THIRD INTERNATIONAL WORKING-MEETING ON SOIL MICROMORPHOLOGY
WROCŁAW, 1969

ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1972 z. 123

# Micromorphological and mineralogical properties of some soil types developed from loess

T. CHODAK and S. KOWALIŃSKI

*Department of Soil Science, University of Agriculture, Wrocław, Poland*

## INTRODUCTION

The qualitative and quantitative composition of clay fraction minerals, as well as their distribution in soil profiles, is the result of the action of determined soil and soil-forming processes. They are decisive of many fundamental properties of the soil mass and condition several factors decisive of soil fertility [1, 3-6, 13, 14].

Therefore, the basic target of this work was to study the distribution and mineral composition of clay fractions contained in following soils: brown, lessivé and podzolic developed from loess of the Trzebnickie Hills.

Typologically different soils developed from loess formations appear as forest soils in similar topographic and climatic conditions. Their elevation is on an average 195 m above sea level, the sum of annual precipitation 550-650 mm, mean temperature of a year 7.7°C, mean temperature of January −1.7°C and mean temperature of July +17.4°C.

The tests were carried out with micromorphological, X-ray, termographic and electronic microscopy methods, completed with determination of some physico-chemical properties in the profiles of the examined soils [2, 4, 7, 9-12].

## RESULTS AND DISCUSSION

Investigation results are presented in Tables 1, 2 and in Figures 1-17.

An analysis of the granulometric composition revealed a differentiation in several soil profiles, particularly in the amount of colloidal clay. This was most pronounced in podzolic and lessivé soils (Table 1).

The reaction of all the tested soils in their upper horizons was acid and weakly acid. In the lower horizons of the brown soil profile the pH increased due to occurrence of $CaCO_3$.

The hydrolytic acidity was found to decrease deeper in the soil. The determined amount of mobile iron shows profile differentiation. The lowest amount of iron always appears in the upper horizons, and the highest one in the middle horizons (Table 1).



Fig. 1. Micromorphology of brown soil developed from loess. Horizon $A_1$, sampling depth 3-13 cm. Fragments of plant remains in initial humifying state. *A* — in plain light, *B* — under crossed polarizers.

Micromorphological tests were carried out with thin section prepared from oriented samples of intact structure according to the method given by Altemüller [1], Kubiëna [9] and Kowaliński and Bogda [8]. The participation and occurrence of primary minerals, some secondary minerals (further on called clay-ferruginous matter), as well as the arrangement and character of voids were determined micromorphologically.

*Table 1. Granulometric composition and physico-chemical properties of some soil developed from loess*

| Soil type, utilization, locality | Horizon | Sampling depth in cm | Colour | Particle size distribution in % 1-0.1 mm | 0.1-0.02 mm | 0.02-0.002 mm | < 0.002 mm | Mobile Fe % | pH $H_2O$ | pH KCl | $CaCO_3$ % | C org. % | $H_h$ | Exchangeable cations Ca | Mg | K | Na | S | T | V % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | meq./100 g | | | | | | | |
| | $A_0$ | 0-3 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Brown soil | $A_1$ | 3-18 | 7.5YR 4/0 | 2.9 | 47.1 | 30 | 20 | 1.1 | 5.7 | 4.5 | 0.0 | 1.17 | 5.4 | 5.6 | 2.0 | 0.5 | 0.5 | 8.6 | 14.0 | 61 |
| Deciduous forest | (B) | 18-60 | 7.5YR 5/4 | 1.7 | 53.3 | 23 | 22 | 1.3 | 5.9 | 4.5 | 0.0 | 0.29 | 3.1 | 5.8 | 2.8 | 0.2 | 0.5 | 9.3 | 12.5 | 74 |
| Trzebnica | (B)/C | 60-80 | 10YR 6/6 | 1.1 | 63.9 | 20 | 15 | 1.1 | 6.7 | 5.3 | 0.0 | 0.27 | 1.5 | 5.0 | 0.8 | 0.2 | 0.4 | 6.4 | 8.2 | 81 |
| | C | 80-150 | 10YR 7/8 | 7.6 | 56.4 | 24 | 12 | 0.9 | 8.6 | 7.9 | 8.9 | 0.15 | 0.8 | 18.2 | 1.3 | 0.0 | 0.7 | 20.2 | 21.1 | 96 |
| | $A_0$ | 0-3 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | $A_1$ | 3-16 | 7.5YR 4/0 | 3.2 | 53.8 | 29 | 14 | 0.8 | 5.2 | 4.2 | 0.0 | 1.70 | 0.8 | 0.6 | 0.0 | 0.2 | 0.3 | 1.1 | 9.8 | 11 |
| Lessivé soil | $A_3$ | 16-35 | 10YR 7/2 | 3.4 | 53.6 | 29 | 14 | 0.7 | 5.2 | 4.1 | 0.0 | 0.34 | 4.8 | 1.3 | 0.0 | 0.0 | 0.2 | 1.5 | 5.3 | 28 |
| Deciduous forest | $A_3/B_3$ | 35-50 | 10YR 5/2 | 1.6 | 52.4 | 34 | 12 | 1.0 | 5.6 | 4.4 | 0.0 | 0.29 | 3.9 | 3.4 | 0.9 | 0.0 | 0.3 | 4.6 | 7.5 | 61 |
| Trzebnica | $B_3$ | 50-75 | 10YR 5/3 | 0.7 | 47.3 | 31 | 21 | 1.7 | 5.6 | 4.3 | 0.0 | 0.17 | 4.1 | 5.8 | 1.1 | 0.1 | 0.3 | 7.4 | 11.5 | 64 |
| | $B_3/C$ | 75-95 | 10YR 6/4 | 1.2 | 53.8 | 26 | 19 | 1.4 | 5.7 | 4.5 | 0.0 | 0.16 | 3.4 | 4.0 | 1.2 | 0.5 | 0.7 | 6.4 | 9.8 | 66 |
| | C | 95-150 | 10YR 7/6 | 5.6 | 53.4 | 23 | 18 | 1.1 | 5.7 | 4.5 | 0.0 | 0.12 | 2.7 | 4.4 | 0.8 | 0.0 | 0.5 | 5.6 | 8.3 | 67 |
| | $A_0$ | 0-5 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | $A_1$ | 5-15 | 10YR 5/1 | 4.0 | 59.0 | 28 | 9 | 0.7 | 4.5 | 4.0 | 0.0 | 1.10 | 8.8 | 0.3 | 0.0 | 0.8 | 0.4 | 1.5 | 10.4 | 15 |
| Podzolic soil | $A_2$ | 15-30 | 10YR 6/1 | 3.8 | 56.6 | 27 | 13 | 0.9 | 4.9 | 4.1 | 0.0 | 0.39 | 5.5 | 0.8 | 0.0 | 0.2 | 0.3 | 1.3 | 6.8 | 19 |
| Mixed forest | $A_2/B$ | 30-50 | 10YR 6/3 | 1.9 | 49.1 | 29 | 20 | 1.5 | 5.3 | 4.3 | 0.0 | 0.16 | 5.0 | 4.4 | 1.1 | 0.3 | 0.5 | 6.3 | 13.3 | 47 |
| Wysoki Kościół | B | 50-90 | 10YR 5/3 | 1.7 | 50.3 | 28 | 22 | 1.6 | 5.2 | 4.4 | 0.0 | 0.12 | 4.7 | 5.6 | 1.7 | 0.9 | 0.7 | 8.9 | 13.6 | 65 |
| | B/C | 90-160 | 10YR 7/6 | 1.9 | 55.1 | 25 | 18 | 1.6 | 5.7 | 4.4 | 0.0 | 0.11 | 4.0 | 4.4 | 1.5 | 0.4 | 0.6 | 6.9 | 10.9 | 63 |
| | C | 160-190 | 10YR 8/8 | 7.1 | 66.9 | 14 | 12 | 0.9 | 5.8 | 4.6 | 0.0 | 0.10 | 2.6 | 3.0 | 1.1 | 0.3 | 0.3 | 4.8 | 7.4 | 64 |

Microscopic observations of soil sections show quartz grains to constitute the major part of the soil mass. They show little differentiation in size (from 25 to 100 μ) and are weakly rounded (Figs. 2, 5, 8). In several genetic horizons they are sprinkled with clay-ferruginous matter in different degrees (Figs. 3-8).

