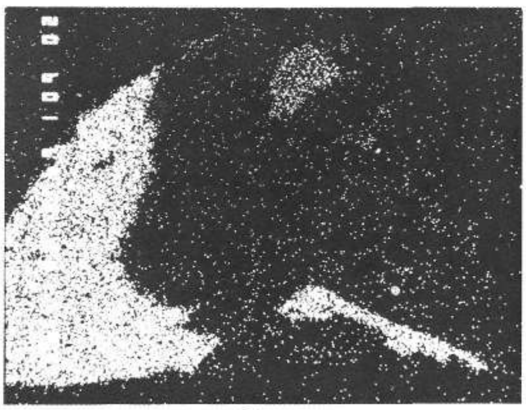
3 $Si_{K\alpha}$



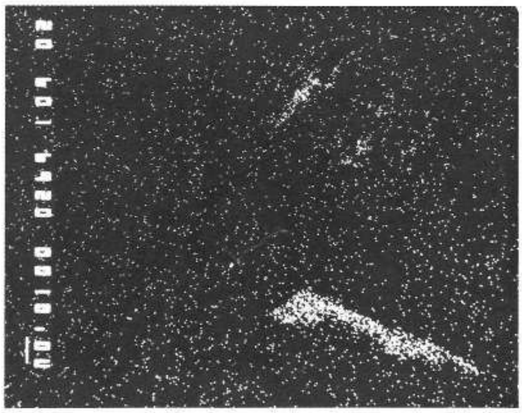
4 $Al_{K\alpha}$



5 $K_{K\alpha}$

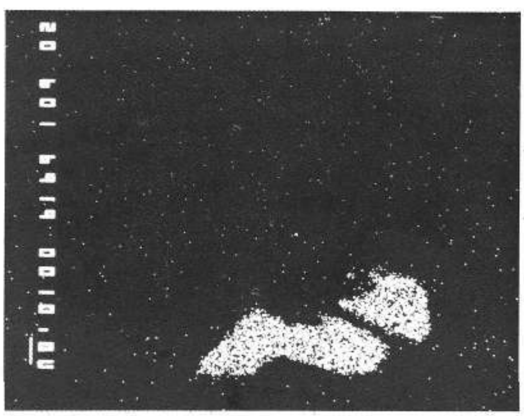


6 $Na_{K\alpha}$



7 $Ti_{K\alpha}$

8 $Ca_{K\alpha}$



9 $P_{K\alpha}$

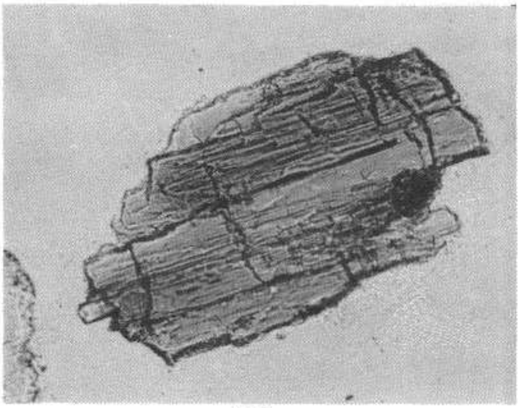
Plate 3

Fig. 10: **Amphibole.**
Albian bauxite (Csehbánya).
Optical microscopic photograph. Plain light. Bar scale: 50μm.

Fig. 11: **Kyanite.**
Albian bauxite (Csehbánya).
Optical microscopic photograph. Crossed polars. Bar scale: 50μm.

Fig. 12: **Apatite and titanite (BEI).**
Albian bauxite (Csehbánya).

Figs. 13–17: **X-ray images of the grains shown by photo 12.**



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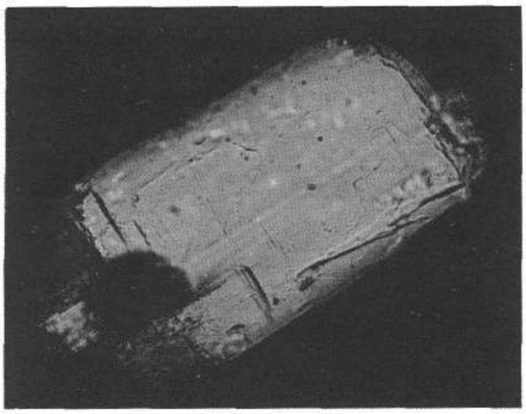

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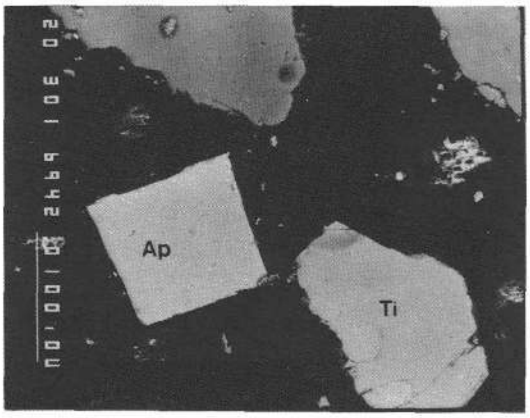
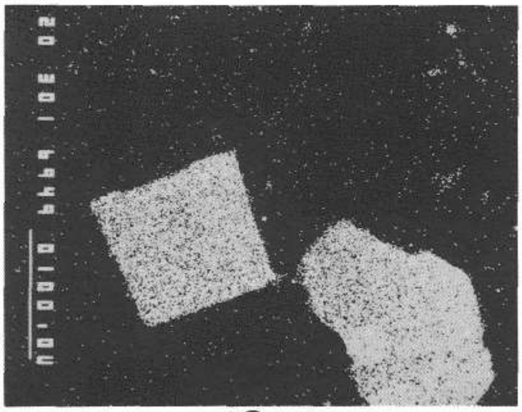
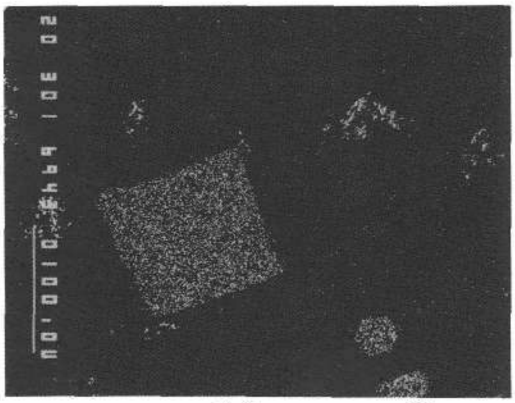


