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Heavy Mineral Composition of the Middle Rhine Lowland Loesses

Skład minerałów ciężkich w lessach Niziny Środkowego Renu

Состав тяжелых минералов в лессах низины среднего Рейна

INTRODUCTION

Recent lithological studies of the loess of France are also concerned with heavy minerals (Duplaix, Malterre, 1946; Cailleux, 1954; Alimen et al., 1965; Blum, Maus, 1967; Lautridou, 1968; Buraczyński, 1971, 1978; Coutard et al., 1972, 1973; Esteoule et al., 1972; Monnier, 1974). It has been shown that there is a differentiation of the mineral composition in different loess series and distinct differences in the weight content of heavy minerals between younger and older loesses. These studies are helpful in the consideration of the distribution of loess dust sources and the dynamics of loess accumulation. The results allow to draw a comparison between the loess of France, other regions within the continent as well as those of other continents (Swineford, Frye, 1955; Briggs, 1965; Buraczyński, 1978).

The first attempt at the interpretation of the heavy mineral analysis in the French literature was made by Alimen, Dubois and Napoleone (1965). They found out that the initial material for the loess of Provence had been formed of different rocks from the neighbouring regions, and quaternary formations from the northern foreland of the area in question. The results of the heavy mineral analyses indicate a local origin of the loess material and a considerable spatial differentiation of the minerals. Loess areas characterized by different sets of heavy minerals have been distinguished (Duplaix, Malterre, 1946).

The studies of the content of heavy minerals are of great importance for the purposes of stratigraphy. They indicate changes in the distribution of heavy minerals in vertical profiles (Alimen et al., 1965; Lautridou, 1968; Buraczyński, 1971). There is however, no distinct differentiation of heavy minerals in particular loess series and in fossil soils. The studies of Alimen et al. (1965) show a certain increase in the occurrence of resistant heavy minerals in soils in comparison to loess.

The present study contains the mineralogical characteristics of the Middle Rhine Lowland loess. In this area classical outcrops of loess can be found, which have long since aroused the interests of geologists and geographers. The Achenheim loess profile was described by Wernert (1957), who gave its stratigraphical characteristics based on archeological and paleontological investigations. Some other profiles have also their detailed stratigraphical descriptions (Gouda, 1962; Bronger, 1966; Khodary-Eissa, 1968). There has been no detailed elaboration of those profiles in the mineralogical respect.

DESCRIPTION OF THE STUDIED PROFILES

Detailed studies of the content of heavy minerals have been made for the loesses of the Rhine valley and for the purpose of a comparison of the loess profiles of Normandy and Provence (Fig. 1).

The morphological situation of the loess profiles under study varies widely (Théobald, 1955; Vogt, Thévenin, 1976). The Achenheim profile No. 3 is situated in the middle Schiltigheim terrace (150 m) and the Achenheim profiles Nos. 1, 2 in the high Hangenbieten-Mundolsheim terrace (170 m). The Blaesheim profile No. 4 (180 m) lies on the slope of the Gloeckelsberg hill. The Griesheim profile No. 5 (180 m) is situated at the foot of the sub-Vosgesian hills on the surface of the Bruche cone. On the border of the upland of Alsace the Niederbetschdorf profile No. 7 (172 m) was described. The profiles situated on the sub-Vosgesian hills: the Bischoffsheim profile No. 6 (225 m) and the Equisheim profile No. 9 (220 m). On the eastern side of the Rhine, in the area of Baden, the Bötzingen profile No. 8 (260 m), situated on the slope of the Kaiserstuhl hill, was described (Khodary-Eissa, 1968). The Allschwil profile No. 11 (320 m), in the upland of Sundgau, lies in the southern part of the Rhinegraben.

The distribution of the loess in the Middle Rhine Lowland and the situation of the examined profiles are shown on the map (Fig. 2).

For the purpose of a comparison of the heavy mineral composition in the loesses of Alsace and of other areas, studies for the selected profiles of Normandy and Provence were made. The Saint Romain profile

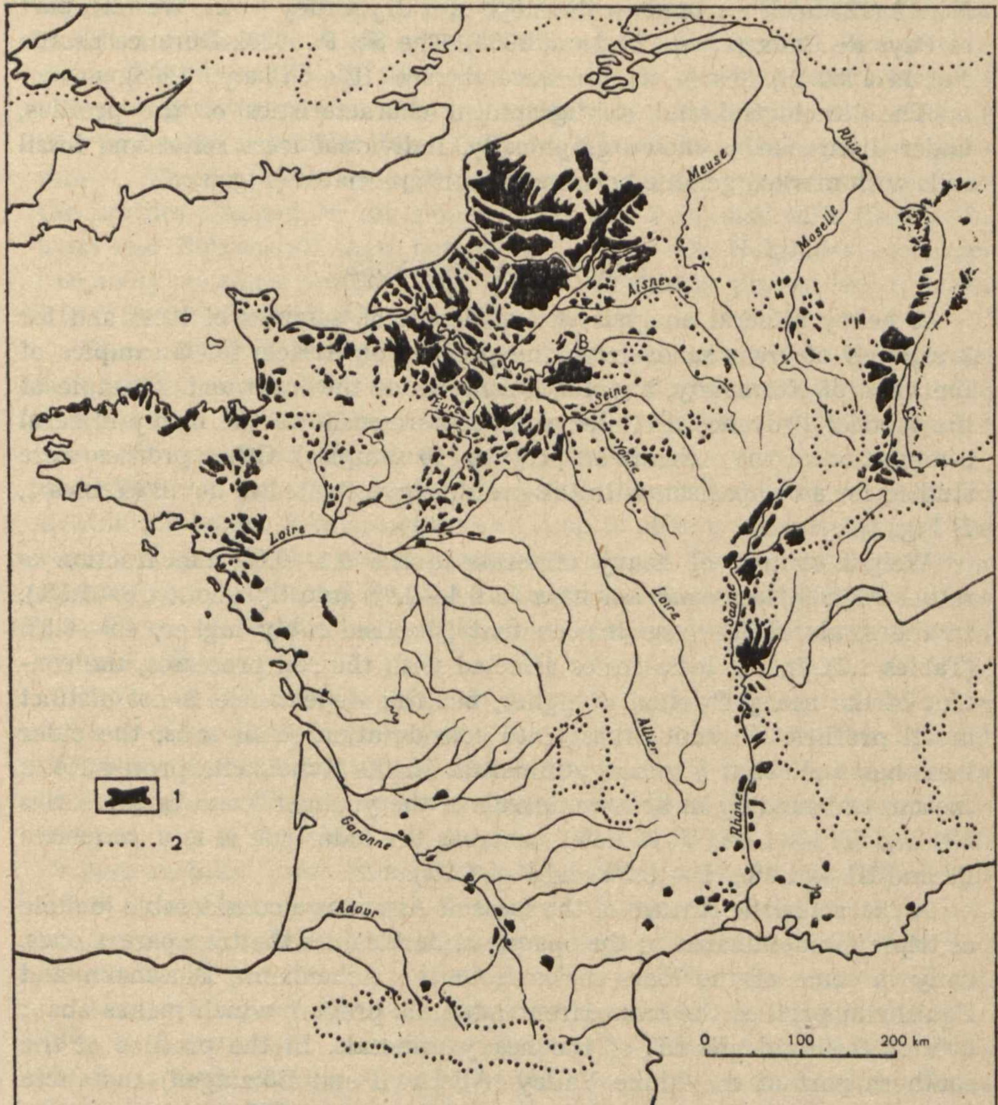

Fig. 1. Distribution of loess in France (according to A l i m e n, 1967, in the Rhinegraben completed by the author); 1 — areas of the loess cover, 2 — maximal range of continental glacier (Riss), A — Rhinegraben (profiles 1—12), N — Normandy (profile 13), P — Provence (profiles 14—15), B — Paris Basin (profile 16)

Rozmieszczenie lessów we Francji (według A l i m e n, 1967, w rowie Renu uzupełnione przez autora); 1 — obszary z pokrywą lessową, 2 — maksymalny zasięg lądolodu (Riss), A — Nizina Środkowego Renu (profile 1—12), N — Normandia (profil 13), P — Prowansja (profile 14—15), B — Basen Paryski (profil 16)

No. 13 (123 m) is exposed on the slope of a dry valley in the western part of Pays de Caux (Lautridou, 1968). The St. Paul-lez-Durance profile No. 14 1280 m) lies in the Durance terrace (Bonifay, 1968).

The lithological and stratigraphical characteristics of the profiles, under discussion, is shown graphically. Individual loess series and fossil soils with marked genetic horizons are differentiated (Fig. 3).

RESULTS OF ANALYSES

A heavy mineral analysis was made for 65 samples of loess and for 2 samples of river sands from the profiles of Alsace, for 3 samples of the loess of Normandy, and for 3 samples of the loess and 1 sample of the sand of Provence. Detailed studies were made of the heavy mineral composition of the Achenheim profiles (40 samples). Other profiles were studied for a comparison with the profiles investigated in detail (Tables 1, 2; Fig. 4).

Weight content of heavy minerals in the 0.1—0.05 mm fraction is rather high in loess and amounts to 0.4—2.9% (mostly about 0.8—1.5%). In the sands of the base this content is considerably higher, 4.9—6.5% (Tables 1,2). In the loess series affected with the soil processes, the content of the heavy fraction is higher, but this dependence is not distinct in all profiles. Without taking into consideration fossil soils, the older loess has somewhat less heavy minerals. In the Achenheim profile No. 2 the most abounding in heavy minerals is the younger loess (in the series VII and VI — 1.4%, V — 1.5%), whereas the older one is less, so (series IV and III — 1.2%, II — 0.7% and I — 1.1%).

A characteristic feature of the loess of Alsace is a considerable (double or triple) predominance of the opaque minerals over the transparent ones. Only in some of the loess series from the Achenheim, Blaesheim and Equisheim profiles the transparent minerals prevail, which makes about 60% of the total amount of the heavy minerals. In the profiles of the southern part of the Rhine Valley (Allschwil and Bötzingen) and those of Normandy the transparent minerals have a decided predominance (60—70%). In this loess there is no glauconite, or it appears in single grains. An exception is the Achenheim profile No. 1, where in some samples of the younger loess there is more of it, at most 6.8%. Muscovite occurs in large but variable quantities. Its amount was approximate because the content over 50% grains made counting impossible. The portion of muscovite in loess is shown in the table as a per cent of the total amount of all the minerals (Tables 1, 2).

In the group of opaque minerals there are: magnetite, ilmenite, iron oxides, and manganese oxides. Iron oxides are most of all to be observed (there is about 50% of them), and their amount in the Bischoffsheim profile reaches 80% of all opaque minerals. The second important constituent is magnetite. In the older loess there can be found nearly as many magnetites as iron oxides, or sometimes magnetite even prevails (the Achenheim profiles Nos. 2, 3 and Blaesheim, Bötzingen and Allschwil). The content of manganese oxides reaches a few per cent, only in the profiles situated on the slopes of the sub-Vosgesian hills (Bischoffsheim and Equisheim) their percentage is 10—30%. Sulphides occur occasionally, in some profiles only. In the Achenheim profile No. 1, series VI—VII, their amount reaches 5.6% (Table 1).

The analysis of transparent heavy minerals comprised on the average about 400 grains in each sample, in some cases considerably more, up to 1,000 grains. In the group of transparent minerals the following are dominant in order: epidotes — amphiboles — zircon — garnet — tourmaline — rutile. A high occurrence of minerals not resistant to weathering (about 30%, sometimes even up to 50%) is characteristic of the French loess. Of the resistant minerals zircon always dominates over tourmaline, garnet and rutile, although in some profiles tourmaline prevails or is in balance with it (Bischoffsheim series IV, Niederbetschdorf series V—VI).

Epidotes occur in variable amounts to 5—25%, up to 45%. The content of epidotes is given both for epidote and zoisite. The amount of zoisite does not exceed 2%, and in the younger loess it appears only in single grains (Fig. 4). In the younger loess 10—15% of epidotes is discovered, and in the older one — often over 20%. The loess on the sub--Vosgesian hills (Bischoffsheim and Equisheim) contains only 5% of epidotes. A similar content was discovered in the Griesheim profile (Buraczyński, 1971). The highest percentage of epidotes (30—40%) was discovered in the loess of Baden (profiles in Bötzingen and Allschwil).

Amphiboles occur in considerably differentiated amounts, 1—40%. In the younger loess there is usually 20% of amphiboles, in the older one their amount drops to 5—10%. In the river sands of the Rhine they constitute 30% of transparent minerals, in the Vosgesian sands only 17%. A prevailing constituent of the amphiboles is hornblende, only in the Equisheim profile actinolite is predominant, occurring in amount 2—4 times as high as hornblende. In the Achenheim profile No. 2 hornblende prevails in the younger loess (8%), in the older one it drops to 2%. In the humus horizon of the brown lessivé soil (series III) there is 19% of amphiboles, while 12% of the amphiboles constitutes hornblende (Fig. 4).

Chlorites occur in loess in the amount of 1—15%, in some cases their amount reaches 2.5%. The highest amount of chlorite can be found in the youngest loess: in series VII — 15—26% and in series VI — 10—15%. The profiles of Bischoffsheim and Niederbetschdorf are an exception here, as there is 1—5% of chlorite. In the older loess chlorites usually occur in amounts smaller than 5%.

Biotite occurs in variable amounts (0—50%), in most cases, however, in the amount of a few per cent. In principle, the younger loess has less biotite than the older one. This dependence, however, best seen in the Achenheim profile No. 2, is not always distinct (Fig. 4). The younger loess (series VI—VII) contains 20—50% of biotite, and the older one (series I—V) — 0.5—2.0%, the highest amount being 5.4%.