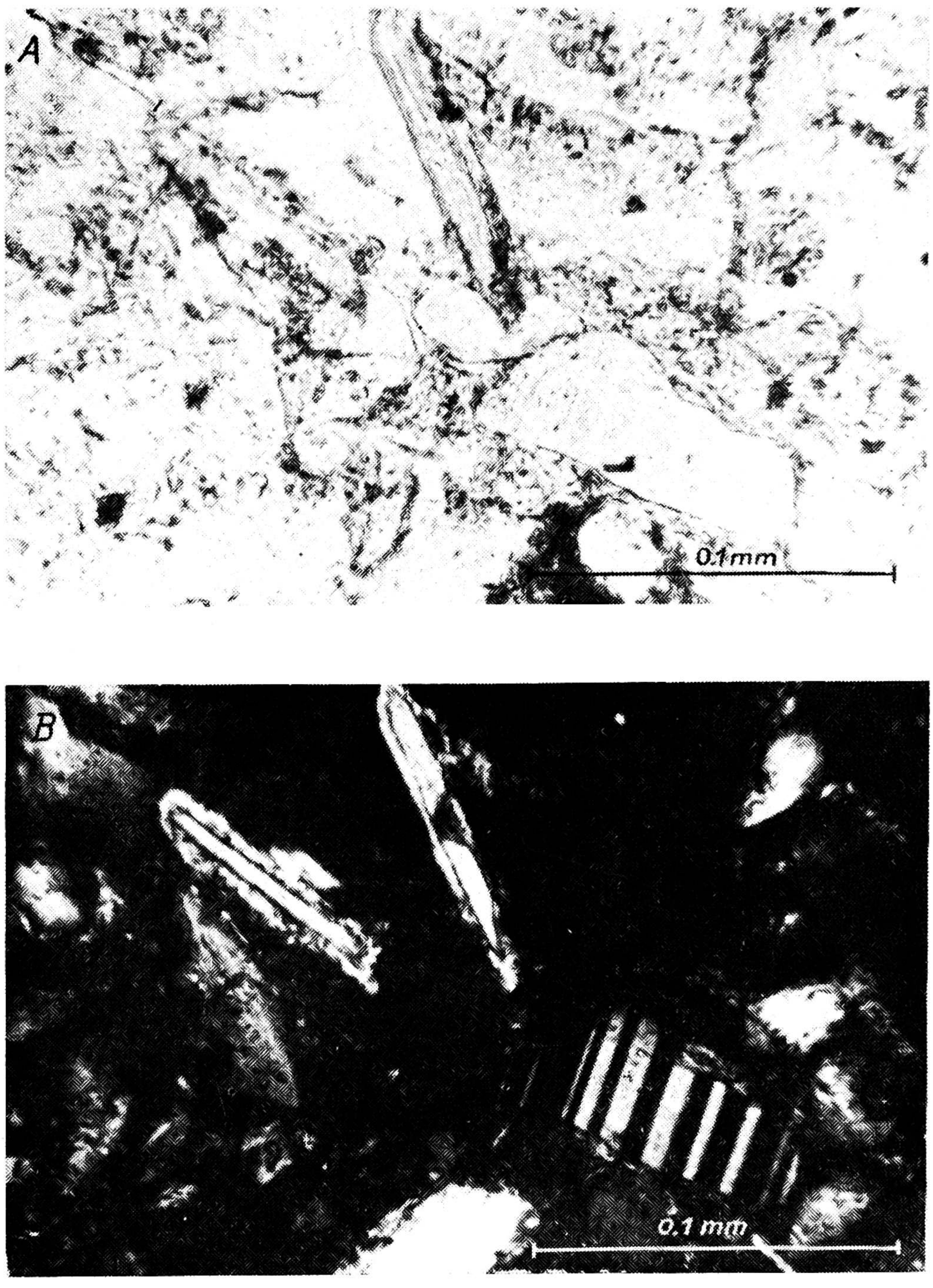



Fig. 2. Micromorphology of brown soil developed from loess. Horizon (B), sampling depth 18-28 cm. Skelsepic. The grains of primary minerals are coated with clay-ferruginous matter. *A* — in plain light, *B* — under crossed polarizers.

The occurring feldspars enter the composition of finer fractions and therefore they are difficult to be determined more closely. However, their amount in eluvial horizons is much lower than in the parent rock. This would point to their decomposition in the upper horizons. Exceptionally there appear green amphiboles with well marked pleochroism. In so little amounts there occurs zircon showing a positive relief and high interferential colours. One of the heavy minerals found in brown soil was garnet. Micromorphological examinations showed a very characteristic distribution of the clay-ferruginous matter in the genetic horizons of the analysed soil types. In humus and eluvial horizons its amount is small, but in illuvial horizons as well as in the browning one this matter occurs in large amounts, showing structures and micromorphological arrangements characteristic for these horizons (Figs. 2, 5, 6, 8).