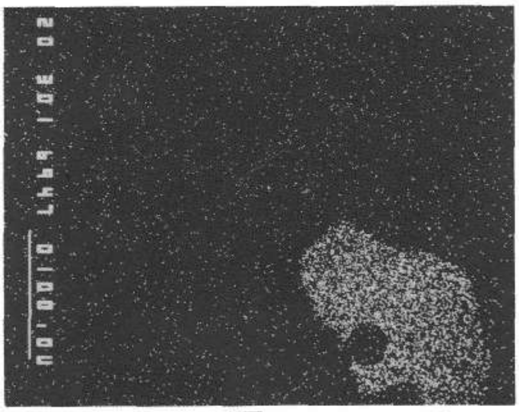
12



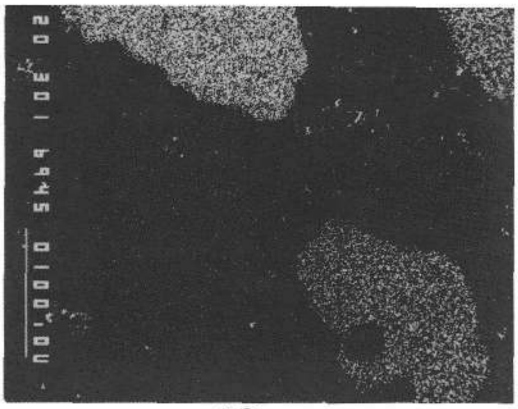
13 $Ca_{K\alpha}$



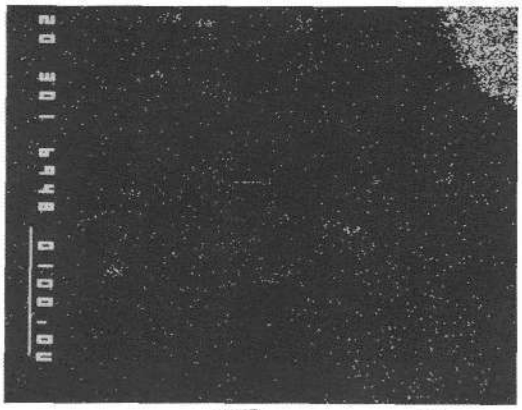
14 $P_{K\alpha}$



15 $Ti_{K\alpha}$



16 $Si_{K\alpha}$



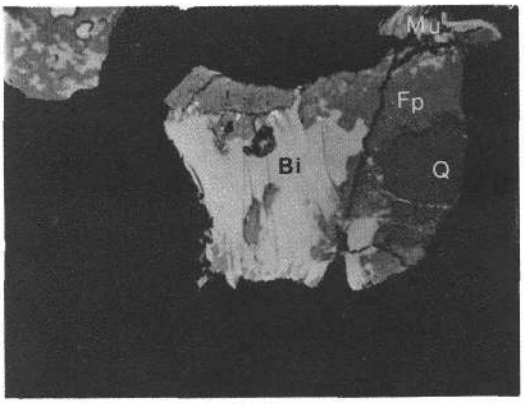
17 $K_{K\alpha}$

Plate 4

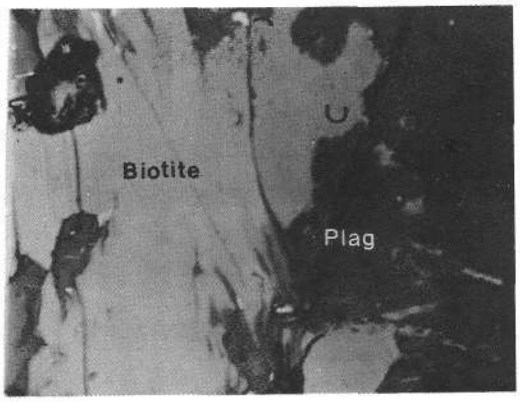
Fig. 18: **Rock-fragment (BEI).**
Senonian bauxite (Halimba).
Bi = biotite, Fp = felspar, Q = quartz.
Bar scale: 200 μm.

Fig. 19: **Detail of Photo 18 (BEI).**
Plag = plagioclase.
Bar scale: 50 μm.

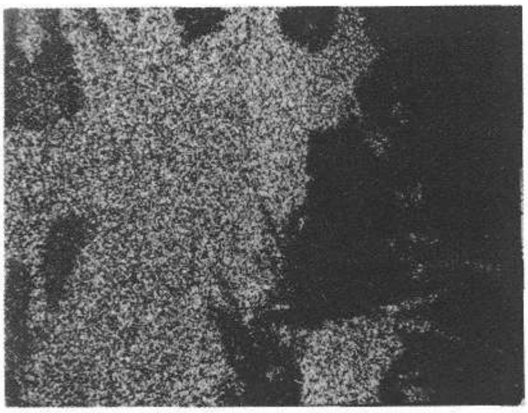
Figs. 20–25: **X-ray images of the grain shown by photo 19.**



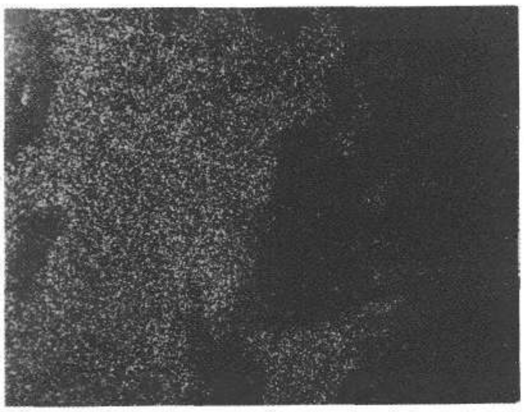
18



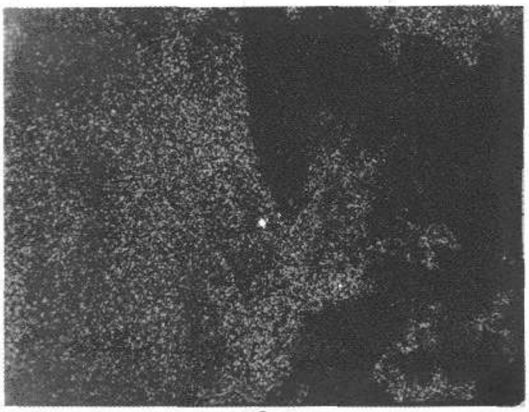
19



20 $Fe_{K\alpha}$

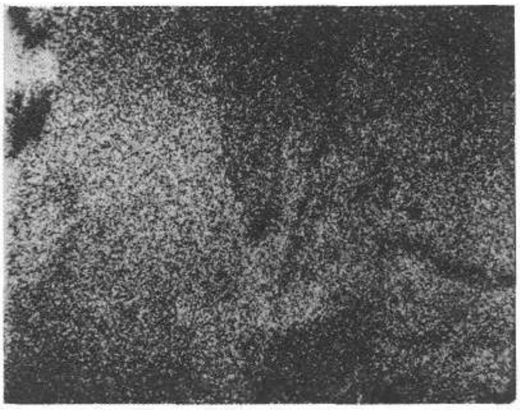


21 $Mg_{K\alpha}$



22 $K_{K\alpha}$

23 $Ca_{K\alpha}$



24 $Si_{K\alpha}$

25 $Al_{K\alpha}$

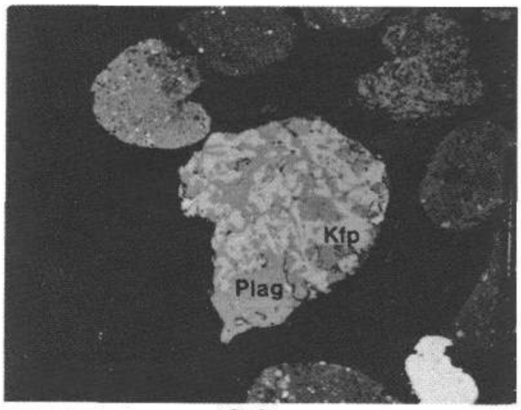
Plate 5

Fig. 26: **Perthitic structure in felspar (BEI).**
Senonian bauxite (Halimba).
Plag = plagioclase, Kfp = K-felspar.
Bar scale: 200 μm.

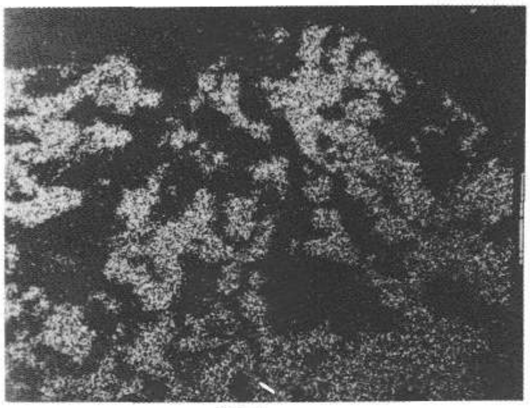
Figs. 27–28: **X-ray images of the grain shown by photo 26.**

Fig. 29: **Composite rock-fragment with K-felspar, plagioclase and Ca-Mg-bearing mafic silicates (BEI).**
Senonian bauxite (Halimba).
Bar scale: 50 μm.

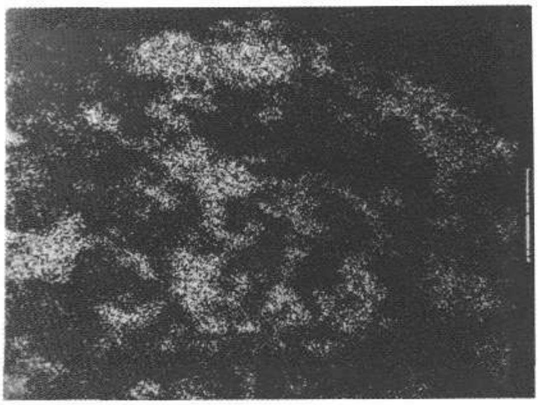
Figs. 30–33: **X-ray images of the grain shown by photo 29.**