Zircon occurs in loess in the amount of 5—28%. In the younger loess its content is a little smaller, about 10%, in the older one it increases up to 20—25%. In the soil horizons a distinct decrease in the content of zircon appears. Blum and Maus (1967) also discovered a small content of zircon (10%) in the soils of Baden.

Garnet constitutes 5—10% of transparent minerals. However, in some profiles it reaches even 25% (Bötzingen and Allschwil). In the older loess (series I) of the Achenheim (No 1) and Bötzingen profiles it occurs in a higher amount than zircon, tourmaline and rutile.

Tourmaline occurs in the amount of 2—15%, up to 35%. In the Achenheim profile (No. 2) in the soil horizons (series V and III) and in the oldest loess (series I) an increase of its content can be seen. In the whole profile of Bischoffsheim, tourmaline occurs in considerable amounts (15—20%), in the Niederbetschdorf profile there is even more of it (30—35%).

Rutile occurs in small amount (1—5%), in some series its content increases up to 12%. The younger loess usually contains below 5% of rutile, the older one about 7%.

In this review of the contents of transparent minerals in loesses, considerable variations in different loess profiles can be seen. Besides the quantitative differences, each series is characterized by different groups of minerals, which play a decisive quantitative role here. For the sake of clarity, each series can be characterized with respect to quality of the occurrence of minerals arranged according to their importance. The mineralogical characterization of the Middle Rhine Lowland loesses appears as follows:

The loesses of Alsace (averages from the profiles of Achenheim, Blaesheim, Griesheim, Bischoffsheim, Niederbetschdorf, Equisheim). *

* In the list of heavy minerals zircon is shown with monazite, and rutile with anatase and brookite. Explanation of symbols: $\geqslant$ twice as much, $>$ 50% more, — more, = similar amount. To the left from the symbol " there is more than 10% of minerals, to the right from the symbol ' there is less than 5%.

Fig. 2. Distribution of loesses in the Rhinegraben
Rozmieszczenie lessów w rowie Renu

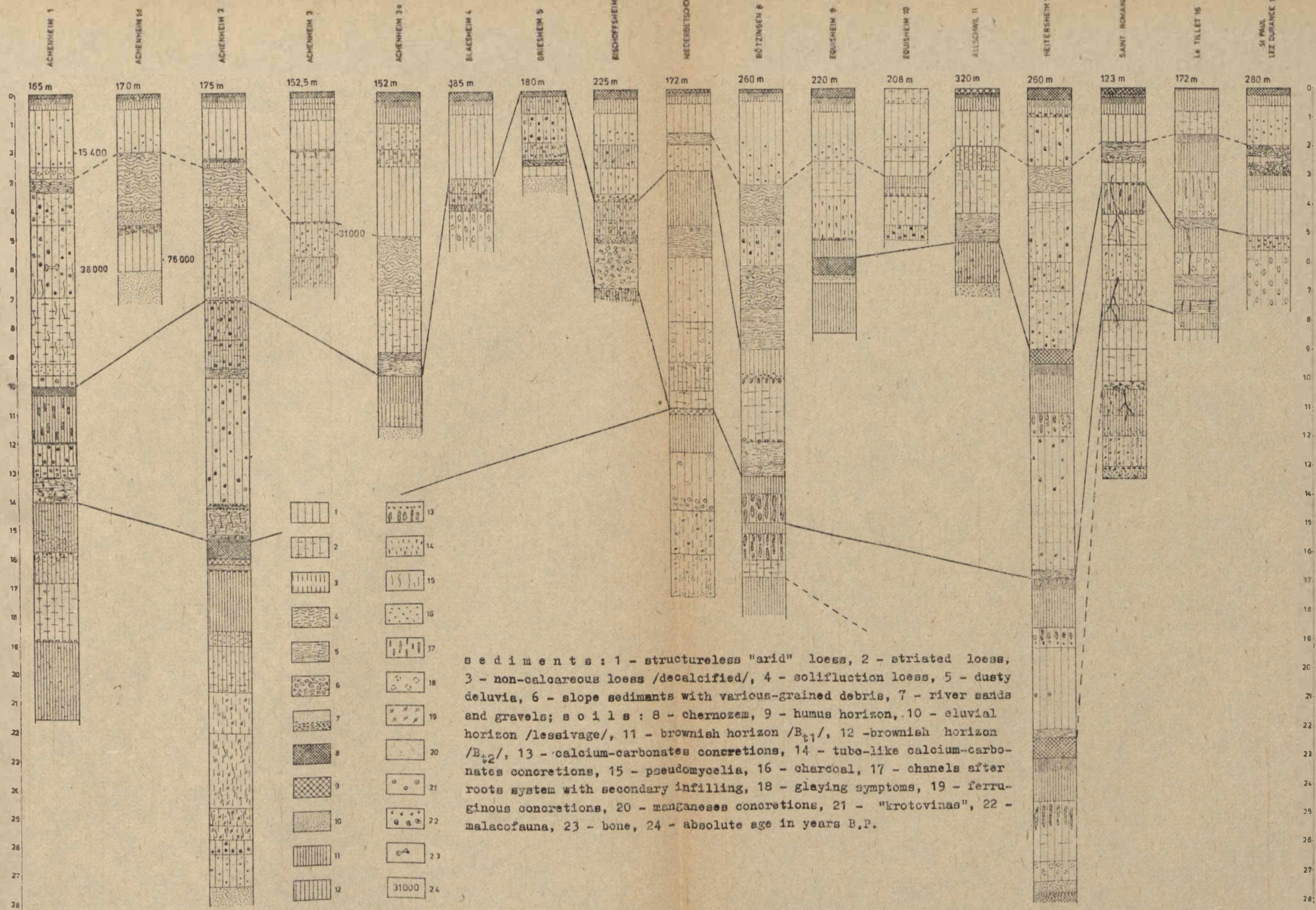

Fig. 3. Lithological-stratigraphical profiles in loess of Middle Rhine Lowland (1—12), Normandy (13), Paris Basin (16), Provence (14)
Profile litologiczno-stratygraficzne lessów Niziny Środkowego Renu (1—12), Normandii (13), Basenu Paryskiego (16), Prowansji (14)

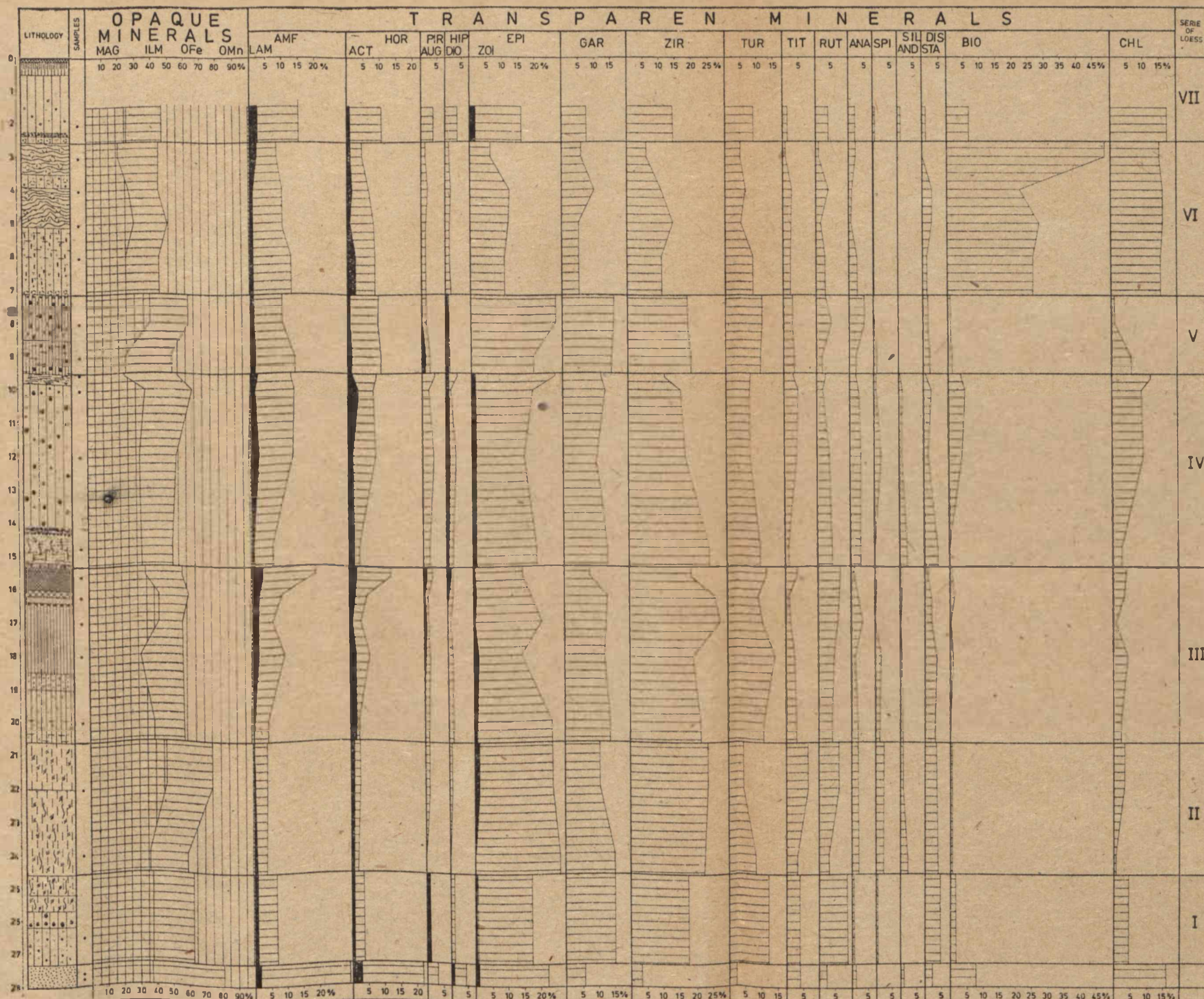

Fig. 4. Content of selected heavy minerals in loess of profile Achenheim 2 (for explanation see Table 1)
Zawartość minerałów ciężkich w profilu Achenheim 2

VII CHL>AMF=EPI−ZIR−GAR″−BIO−RUT−TUR−TIT′−PYR

VI AMF>BIO−ZIR=CHL−EPI−TUR″−RUT−GAR′>TIT>PYR

V AMF−EPI>ZIR=TUR>GAR=RUT″>CHL=BIO′−TIT−PYR

IV ZIR−AMF−TUR=EPI>GAR−RUT−CHL−BIO″>′TIT−PYR

III EPI>ZIR−GAR=TUR=AMF−RUT″≥′CHL−TIT−PYR−BIO

II EPI=ZIR≥GAR−RUT=TUR=AMF″>′TIT−BIO−CHL>PYR

I EPI≥GAR−AMF=ZIR>TUR=RUT″>′BIO>CHL−TIT−PYR

The loesses of Baden (averages from the profiles of Bötzingen and Allschwil).

VII EPI>GAR=CHL>BIO=AMF>ZIR″>′TUR−RUT−TIT−PYR

VI EPI≥CHL−GAR−AMF−ZIR≥BIO″>′TUR−RUT=TIT>PYR

V EPI≥ZIR−GAR−CHL−AMF>BIO=PYR″>′RUT≥TUR−TIT

IV EPI≥ZIR>GAR=PYR>BIO″−′AMF=TIT=TUR−RUT>CHL

III EPI≥ZIR>GAR−CHL−BIO″≥′TUR−AMF−RUT−TIT−PYR

I GAR>ZIR=EPI≥CHL=BIO″≥′TUR−RUT≥TIT=AMF=PYR

From the above list it appears that in each series of loesses important roles are played only by six minerals, with the content above 10%. The remaining minerals occur in small variable amounts. In the younger loess amphiboles and epidotes stand out. Additionally, in series VII chlorites appear and in series VI biotites. Zircon occurs in the third place, often in balance with tourmaline. Garnet usually occurs in the fifth place.

The younger loess of Alsace is characterized by the set: amphiboles — epidotes — zircon — tourmaline — garnet with a variable amount of chlorite and biotite. In series IV zircon and tourmaline prevail, with amphiboles and epidotes occurring in variable amounts. In the older loess epidotes prevail and of resistant minerals — zircon. It is characterized by the set: epidote — zircon — garnet and tourmaline — rutile — amphiboles occurring in variable order.

In the loesses of Baden epidotes and garnet prevail, with chlorite — biotite and zircon — amphiboles occurring in variable amounts. The older loess is characterized by the set: epidote — zircon — garnet and chlorite — biotite, occurring in different amounts. This set is similar to the one observed in Alsace, tourmaline and rutile playing a smaller role in it.

WEATHERING OF MINERALS

Variations of the heavy mineral content are effected by the changes of the feeding areas as a source of loess. They are also caused by the processes of weathering (Alimen et al., 1965; Andel, 1959; Briggs, 1965; Chalczeva, 1972; Duplaix, Malterre, 1946;

Griffiths, 1967; Malicki, Morawski, 1973; Maruszczak, Morawski 1976; Maruszczak, Racinowski, 1968; Morawski, Trembaczowski, 1971; Racinowski, 1976; Rjabczenkov, 1960; Young, 1966).

Unweathered younger loess contains less opaque minerals and less resistant minerals of the transparent mineral group; whereas in older weathered loess these types of minerals prevail. The differences in the content between the opaque minerals of younger and older loesses are slight. To support them by documentary evidence the per cent contents of opaque and transparent minerals in different loess profiles of Alsace, Baden, Normandy and Provence were compiled (Tables 1, 2). The increased occurrence of the opaque minerals and of the most resistant ones among the transparent group is one of the manifestations of weathering and a standard in weathering-soil processes. The differences in contents of heavy minerals in older and younger loesses can also be the result of primary differences of accumulated dust.

