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# Micromorphological and physico-chemical investigations on the decomposition rate of organic matter in some muck soils

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## 1. INTRODUCTION

The determination of the decomposition rate of organic matter is one of the basic determinations in organogenic soil researches. In peat formed soils, beside layers formed of plant fragments of well conserved cellular structure, we may observe the appearing of wholly humified material and several transitional stages between those formations. The determination of the decomposition rate in respective layers allows to penetrate several problems related to genetic processes of the examined peaty soils complex, at the same time being the starting point for further botanic, chemical, physical and physico-chemical researches of the peat stratum. The main objective of our researches was a comparative evaluation of the micromorphological method of determining the decomposition rate of organic substances against the field method and other physico-chemical methods applied in soil science. These researches were supplemented by spectrophotometric analysis in infra-red light of suitably prepared fractions of humus compounds isolated out of several genetic horizons of the examined soils.

## 2. THE INVESTIGATION OBJECTS

Two profiles of muck soils were examined:

profile I — flat muck on peat,

profile II — medium deep muck on slightly loamy sand. They occurred in the meadow soil complex of the inundation area of the river Środzianka, district Środa Śląska. This complex comprises the area of typical low moor, partly ameliorated by open ditches, where the peat-forming process got inhibited, giving way to the muck-forming one induced by variable anaerobic-aerobic conditions.

Here is the macromorphology of the examined soil profiles:

*Profile I*

$M_1$ 0-28 cm — black, humid humus-sod horizon, thick tangle of roots, visible small shells; gradual transition.

$T_1$ 28-55 cm — medium-decomposed peat, dark-grey-brown with large brown patches; clear transition.

$T_2$ 55-95 cm — poorly decomposed peat, mucky grey with brown shade well visible plant remains.

D below 95 cm — slightly loamy sand, markedly gleyed, sorted, coarse-grained.

In summer water appears at average depth of about 60 cm.

In the plant complex following species occur: alder shrubs, single willows, sedges, cannabinaceous thoroughworts, creeping buttercups, bittersweets, forget-me-nots, bistorts and peppermints.

*Profile II*

$M_1$ 0-25 cm — the humus-sod horizon, black in humid condition, structural, tangled with a mass of roots; indistinct transition.

$M_2$ 25-30 cm — black illuvial horizon of muck, more compact, more coarse-crumble structure; gradual transition.

$T_1$ 30-40 cm — markedly decomposed peat, brown, tangled with fine roots; clear transition.

D below 45 cm — slightly loamy sand, light-grey-yellow with rusty patches; visible dead roots.

In summer water appears at average depth of 50 cm.

In the plant complex following species occur: sedges, bedstraw, vegetable thistle, narrow-leaved plantain, Yorkshire fog, buttercup, red fescue, silver-weed and moss.

As both profiles were of strong floated character, a detailed botanic analysis of plant fragments in respective peat layers turned rather difficult. Only by the preserved plant remnants and the present structure of soil profiles it may be supposed that the peat-bog forming flora belonged to spring water low moor vegetation type, thus having been different from the present one. Depending on the processes conditioned, among others, by hydrologic changes, some species prevailed over other ones [5].

Detailed laboratory examinations were carried out on five soil samples taken from following horizons of the muck soil profiles:

Samples from profile I: (1) muck floated with carbonaceous shells, horizon $M_1$, depth 5-15 cm; (2) peat, horizon $T_1$, depth 30-40 cm; (3) peat, horizon $T_2$, depth 70-80 cm.

Samples from profile II: (1) muck, horizon $M_1$, depth 5-15 cm, (2) highly decomposed peat, horizon $T_1$, depth 35-45 cm.

For a general characteristic of the examined muck soil samples there were determined their reaction properties, ignition losses and total content of carbon and nitrogen. Besides, there were determined the degrees of organic matter decomposition with particular consideration of micromorphological and micromorphometric properties, as well as some chemical and physicochemical properties of the organic matter and soil humus.

The results of analyses are shown in Tables 1-4 and Figs. 2-11.

*Table 1. Some properties of the examined muck soils*

| Profile | Horizon | Sampling depth, cm | Hygroscopic water | Ignition loss (400°C) % | pH in $H_2O$ | pH in KCl | $CaCO_3$ % | C total % | N total % | C:N total |
|---|---|---|---|---|---|---|---|---|---|---|
| I | $M_1$ | 5-15 | 9.95 | 58.63 | 7.5 | 6.8 | 11.8 | 24.21 | 2.20 | 11.04 |
| | $T_1$ | 30-40 | 10.88 | 79.80 | 5.1 | 4.6 | traces | 35.37 | 2.40 | 14.74 |
| | $T_2$ | 70-80 | 7.61 | 61.55 | 2.1 | 2.0 | — | 26.35 | 2.23 | 11.81 |
| II | $M_1$ | 5-15 | 8.99 | 55.71 | 5.7 | 5.2 | — | 24.32 | 2.42 | 10.05 |
| | $T_1$ | 35-45 | 8.14 | 62.71 | 4.3 | 3.9 | — | 29.05 | 2.10 | 13.83 |

As seen in the Table 1, the examined profiles contained relatively high amount of hygroscopic water, ranging from 7.61% to 10.88%. The highest amount of hygroscopic water was contained in horizon $T_1$ of muck soil on peat. In this horizon, too, were noted highest ignition losses and largest range of C:N total ratio. High ignition losses as well as C:N total ratio were noted in horizon $T_1$ of medium-deep muck soil on slightly loamy sand.