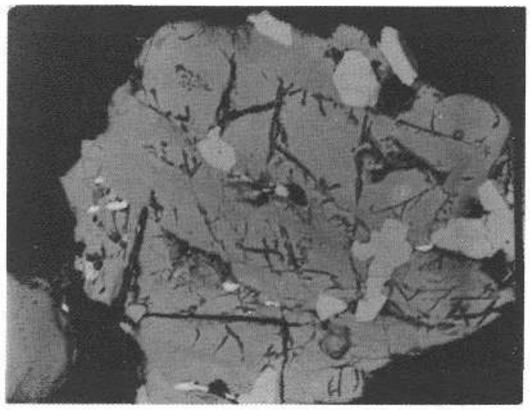
26



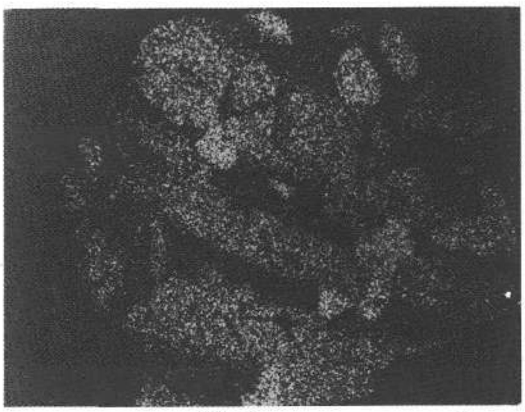
27 $K_{K\alpha}$



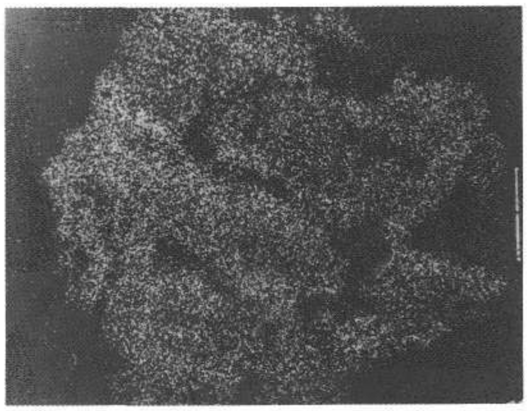
28 $Na_{K\alpha}$



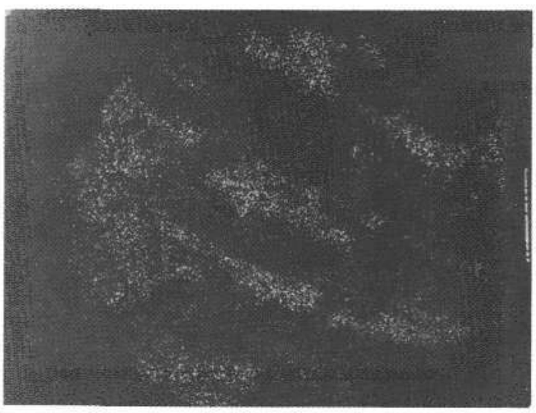
29



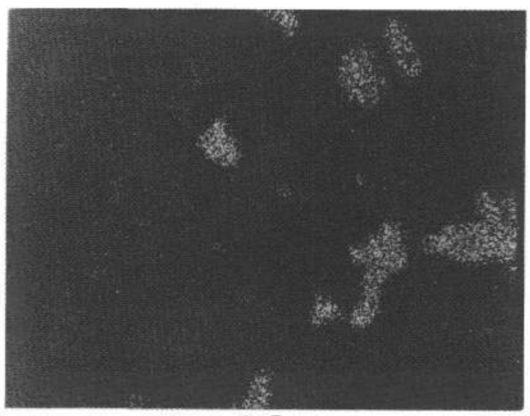
30 $Ca_{K\alpha}$



31 $Na_{K\alpha}$



32 $K_{K\alpha}$



33 $Mg_{K\alpha}$

Plate 6

Fig. 34: **Euhedral garnet inclusions in felspar.**
Senonian bauxite (Halimba).
Optical microscopic photograph. Plain light. Bar scale: 50 μm.

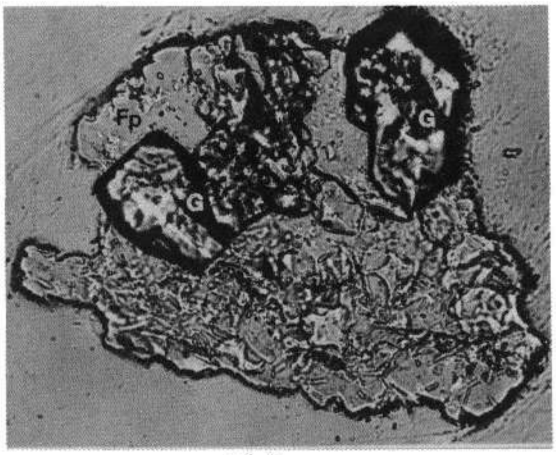
Fig. 35: **The same as on photo 34.**
With crossed polars.

Fig. 36: **U-rich inclusion in quartz (BEI).**
Senonian bauxite (Halimba).
Bar scale: 50 μm.

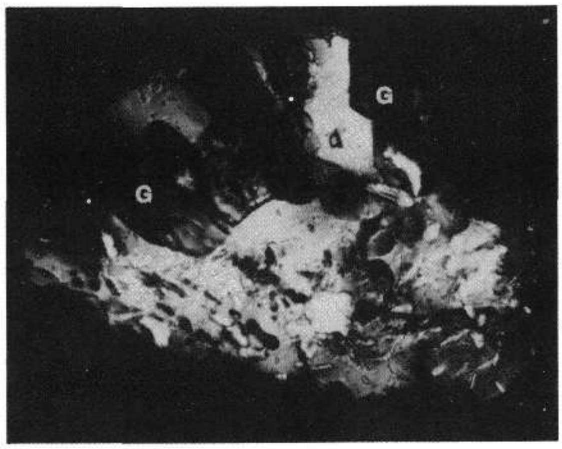
Fig. 37: **Detail of photo 36 (BEI).**
The white line stands for U.
Bar scale: 10 μm.

Fig. 38: **Kyanite in micaceous rock fragment (BEI).**
Eocene bauxite (Iszka/Rákhegy).

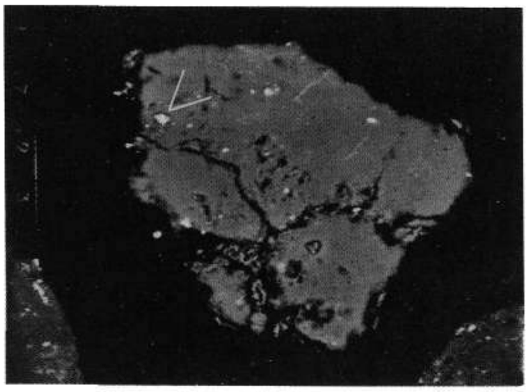
Figs. 39–41: **X-ray images of the rock-fragment shown by photo 39.**
Bar scale: 100 μm.



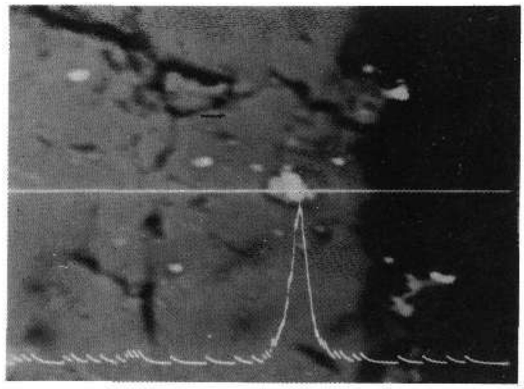
34



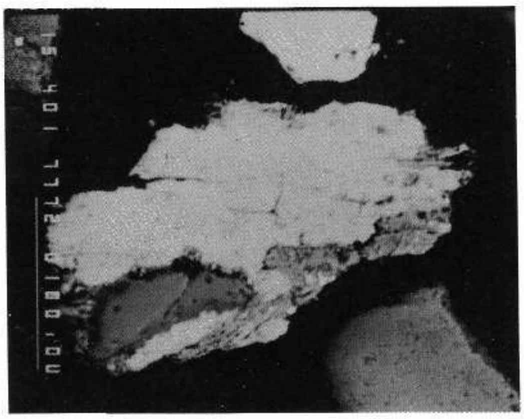
35



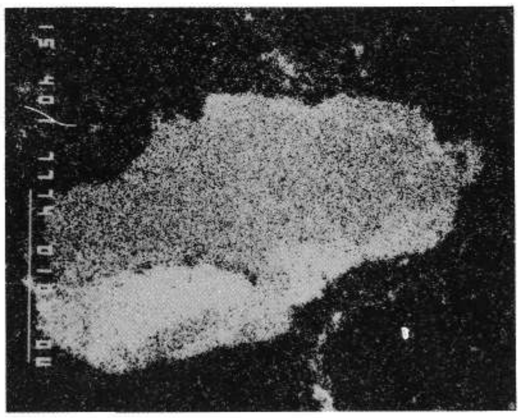
36



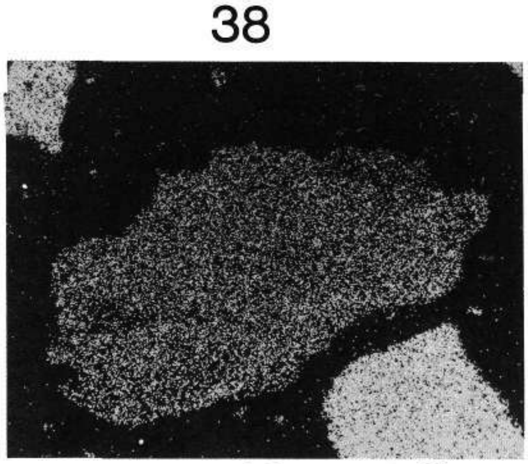
37 $U_{M\alpha}$



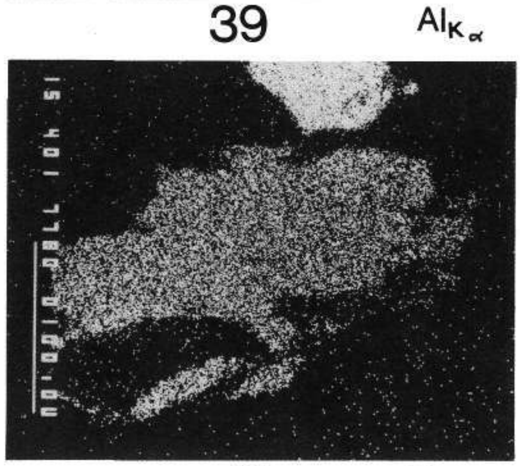
38



39 $Al_{K\alpha}$



40 $Si_{K\alpha}$



41 $Fe_{K\alpha}$

Plate 7

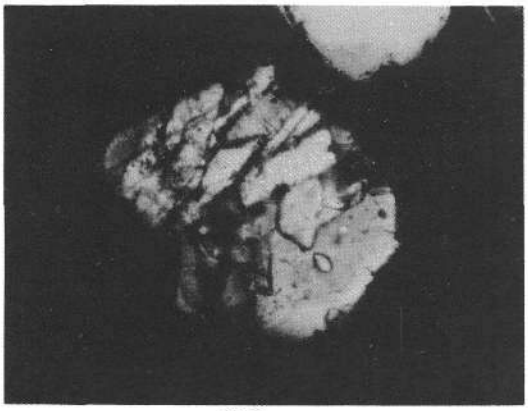
Fig. 42: **Kyanite-bearing rock-fragment.**
Eocene bauxite (Iszka/Rákhegy).
Ky = kyanite, Fp = felspar.
Optical microscopic photograph. Crossed polars. Bar scale: 50 μm.