Under the influence of weathering in the loess profiles there occur changes in the proportion of the groups of transparent minerals, connected with their different resistance levels to mechanical and chemical deterioration. As a result of weathering, the medium resistant and little resistant components pass into the group of opaque minerals and turn into secondary loamy minerals (Rohdenburg, Meyer, 1966, according to Maruszczak, Morawski, 1976). The content of resistant minerals does not change, showing only a relative increase.

In order to present the intensity of the content changes of the minerals, under the influence of weathering various coefficients showing proportions of the selected minerals are used — zircon/garnet, zircon/amphibole and the like (Manikowska, 1966; Racinowski, 1969; Morawski, Trembaczowski, 1971). The coefficients used in the Polish literature were compiled by Morawski and Trembaczowski (1971). Chalczeva (1972) proposed additional coefficients indicating the intensity of the variations of primary minerals under weathering conditions: $K_3 = \frac{\text{unweathered epidote}}{\text{weathered epidote}}$, $K_4 = \frac{\text{rutile without secondary transformations}}{\text{rutile with secondary transformations}}$, and

$$K_5 = \frac{\text{ore minerals} + \text{titanium group}}{\text{secondary ore minerals} + \text{titanium group}}$$

To estimate the degree of weathering of heavy minerals in loesses the most frequent mineral content index is: $\frac{O}{S+N}$, where O — stands for zircon, rutile, tourmaline, disthene, staurolite; S — for apatite, epidotes, garnet, sillemanite; N — for amphiboles, biotite, chlorite, pyroxenes (Racinowski, 1969; Buraczyński, 1971; Morawski, Trembaczowski, 1971; Maruszczak, Morawski, 1976; Maruszczak, Racinowski, 1976).

The relation of the resistant minerals to those little and medium resistant varies in younger and older loesses. In the loess of Alsace coefficient $\frac{O}{S+N}$ shows little differentiation, from 0.2 to 1.0 (Achenheim 2). When calculating this coefficient for every mineral, little differentiation is observed and the relevant differences often become less discernible. It seems more suitable to take into account only the selected resistant and little resistant minerals, which are characteristic of a given set of minerals. Characteristic resistant minerals of the Middle Rhine Lowland are zircon and tourmaline, and the slightly resistant mineral hornblende. Zircon and tourmaline occur in the granites and gneisses of the Vosges and of the Schwarzwald, and hornblende is a component of the metamorphic and magma rocks of those mountains.

In the present paper the coefficient $\frac{ZIR+TUR}{HOR}$ is used. Based on the investigation of the degree of weathering of some minerals, the coefficient of weathering of chlorite, epidote and hornblende were calculated as the relation of unweathered to weathered material. Detailed investigations of the opaque minerals were also made, from which the coefficient $\frac{Fe_2O_3 + \text{ilmenite}}{\text{magnetite}}$ was calculated. This coefficient is an attempt of employing the opaque minerals to specify the degree of an advancement of the weathering-soil processes.

The coefficient of weathering $\frac{ZIR+TUR}{HOR}$ in the Achenheim profile No. 2 ranges from 0.2 to 14.0 (Fig. 5). In the younger loess in series VI—VII it amounts to 2.0—2.5, and in series IV—V — to about 3.0. In the slope wash of the floor of series IV it increases to 10.9. By the mineral content of the slope wash it indicates that they are originated and have a close connection with the denudation of series III. In the older loess zircon and tourmaline considerably prevail over hornblende. In the brown lessivé soil the coefficient under discussion amounts to 5.7—13.5 (series III). In the humus horizon of this soil it drops to 2.6, in the B_{t1} horizon it amounts 11.7, and in B_{t2} — 5.75. The loess of series I—II have a high coefficient, 8—14. In subloessial sands of the Rhine; on the other hand, the coefficient is very low — 0.3, with a small part of resistant minerals. In the younger loess of the Bötzingen profile (series V—VII) the coefficient amounts to 0.8. In the older loess in series III—IV it amounts to

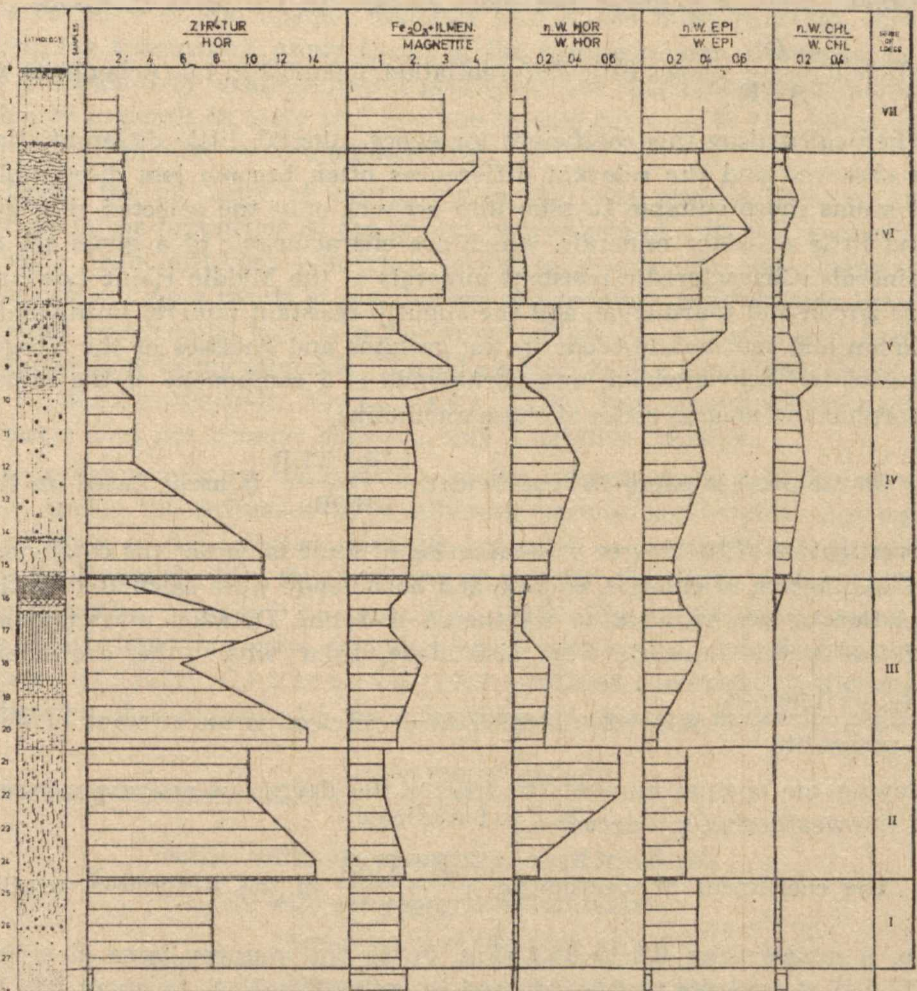

Fig. 5. Coefficients of weathering of heavy minerals in loess of profile Achenheim 2
Wskaźniki zwietrzenia minerałów ciężkich w lessach profilu Achenheim 2

Table 1. Heavy minerals in loess of Achenheim profiles
Minerały ciężkie w profilach lessowych Achenheim

Content of the main groups of heavy minerals: OPM, GLA, TRM; OPAQUE MINERALS: MAG, ILM, FeO, MnO, SUL; TRANSPARENT MINERALS = 100 %: AMPHIBOLES (AMP, HOR, ACT, LAM), PYROXENES (PYR, AUG, DIO, HYP)

Series of loess	Number of the Sample	Depth m	Content of heavy miner. % by weight	MUS	OPM	GLA	TRM	MAG	ILM	FeO	MnO	SUL	AMP	HOR nw	HOR w	ACT nw	ACT w	LAM	PYR	AUG nw	AUG w	DIO	HYP
A C H E N H E I M - 1																							
VII	6	1.0	1.61	20	59.5	6.8	33.7	17.9	12.1	68.4	no	1.4	11.7	5.9		3.2		1.3	3.0	1.3		0.4	1.3
VII	11	2.0	0.81	5	66.9	1.1	32.0	25.7	14.7	54.3	no	5.3	17.8	11.0		3.8		2.0	2.5	0.7		0.3	1.5
VI	19	3.6	1.19	10	63.7	-	36.3	20.4	20.2	53.8	no	5.6	28.3	20.5		1.3		3.9	5.2	2.9		-	2.3
VI	26	5.0	1.04	15	70.0	-	30.0	23.1	18.8	55.5	no	2.6	15.9	4.2		4.2		4.5	2.7	1.2		0.3	0.9
V	50	9.8	0.77	5	43.1	-	56.9	34.2	27.6	37.0	no	1.2	32.4	23.8		2.4		5.0	5.3	0.9		1.7	1.2
V	52	10.2	0.89	2	57.5	3.6	38.9	31.2	28.4	39.8	no	0.6	37.1	29.8		3.2		1.9	4.8	1.6		1.9	1.3
V	52a	10.5	0.62	5	52.3	1.5	46.2	25.2	29.2	44.2	no	1.4	38.8	32.1		3.0		2.1	4.3	-		2.1	1.5
V	56	11.0	0.86	-	47.9	-	52.1	27.5	31.5	40.3	0.7	-	12.0	2.8	4.8	0.9	0.2	2.2	2.0	-	-	-	2.0
V	61	12.0	0.49	+	60.6	-	39.4	43.0	19.6	37.4	-	-	20.9	4.0	11.2	1.6	1.6	2.0	2.5	-	-	0.7	1.8
III	71	14.0		+	64.2	-	35.8	23.7	15.3	60.7	0.3	-	9.2	2.0	4.0	0.9	0.1	0.5	1.9	0.3	0.2	0.2	1.2
III	76	15.0	1.15	+	57.0	-	43.0	25.6	31.2	42.5	0.7	-	20.2	5.4	8.6	1.5	1.7	1.1	1.4	-	-	-	1.4
II	81	16.0	1.21	+	45.2	-	54.8	23.2	23.3	52.9	0.6	-	19.2	6.1	3.7	3.5	1.6	1.8	2.5	-	-	-	2.5
I	83	19.7	1.88	+	45.7	-	54.3	13.8	13.6	72.6	-	-	10.8	1.1	3.9	1.4	1.5	1.0	3.7	-	-	0.5	3.2
I	85	20.7	2.37	+	39.8	-	60.2	36.5	15.7	47.8	-	-	20.5	1.5	10.5	1.2	3.2	3.1	0.8	-	-	0.5	0.3
A C H E N H E I M - 1 d																							
V	95	5.5	2.26	20	41.1	-	58.9	22.4	39.0	37.9	0.7	-	15.1	0.7	11.7	0.2	0.8	1.1	2.1	-	0.5	0.2	1.3
sand	96	6.5	4.87		72.2	-	27.8	64.7	8.4	26.9	-	-	17.0	2.4	9.2	0.3	1.5	2.0	1.7	-	0.3	-	1.2
A C H E N H E I M - 2																							
VII	10	2.0	1.25	5	56.9	-	43.1	25.0	20.1	54.5	0.4	-	15.1	0.9	9.6	0.3	0.4	2.6	3.8	-	0.2	-	3.6
VI	14	3.0	2.93	40	36.1	0.1	63.8	19.6	24.7	55.3	0.4	-	8.3	0.4	4.0	0.3	0.4	2.3	1.2	-	0.1	0.1	1.0
VI	18	4.0	1.04	10	57.0	0.1	42.9	25.9	17.9	56.2	-	-	9.9	0.7	5.8	-	1.5	1.1	1.9	-	-	0.4	1.5
VI	22	5.0	1.71	50	37.1	-	62.9	29.3	20.3	50.1	0.3	-	9.9	0.4	7.5	0.4	0.3	1.1	1.6	-	0.1	-	1.5
VI	26	6.0	1.64	10	49.9	0.2	49.9	24.7	19.3	55.4	0.2	-	12.6	0.7	7.7	0.4	1.6	1.2	1.4	-	-	0.2	1.2
V	34	8.0	1.38	-	58.4	-	41.6	39.0	23.5	37.5	-	-	10.3	1.9	7.0	0.3	+	1.1	1.4	0.2	-	0.6	0.6
V	38	9.0	1.65	3	54.5	-	45.5	23.9	27.8	48.3	-	-	13.6	0.7	9.4	0.5	0.4	1.7	2.6	-	1.1	0.6	0.9
IV	41	9.6	1.16	+	42.4	-	47.6	22.9	32.2	44.9	-	-	12.3	0.7	7.7	0.2	1.0	2.0	3.9	-	-	0.5	3.2
IV	42	10.0	0.89	+	50.7	-	49.3	35.1	29.4	34.9	0.6	-	13.2	1.3	6.3	0.7	2.2	1.1	2.0	-	-	0.7	1.3
IV	48	12.0	1.29	+	54.7	-	45.3	32.1	22.3	44.3	1.3	-	12.8	2.4	5.8	0.2	0.7	2.3	3.5	0.2	-	0.5	2.8
IV	61	14.7	1.52	5	58.5	-	41.5	33.3	18.2	45.7	0.8	-	6.4	0.6	2.6	0.1	1.1	0.6	2.0	0.1	0.1	0.3	1.5
III	66	15.6	1.43	+	55.2	-	44.8	34.7	23.2	41.4	0.7	-	19.4	1.0	11.0	0.2	1.7	3.0	2.8	0.7	0.2	0.6	1.3
III	69	16.2	0.99	+	65.0	-	35.0	43.1	18.5	36.9	1.5	-	9.1	0.3	4.8	0.1	1.2	1.6	1.3	-	-	-	1.3
III	73	17.0	1.25	+	66.5	-	33.5	43.0	13.8	41.9	1.3	-	6.2	0.2	3.1	0.1	0.4	1.6	1.6	-	0.8	0.3	0.5
III	78	18.0	1.31	+	57.8	-	42.2	31.2	25.8	42.5	0.5	-	9.8	1.1	4.8	-	1.6	1.5	2.1	0.2	0.3	0.3	1.3
III	82	20.0	1.50	+	59.8	-	40.2	39.5	18.8	40.6	1.1	-	4.8	0.4	2.0	0.4	1.2	0.3	1.6	-	0.3	-	1.3
II	86	22.0	0.60	+	60.1	-	39.9	46.6	28.0	24.2	0.6	0.6	4.3	1.1	1.7	0.3	0.6	0.3	1.2	-	0.3	0.3	0.6
II	90	24.0	0.81	+	60.9	0.4	38.7	36.6	23.6	39.3	0.5	-	3.8	0.3	1.9	-	0.8	0.8	-	-	-	-	-
I	95	26.5	1.09	+	64.2	-	35.8	38.3	25.1	36.1	0.4	0.1	6.8	0.1	3.7	0.2	0.5	1.2	1.4	0.1	0.1	-	1.0
sand	96	27.0	6.55		17.3	-	82.7	36.5	45.2	18.3	-	-	29.0	0.4	21.2	0.3	2.4	1.4	3.4	-	0.4	0.7	2.3
A C H E N H E I M - 3																							
VII	2	1.5	0.74	+	61.5	0.2	38.3	35.3	24.3	40.4	-	-	8.5	1.8	3.9	0.4	0.7	0.4	3.2	0.2	0.5	1.1	1.4
VI	5	4.0	2.11	20	31.7	0.6	67.7	34.0	22.2	43.8	-	-	4.6	0.3	3.9	+	0.1	0.3	0.7	-	-	-	0.7
VI	7	5.0	1.17	5	57.2	0.1	42.7	17.1	22.4	60.5	-	-	11.3	0.3	7.1	-	1.4	1.0	3.4	-	0.2	0.2	3.0
V	9	6.0	1.78	10	63.1	-	36.9	19.4	22.1	58.5	-	-	11.7	0.2	9.0	-	1.4	0.2	1.4	-	0.3	0.2	0.9