Both the examined profiles show some differentiation of the reaction. Particularly profile I, because of a considerable amount of shells occurring in the upper horizon, shows a profile differentiation of acidity. Horizon $M_1$ is alkaline, while the lower horizon $T_2$ shows a strongly acid reaction. Profile II shows an acid reaction already in the upper horizon; it increases down the profile, but not so rapidly as in profile I (Table 1).

## 3. DETERMINATION OF THE DECOMPOSITION RATE

The decomposition rate of organic matter in several muck soil samples was determined by a few methods:

(1) The field ten-grade method acc. to von Post, consisting in organoleptic determination of the decomposition of organic matter in peaty soils. This method may be used in field experiments not wanting a too accurate determination of the advance of plant parts decomposition.

(2) The laboratory-chemical method developed by Czyżewski [2]. This method consists in boiling a soil sample with 0.1 n NaOH, laying the extract (or slurry) on blotting paper, followed by colorimetric determination of the decomposition degree of peat by comparing with adequate standards. The results obtained by this method are strikingly consistent with those obtained by the organoleptic von Post's method.

(3) The humification degree of the examined samples was determined according to the formula proposed by Kozakiewicz [3], being a modification of the Ponomarieva and Nikołajeva [4] formula. The obtained result approximately corresponds to the decomposition degree of organic matter determined by microscopic examinations.

The Kozakiewicz formula takes into account the per cent content of humic and fulvic acids in 0.1 n NaOH extract of a given sample, as well as the contents of $C_{org.}$ and N in the extract and in the primary sample. The dependence of humic acids content on the degree of humification is shown in Fig. 1.

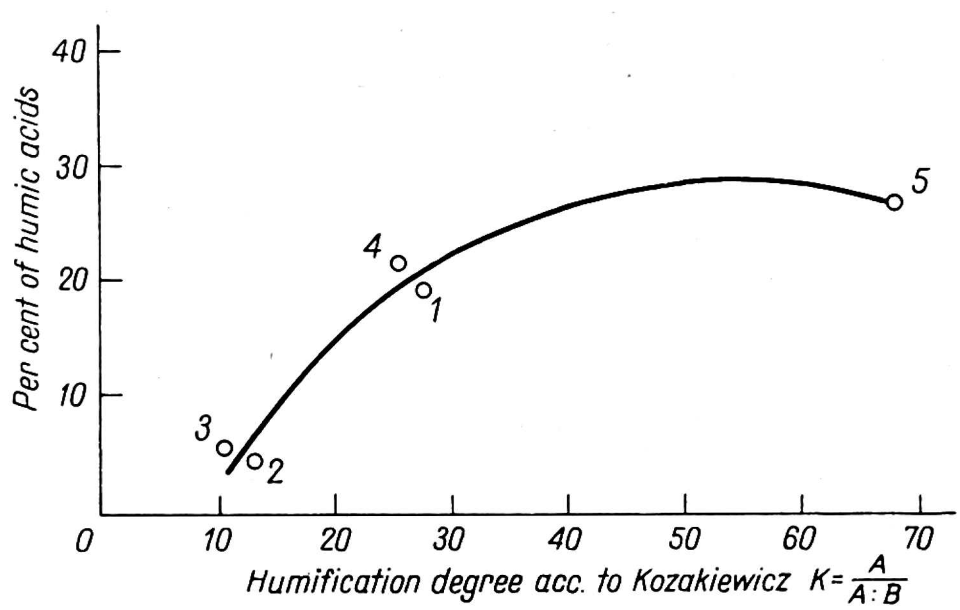


Fig. 1. The dependence of humic acids contents on the degree of humification. C = C org. of extract 0.1 n NaOH; A = C:N in sample; B = C:N in extract; O sample number.

However, thus calculated results diverge from those obtained by the von Post field method and by the laboratory method acc. to Czyżewski, though it should be noted that it is the method of determining not the degree of decomposition but of humification, which is not the same. Therefore, the results may be considered as approximate only. Besides, Kozakiewicz already calls attention to the fact that in case of markedly floated peats the results of analyses are lowered [3]. However, the general trends of respective results are rather similar. Samples of similar degrees of decomposition show approximate numerical values in this method, too.

Apart from the von Post method, the other laboratory ones are rather long and inconvenient, wanting an adequate laboratory base.