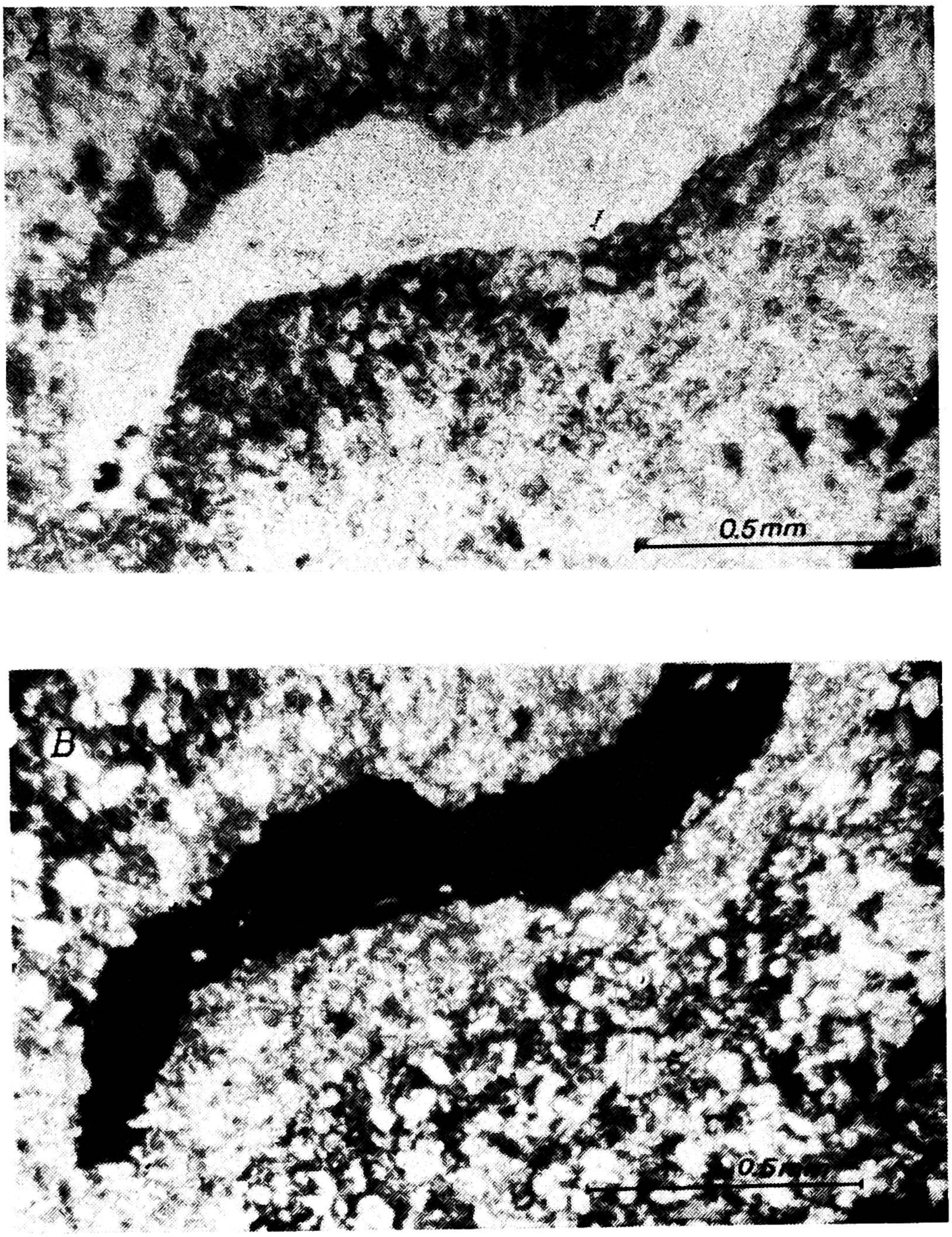



Fig. 3. Micromorphology of brown soil developed from loess. Horizon C. sampling depth 100-110 cm. Precipitations of the calcium carbonate. *A* — in plain light, *B* — under crossed polarizers.

Micromorphological examinations have also suggested a dislocation of the clay-ferruginous matter in the soil profile. First there gets dislocated the clay-ferruginous matter, and then the clay matter without any higher content of iron compounds.

The most intensive dislocation of clay-ferruginous matter occurs in lessivé and podzolic soils. Clay-ferruginous matter accumulated in horizons B and B/C mostly impregnates the internal walls of voids, the internal parts of coatings containing less iron compounds than the external ones (Fig. 5, 6, 8).

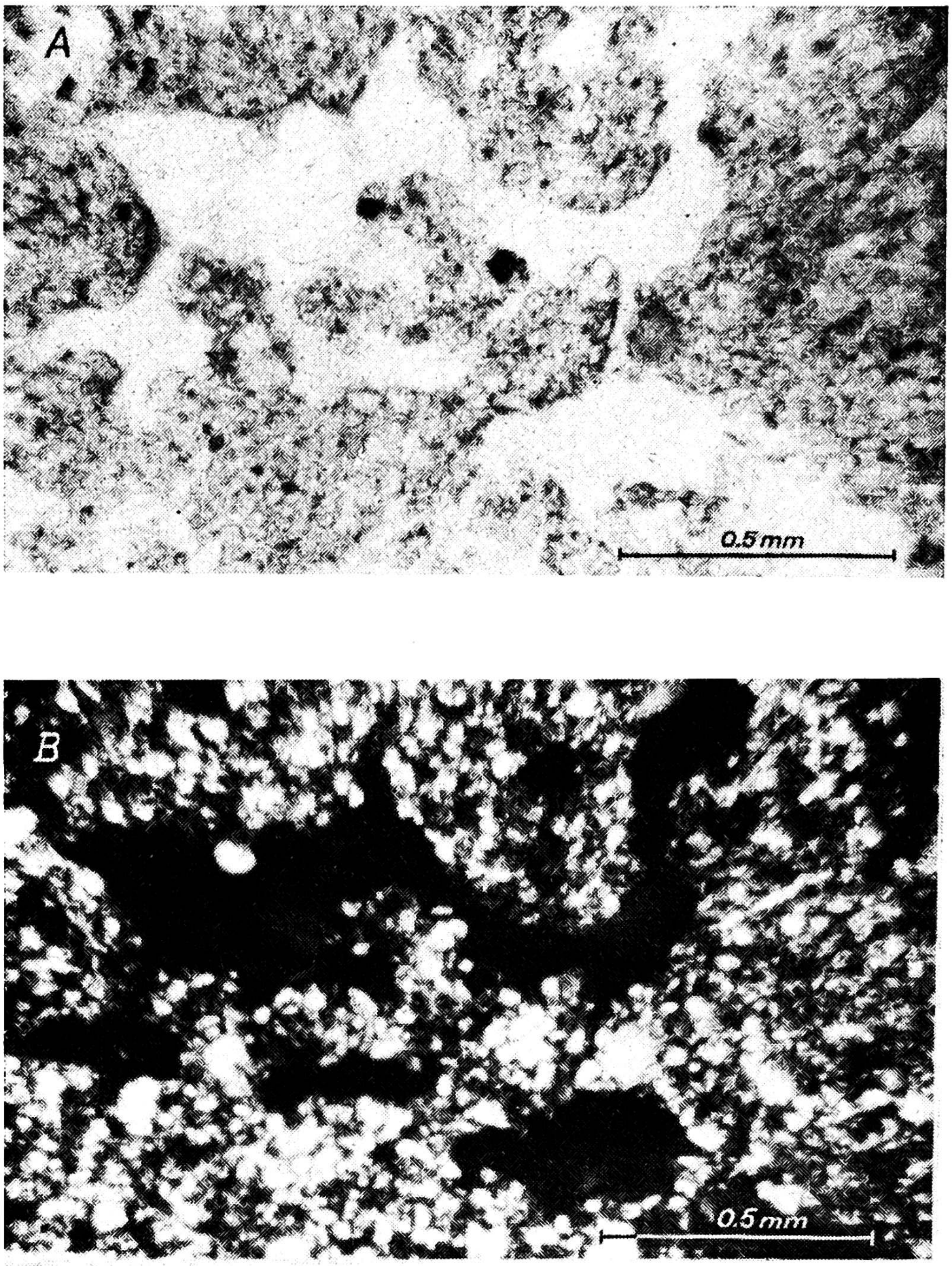



Fig. 4. Micromorphology of lessivé soil developed from loess. Horizon $A_3$, sampling depth 16-26 cm. Biogenic character of voids. *A* — in plain light, *B* — under crossed polarizers.

Micromorphological analysis of thin sections reveals a characteristic appearance of voids in different genetic horizons of the examined soils.

In humus horizons the voids have various shapes and are not coated with clay-ferruginous matter. In cases of aggregate structure of the soil mass they are bigger, but less numerous. A characteristic arrangement of voids is observed in eluvial horizons, where they are evenly spread almost all over the surface of the section. The voids in illuvial horizons have almost always the longer axis privileged. These voids, sometimes dead-ending, have bottoms and walls coated with the clay-ferruginous matter. There is marked a flow character of the observed fragments (Figs. 6, 8).