TRANSPARENT MINERALS = 100 % (continued): EPIDOTES (EPZ, EPI, ZOI) and the remaining minerals

Series of loess	Number of the Sample	EPZ	EPI nw	EPI w	ZOI	GAR	TUR	ZIR	MON	RUT	TIT	ANA	BRU	SPI	AND	SIL	DIS	STA	SER	BIO nw	BIO w	CHL nw	CHL w	Others
A C H E N H E I M - 1																								
VII	6	9.4	8.5		0.9	10.3	8.5	8.1	-	2.8	3.6	1.7	-	0.9	-	-	1.5	0.2	-	11.7		26.2		0.4
VII	11	15.5	14.5		0.3	9.4	7.9	5.4	0.5	4.3	16.8	1.8	0.5	1.3	-	1.5	0.5	1.0	0.3	3.3		9.4		0.3
VI	19	27.7	26.4		1.0	4.6	2.6	8.5	-	6.2	8.5	0.6	-	2.3	-	-	0.6	-	-	0.3		4.6		-
VI	26	17.1	15.3		1.2	12.6	3.0	8.4	-	12.0	15.0	2.1	0.6	0.6	-	0.9	0.6	0.3	-	0.6		7.5		-
V	50	17.3	15.0		0.9	6.8	6.7	6.2	1.5	5.6	12.6	1.2	-	0.9	-	-	0.3	0.3	-	0.6		2.3		-
V	52	14.9	13.3		0.9	5.7	3.5	6.3	1.0	4.8	11.1	1.0	-	2.2	-	-	1.3	0.6	2.2	0.6		2.9		-
V	52a	14.6	11.8		2.4	8.5	3.0	4.6	0.3	3.0	10.3	1.2	-	2.4	-	-	0.9	0.9	2.7	0.9		3.6		-
V	56	18.3	5.0	11.7	1.1	7.1	10.7	15.2	0.2	8.0	2.0	3.1	-	-	0.2	-	0.7	1.3	-	0.3	10.4	0.5	7.5	0.4
V	61	10.9	2.5	7.3	0.2	5.5	12.1	11.1	-	6.2	0.9	2.7	0.2	0.2	0.2	-	1.1	1.4	0.2	0.2	18.0	0.1	6.0	0.5
III	71	19.5	7.3	11.2	0.5	8.9	13.3	28.7	-	7.5	3.1	0.7	0.5	0.2	0.5	0.5	1.0	1.2	-	-	0.2	0.2	2.7	0.2
III	76	21.8	7.9	13.2	0.7	10.3	9.6	10.8	0.2	6.0	1.8	0.7	0.2	0.5	0.2	-	0.9	1.2	-	0.3	6.3	0.2	6.7	0.7
II	81	14.6	7.0	7.6	-	6.8	14.7	12.6	0.5	5.8	1.3	3.0	0.5	0.2	0.5	-	0.8	0.8	-	2.0	7.9	1.0	5.3	-
I	83	33.9	8.7	23.4	1.6	12.6	7.4	8.7	-	6.6	2.6	2.1	-	0.3	0.5	-	1.3	2.4	0.5	-	5.3	0.1	0.9	0.3
I	85	28.1	4.9	22.9	0.3	13.8	8.1	9.9	-	5.2	1.6	1.0	0.2	0.2	0.5	-	0.2	2.1	-	-	2.3	0.2	5.3	-
A C H E N H E I M - 1 d																								
V	95	26,4	4.5	20.6	1.3	9.5	3.7	17.7	-	4.0	1.9	1.3	-	0.5	1.1	0.8	0.3	0.5	-	-	0.3	0.4	14.1	0.3
sand	96	21.1	2.5	17.2	1.1	1.0	4.5	13.3	-	8.2	2.9	1.0	0.2	-	0.5	-	0.2	0.3	-	-	20.2	-	4.0	3.4
A C H E N H E I M - 2																								
VII	10	15.5	3.9	9.9	1.7	7.9	8.6	14.1	-	3.8	1.4	1.9	1.0	0.5	0.5	0.5	0.5	0.5	0.3	-	6.7	1.7	15.5	0.2
VI	14	6.1	1.5	4.2	0.3	6.3	4.7	6.0	-	0.9	0.8	2.2	-	-	-	0.2	0.2	0.1	0.2	-	48.0	1.1	13.6	0.1
VI	18	12.1	3.8	7.5	0.6	10.3	6.2	10.4	-	3.7	2.8	1.3	0.2	0.2	0.2	-	2.4	0.6	0.2	1.5	19.7	2.2	13.8	0.4
VI	22	11.4	4.3	6.4	0.5	5.4	4.6	14.1	-	1.3	2.3	1.0	0.5	0.3	-	0.3	2.0	0.8	-	-	28.0	1.2	14.9	0.4
VI	26	10.3	2.6	7.1	0.5	5.6	8.2	10.6	-	2.9	2.2	2.6	0.3	0.2	0.2	-	1.4	-	-	-	26.0	0.9	14.5	0.2
V	34	26.0	8.8	16.9	0.3	16.0	10.9	18.3	-	4.9	2.9	4.6	0.3	-	-	0.3	0.6	0.9	-	0.1	0.8	0.1	1.0	0.6
V	38	18.8	3.9	14.6	0.3	15.3	10.4	19.4	-	2.0	3.5	2.3	0.3	1.1	0.3	-	1.4	0.3	0.3	+	1.4	0.1	6.0	0.3
IV	41	25.6	7.0	17.4	1.2	11.9	7.2	11.3	-	3.0	3.2	2.2	0.5	0.7	0.5	-	0.5	0.5	-	-	3.9	2.4	9.7	0.4
IV	42	18.6	4.1	13.4	1.1	12.8	6.9	16.1	-	1.8	4.5	2.9	1.8	0.7	1.3	-	1.6	0.9	0.2	-	5.4	1.2	7.7	0.4
IV	48	16.1	4.1	10.6	1.4	10.5	7.2	17.5	0.9	4.0	4.0	3.5	1.4	2.3	0.9	-	0.9	0.5	-	-	4.4	1.6	8.0	-
IV	61	19.4	3.0	15.3	1.2	13.6	10.4	24.4	0.3	4.9	1.7	3.5	2.6	0.3	2.3	0.3	1.2	3.2	0.3	-	0.3	0.3	2.6	-
III	66	14.9	2.5	11.6	0.4	8.1	12.0	19.0	0.2	7.1	3.4	1.5	1.1	0.6	1.1	-	1.1	0.4	0.6	-	1.3	0.3	4.0	1.1
III	69	17.5	3.2	13.2	0.8	13.4	9.6	26.3	-	7.2	1.4	2.4	1.9	0.5	0.8	0.3	1.3	1.1	0.3	-	1.9	0.1	3.6	-
III	73	21.2	5.4	15.5	0.3	13.1	10.9	27.7	-	6.3	1.9	3.8	1.1	0.3	0.5	-	2.2	0.5	0.8	-	0.5	-	1.1	0.3
III	78	14.7	3.1	10.1	1.5	12.4	14.5	19.4	-	5.2	3.1	1.8	1.8	2.1	0.3	0.5	1.8	2.3	0.5	-	1.5	-	4.7	1.5
III	82	24.0	1.9	20.5	1.1	14.2	10.9	21.6	0.5	4.5	3.5	2.4	2.1	1.6	1.1	-	1.3	2.1	0.3	-	-	-	2.4	1.1
II	86	23.9	4.6	17.0	1.4	10.8	4.8	23.3	0.8	6.5	7.1	2.3	2.8	2.8	1.1	-	1.4	2.3	0.3	-	0.6	-	3.7	-
II	90	26.2	5.4	20.8	-	15.6	8.5	22.4	0.3	3.3	3.8	2.5	2.2	2.5	1.6	0.8	1.9	2.7	0.5	-	0.6	-	0,8	-
I	95	17.4	4.1	12.8	0.5	15.3	12.2	17.6	-	8.9	4.2	0.9	2.4	0.5	0.2	-	3.3	1.4	-	-	1.9	0.3	4.2	1.1
sand	96	22.2	0.8	19.5	1.1	5.8	2,5	3.4	0.7	2.5	4.3	1.6	1.4	-	0.4	0.7	1.6	0.7	1.4	0.1	7.8	0.6	8.8	1.1
A C H E N H E I M - 3																								
VII	2	12.1	3.8	7.9	0.4	10.3	11.0	16.0	0.3	12.1	6.8	4.3	2.5	-	1.4	-	1.1	-	-	-	5.0	-	5.0	0.4
VI	5	5.7	0.5	4.9	0.3	6.0	4.9	10.2	-	2.9	1.0	0.7	0.1	-	0.4	0.3	0.5	-	-	-	44.5	-	17.4	0.1
VI	7	20.9	0.8	18.6	1.2	6.2	10.3	13.0	-	5.4	2.0	3.9	1.0	-	0.7	-	1.0	1.7	0.7	-	2.7	-	15.5	0.3
V	9	17.1	1.1	15.3	0.5	9.0	12.4	10.4	0.5	9.2	2.1	4.1	1.8	0.2	0.5	0.5	2.3	0.2	-	-	8.8	-	7.8	-

E x p l a n a t i o n s:
MUS - muscovite, OPM - opaque minerals, GLA - glauconite, TRM - transparent minerals, MAG - magnetite, ILM - ilmenite, OFe - oxide Fe, OMn - oxide Mn, SUL - sulphure, AMP - amphibole, HOR - hornblende, ACT - actinolite, LAM - lamprobolite, PYR - pyroxene, AUG - augite, DIO - diopside, HYP - hypersthene, EPZ - epidote + zoisite, EPI - epidote, ZOI - zoisite, GAR - garnet, TUR - tourmaline, ZIR - zircon, MON - monazite, RUT - rutile, TIT - titanite, ANA - anatase, BRU - brookite, SPI - spinel, AND - andalusite, SIL - sillimanite, DIS - disthene, STA - staurolite, SER - serpentine, BIO - biotite, CHL - chlorite, nw - unweathered minerals, w - weathered minerals, no - not examined.