Fig. 43: **The same as on photo 42 (BEI).**

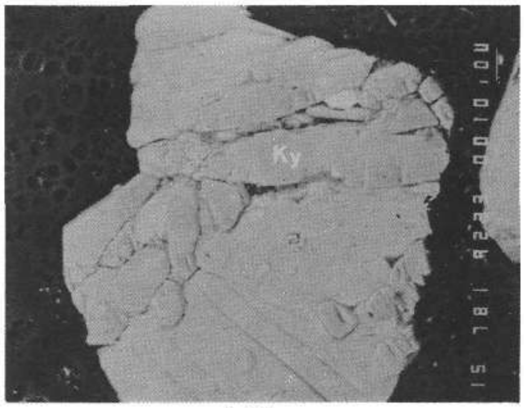
Figs. 44–47: **X-ray images of the rock-fragment shown by photo 43.**

Fig. 48: **Kyanite.**
Eocene bauxite of Iszka/Rákhegy.
Optical microscopic photograph. Crossed polars. Bar scale: 50 μm.

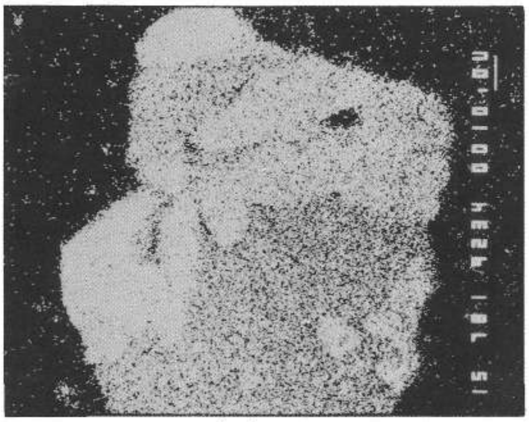
Fig. 49: **Kinked kyanite.**
Eocene bauxite (Iszka/Rákhegy).
Optical microscopic photograph. Crossed polars. Bar scale: 50 μm.



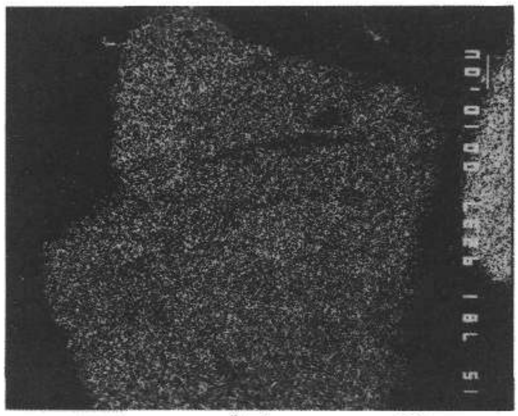
42



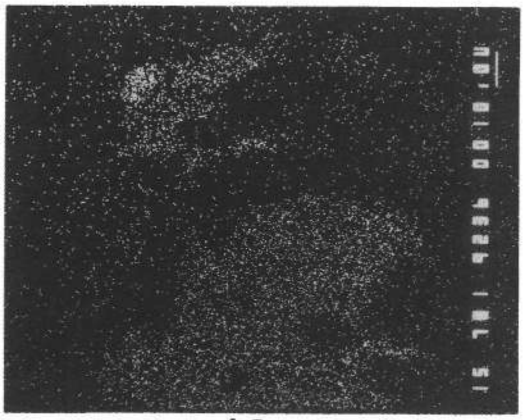
43



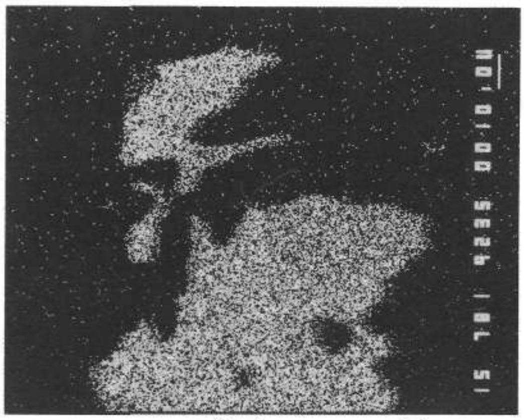
44 Al_{K_α}



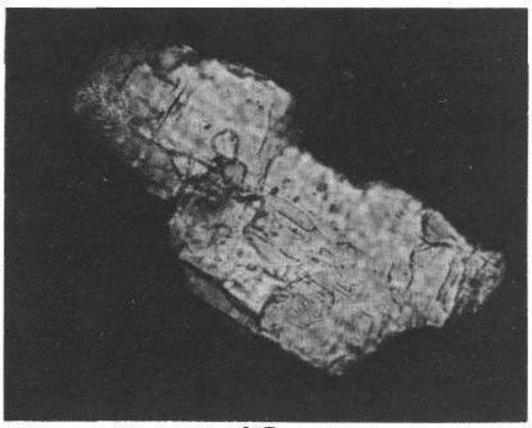
45 Si_{K_α}



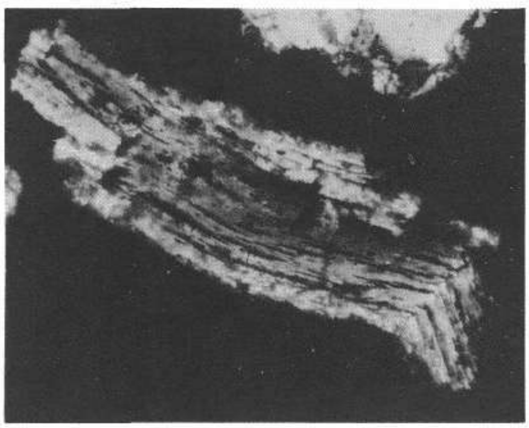
46 Na_{K_α}



47 K_{K_α}



48



49

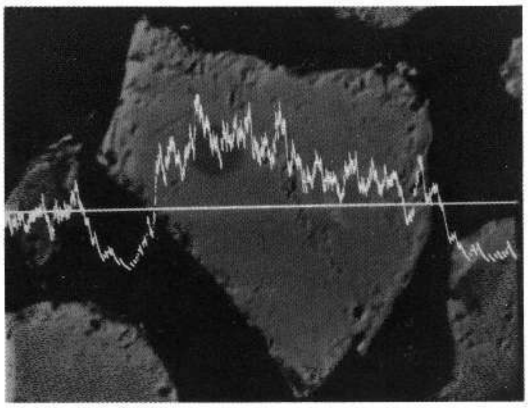
Plate 8

Fig. 50: **Mn-bearing Fe-Mg garnet grain (BEI).**
Eocene bauxite (Csabpuszta/Nagytárkány).
Bar scale: 50 μm.

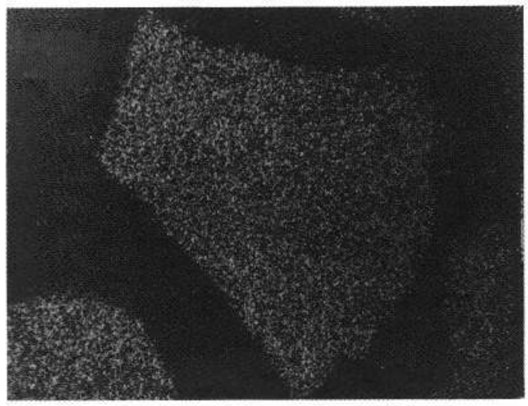
Figs. 51–53: **X-ray images of the grain shown by photo 50.**

Fig. 54: **Amphibole grain (A).**
Eocene bauxite of Csabpuszta (BEI).