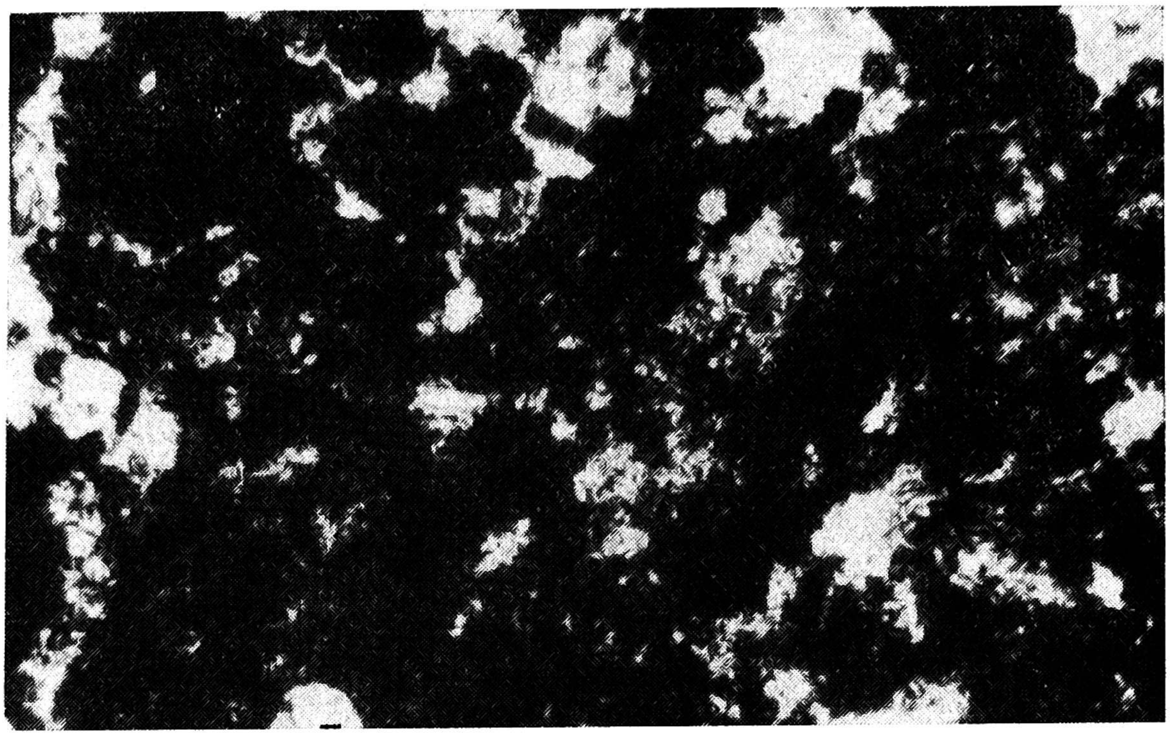

Fig. 2. Muck silted up with $CaCO_3$ — profile I (1-15 cm). Visible markedly humified plant remains, mixed up with mineral substance.