Table 2. Heavy minerals in loess of Alsace, Normandy and Provence

Minerały ciężkie w profilach lessowych Alzacji, Normandii i Prowansji

Series of loess	Number of the sample	Depth m	Content of heavy miner. % by weight	MUS	Content of the main groups of heavy minerals			OPAQUE MINERALS					TRANSPARENT MINERALS = 100 %																																	
													AMPHIBOLES						PYROXENES					EPIDOTES																						
					OPM	GLA	TRM	MAG	ILM	FeO	MnO	SUL	AMF	HOR		ACT		LAM	PYR	AUG		DIO	HYP	EPZ	EPI		ZOI	GAR	TUR	ZIR	MON	RUT	TIT	ANA	BRU	SPI	AND	SIL	DIS	STA	SER	BIO		CHL		Others
														nw	w	nw	w			nw	w				nw	w																nw	w	nw	w	
BLAESHEIM - 4																																														
VII	5	2.5	1.94	15	31.7	0.1	68.2	32.4	21.9	45.7	-	-	20.1	9.4	7.3	2.1	-	0.5	1.8	-	-	0.2	1.6	15.9	1.9	12.8	0.7	9.3	2.1	6.5	-	1.1	2.8	0.3	0.2	0.3	-	0.2	0.3	0.3	0.3	-	10.8	0.7	26.0	0.5
VI	13	3.5	0.95	5	47.6	-	52.4	58.6	23.3	15.6	2.5	-	8.7	2.7	4.5	0.4	1.0	-	0.5	-	-	0.1	0.4	8.2	1.5	6.6	0.1	2.2	8.8	8.8	-	2.7	2.5	0.5	0.4	0.1	0.1	-	0.5	0.3	0.3	-	3.0	-	52,1	0.3
V	20	4.5	0.91	15	70.7	0.2	29.1	57.7	12.6	27.9	1.8	-	9.2	4.6	3.3	0.2	-	0.4	0.2	-	-	-	0.2	19.1	5.1	13.2	0.4	9.7	10.8	11.2	-	8.8	3.7	0.9	0.2	0.7	0.4	0.2	0.9	2.4	-	-	9.9	-	10,6	1.1
BISCHOFFEHEIM - 6																																														
VI	12	2.5	1.42	10	82.7	+	17.3	10.0	7.8	79.1	3.1	-	19.1	12.4	3.0	2.0	-	1.5	0.5	-	-	-	0.5	4.0	1.0	2.0	0.8	11.7	15.2	14.7	0.5	11.2	2.0	1.3	0.8	-	-	-	0.2	-	0.5	-	12.4	-	5.0	0.2
VI	15	3.0	1.49	5	84.3	-	15.7	8.9	6.4	76.9	7.8	-	32.6	22.8	2.7	2.7	-	3.0	0.3	-	-	-	0.3	6.8	2.7	3.3	0.5	7.9	11.7	15.2	0.3	4.9	7.3	0.8	-	-	-	-	0.5	-	0.3	2.4	4.3	-	4.3	0.3
V	20	4.0	2.08	15	88.0	-	12.0	7.9	5.6	77.6	8.9	-	23.7	19.2	0.9	1.1	-	1.1	1.4	-	-	-	1.4	4.8	2.3	2.5	-	11.8	17.2	12.7	-	11.8	3.4	2.8	0.8	-	-	-	0.3	0.3	-	1.1	3.7	0.3	3.9	-
IV	25	5.6	1.93	5	86.0	-	14.0	5.5	6.9	77.7	9.9	-	23.8	18.5	1.5	2.4	-	0.5	1.0	-	-	-	1.0	3.9	1.7	1.9	0.3	6.1	16.3	11.7	-	9.7	2.9	1.2	0.2	0.2	-	0.2	0.2	-	-	1.7	13.1	-	6.8	1.0
IV	26	6.6	1.81	+	88.9	-	11.1	8.2	7.6	70.9	13.3	-	24.2	13.1	6.5	2.4	-	1.1	0.8	-	0.3	-	0.5	5.2	1.1	4.1	-	11.2	19.9	15.5	-	7.9	1.1	1.9	-	-	-	-	0.8	-	-	-	8.2	-	2.7	0.6
NIEDERBETSCHDORF - 7																																														
VI	1	2.0	0.26	+	53.9	-	46.1	26.5	67.2	5.9	0.4	-	2.8	1.3	0.8	-	-	0.5	0.2	-	-	-	0.2	11.0	2.8	6.9	1.0	1.3	35.6	28.0	-	11.7	1.8	1.8	-	-	0.5	-	-	1.0	-	-	2.6	0.5	1.0	0.2
V	5	7.0	0.53	30	68.8	-	31.2	17.4	43.7	35.9	3.0	-	1.3	-	0.3	-	-	0.3	-	-	-	-	-	9.7	4.9	3.2	1.0	6.5	29.9	12.0	-	7.5	2.3	2.3	-	-	0.3	-	-	0.3	-	-	10.4	0.6	16.9	-
IV	10	13.0	0.37	20	68.9	0.1	31.0	5.4	37.7	38.9	18.0	-	1.8	-	0.9	0.9	-	-	0.9	0.5	-	0.4	-	22.9	8.5	12.6	1.4	8.5	14.4	18.4	-	8.5	4.0	1.8	0.4	0.4	0.9	-	1.4	1.4	-	-	6.7	-	7.6	-
BÖTZINGEN - 8																																														
VII	1	3.0	1.30	15	21.5	0.3	78.2	34.2	25.3	33.5	7.0	-	22.4	13.2	3.8	5.2	-	-	1.9	1.4	-	0.2	0.3	16.9	7.2	8.3	1.2	17.7	3.9	9.5	-	2.2	1.7	-	-	-	0.2	0.3	1.4	1.4	-	-	[illegible].6	1.4	9.3	0.2
VI	2	7.0	1.47	20	20.6	-	79.4	31.4	38.0	28.1	2.5	-	19.6	11.8	3.7	4.1	-	-	3.9	1.9	-	1.1	0.9	18.3	6.7	11.0	0.6	15.1	4.5	8.6	-	2.4	1.3	0.2	0.6	0.2	-	0.2	3.2	0.2	-	0.4	6.9	6.4	7.7	0.2
VV	3	11.0	1.53	10	24.2	-	75.8	48.8	24.4	26.2	0.6	-	21.5	12.2	3.6	4.2	-	0.8	6.3	3.4	-	1.5	1.3	14.8	3.4	9.3	1.3	21.5	1.9	11.4	-	2.1	1.0	0.4	-	0.8	0.2	-	1.0	1.5	-	0.4	4.4	-	10.4	0.4
V	4	12.4	0.91	10	25.6	-	74.4	33.1	32.1	34.8	-	-	5.6	3.4	0.4	0.7	-	0.2	13.5	8.6	-	3.0	1.9	23.8	7.5	15.7	0.4	14.4	2.1	6.4	-	1.5	0.3	0.4	-	-	-	-	2.1	0.9	-	-	12.2	0.5	16.3	-
IV	7	13.3	0.71	+	35.9	-	64.1	58.3	24.1	15.4	2.2	-	4.2	2.0	0.7	1.0	-	0.5	8.8	4.2	8.2	1.5	1.0	41.3	15.2	23.1	1.0	8.8	3.4	16.2	0.2	1.5	3.7	1.0	0.5	0.2	-	0.5	1.0	1.0	-	1.5	3.9	-	1.7	0.5
III	8	14.0	0.92	+	33.4	0.1	66.5	32.2	26.3	37.0	1.7	-	2.8	0.4	1.8	0.2	-	-	0.9	0.2	0.5	-	0.2	31.7	5.9	24.1	1.1	14.1	3.1	18.9	-	2.2	1.3	0,2	-	-	0.2	-	0.2	0.9	-	-	10.4	-	12.9	0.2
I	10	18.0	0.82	20	39.9	0.1	60.0	45.2	33.2	19.2	2.4	-	0.7	0.7	-	-	-	-	0.7	0.2	-	-	0.5	19.1	6.1	12.8	0.2	24.5	3.6	20.0	-	2.3	0.9	0.7	0.2	-	-	0.2	1.8	0.9	-	-	11.6	0.2	12.3	0.2
EQUISHEIM - 9																																														
VII	9	2.0	1.34	20	44.2	-	55.8	24.8	17.6	40.4	17.2	-	11.2	2.7	1.1	3.7	0.3	1.1	1.6	-	-	0.2	1.4	12.8	2.3	9.9	0.6	9.6	2.7	12.2	-	3.0	1.3	1.1	0.3	-	0.2	0.3	1.0	1.0	-	1.3	11.0	2.6	26.8	-
VI	15	4.0	1.33	5	60.1	-	39.9	16.1	12.3	60.8	10.8	-	37.7	2.2	1.9	20.9	-	2.7	3.6	-	-	0.2	3.4	4.9	2.0	1.7	1.0	5.4	6.8	17.3	-	4.1	4.6	2.7	0.5	-	-	-	-	0.2	-	-	7.8	2.6	2.4	-
VI	20	5.0	1.34	10	62.4	-	37.6	20.4	9.9	49.8	19.9	-	31.0	3.9	5.3	18.2	-	1.2	2.0	-	-	-	2.0	5.5	0.6	4.9	-	3.5	6.9	13.7	-	4.5	3.5	1.0	0.6	-	-	-	-	-	-	0.6	19.2	0.2	7.8	-
IV	28	6.0	0.75	5	72.5	-	27.5	24.2	13.4	31.9	30.5	-	21.2	4.2	0.8	11.0	-	0.5	4.7	-	-	-	4.7	7.9	2.9	5.0	-	10.5	11.3	21.7	-	6.5	4.2	1.0	0.3	-	-	-	-	-	-	0.2	3.7	-	6.8	-
IV	34	7.6	1.48	10	73.3	-	26.7	12.6	13.6	44.4	29.4	-	33.0	4.1	0.9	19.7	-	2.5	3.0	-	-	-	3.0	7.6	1.4	5.5	0.2	8.3	9.0	15.1	0.2	4.1	3.7	2.5	0.2	0.2	-	-	0.5	-	-	-	8.5	-	4.1	-
ALLSCHWIL - 11																																														
VII	3	1.0	1.70	5	32.4	0.1	67.5	28.5	22.0	46.6	2.9	-	6.9	3.3	1.7	0.2	-	0.7	1.2	-	0.3	0.3	0.6	35.3	10.4	24.4	0.5	12.1	2.6	7.6	-	1.7	1.9	0.2	0.2	-	-	0.3	1.0	0.3	-	0.3	15.6	1.2	10.8	0.5
VII	4	1.5	1.75	10	28.3	0.4	71.3	33.0	25.0	39.5	2.5	-	5.9	2.3	2.6	0.4	-	0.4	0.8	-	0.2	0.4	0.2	23.4	6.0	17.2	0.2	18.8	2.2	7.3	-	2.0	1.2	-	-	-	0.2	-	0.4	0.4	-	-	11.9	2.2	23.3	-
VI	5	2.2	1 25	5	42.3	-	57.7	28.9	23.4	43.9	3.8	-	11.7	2.6	6.1	2.1	-	0.2	0.2	-	-	0.2	-	35.0	9.7	24.0	1.3	8.4	2.6	10.2	-	2.6	3.6	-	-	-	0.2	-	0.8	2.6	-	-	6.6	-	14.8	0.2
VI	6	4.0	0.87	10	23.6	-	76.4	34.3	53.7	10.5	1.5	-	7.2	2.6	1.6	1.7	0.2	0.2	0.7	-	-	-	0.7	30.5	6.7	22.9	0.9	18.9	4.4	11.8	-	1.6	2.5	-	0.5	-	-	-	0.5	0.9	-	0.5	2.5	1.1	16.4	0.5
V	8	5.0	0.65	10	48.3	-	51.7	36.5	19.4	31.9	12.2	-	2.4	-	1.8	-	0.3	0.3	0.5	-	-	-	0.5	43.6	9.0	32.5	1.6	4.0	2.7	22.6	-	3.4	2.9	0.3	0.3	-	0.8	0.5	2.1	0.8	-	-	3.5	-	9.3	-
SAINT ROMAIN - 13																																														
VII	6	2.2	0.53	15	57.3	-	42.7	11.6	41.4	47.0			18.0	3.6	7.2	1.1	1.6	2.1	3.5	-	1.1	1.1	1.3	15.9	1.2	11.2	1.9	11.3	9.7	10.2	2.7	8.6	8.6	0.3	1.4	1.9	-	0.3	2.7	0.8	-	-	-	0.2	3.8	-
IV	16	4.9	0.68	20	65.8	2.1	32.1	13.6	41.9	44.2			8.1	0.3	3.2	1.3	-	1.3	1.0	-	0.3	0.7	-	15.8	1.8	10.8	2.2	6.1	23.2	21.3	1.3	9.7	5.8	-	0.6	1.3	-	0.6	2.3	0.3	-	-	-	0.2	2.4	-
II	26	9.7	0.37	2	58.9	-	41.1	24.9	39.4	35.7			3.3	-	2.4	-	0 3	-	1.2	-	-	1.2	-	4.4	0.4	2.3	1.8	1.2	23.5	23.5	1.8	19.7	5.6	-	0.6	8.7	0.9	-	3.3	1.2	-	-	-	-	0.9	-
St. PAUL-lez-DURANCE - 14																																														
VII	2	1.0	1.36	10	57.9	0.1	42.0	12.5	14.3	69.0	3.6	0.6	9.1	2.1	3.7	0.9	-	0.2	0.7	-	-	0.3	0.4	22.6	2.3	19.5	0.7	8.9	7.0	6.3	0.2	1.6	2.8	0.2	0.3	0.9	0.5	0.2	0.7	0.5	1.9	-	6.5	2.8	25.2	0.7
V	9	5.0	2.81	15	47.2	0.1	52.7	18.4	10.3	66.1	4.9	0.3	7.2	3.6	1.3	0.6	-	0.1	1.6	0.1	-	0.6	0.9	10.4	4.3	5.2	0.6	5.2	2.7	4.2	-	0.5	4.4	0.6	0.2	0.2	0.2	-	0.7	0.6	0.1	0.3	35.2	3.5	21.9	0.3
IV	16	6.7	1.68	10	38.0	-	62.0	16.4	18.8	61.9	2.9	-	4.3	0.9	1.1	0.4	0.3	0.2	1.2	-	0.1	0.5	0.6	8.0	2.4	4.6	0.8	1.4	1.6	4.5	-	0.9	1.3	0.2	-	0.1	0.1	0.3	0.4	0.6	0.4	0.1	25.2	1.5	47.4	0.5
COUDOUX - 15																																														
	1	6.0	2.72	5	42.2	-	57.8	24.3	24.3	42.9	8.5	-	1.7	-	0.5	-	-	0.5	1.0	0.2	-	-	0.7	26.6	6.7	18.7	1.0	20.4	6.0	15.3	0.5	3.6	3.4	0.5	-	0.5	1.2	0.2	1.0	4.3	0.7	-	2.4	0.2	9.1	1.4