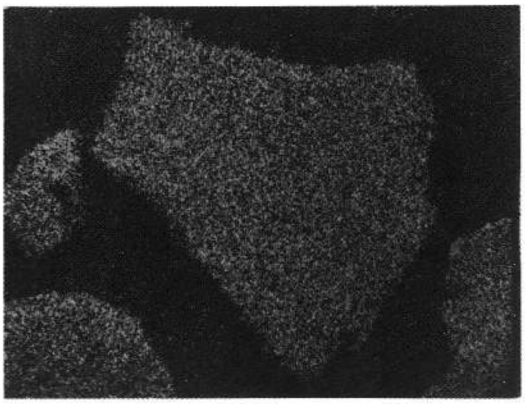
Figs. 55–57: **X-ray images of the amphibole grain shown by photo 54.**



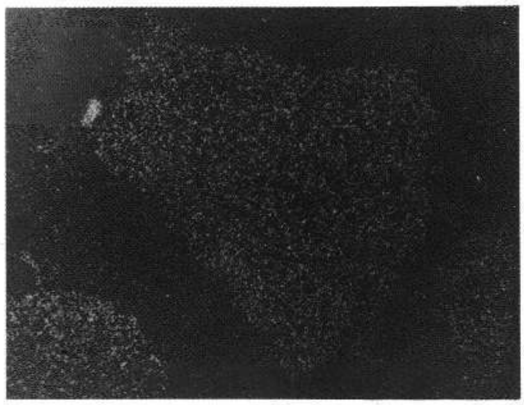
50 $Mn_{K\alpha}$



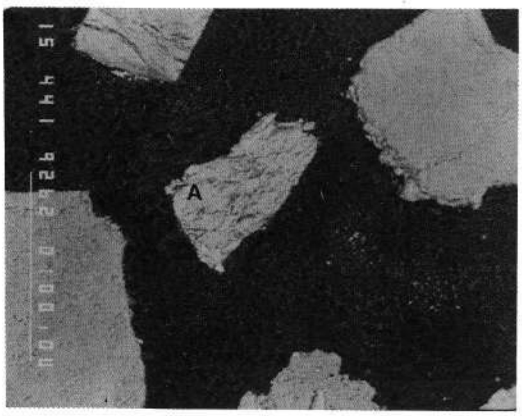
51 $Fe_{K\alpha}$



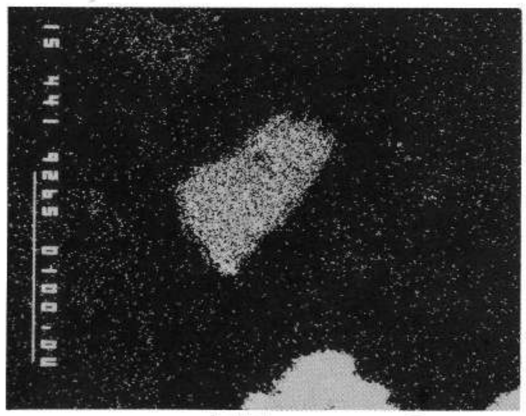
52 $Al_{K\alpha}$



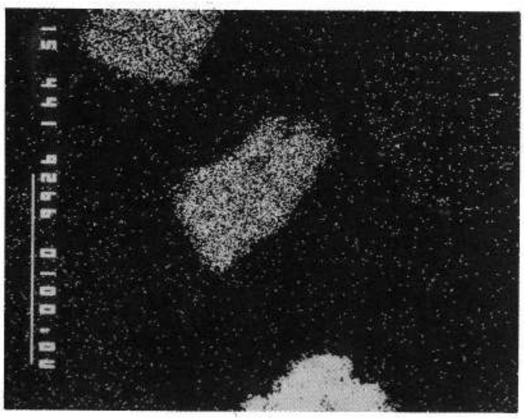
53 $Mg_{K\alpha}$



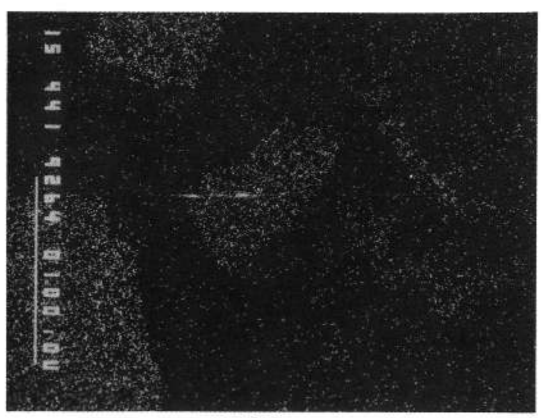
54



55 Ca_{K}



56 $Mg_{K\alpha}$



57 $Na_{K\alpha}$

Plate 9

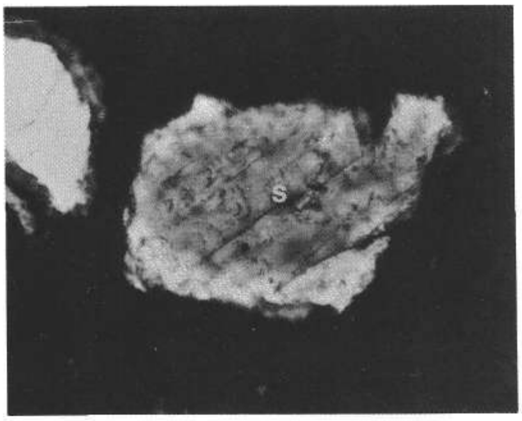
Fig. 58: **Staurolite grain.**
Eocene bauxite (Iszka/Rákhegy).
Optical microscopic photograph. Crossed polars. Bar scale: 50 μm.

Fig. 59: **Back scattered electron image of the staurolite grain (s) shown by photo 58.**

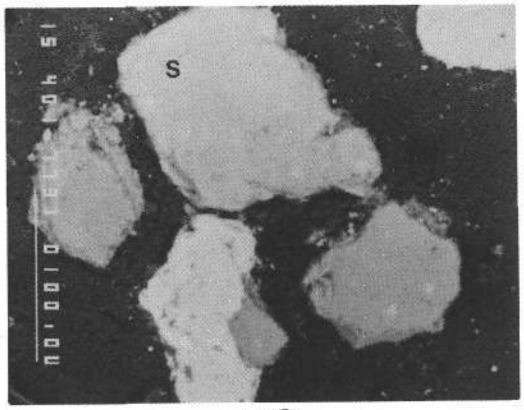
Figs. 60–62: **X-ray images of the staurolite grain shown by photo 59.**

Fig. 63: **Epidote grain (BEI, inverse picture).**
Eocene bauxite (Iszka/Rákhegy).

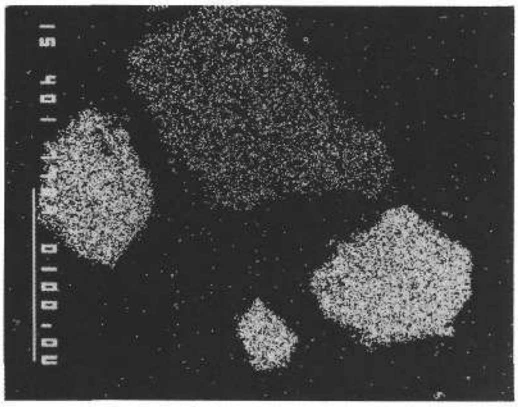
Figs. 64–65: **X-ray images of the grain shown by photo 63.**