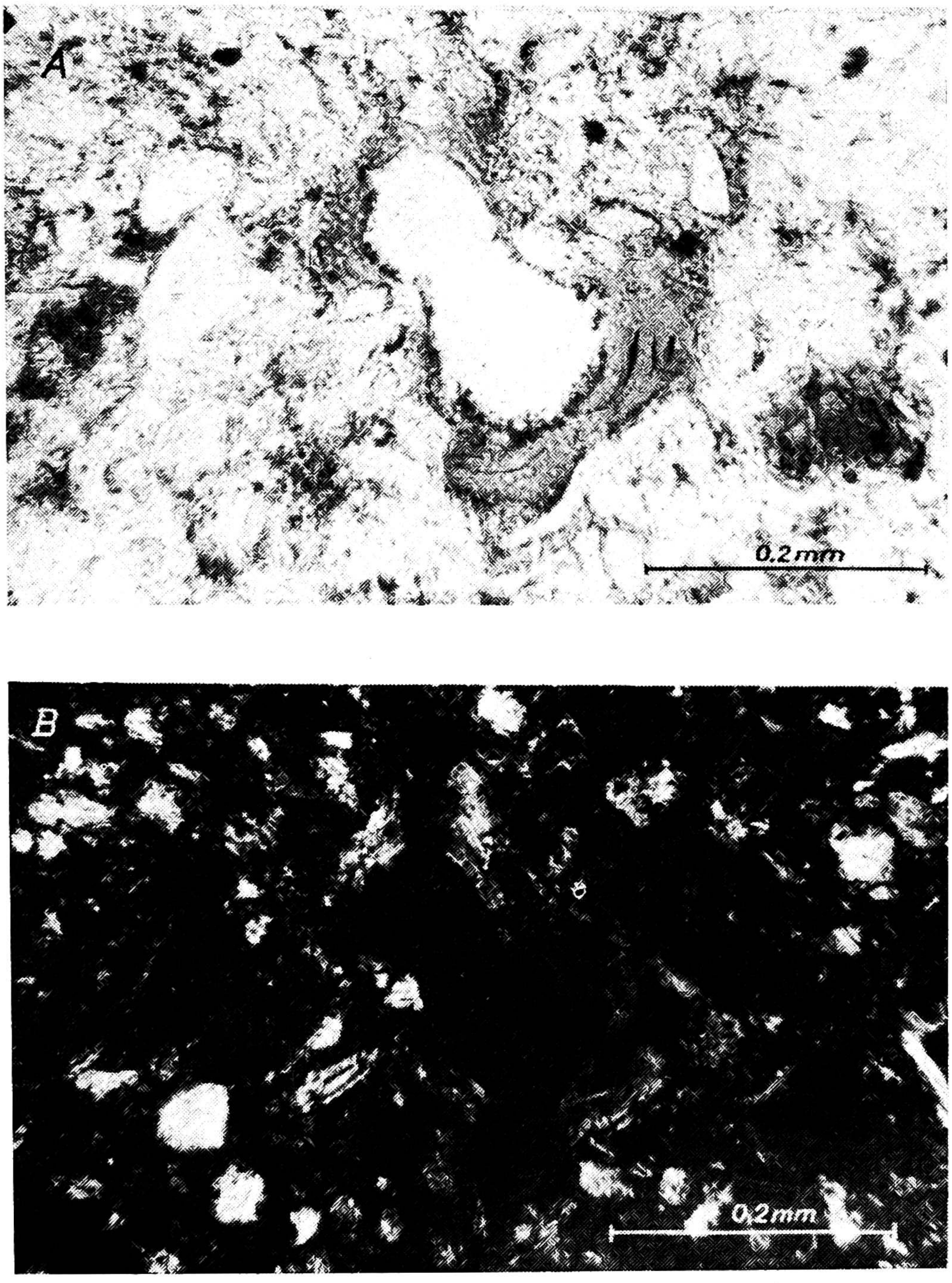



Fig. 5. Micromorphology of lessivé soil developed from loess. Horizon $B_3$, sampling depth 54-64 cm. Vosepic. Occurring clay-ferruginous matter coating voids. *A* — in plain light, *B* — under crossed polarizers.

This was not observed in the browning horizon, as the clay-ferruginous matter is there distributed evenly on the surface of the section. However, there are found tubules with coated walls, which are often stopped with this matter. In the examined soils the horizons transitional to the parent rock showed similar features. In particular, the clay-ferruginous matter coating the voids contained more iron compounds than in the upper horizons; in the thin section this is attested to by an increased intensity of yellow-brown colour. The parent material of the examined soils has voids distributed unevenly, often in form of tubules with walls differently

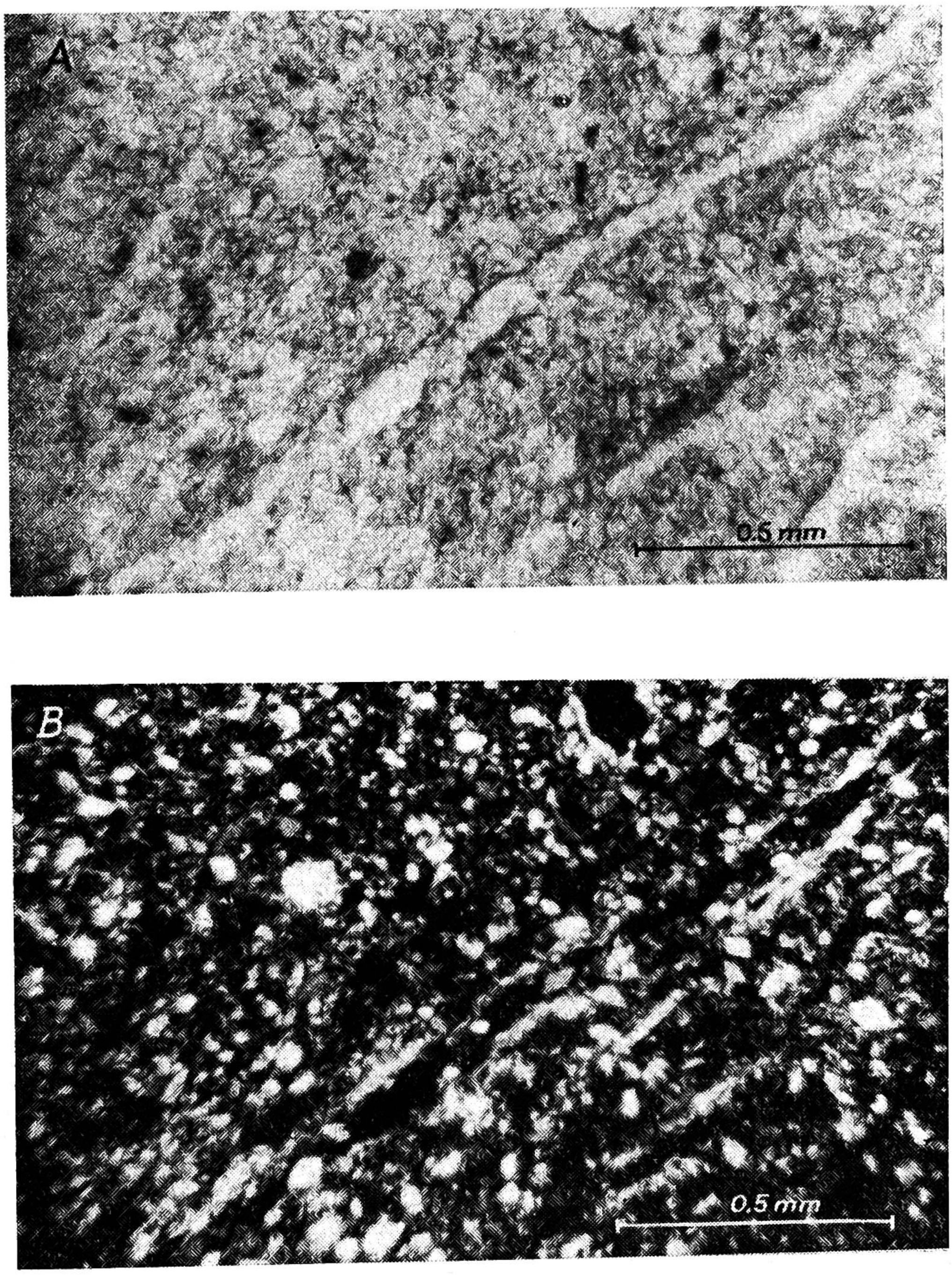



Fig. 6. Micromorphology of lessivé soil developed from loess. Horizon $B_3/C$, sampling depth 76-86 cm. Sila-vosepic. Some voids are coated with clay-ferruginous matter. *A* — in plain light, *B* — under crossed polarizers.

coated with the clay-ferruginous matter. Pores and tubules in the C horizon of brown soil are coated with $CaCO_3$ (Fig. 3).