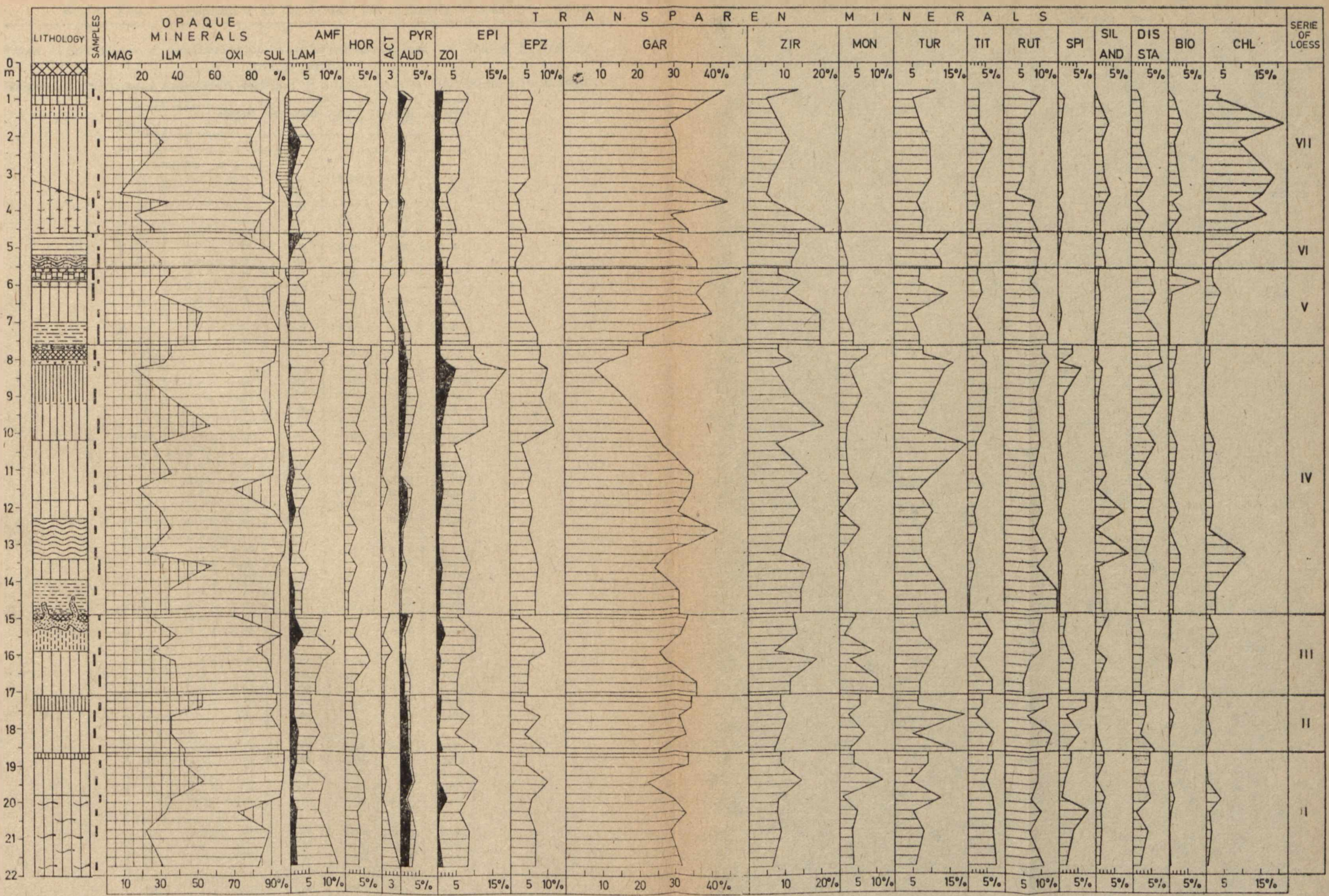

Fig. 6. Content of selected heavy minerals in loess of Ratyczów I, profile the Lublin Upland (according to Buraczyński et al., 1978). For explanation see Table 1
Zawartość minerałów ciężkich w profilu Ratyczów, Wyżyna Lubelska (według Buraczyńskiego et al., 1978)

Table 3. Coefficient of weathering of heavy minerals in loess of Alsace, Normandy and Provence

Wskaźniki zwietrzenia minerałów ciężkich w lessach Alzacji, Normandii i Prowansji

Series of loess	Depth m	ZIR+TUR / HOR	Fe_2O_3+ILM / MAG	n.w.HOR / w. HOR	n.w.EPI / w. EPI	n.w.CHL / w. CHL
1	2	3	4	5	6	7
Achenheim 2						
VII	2.0	2.16	2.98	0.09	0.39	0.11
VI	3.0	2.43	4.08	0.10	0.36	0.08
VI	4.0	2.55	2.86	0.12	0.51	0.16
VI	5.0	2.37	2.40	0.05	0.67	0.08
VI	6.0	2.24	3.04	0.09	0.37	0.06
V	8.0	3.28	1.56	0.27	0.52	0.10
V	9.0	2.95	3.18	0.07	0.27	0.17
IV	9.6	2.20	3.37	0.09	0.40	0.25
IV	10.0	3.03	1.83	0.21	0.31	0.16
IV	12.0	3.01	2.07	0.41	0.39	0.20
IV	14.7	10.87	1.92	0.23	0.20	0.11
III	15.6	2.58	1.86	0.09	0.21	0.07
III	16.2	7.04	1.28	0.06	0.24	0.03
III	17.0	11.70	1.29	0.06	0.35	0.00
III	18.0	5.75	2.19	0.23	0.31	0.00
III	20.0	13.54	1.50	0.20	0.09	0.00
II	22.0	10.03	1.12	0.65	0.27	0.00
II	24.0	14.04	1.72	0.16	0.26	0.00
I	26.5	7.84	1.60	0.03	0.32	0.04
sand	27.0	0.27	1.74	0.02	0.04	0.07
Bischoffsheim 6						
VI	2.5	1.97	8.69	4.13	0.50	0.00
VI	3.0	1.07	9.35	8.44	0.82	0.00
V	4.0	1.49	10.53	21.33	0.92	0.08
IV	5.6	1.40	15.38	12.33	0.89	0.00
IV	6.6	1.81	9.57	2.02	0.27	0.00
Bötzingen 8						
VII	3.0	0.79	1.72	3.47	0.87	0.15
VI	7.0	0.85	2.10	3.19	0.61	0.83
V	11.0	0.84	1.04	3.39	0.36	0.00
V	12.4	2.24	2.02	8.50	0.48	0.03
IV	13.3	7.26	0.68	2.86	0.66	0.00
III	14.0	10.00	1.97	0.22	0.24	0.00
I	18.0	33.71	1.16	0.00	0.48	0.02
Egisheim 9						
VII	2.0	3.92	2.34	2.45	0.23	0.10
VI	4.0	5.88	4.54	1.16	1.18	1.08
VI	5.0	2.24	2.93	0.74	0.12	0.03
IV	6.0	6.60	1.87	5.25	0.58	0.00
IV	7.6	4.82	4.60	4.55	0.25	0.00
Allschwil 11						
VII	1.0	2.04	2.41	1.94	0.43	0.11
VII	1.5	1.94	1.95	0.88	0.35	0.09
VI	2.2	1.47	2.33	0.43	0.40	0.00
VI	4.0	3.06	1.87	1.62	0.29	0.07
V	5.0	14.06	1.40	0.00	0.28	0.00
St. Romain 13						
VII	2.2	1.84	7.62	0.50	0.11	0.05
IV	4.9	12.71	6.33	0.09	0.17	0.08
II	9.7	19.58	3.02	0.00	0.17	0.00
St. Paul-les-Durance 14						
VII	1.0	2.29	6.66	0.57	0.12	0.11
V	5.0	1.41	4.15	2.77	0.83	0.16
II	6.7	3.05	4.92	0.82	0.52	0.03
sand		42.60	2.76	0.00	0.36	0.02

7—10, while in series I, characterized by a strong weathering of hornblende, it reaches even 34.0 (Table 3).

The degree of weathering of loesses can be defined by examining the content of weathered materials. Such investigations were carried out for hornblende, actinolite, augite, epidote and chlorite (Tables 1, 2). In all the series of the examined loesses a strong weathering of the little resistant minerals (amphiboles, biotite, chlorite and pyroxene) was found. Unweathered minerals constitute only 5—10%, exceptionally 30%. Biotites are almost altogether weathered in the whole profile (Tables 1, 2). Chlorites and hornblende, on the other hand, show a considerable content of some unweathered minerals. In the younger loess of the Achenheim profile No. 2 (series VI—VII) the coefficient of weathering of chlorite hornblende amounts to 0.1, while in series IV—V it increases to 0.2, for hornblende up to 0.4 (Table 3). In the older loess (series I—III) chlorites are almost altogether weathered. The content of unweathered hornblende shows large fluctuations. In the brown lessivé soil in horizons A_1 and B_t hornblende is strongly weathered, with the coefficient 0.06—0.09, while in loess the coefficient increases to 0.2 (series III). The decalcified loamy loess of series II contains much fresh hornblende, with the coefficient 0.65. The eolic carbonate loess of series I shows a strong weathering of chlorite and hornblende, with the coefficient 0.03. The subloessial sands of the Rhine contain strongly weathered chlorites (0.07) and hornblende (0.02). Vosgesian river sands have a lot of unweathered hornblende (0.25).

Much more unweathered hornblende occurs in the loess of piedmont hills where in the Bischoffsheim and Bötzingen profiles it considerably prevails and makes over 90%. The coefficient of weathering of hornblende is the highest here, over 3.0; in the Equisheim and Allschwil profiles it is somewhat less — 1.0—2.0 (Table 3).

In the loess of Alsace epidotes have a considerably higher percentage of unweathered minerals. In the younger loess of the Achenheim profile No. 2 (series VI—VII) epidotes are little weathered (0.4). There are even more unweathered epidotes in the solifluction loess, where the coefficient amounts to 0.5. Brown soil (series V) contains a lot of unweathered epidotes, in the upper part of the brown horizon the coefficient amounts to 0.52, and in the lower one — 0.27. More weathered epidotes occur in the brown lessivé soil (series III); in A_1 and A_3 horizons the coefficient amounts to 0.2, and in the B_{t2} horizon it increases to 0.3—0.35. For the older loess (series I—II) the index amounts to 0.3. The subloessial sands of the Rhine have strongly weathered epidotes (0.04), the Vosgesian sands show a smaller degree of weathering of epidotes (0.15). A smaller coefficient of weathering have epidotes in the loess on piedmont hills. For the younger loess in the Bischoffsheim and Bötzingen profiles it amounts to 0.6—0.9, and for the older loess to about 0.3.

The loess of the Middle Rhine Lowland shows irregular weathering of minerals. The spatial differentiation of the weathering degree indicates a large supply of unweathered material originating from the mountains that surround the Rhinegraben. In the Bischoffsheim profile a large supply of unweathered material from the slopes of the Vosges is marked. This supply is of a very short local transport. Hence, in this loess there occur unweathered minerals of hornblende and epidotes, with a small addition of weathered minerals. However, the loess in the axial part of the Rhine valley, contains a lot of heavily weathered minerals. The differentiation of the weathering degree indicates different feeding areas. This opinion is supported by the investigations of mineral weathering in the loess of other areas of France. The loess of Provence contains mainly unweathered minerals, which is connected with a short transport of material from nearby areas. A similar fact was found by Alimen et al. (1965). However, the loess of Normandy has strongly weathered minerals. According to Lautridou (1968) they come from the estuary of the Seine, composed of the sediments of different ages, that occur in the Paris Basin (Table 3).

COMPARISON OF HEAVY MINERAL COMPOSITION OF THE LOESSES OF FRANCE WITH THOSE OF OTHER AREAS

In loesses of different areas a quantitative and qualitative differentiations of heavy minerals are observed. The content of heavy minerals in fraction of 0.1—0.05 mm in the loess of Alsace is rather large and in the younger loess amounts to 1.5% of the weight and in the older one — 1.0%. In this respect the loess of Alsace is similar to the proluvial loess of Central Asia, where the younger loess contains 2.0% of heavy minerals, and the older one only 0.5% (Mavljanov, 1958). The younger loess of Brittany contains less heavy minerals than the older one. In the upper younger loess there is 0.1% of them, in the lower one about 2.0% however, in the older loess their content increases to 3—6% (Monnier, 1974). The loess of Provence contains 1—3% of heavy minerals. In the Polish loesses small amounts of heavy minerals are observed, usually below 0.5% (Maruszczak, Racinowski, 1968; Racinowski, 1976). In the Lublin Upland in the younger loess of the Ratyczów profile, 0.3% of heavy minerals were found, and in the older loess slightly more 0.35% (Buraczyński et al., 1978).

Transparent and opaque minerals occur in loesses of different areas in different proportion. A characteristic feature of the loesses of Alsace is twice as large a part of opaque minerals in comparison to that of the transparent ones. In the southern part of the Rhine Valley transparent minerals slightly prevail. The loess of Normandy and the younger loess of Central Asia show some similarity to the loesses of Alsace as far as the prevalence of the opaque minerals is concerned. The loesses of Provence have a little more transparent minerals. In the Polish loess transparent minerals prevail over opaque ones twice or even three times, as shown by Buraczyński et al. (1978).