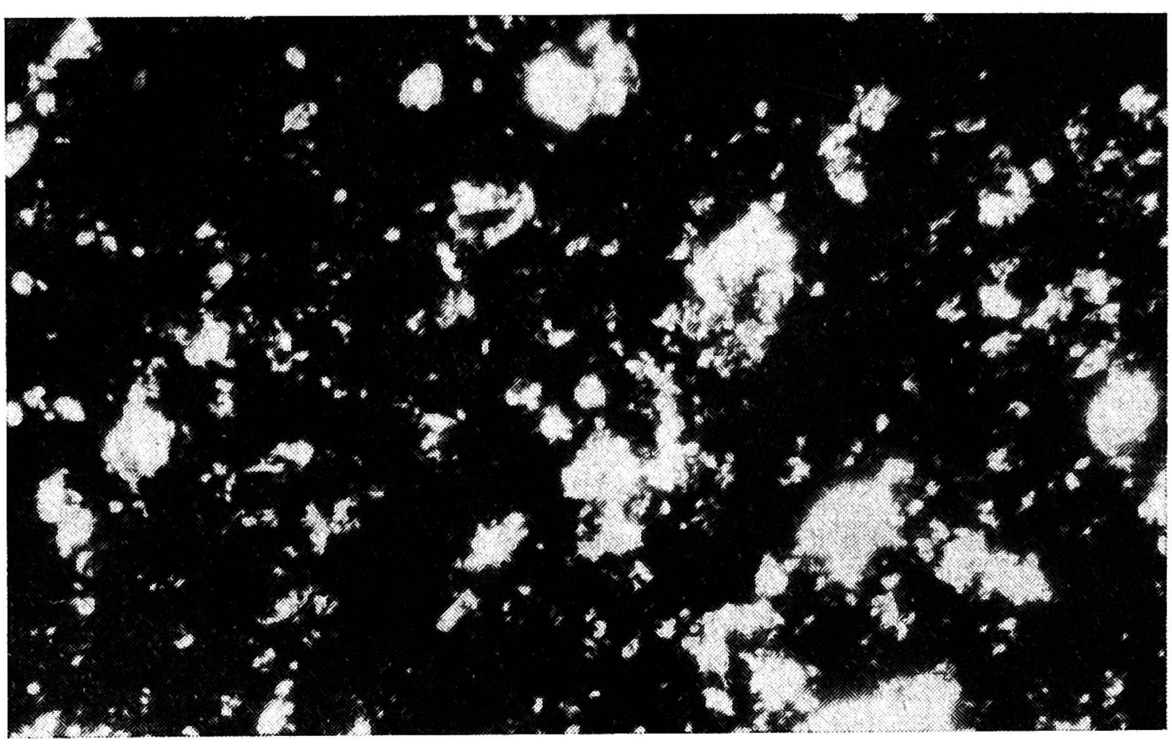

Fig. 3. The same as Fig. 2 but by crossed polarizers.

(4) The methods mentioned above have not given a detailed picture of the decomposition processes which had occurred in the examined muck soils. Therefore, there was used the micromorphological method described by Babel, suitable — among others — for determination of the decomposition degree of humus preparations [1].

Thin soil sections were prepared after generally applied methods and then described under a microscope.

Micromorphological description of the tested samples turned to be considerably difficult because of high disintegration of organic and min-

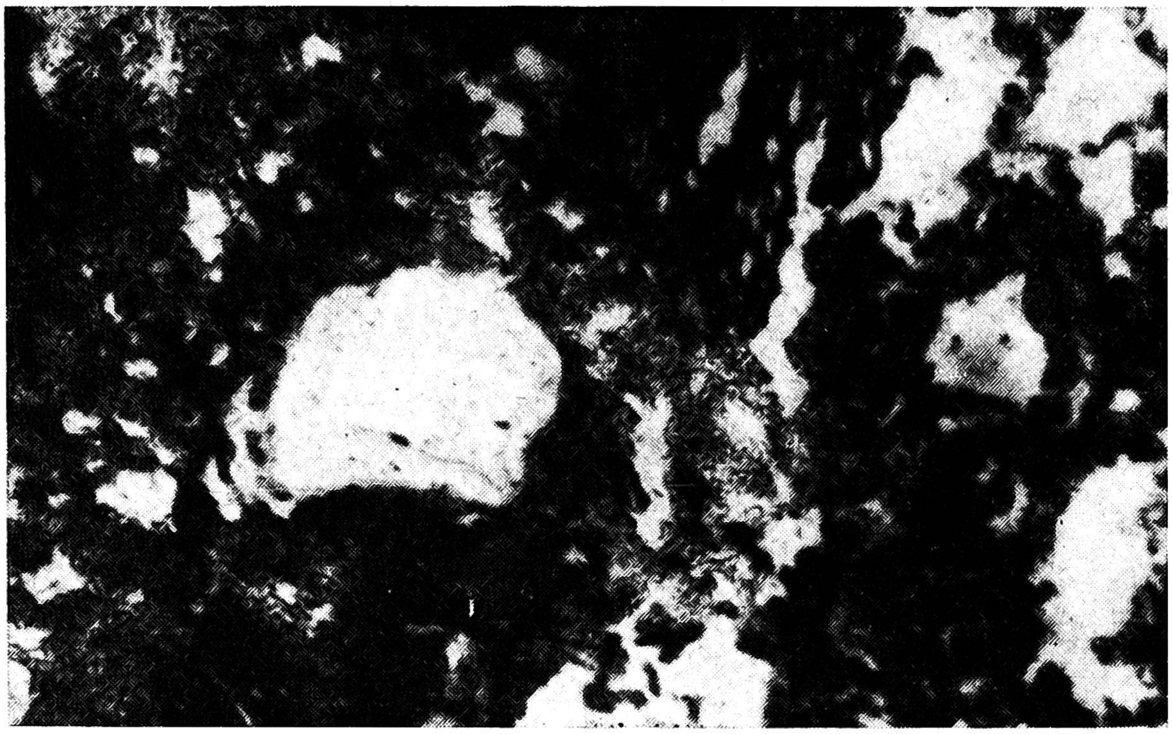

Fig. 4. Medium-decomposed peat — profile I (30-40 cm). Partly preserved anatomic structure of plant remains of parenchymal and ligneous type.