The mineral composition of separated fractions 2-0.2 $\mu$ and $< 0.2\mu$ was examined roentgenographically with the powder method D.S.H., thermographically by means of a derivatograph and by means of an electronic microscope [2, 4, 8, 10-12].

The examinations have shown the fraction 2-0.2 μ to contain mostly quartz, beside small amounts of illite, kaolinite and montmorillonite. In the fraction < 0,2 μ quartz was missing, but there was found illite, kaolinite and montmorillonite. Deeper into the profile the content of kaolinite decreases, while that of montmorillonite increases, the amounts of illite being similar in several horizons (Table 2).

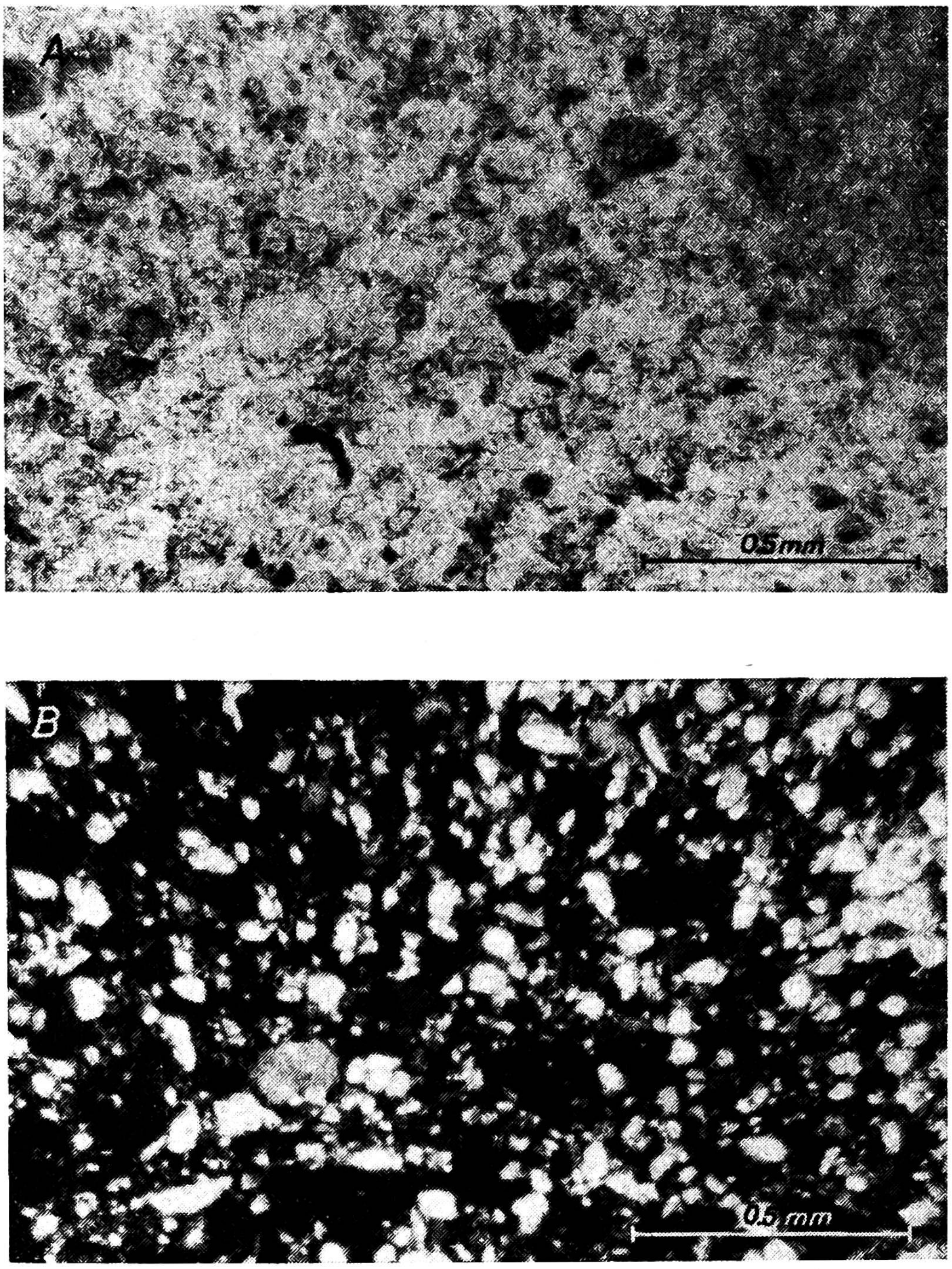



Fig. 7. Micromorphology of podzolic soil developed from loess. Horizon $A_2$, sampling depth 20-30 cm. Argillasepic. Considerable microporosity, little contents of clay-ferruginous matter. *A* — in plain light, *B* — under crossed polarizers.

In some genetic horizons of the examined soils the secondary minerals were characteristic with a week crystallization degree. This results particularly from the character of X-ray lines, DTA curves (Figs. 9-11), as well as from electronomicroscopic photographs (Figs. 12-17).