Transparent minerals are characterized by a large variability and by different sets of minerals depending upon the area. In younger and older loesses they show a different content in the vertical profile (Fig. 4, 6). In the loesses of Alsace among the transparent minerals prevail amphiboles (20 and 10%), * epidotes and zircon (10 and 20%), garnet (about 10%), tourmaline (5—10%). Biotite (10—30 and 2%) and chlorite (15 and 3%) occur in variable amounts. In the loesses of Normandy the composition of minerals is as follows — zircon (20 and 30%), epidotes (20 and 10%), amphiboles (15 and 5%), tourmaline and rutile (5 and 15%), garnet (8 and 3%), and in the loesses of Provence — garnet (20 and 15%), epidote (15 and 10%), amphiboles and tourmaline (10 and 5%), rutile (about 10%), zircon (7 and 20%), biotite (20 and 2%) and chlorite (over 25%) in variable amounts (Lautridou, 1968; Alimen et al., 1965).

In the Polish loess the minerals that appear in the highest quantities are garnet and resistant minerals. On the example of the Ratyczów profile (Fig. 6) the content of minerals (which is altogether comparable with the profiles of the Rhinegraben on the account of the identical method of investigations — (Buraczyński et al. 1978) is as follows — garnet (35 and 25%), zircon (12 and 10%), tourmaline and rutile (about 9%), epidotes and amphiboles (4 and 8%).

The mineralogical composition of the loesses of Central Asia is represented by profile from Tashkent (Mawljanow, 1958). In this profile medium resistant minerals — amphiboles (37 and 46%), epidotes (25 and 20%), as well as zircon (20%), biotite (6%), garnet (3%), tourmaline and rutile (2 and 0.5%) decidedly prevail.

The qualitative content of heavy minerals in the loess of different areas appears as follows:
The loess of Alsace
younger — AMF>EPI—ZIR—TUR—GAR and CHL—BIO variably
older — EPI=ZIR>GAR and TUR—RUT—AMF variably
The loess of Normandy
younger — EPI—ZIR>AMF≥GAR—RUT—TUR
older — ZIR≥TUR—RUT>EPI—DIS=AMF

* The first number denotes an average quantity of the mineral in the younger loess, and the second — in the older loess.

The loess of Provence
younger — GAR−EPI>TUR−AMF−ZIR−RUT
older — ZIR−GAR>RUT=EPI>TUR>AMF
The Polish loess (Ratyczów)
younger — GAR≥ZIR−TUR=RUT−CHL>AMF=EPI
older — GAR≥ZIR−TUR=RUT−EPI−AMF>TIT
The loess of Central Asia (Tashkent)
younger — AMF≥EPI>ZIR≥BIO>GAR
older — AMF≥ZIR−EPI≥BIO>GAR

A large variability of the sets of minerals can be seen above. In the loesses of Alsace and Central Asia amphiboles and epidotes as medium resistant minerals prevail. Zircon occurs in the second or third place, and garnet only in the fifth. In the loesses of Alsace chlorite and biotite occur in variable amounts, occupying very different places. Also in Brittany in the Port-Morvan profile (Monnier, 1974), amphiboles (60 and 45%) and epidotes (20 and 40%) prevail on the understanding that there is twice or three times as many of them as in the loesses of Alsace. In the loesses of Normandy a greater role is played by resistant minerals — zircon, tourmaline and rutile. Epidotes and amphiboles play a great role in younger loesses, where they occur in amounts similar to those of resistant minerals. In the loesses of Provence, however, garnet comes first. The Polish loesses show a different qualitative composition. In the first place occurs garnet, then resistant minerals — zircon, tourmaline and rutile.

The coefficient of weathering $\frac{\text{ZIR+TUR}}{\text{HOR}}$ is different and does not change in the vertical of loess profile. The younger loess of Alsace has the coefficient 2—3, and the older one 8—14. The younger loess of Normandy has a similar coefficient 1—2. However in the older loess it amounts to much more — 15 and even 33. In the formations of the base, in the strongly weathered loams the coefficient reaches the value of 72 (counted by the data of Lautridou, 1968). The loesses of Brittany and Provence have a low coefficient, which suggests a small weathering.

The coefficient appears quite different in the Polish loesses, which decidedly distinguishes them from the French ones. Its value is relatively high and shows great fluctuations. In the younger loess the coefficient is high — 5—15. In the brown lessivé soil it amounts to 2—8, and in the loess under the soil — 6—16, up to 32, similarly as in the Achenheim profile No. 2. However, in the older aeolian loess the coefficient is smaller than that in the younger loess and amounts to 4—6.

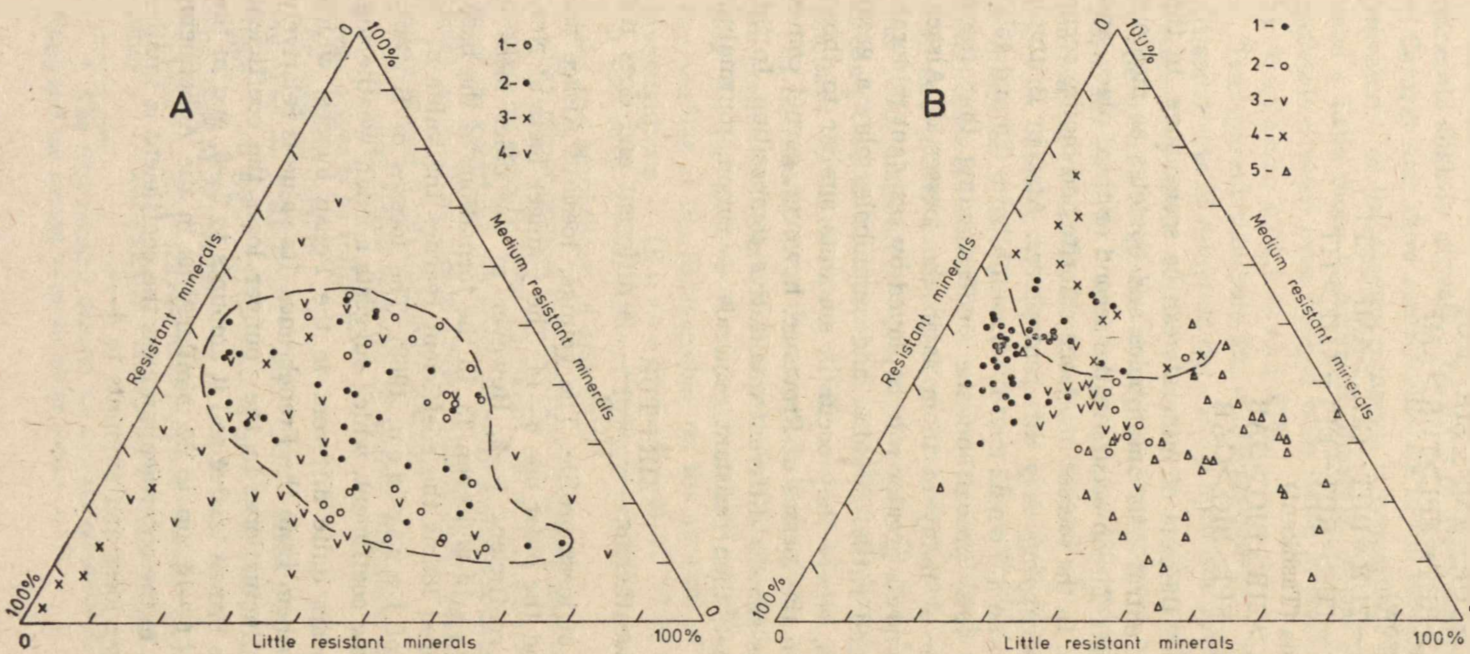

Fig. 7. Comparison of the content of the minerals of various resistance to weathering in loess of different areas. A — loess of France: 1 — Achenheim, 2 — Alsace, 3 — Normandy, 4 — Provence; B — loess of Poland and Asia: 1 — Ratyczów, 2 — Nieledew, 3 — Kazimierz, 4 — Przemyśl, 5 — Tashkent (diagram B according to the data of Buraczyński et al. 1978, Racinowski 1976 and Mavljanov 1958)

Porównanie zawartości minerałów o różnej odporności na wietrzenie w lessach różnych obszarów; A — lessy Francji: 1 — Achenheim, 2 — Alzacja, 3 — Normandia, 4 — Prowansja: B — lessy Polski i Azji: 1 — Ratyczów, 2 — Nieledew, 3 — Kazimierz, 4 — Przemyśl, 5 — Taszkent (wykres B według danych Buraczyńskiego et al. 1978, Racinowskiego 1976, Mawljanowa 1958)

CONCLUSIONS

On the basis of the investigations carried out a certain connection between the heavy mineral composition in loess and its facial character was shown. In the aeolian loess of the Middle Rhine Lowland a slight prevalence of amphiboles and chlorite or biotite is observed. In some profiles (Bischoffsheim, Bötzingen), a high content of chlorite and biotite in the younger loess is also found in the solifluction loess. This regularity is more distinct in the Polish loess (Racinowski, 1976; Buraczyński et al., 1978).

The mineral composition reflects, to a large extent, the weathering and soil processes. In horizon A_1 heavy minerals occur in smaller amounts. In fossil soils (horizons A_1, B) an increased amount of opaque minerals was found. Soil horizons are differentiated by a higher degree of weathering of transparent minerals which indicates an increased coefficient of weathering (Morawski, Trembaczowski, 1971; Maruszczak, Morawski, 1976).

The characterization of heavy minerals of the loess of the Rhinegraben indicates that their source material were different local rocks (magma, metamorphic and sedimentary), Rhine alluvial and deluvial covers. Hence, in loesses of different areas a considerable differentiation of the heavy mineral content is observed, depending on local conditions. Attention has been paid to the connection of mineral composition of loess with base rocks, and to the local character of the heavy mineral set (Tokarski, 1936, 1961; Duplaix, Malterre, 1946; Malicki, 1949, 1967; Alimen et al., 1965; Blum, Maus, 1967; Lautridou, 1968; Maruszczak, Racinowski, 1968; Buraczyński, 1971; Morawski, Trembaczowski, 1971; Malicki, Morawski, 1973; Racinowski, 1976). A differentiation of mineral composition in the younger and older loess of the same profile and in loesses of different areas are shown (Fig. 7). A change of the qualitative and quantitative composition of heavy minerals is connected with different feeding areas and by weathering processes.

REFERENCES

1. Alimen H., 1967: The Quaternary of France. In: The Quaternary. Ed. Rankams. Vol. 2.
2. Alimen H., Dubois N., Napoleone I., 1965: Petrographie des limons de Provence. Bull. AFEQ, 2, 2.
3. Andel T. H. van., 1959: Reflection on the Interpretation of Heavy Mineral Analyses. J. Sed. Petr. 29, 2.
4. Blum E. V., Maus H. I., 1967: Mineralogische Untersuchungen an Sediment-

gesteinen und Böden des Südlichen Oberrheingrabens und der Schwarzwaldvobergzone. Mineralbestand der Gesteine. Berichte Naturf. Ges. Freiburg i. Br., 57.

5. Bordes F., 1969: Le loess en France. Etude françaises sur le quaternaire. Bull. AFEQ, suppl. Paris.
6. Briggs L. I., 1965: Heavy Mineral Correlations and Provenances. J. Sed. Petr., 35, 4, Menasha.
7. Bronger A., 1966: Lösse, ihre Verbraunungszonen und fossilen Böden. Ein Beitrag zur Stratigraphie des oberen Pleistozäns in Südbaden. Schriften des Geographischen Instituts der Universität Kiel, XXIV, 2.
8. Buraczyński J., 1971: Lessy okolic Strasburga, Francja (Les loess des environs de Strasbourg). Ann. Univ. Mariae Curie-Skłodowska, sectio B, 26, Lublin.
9. Buraczyński J., 1978: Litologia i stratygrafia lessów Niziny Środkowego Renu. Uniwersytet Marii Curie-Skłodowskiej, Wydział Biologii i Nauk o Ziemi. Lublin.
10. Buraczyński J., Rzechowski J., Wojtanowicz J., 1978: Studium sedymentologiczne i stratygrafia lessów w Ratyczowie na Grzędzie Sokalskiej (On Sedimentation and Stratigraphy of Loesses of Ratyczów on the Grzęda Sokalska — Sokal Range). Biuletyn I. Geol., 300. Warszawa.
11. Cailleux A., 1954: Les loess et limons éoliens en France. Bull. S. C. Géol. Fr. t. 51, 240. Paris.
12. Chalczewa T. A., 1972: Razliczije minierałogiczeskogo sostawa lossowych gorizontow Russkoj Rawniny. Lossy, pogriebiennyje poczwy. Akad. Nauk SSSR, Inst. Gieogr. Moskwa.
13. Coutard J. P., Goresse P., Lautridou J. P., 1972: Les limons du Nord-Ouest du Bocage Normand (Manche). Bull. Soc. Linn. de Normandie. Vol. 103.
14. Coutard J. P., Helluin M., Lautridou J. P., Ozouf J. C., Pellerin J., 1973: Formation quaternaires de Normandie. Ann. Sc. de l'Univ. de Besançon. Géol. fasc. 21.
15. Dubois G., Dubois P., 1955: La géologie de l'Alsace. Mém. Serv. Carte géol. Als. Lorr. 13. Strasbourg.
16. Duplaix S., Malterre H., 1946: Les association de minéraux lourds dans les limons quaternaires du Bassin de Paris. Bull. Soc. Géol. Fr., 16.
17. Gouda G. H., 1962: Untersuchungen an Lössen der Nordschweiz. Geographica Helvetica, 17, 3. Bern.
18. Griffiths J. C., 1967: Scientific Method in Analysis of Sediments. Mc. Graw-Hill Book Comp. New York.
19. Jahn A., 1956: Wyżyna Lubelska. Rzeźba i czwartorzęd (Geomorphology and Quaternary History of Lublin Plateau). Prace Geogr. I. G. PAN, 7. Warszawa.
20. Khodary-Eissa O., 1968: Feinstratigraphische und pedologische Untersuchungen an Lössaufschlüssen im Kaiserstuhl (Südbaden). Freiburger Bodenkundliche Abhand. 2. Freiburg im Breisgau.
21. Lautridou J. P., 1968: Les loess de Saint Romain et de Mesnil-Esnard (Pays de Caux). Bull. No 2 Centre Géomorph. Caen.
22. Lautridou J. P., 1975: Les loess de Haute Normandie. Com. des loess INQUA. Excursion 15—19 Sept. 1975. Paris.
23. Malicki A., 1949: Geneza i rozmieszczenie lessów w środkowej i wschodniej Polsce (The Origin and Distribution of Loess in Central and Eastern Poland). Ann. Univ. Mariae Curie-Skłodowska, sectio B, 4, Lublin.
24. Malicki A., 1967: Lessy na obszarze Polski i ich związek z czwartorzędem. In: Czwartorzęd Polski. Warszawa.
25. Malicki A., Morawski J., 1973: Ciężkie minerały opoki oraz lessu w okolicy Lub-