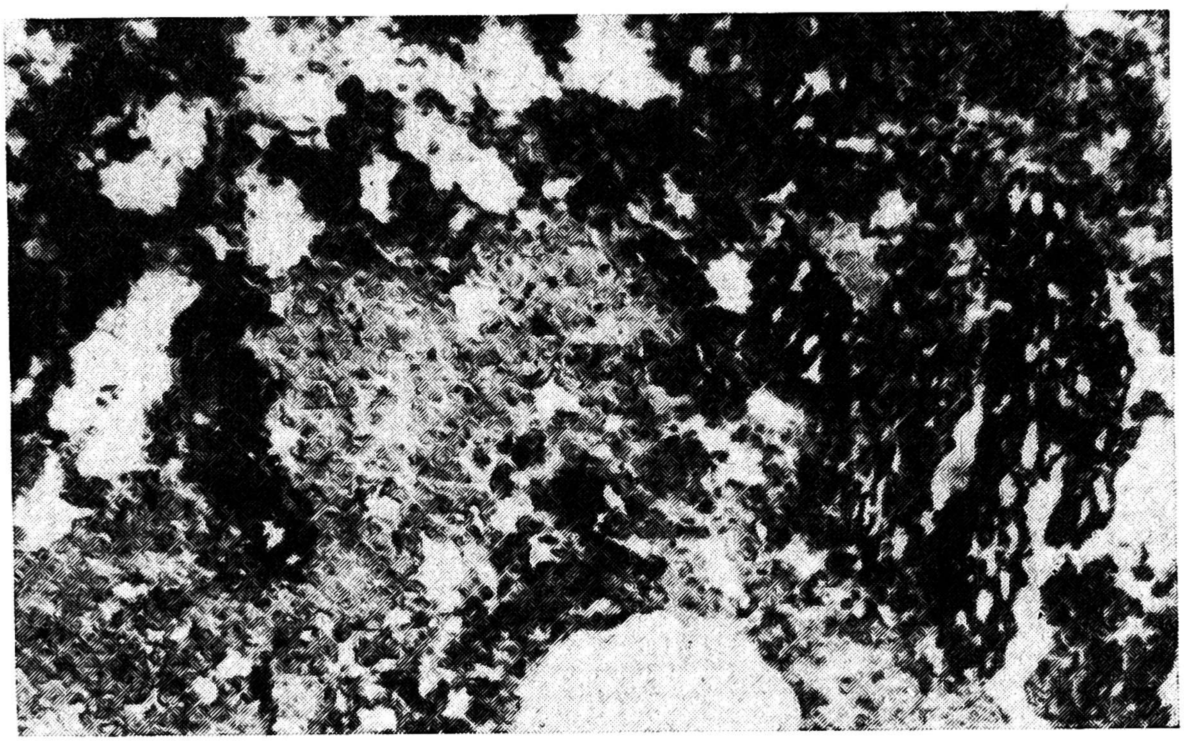

Fig. 5. Medium-decomposed peat — profile I (30-40 cm).

eral parts. Nevertheless, using extreme enlargements, we managed to distinguish the essential types of structure, namely: (1) ligneous, (2) parenchymal, (3) phlobaphene. These structure types of differently decomposed organic matter were observed in all thin sections of the examined muck soils.

Similarly it was with the degrees of humification. Here, too, in each thin section from each examined layer fragments of organic matter in low, medium and high degree of decomposition could be met. This was evident by well preserved fragments of plant tissues and by the form and colour of humified organic remnants. The preponderance of this or that decomposition degree of organic substance contained in a given sample was, of course, only too visible. Some more important micromorphological traits of the examined soil samples are shown in Figs. 2-11.

When determining mineral components by the microscopic method we came across some difficulties, too. Although the presence of quartz, feldspars and ferruginous minerals was unquestionable, the determination of calcite, or rather carbonates, presented a certain problem. Only in

Fig. 6. Medium-decomposed peat — profile I (30-40 cm). Plant remains of phlobaphene, parenchymal and ligneous type structure, Visible mineral substance and charred organic remains.