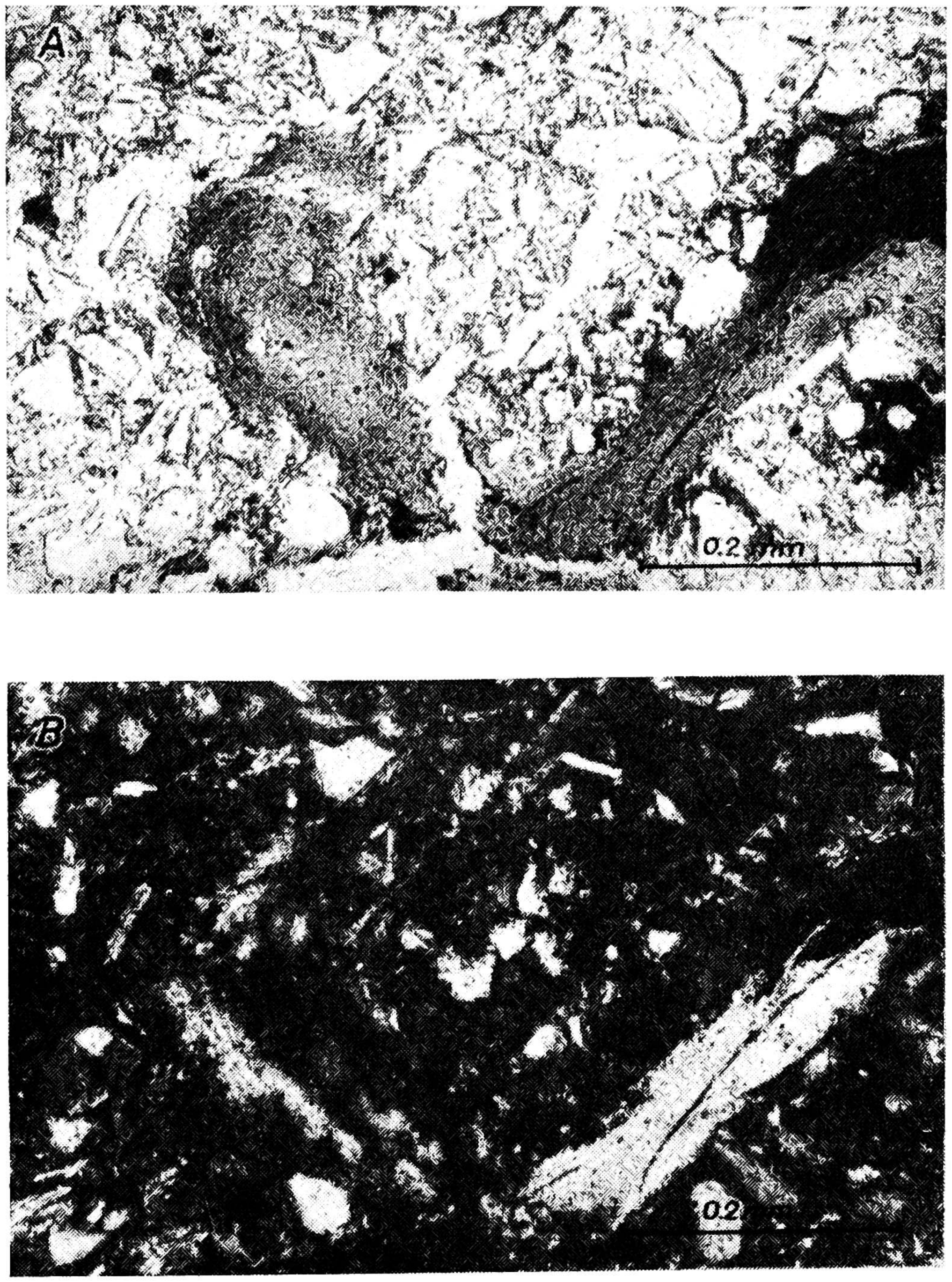



Fig. 8. Micromorphology of podzolic soil developed from loess. Horizon $A_2$/B, sampling depth 35-45 cm. Argilla-vosepic. Flown forms of clay-ferruginous matter. *A* — in plain light, *B* — under crossed polarizers.

## CONCLUSIONS

These investigation results indicate a high dependence between the genetic horizons on one hand, and the mineral composition and distribution of high-dispersion fractions in soil profiles on the other, namely:

1. In brown soil the clay-ferruginous matter is distributed evenly, dependently on the differentiation of the horizons in soil profile. In lessivé and podzolic soils, particularly in eluvial and illuvial horizons, this matter shows the features of flow and concentration around voids.

2. In soil profiles the clay-ferruginous matter enriched in iron compounds gets dislocated first. This may be seen best in the thin sections from the horizons transitional to the parent material.

*Table 2. Mineral composition of clay fractions of some soil developed from loess*

| Soil type, utilization, locality | Horizon | Sampling depth in cm | Fraction 2-0,2 μ | | | | | Fraction < 0,2 μ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Q | H | I | K | M | H | I | K | M |
| Brown soil | $A_1$ | 3-18 | +++ | × | ++ | ++ | — | — | ++ | ++ | + |
| Deciduous forest | (B) | 18-60 | +++ | × | ++ | ++ | — | — | ++ | + | ++ |
| Trzebnica | C | 80-150 | +++ | — | ++ | + | — | × | ++ | + | ++ |
| Lessivé soil | $A_1$ | 3-16 | +++ | — | ++ | + | — | × | ++ | ++ | × |
| Deciduous forest | $A_3$ | 16-35 | +++ | — | ++ | — | — | — | ++ | ++ | + |
| Trzebnica | $B_3$ | 50-75 | +++ | — | ++ | + | — | — | ++ | + | + |
| | C | 95-150 | +++ | — | ++ | × | — | — | ++ | + | ++ |
| Podzolic soil | $A_1$ | 5-15 | +++ | — | ++ | + | — | — | + | ++ | + |
| Mixed forest | $A_2$ | 15-30 | +++ | — | ++ | + | — | — | + | ++ | + |
| Wysoki Kościół | B | 50-90 | +++ | — | ++ | + | + | — | ++ | + | ++ |
| | C | 160-190 | +++ | — | ++ | — | × | — | ++ | × | ++ |

*Explanations*: Q — Quartz; H — Hydrobiotite group; I — Illite group; K — Kaolinite group; M — Montmorillonite group; +++ > ++ > + > ×; — not identified.

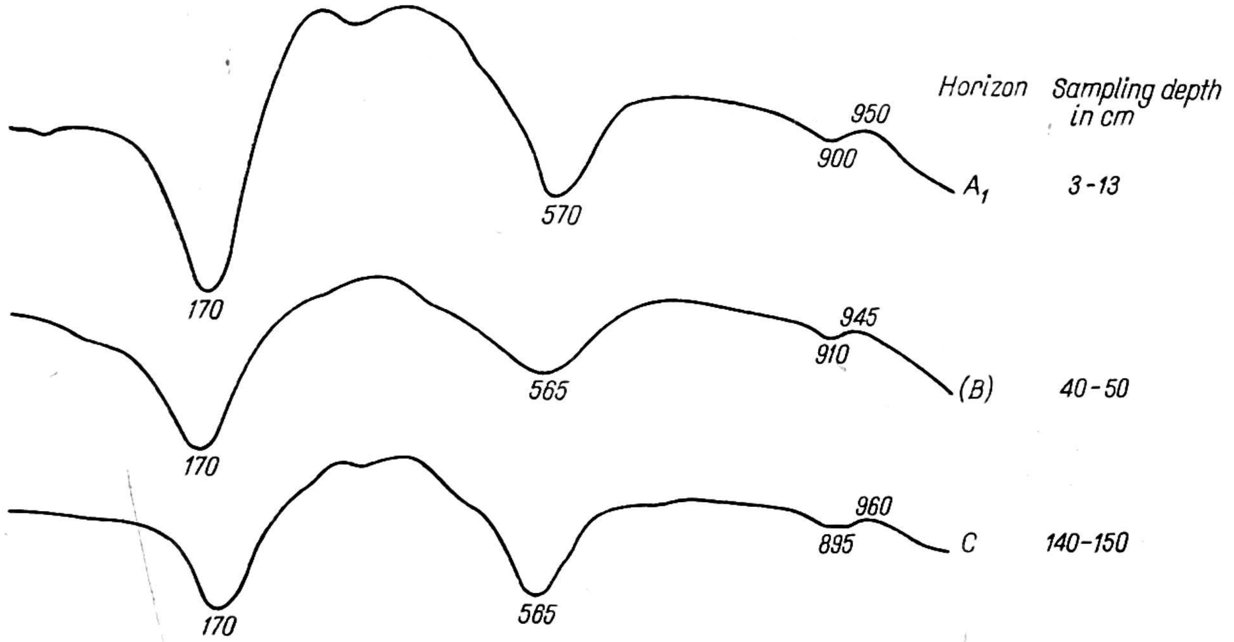



Fig. 9. DTA-curves of clay fraction < 0.2 μ of brown soil developed from loess.