lina (Heavy Minerals of Gaize and Loess in the Vicinity of Lublin). Ann. Univ. Mariae Curie-Skłodowska, sectio B, 28, Lublin.
26. Maruszczak H., Morawski J., 1976: Zróżnicowanie składu minerałów ciężkich w podstawowych jednostkach litologiczno-stratygraficznych lessów Polski (Differentiation of the Heavy Minerals Composition in the Principal Lithological--Stratigraphic Units of the Polish Loesses). Biuletyn I. Geol. 297. Warszawa.
27. Maruszczak H., Racinowski R., 1968: Peculiarites of the Conditions of Loess Accumulation in Central Europe in Light of Results of Heavy Mineral Analyses. Geogr. Polonica, 14. Warszawa.
28. Mawljanow G. A., 1958: Gienieticzeskije tipy liessow Sriedniej Azji i ich inżenierno-gieołogiczeskije swojstwa. A. N. Uzbiekskoj SSR. Taszkient.
29. Monnier J. L., 1974: Les dépôts pleistocènes de la région de Saint-Brieuc. Bull. Soc. Géol. minéral. Bretagne, s. C, VI, 1. Rennes.
30. Morawski J., Trembaczowski J., 1971: Charakterystyka mineralogiczna lessów profilu „Kwaskowa Góra" w Kazimierzu nad Wisłą (The Mineralogical Characteristic of "Kwaskowa Góra" Loess Profile in Kazimierz upon Vistula). Ann. Univ. Mariae Curie-Skłodowska, sectio B, 26. Lublin.
31. Racinowski R., 1969: Le profil du loess à Nieledew sur Plateau de Lublin à la lumière de l'analyse de minéraux. Biuletyn Perygl. 20. Łódź.
32. Racinowski R., 1976: Uwagi o składzie minerałów ciężkich lessów lubelskich i przemyskich (Remarks on the Heavy Minerals Composition of the Lublin and Przemyśl Loesses). Biuletyn I. Geol., 297. Warszawa.
33. Riabczenkow A. S., 1960: O proischożdienii lossa i lossowidnych porod Russkoj rawniny w swietie minieralogiczeskich dannych (On the Origin of the Loess and Loess-like Rocks of the Russian Plain from the View-point of Mineralogical Data). Biul. MOIP, otd. geol., 35, 2. Moskwa.
34. Rohdenburg H., Meyer B., 1966: Zur Feinstratigraphie und Paläopedologie des Jungplaistozäns nach Untersuchungen von der Lössprofilen. Mitteil. Deutsch. Bodenkundl. Ges. B. 5.
35. Swineford A., Frye J. C., 1955: Petrographic Comparison of Some Loesses Samples from Western Europe with Kansas Loess. J. Sed. Petr., 25, 1. Menasha.
36. Théobald N., 1948: Carte de la base des formations alluviales dans le Sud du fossé rhénan. Mém. Serv. Carte géol. Als. Lorr., 19. Strasbourg.
37. Tokarski J., 1936: Physiographie des podolischen Lösses und das Problem seiner Stratigraphie. Mém. Acad. Pol. Sc. sér. A, 4. Kraków.
38. Tokarski J., 1961: Materiały do znajomości lessów (Remarks on the Loess). Rocznik PTGeol., 31. Kraków.
39. Vogt H., Thévenin A., 1976: Les limons quaternaires et les dépôts de pente en Alsace. In: Le préhistoire française, t. I.
40. Wernert P., 1957: Stratigraphie, paléontologique et préhistorique des sédiments quaternaires d'Alsace. Achenheim. Mém. Serv. Carte géol. Als. Lorr., 14. Strasbourg.
41. Young E. J., 1966: A Critique of Methods for Comparing Heavy Mineral Suites. J. Sed. Petr., 36, 1. Menasha.

STRESZCZENIE

W pracy przedstawiono charakterystykę minerałów ciężkich w lessach Niziny Środkowego Renu, które badano w profilach lessowych położonych w różnej sytuacji morfologicznej, na terasie średniej i wysokiej, na wzgórzach wogeskich, wy-

żynie Alzacji i Sundgau. Poszczególne profile lessowe scharakteryzowano pod względem zawartości minerałów, składu ilościowego oraz stopnia zwietrzenia niektórych minerałów przeźroczystych. Badania mineralogiczne pozwoliły ustalić pochodzenie pyłu oraz były pomocne przy podziale stratygraficznym lessu.

Zawartość wagowa minerałów ciężkich w lessach we frakcji 0,1—0,05 mm jest wysoka i wynosi przeciętnie 0,8—1,5%. Less młodszy jest bogatszy w minerały ciężkie (1,5%) w porównaniu z lessem starszym (0,7—1,1%). Charakterystyczną cechą lessów Alzacji jest dwu-, trzykrotna przewaga minerałów nieprzeźroczystych nad przeźroczystymi. Zawartość minerałów przeźroczystych w lessach wykazuje dużą zmienność w różnych profilach, charakterystyczną dla poszczególnych poziomów lessowych. Lessy Alzacji charakteryzują zespoły: w lessie młodszym: amfibole—epidoty-cyrkon—turmalin—granat, ze zmiennym udziałem chlorytu i biotytu; a w lessie starszym: epidot—cyrkon—granat oraz turmalin—rutyl—amfibole występujące w zmiennej kolejności.

Niezwietrzały less młodszy zawiera mniej minerałów nieprzeźroczystych oraz odpornych z grupy przeźroczystych, zaś w lessie starszym zwietrzałym przeważają te minerały. Wzrost minerałów nieprzeźroczystych oraz najbardziej odpornych wśród przeźroczystych jest jednym z przejawów zwietrzenia lessów. Pod wpływem wietrzenia zachodzą zmiany proporcji grup minerałów przeźroczystych związane z ich różną odpornością na niszczenie mechaniczne i chemiczne. Zawartość minerałów odpornych nie zmienia się, wykazuje tylko względny wzrost.

Celem uwypuklenia zmian składu minerałów odpornych i nieodpornych pod wpływem wietrzenia zastosowano wskaźnik $\frac{\text{cyrkon}+\text{turmalin}}{\text{hornblenda}}$ uwzględniający charakterystyczne minerały dla Niziny Środkowego Renu. Wskaźnik ten w lessie młodszym wynosi 2,0—3,0, a w lessie starszym 5,7—13,5. Natomiast w piaskach podlessowych jest on bardzo niski (0,3). Stopień zwietrzenia lessu określono także przez badanie stopnia zawartości zwietrzałych amfiboli, epidotów i chlorytów. Lessy Niziny Środkowego Renu wykazują zmienne zwietrzenie minerałów zarówno w profilach pionowych, jak i w rozmieszczeniu przestrzennym. Lessy położone w osiowej części doliny zawierają dużo minerałów silnie zwietrzałych, a położone na wzgórzach piemontowych mają ich niewiele. Przestrzenne zróżnicowanie stopnia zwietrzenia minerałów wskazuje na dużą dostawę materiału niezwietrzałego pochodzącego z gór otaczających rów Renu.

Stwierdzono duże zróżnicowanie jakościowe i ilościowe zespołów minerałów ciężkich w lessach różnych obszarów Francji, związane z budową geologiczną obszaru. Potwierdza to pogląd o związku składu mineralnego lessu ze skałami podłoża oraz o lokalnym charakterze zespołu minerałów ciężkich. Zmiany składu jakościowego i ilościowego minerałów ciężkich wskazują na różne obszary alimentacyjne, jak również spowodowane są procesami wietrzenia.

РЕЗЮМЕ

В работе представлена характеристика тяжелых минералов в лессах низины среднего Рейна, которые исследовались в лессовых профилях расположенных в разных морфологических обстановках, на средней и высокой террасах, на вогезских вершинах, возвышенности Эльзаса и Сундгау. Отдельные лессовые профили охарактеризованы по содержанию минералов, количественного состава

и степени выветривания некоторых прозрачных минералов. Минералогические исследования позволили определить происхождение пыли и помогли в стратиграфическом подразделении лессов.

Весовое содержание тяжелых минералов в лессах, во фракции 0,1—0,05 мм высокое и в среднем составляет 0,8—1,5%. Более молодый лесс богаче тяжелыми минералами (1,5%). Характерной чертой лессов Эльзаса является дву и трехкратное преобладание минералов непрозрачных над прозрачными. Содержание прозрачных минералов указывает на большую изменчивость в отдельных профилях, характерную для отдельных лессовых горизонтов. Лессы Эльзаса характерны составами: лессы более молодые — амфиболы — эпидоты — цирконий — турмалин — гранат, с изменяющимся содержанием хлорита в биотита; лессы более древние — эпидот — цирконий — гранат, а также турмалин — рутиль — амфиболы присутствующие в изменяющийся последовательности.

Невыветрившийся более молодой лесс содержит менее минералов непрозрачных, а также устойчивых из группы прозрачных, в место того в лессе более древним выветрившимся преобладают именно указанные минералы. Рост участья минералов непрозрачных и наиболее устойчивых из прозрачных является показателем степени выветривания лессов. Под влиянием выветривания происходят изменения пропорции групп минералов прозрачных связанные с их разной устойчивостью на механические и химические разрушения. Содержание устойчивых минералов не изменяется, но лишь ведет к относительному росту.

Для того чтобы подчеркнуть изменения состава минералов устойчивых и неустойчивых выветриванию, принято показатель $\frac{\text{цирконий} + \text{турмалин}}{\text{роговая обманка}}$ учитывающий характерные минералы для низины среднего Рейна. Этот показатель для более молодого лесса составляет 2,0—3,0, а для более древнего 5,7—13,5. Для песков подстиляющих лессы он составляет лишь 0,3. Кроме того степень выветривания лесса определялась исследованием степени содержания выветрившихся амфиболов, эпидота и хлорита. Лессы низины среднего Рейна показывают изменения в степени выветривания минералов как в вертикальном так и в горизонтальном направлениях. Лессы простиряющиеся в осевой части долины содержат много минералов сильно выветревшихся, в то время как лессы расположенные на пемондских возвышениях содержат их немного. Пространственная дифференциация степени выветривания минералов указывает на большой привнос невыветревшегося материала из гор окаймляющих ров Рейна.

Констатировано большую дифференцировку качественную и количественную тяжелых минералов в лессах разных районов Франции, связанную с геологическим строением данного района. Это подтверждает взгляд о связи минерального состава лесса с породами основания и о локальном характере состава тяжелых минералов. Изменения качественного и количественного состава тяжелых минералов указывают на разные алиментационные площади и на то, что они подвергались в разной степени процессам выветривания.

ОБЪЯСНЕНИЯ РИСУНКОВ И ТАБЛИЦ

Рис. 1. Расположение лессов во Франции (по Г. Алимен 1967, в рове Рейна с дополнительным материалом автора); 1 — площади с лессовым покровом, 2 — максимальная граница оледенения (Рисс), A — ров Рейна (профили 1—12), N — Нормандия (профиль 13), P — Прованс (профили 14—15), B — Парижский Бассейн (Северофранцузская низменность), профиль 16.

Рис. 2. Расположение лессов в рове Рейна.

Рис. 3. Литологическо-стратиграфические профили лессов низменности среднего Рейна (1—12), Нормандии (13), Парижского бассейна (16), Прованса (14).

Рис. 4. Содержание тяжелых минералов в профиле Ахенхайм 2.

Рис. 5. Показатели выветривания тяжелых минералов в лессах профиля Ахенхайм 2.

Рис. 6. Содержание тяжелых минералов в профиле Ратычув — Люблинская возвышенность (по Я. Бурачинскому и других 1978).

Рис. 7. Составление содержания минералов разной устойчивости против выветриванию в лессах разных районов; А — лессы Франции: 1 — Ахенхайм, 2 — Эльзас, 3 — Нормандия, 4 — Прованс; В — лессы Польши и Азии: 1 — Ратычув, 2 — Неледев, 3 — Казимеж, 4 — Пшемысль, 5 — Ташкент (график В по данным Я. Бурачински и др. 1978, Р. Рациновски 1976, Г. А. Мавлянова 1958).

Табл. 1. Тяжелые минералы в лессах профилей Ахенхайм.

Табл. 2. Тяжелые минералы в лессах Эльзас, Нормандии и Прованса.

Табл. 3. Показатели выветривания тяжелых минералов в лессах Эльзас, Нормандии и Прованса.