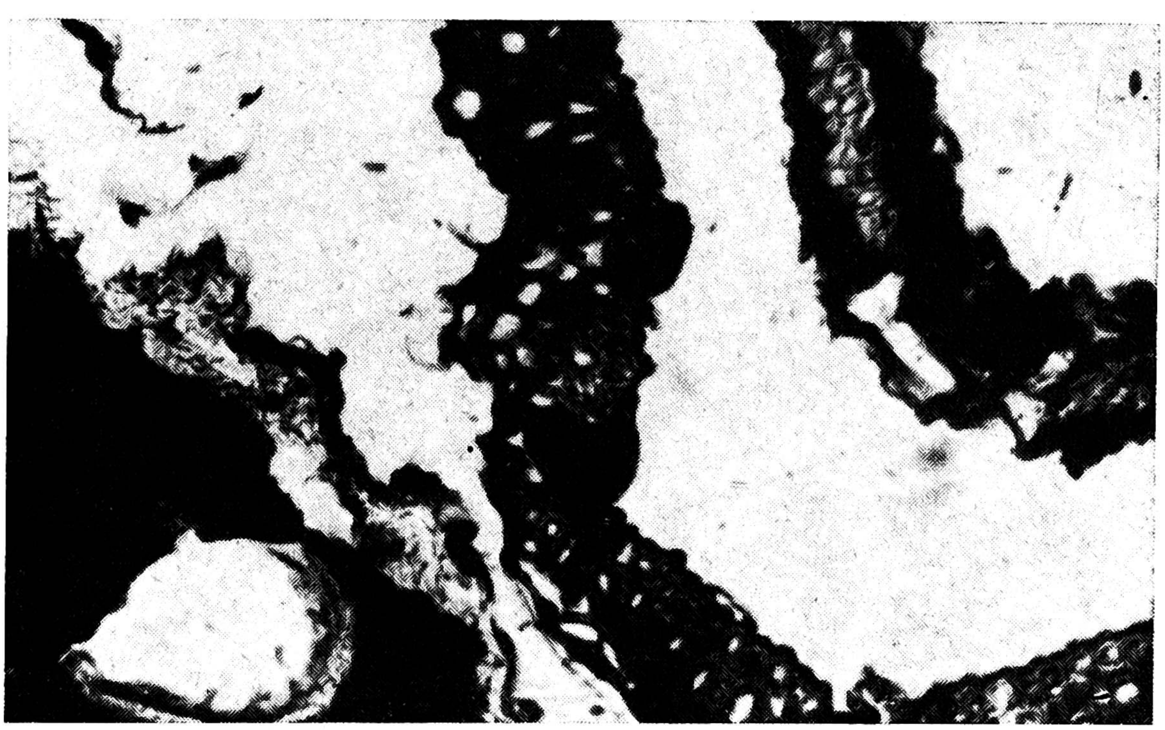

Fig. 7. Slightly decomposed peat — profile I (70-80 cm). Plant tissues slightly humified, of phlobaphene, parenchymal and ligneous type structure.

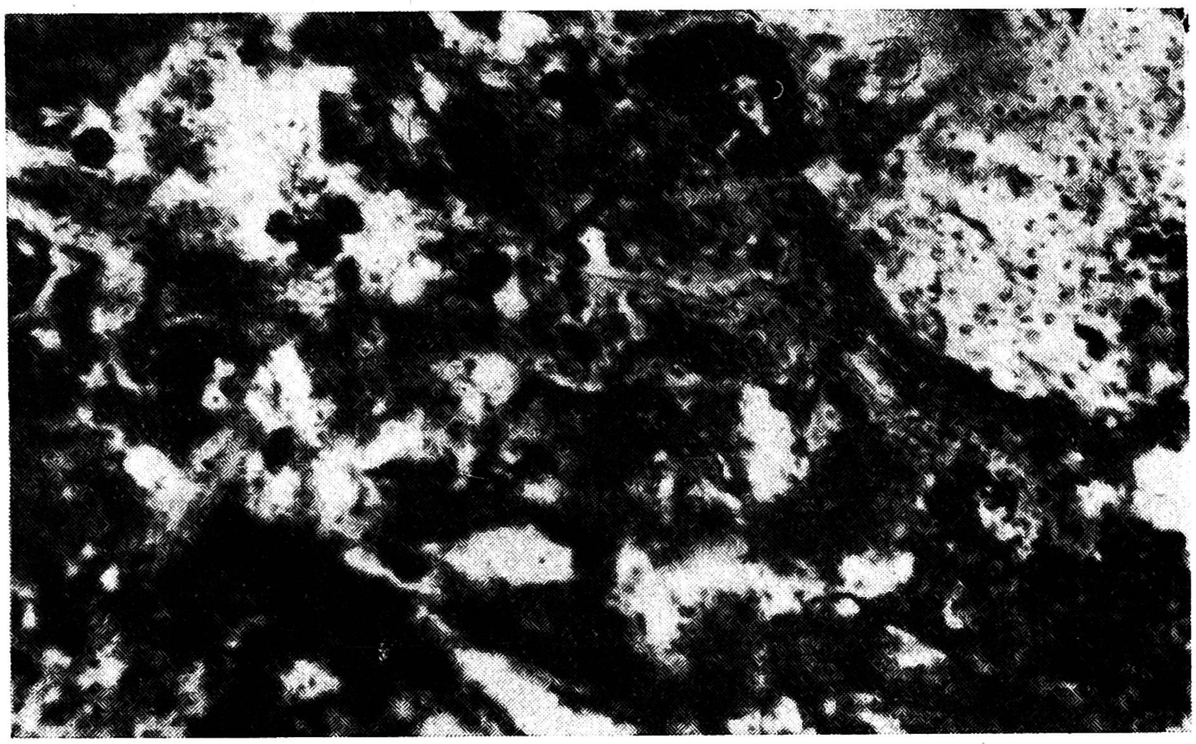

Fig. 8. Muck — profile II (5-15 cm). Markedly humified plant remains, silted up with mineral substance. Plant remains of ligneous, parenchymal and phlobaphene type, coprogenic elements and charred organic substance.

a sample of muck soil with carbonate mud the presence of calcite was evident. The presence of calcite grains and sections of shells, which were visible in thin soil sections, have been confirmed by chemical analysis where $CaCO_3$ was determined by the Scheibler method (Table 1).