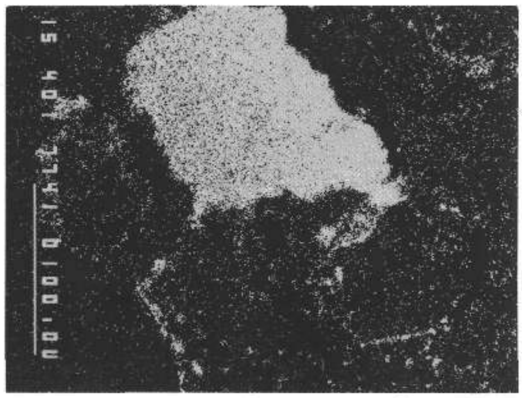
58



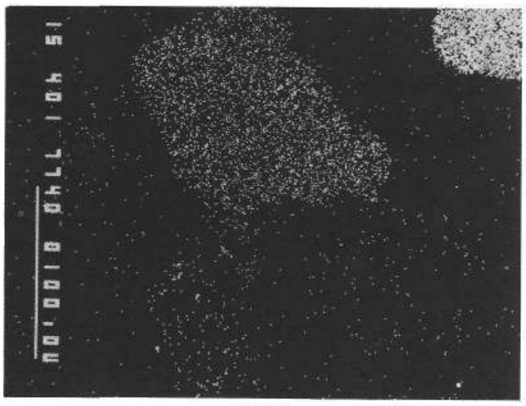
59



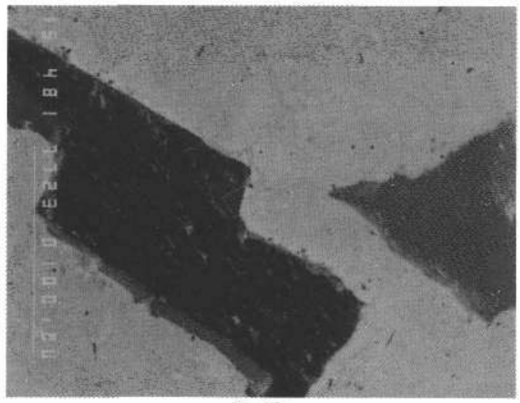
60 $Si_{K\alpha}$



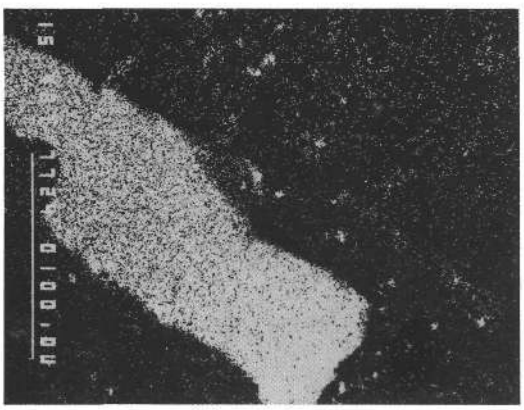
61 $Al_{K\alpha}$



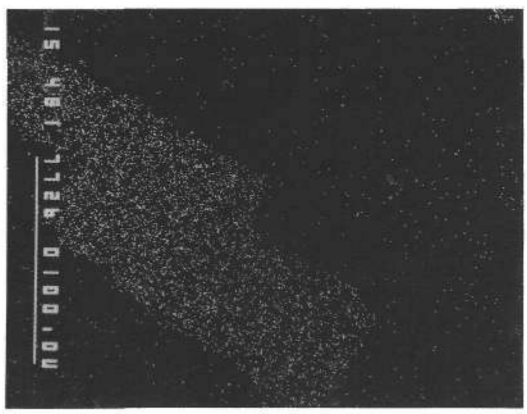
62 $Fe_{K\alpha}$



63

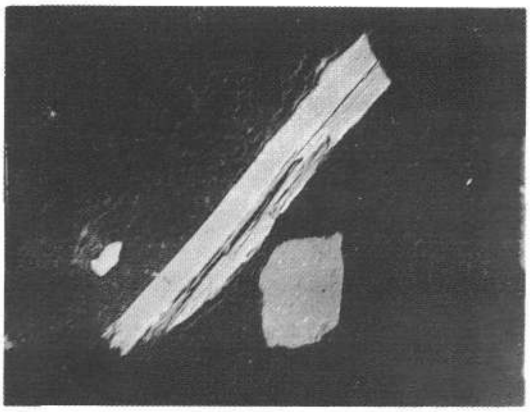


64 $Ca_{K\alpha}$

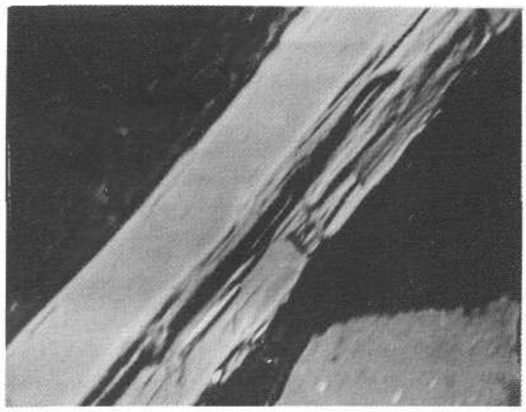


65 $Fe_{K\alpha}$

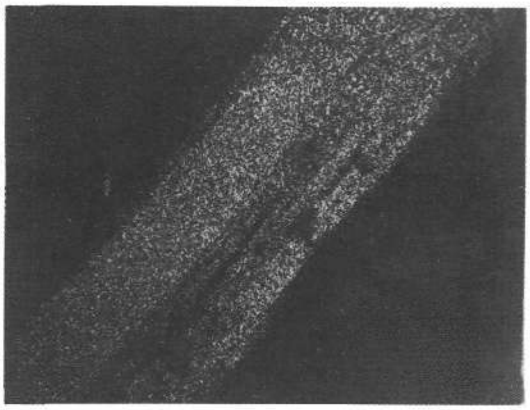
Plate 10



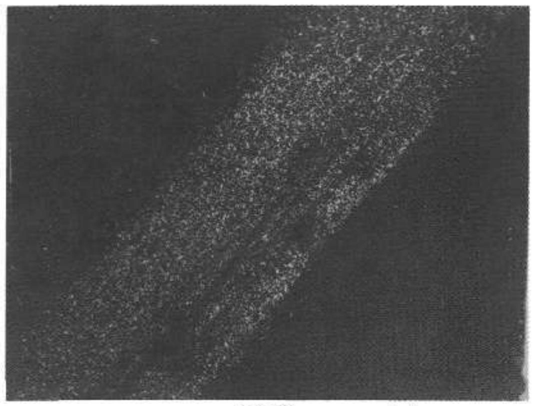
66



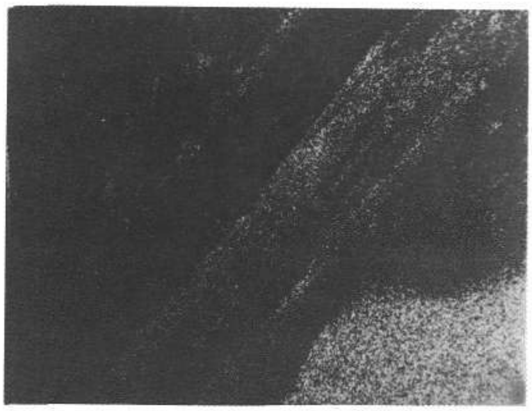
67



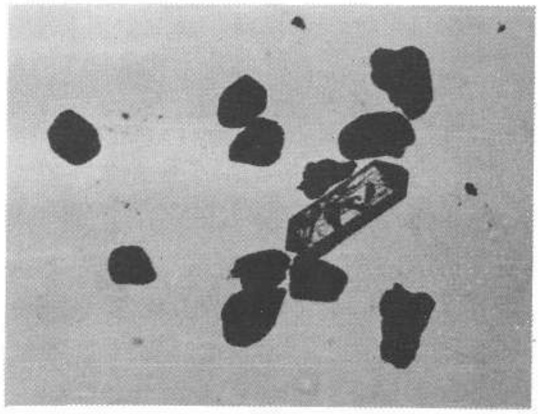
68 $Si_{K\alpha}$



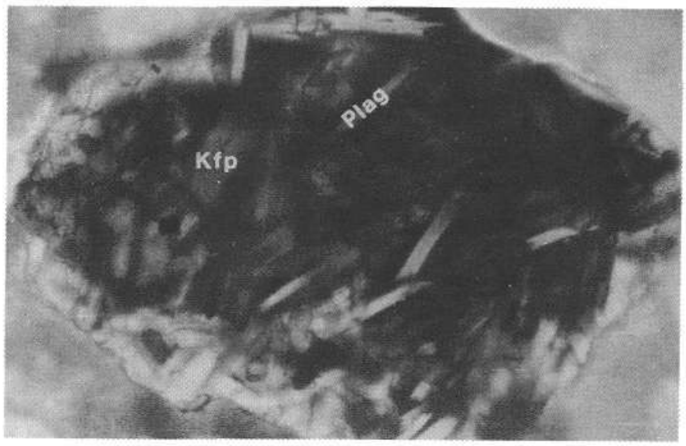
69 $Mg_{K\alpha}$



70 $Al_{K\alpha}$



71



72

Fig. 66: **?Antophyllite (BEI).**
Eocene bauxite (Fenyőfő).
Bar scale: 200 μm.

Fig. 67: **Detail of photo 66.**
Bar scale: 50 μm.

Figs. 68–70: **X-ray images of the grain shown by photo 67.**

Fig. 71: **Euhedral zircon and ilmenite grains.**
Eocene bauxite (Iszka/Rákhegy).
Optical microscopic photograph. Bar scale: 100 μm.

Fig. 72: **Volcanic rock fragment of trachytic texture.**
Plag = plagioclase; Kfp = K-felspar.
Optical microscopic photograph. Plain light.
Bar scale: 50 μm.