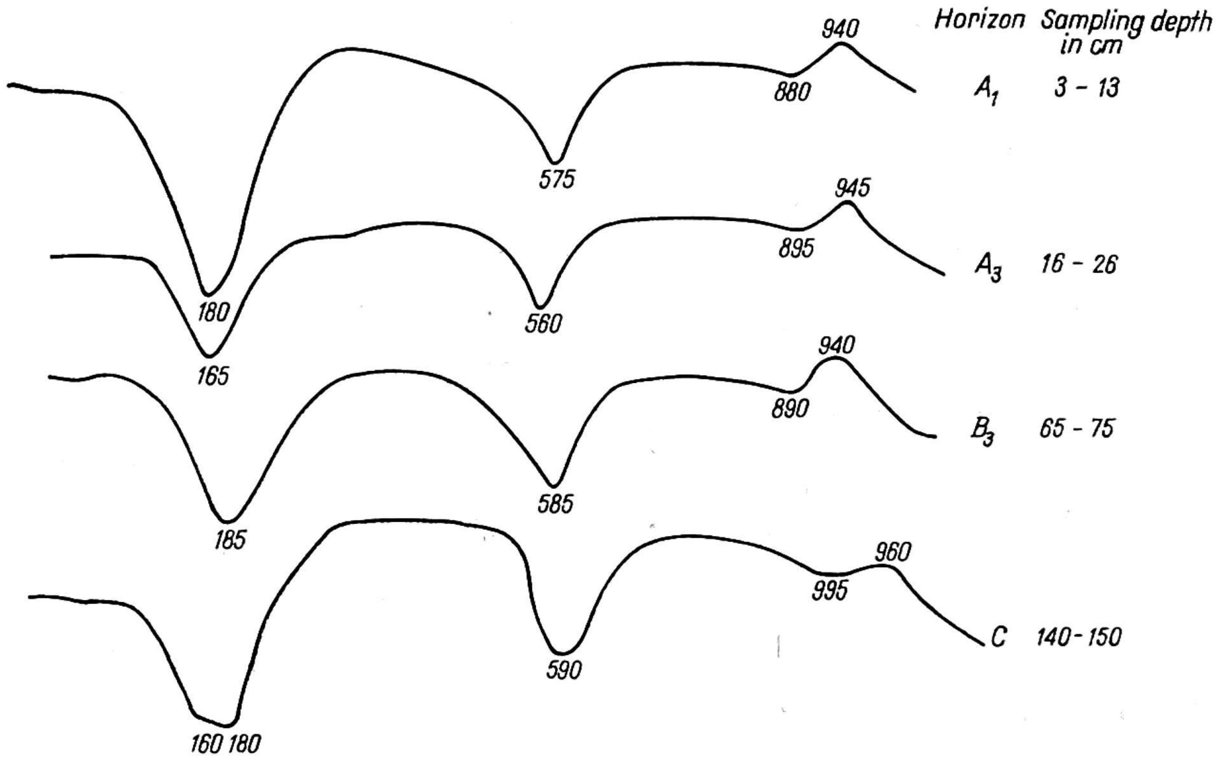



Fig. 10. DTA-curves of clay fractions $< 0.2\,\mu$ of lessivé soil developed from loess.

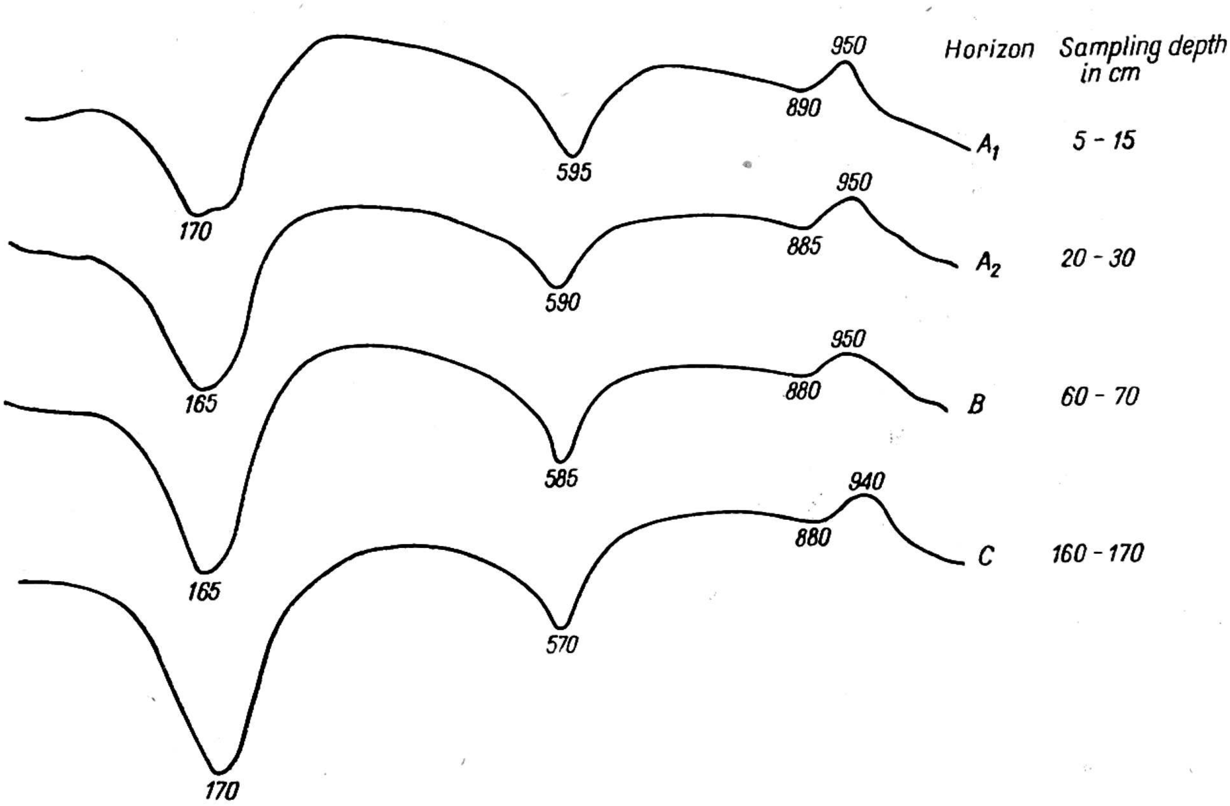
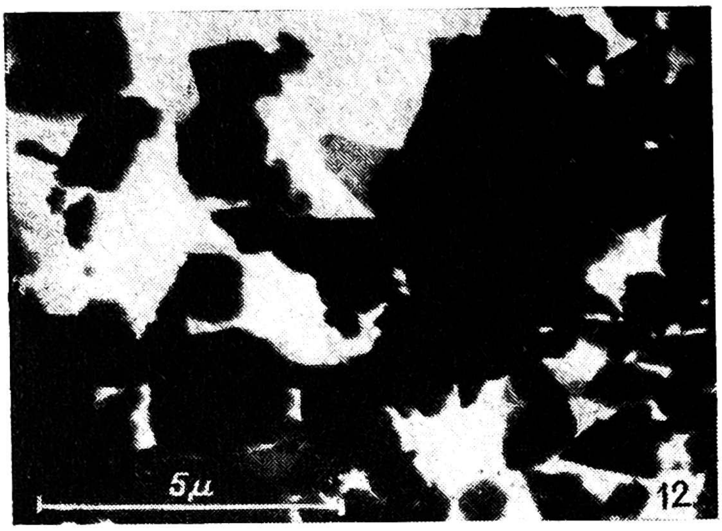
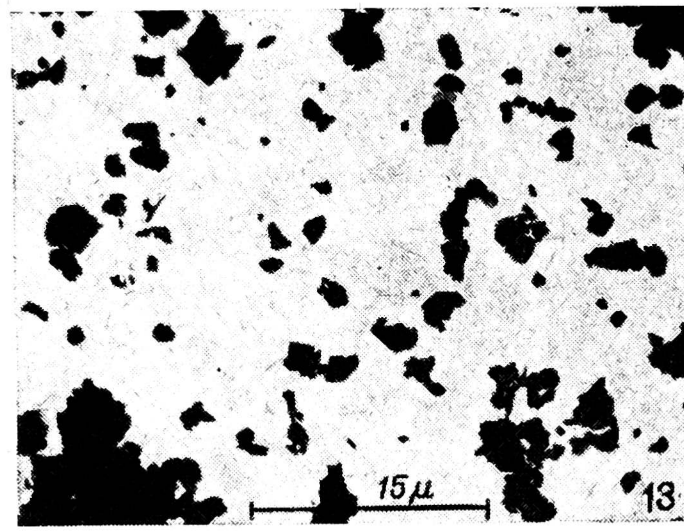



Fig. 11. DTA-curves of clay fraction $< 0.2\,\mu$ of podzolic soil developed from loess.