In the remaining samples microscopic observation helped to reveal small crystals of secondary crystallization, showing characteristic reflexes with crossed polarizers. These crystals appeared most often on plant rem-

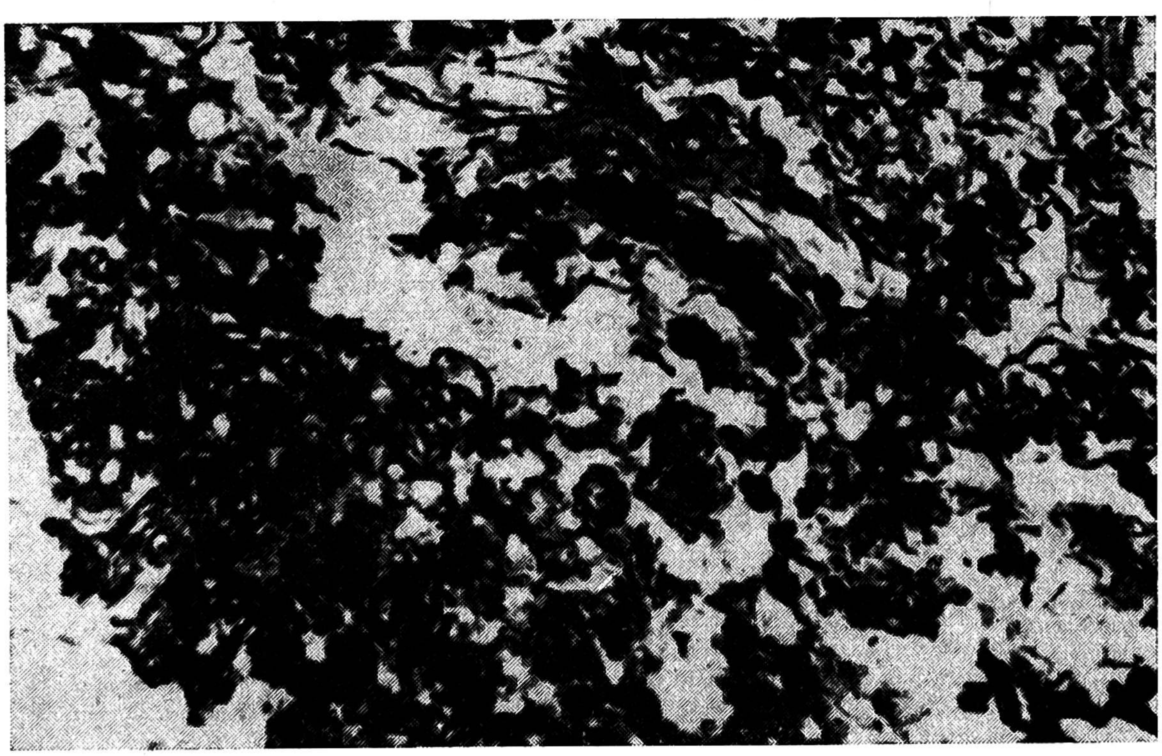

Fig. 9. Muck — profile II (5-15 cm). Coprogenic elements in the central part of the photograph.