73

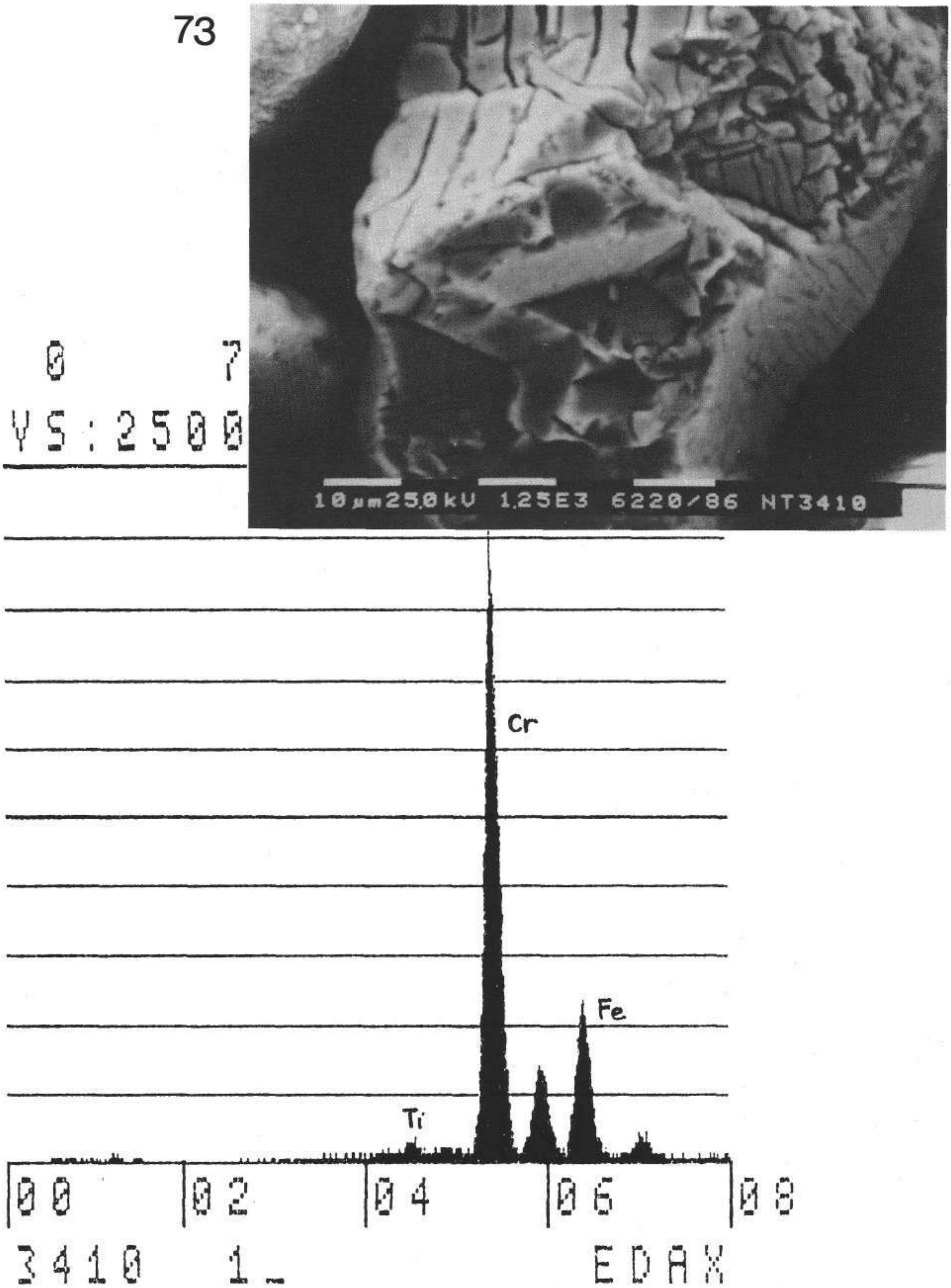


Fig. 73: **Chromite grain (BEI).**
Eocene bauxites (Csabpuszta/Nagytárkány).

74

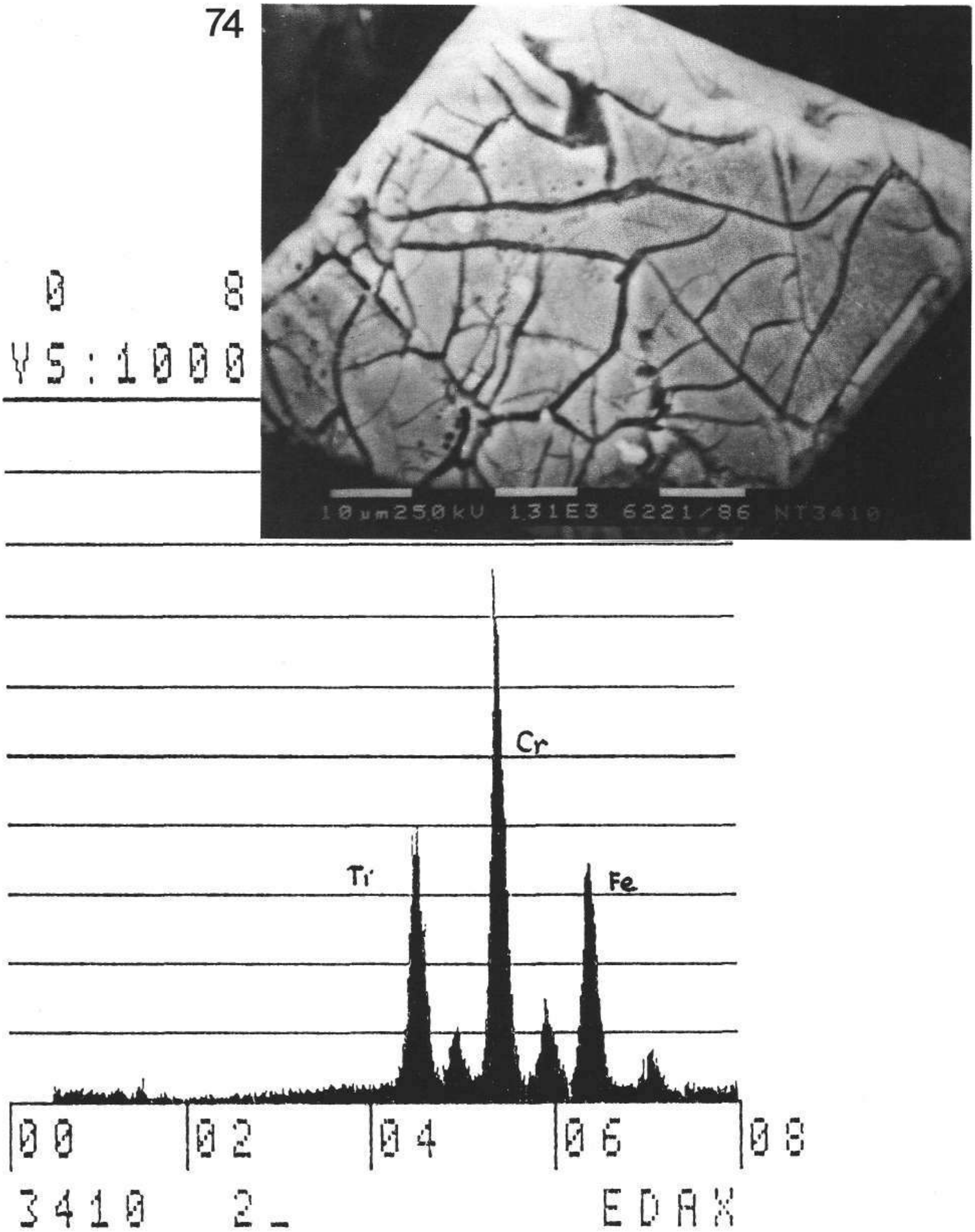


Fig. 74: **Ti-bearing chromite grain (BEI).**
Eocene bauxite (Csabpuszta/Nagytárkány).