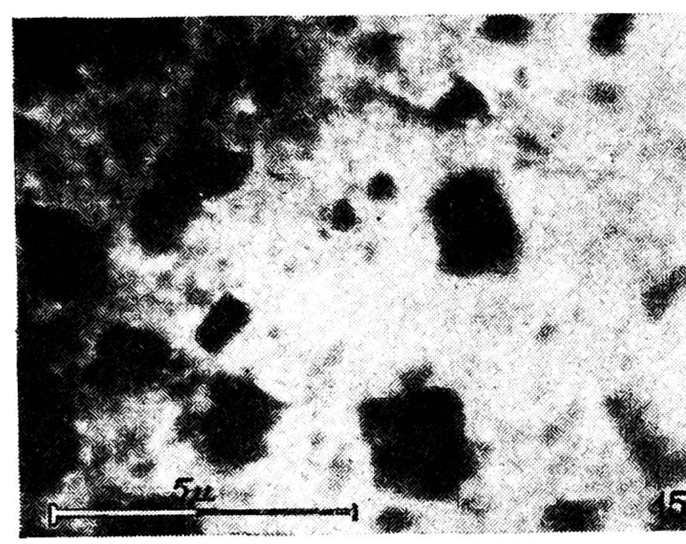
3. Independently on the soil type illite is the predominating clay mineral, while kaolinite and montmorillonite are the accompanying ones.

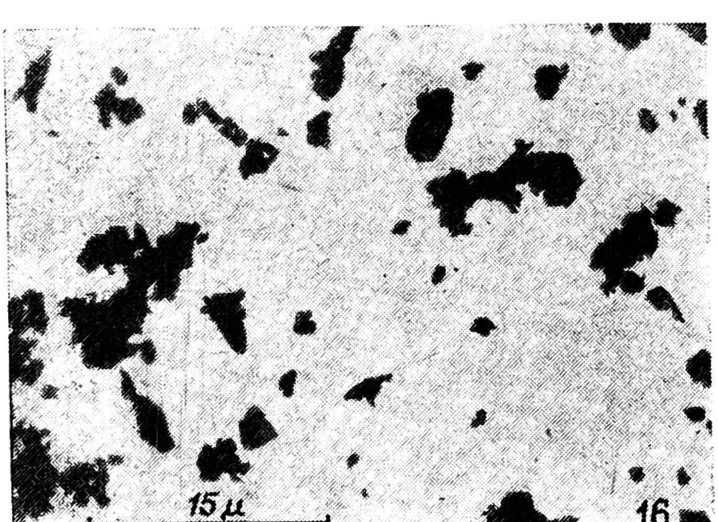
4. In all the examined genetic horizons illite occurred in similar amounts, however deeper into the profile the kaolinite content decreases and that of montmorillonite increases.

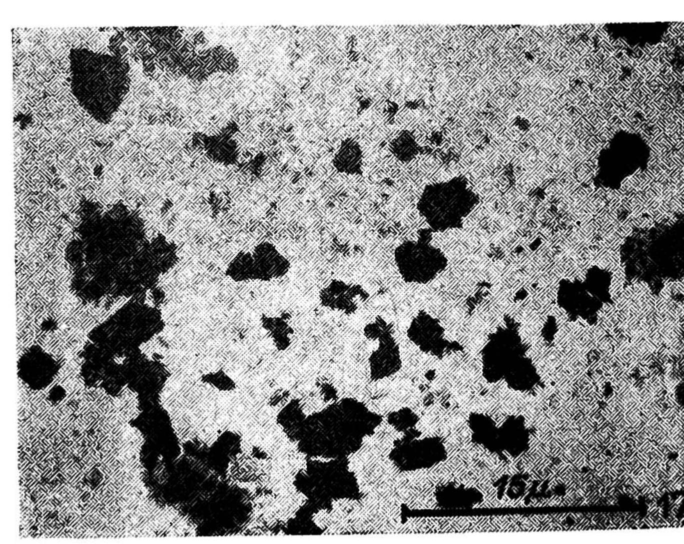







Micromorphology of clay fractions under electronic microscopy:

Fig. 12. Brown soil, horizon $A_1$.

Fig. 13. Brown soil, horizon (B)C.

Fig. 14. Lessivé soil, horizon $A_3$.

Fig. 15. Lessivé soil, horizon $B_3$.

Fig. 16. Podzolic soil, horizon $A_2$.

Fig. 17. Podzolic soil, horizon B.

## SUMMARY

The aim of this work was the examination of the distribution and composition of clay fractions substances contained in brown, lessivé and podzolic soils formed out of loess of the Trzebnickie Hills. The micromorphologic examinations have shown that in the investigated soil profile, first of all, the clay-ferruginous substance is displaced, and then that the clay-substance without any higher amount of iron compounds is displaced too. The most intensive displacement of clay-ferruginous substances occurs in lessivé and podzolic soil.

The mineralogical examinations of clay fractions have shown that the kaolinite contents decreases and that of montmorillonite increases along with the depth of the profile; the amounts of illite in several horizons being more or less stable. In some genetic horizons secondary minerals are characteristic with weak crystallization degree.


## REFERENCES


1. Altemüller H.-J., 1956. Mikroskopische Untersuchung einiger Lössbodentypen mit Hilfe von Dünnschliffen. Z. Pflanzenernähr. Düng. Bodenkunde 72, 2, 57-152.
2. Chodak T., Kowaliński S., 1967. Próba ilościowego oznaczenia substancji mineralnej metodą wzorca wewnętrznego. Zeszyty Naukowe WSR we Wrocławiu, Rolnictwo XX, 65, 17-24.
3. Duchaufour Ph., 1951. Lessivage et podzolisation. Rev. forest. franc. 10, 647-652.
4. Gorbunow N. I., 1967. Glebowe minerały wysokodyspersyjne i metody ich określenia. Warszawa.
5. Komornicki T. i in., 1965. Minerały ilaste wytworzone ze skał górnotriasowych w Tatrach. Rocz. glebozn. XV, 1, 3-20.
6. Konecka-Betley K., 1963. Przyczynek do poznania minerałów ilastych w glebach wytworzonych z lessów. Rocz. glebozn. XIII, 1, 51-65.
7. Kowaliński S., Bogda A., 1966. Przydatność polskich żywic syntetycznych do sporządzania mikroskopowych szlifów glebowych. Rocz. glebozn. XVI, 2, 327-355.
8. Kowaliński S., Bogda A., Chodak T., 1967. Wstępne badania mikromorfologiczne produktów wietrzenia biotytu w niektórych glebach wytworzonych z granitu karkonoskiego. Zeszyty Naukowe WSR we Wrocławiu, Rolnictwo XXI, 66, 19-30.
9. Kubiëna W. L., 1968. Micropedology Collegiata. Press Ames Yova.
10. Langier-Kuźniarowa A., 1967. Termogramy minerałów ilastych. Wydawnictwa Geologiczne, Warszawa.
11. Mückenhausen E., 1964. Elektron microscopic research of different soil types. VIIIth International Congress of Soil Science. Bucharest, 25-27.
12. Przybora E., 1967. Rentgenostrukturalne metody identyfikacji minerałów i skał. Warszawa.
13. Thorp I., Strongl, Samble E., 1957. Experiments of soil genesis. The role of leaching. Soil Sci. Soc. America Proc. 1, 21.
14. Uziak S., 1964. Mineralogical Composition of the Clay Fraction of Soil Formed from Silt Deposits of Different Origin. Rocz. glebozn. Dodatek do t. XIV, 367-375.