75

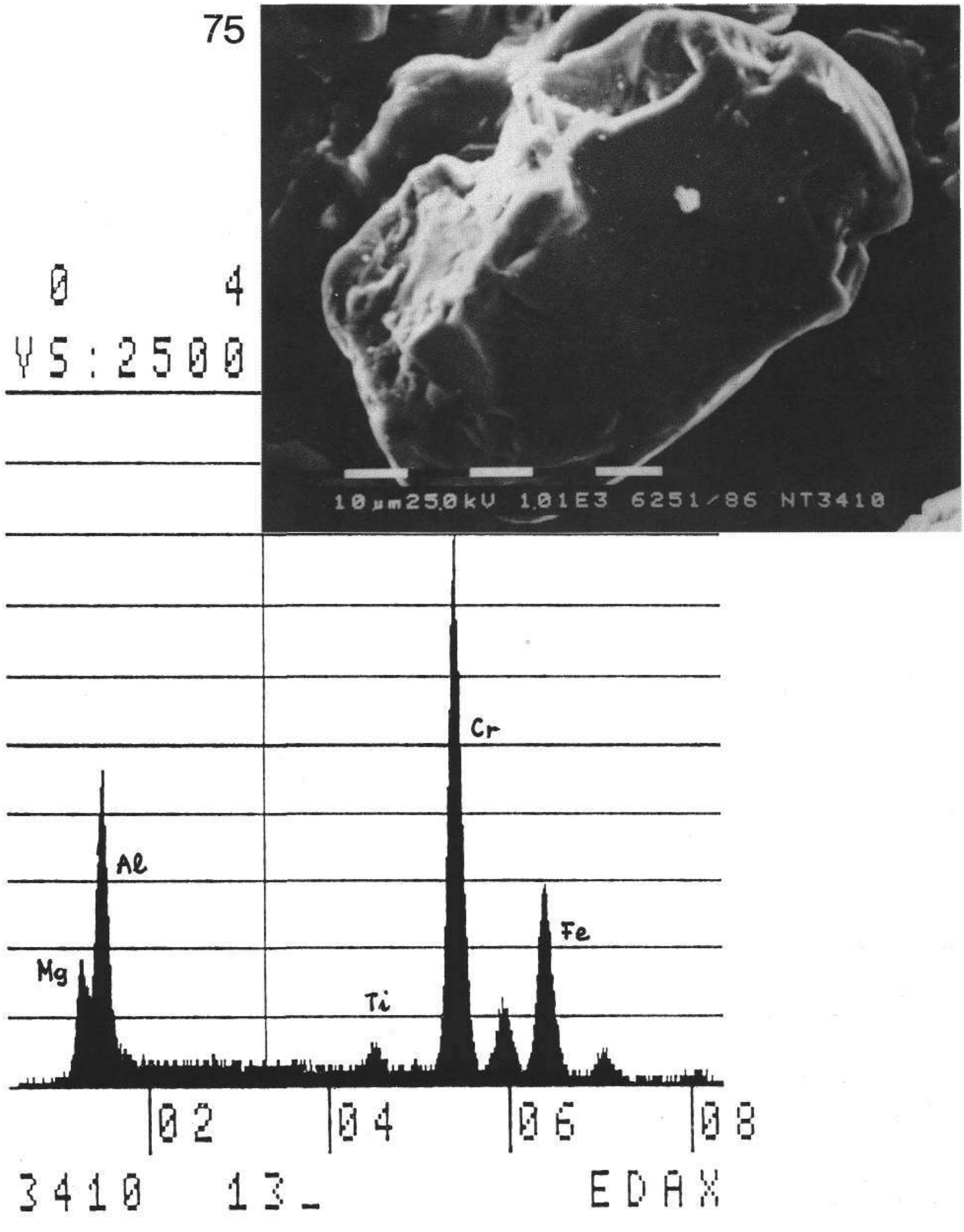


Fig. 75: **Chromium-spinell grain (BEI).**
Eocene bauxite (Csabpuszta/Nagytárkány).

Plate 14

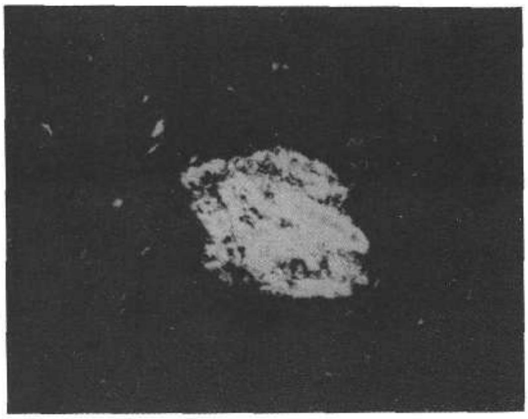
Fig. 76: **Micaceous rock-fragment.**
Turonian/Senonian bauxite (Dreistätten).
Optical microscopic photograph. Crossed polars. Bar scale: 100 µm.

Fig. 77: **Schistose micaceous rock-fragment.**
Turonian/Senonian bauxite (Dreistätten).
Optical microscopic photograph. Crossed polars. Bar scale: 100 µm.

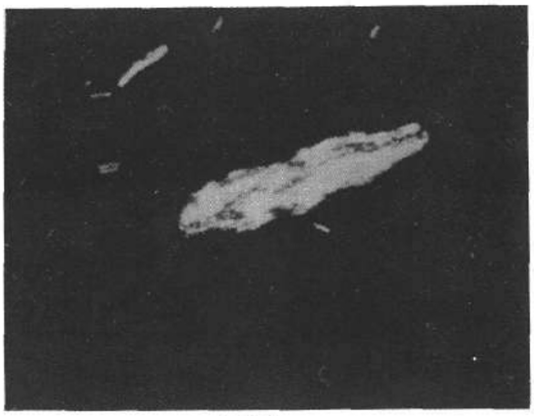
Fig. 78: **Weathered micaceous rock fragment (BEI).**
Turonian/Senonian bauxite (Dreistätten).
Bar scale: 50 µm.

Figs. 79–81: **X-ray images of the rock-fragment shown by photo 78.**

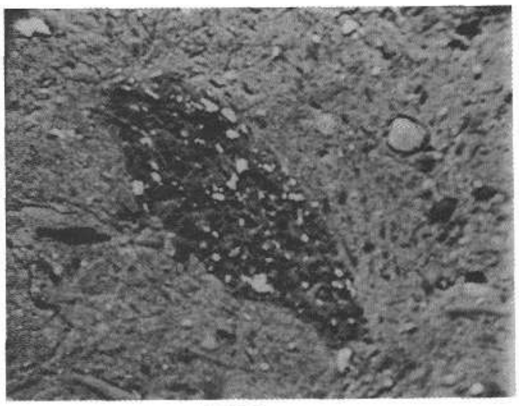
Figs. 82–83: **X-ray images of a chromium-spinell grain.**
Dreistätten bauxite (Turonian/Senonian).
Bar scale: 50 µm.



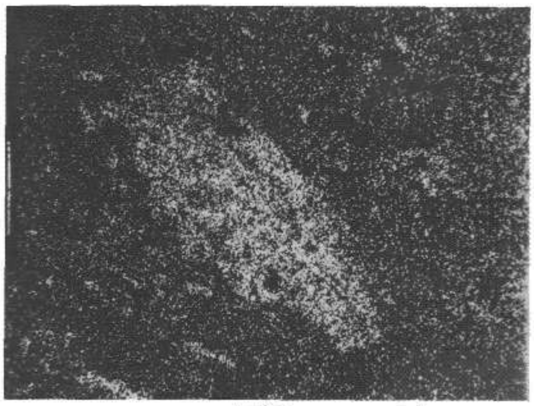
76



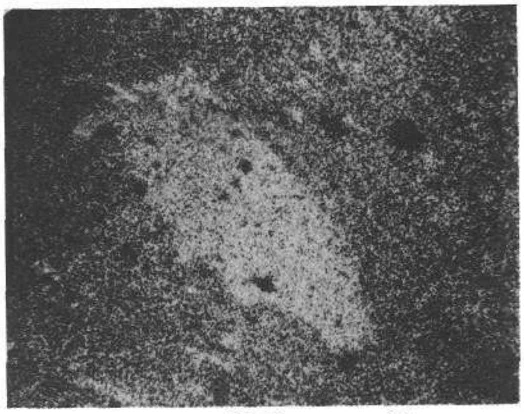
77



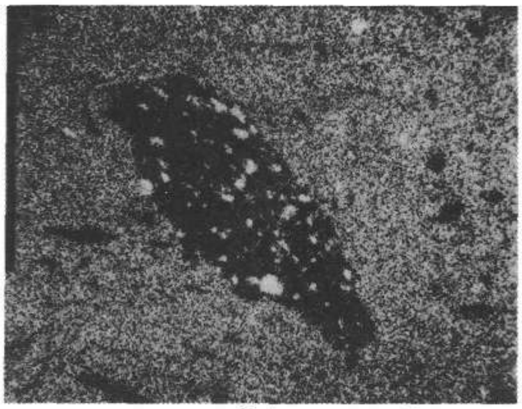
78



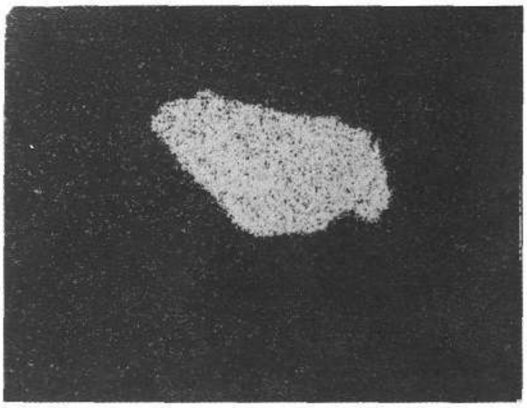
79 $K_{K\alpha}$



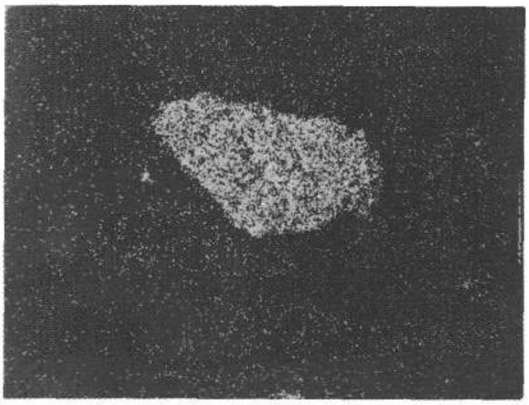
80 $Si_{K\alpha}$



81 $Fe_{K\alpha}$



82 $Cr_{K\alpha}$



83 $Mg_{K\alpha}$

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