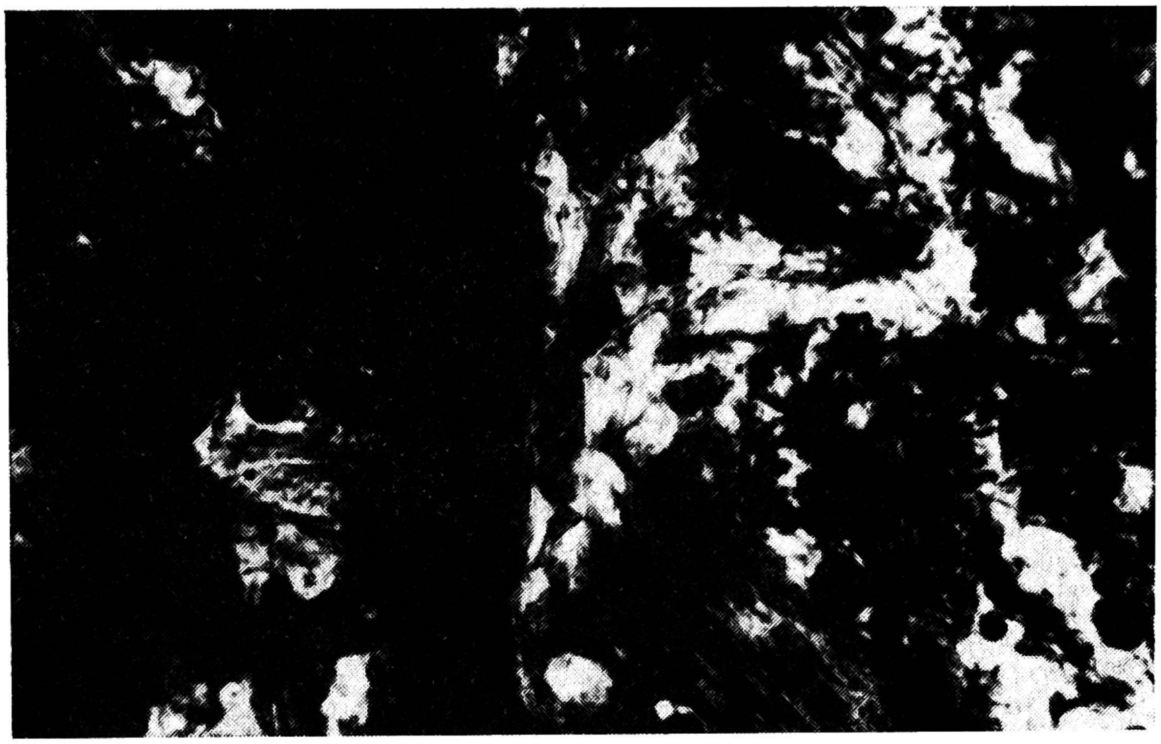

Fig. 10. Markedly decomposed peat — profile II (55-65 cm). Markedly humified plant remains mostly of ligneous and parenchymal type, coprogenic elements and charred organic substance.

nants, and to a lesser degree among markedly disintegrated and humified organic matter. Micromorphological identification of these minerals did not give any definite results. Therefore chemical analyses were carried out, which allowed to qualify some compounds, probably being the components of those secondary precipitates, as the salts of such organic acids like oxalic, benzoic, tartaric and phenylacetic ones.

Then, to quantitatively characterize the decomposition degree of organic matter, a planimetric analysis of thin soil sections was carried out. The re-

Fig. 11. Markedly decomposed peat — profile II (55-65 cm). Clearly visible coprogenic elements and charred organic parts.

*Table 2. The decomposition of organic matter of the examined muck soils*

| Profile | Horizon | Sampling depth, cm | Definition of soil formation | Kind of organic matter | Decomposition degree after the method of: von Post | Czyżewski | Kozakiewicz |
|---|---|---|---|---|---|---|---|
| I | $M_1$ | 5-15 | muck silted up with carbonate shells | Magnocaricioni | 7 | 65 | 27.0 |
| | $T_1$ | 30-40 | medium decomposed peat | Bryalo-Parvocaricioni | 6 | 70 | 13.0 |
| | $T_2$ | 70-80 | weakly decomposed peat | Magnocaricioni | 4 | 45 | 10.5 |
| II | $M_1$ | 5-15 | muck | Bryalo-Parvocaricioni | 8 | 75 | 25.5 |
| | $T_1$ | 35-45 | strongly-decomposed peat | Alnioni | 8 | 75 | 67.5 |

sults are presented in Table 3. The per cent lot of differently decomposed organic matter in a given sample gives a view upon the decomposition process occurring in the given material. The results of planimetric analysis not only confirm those obtained by other methods, but give some knowledge of detailed inner structure of the examined samples. This particularly important considering soils markedly silted up, for which macromorphological and chemical methods of analyses are burdened with a significant error.

*Table 3. Planimetric analysis of thin sections of the examined muck soils* (%)

| Profile | Horizon | Sampling depth, cm | Decomposition of organic matter: weak | medium | strong | Coprogenic elements charred organic matter | Carbonates and salts of organic acids | Quartz | Feldspars | Ferruginous minerals |
|---|---|---|---|---|---|---|---|---|---|---|
| I | $M_1$ | 5-15 | 0.2 | 11.6 | 60.9 | weakly marked | 10.0 | 10.7 | 3.4 | 3.2 |
| | $T_1$ | 30-40 | 0.4 | 39.2 | 31.9 | weakly marked | 15.7 | 7.3 | 2.2 | 3.3 |
| | $T_2$ | 70-80 | 78.4 | 4.2 | 2.9 | weakly marked | 6.6 | 3.2 | 1.3 | 3.4 |
| II | $M_1$ | 5-15 | 0.7 | 12.5 | 66.9 | 7.3 | 8.9 | 1.7 | 1.9 | weakly marked |
| | $T_1$ | 35-45 | 0.5 | 8.4 | 64.4 | 18.7 | 6.7 | 0.1 | 1.2 | weakly marked |

Nevertheless, no far-reaching conclusions regarding the composition of organic matter can be drawn on the grounds of micromorphological examinations of thin soil section samples containing thoroughly humified organic matter. Partial secondary crystallization of this organic matter would make it still more difficult. Therefore, to recognize humified organic matter, we had to use chemical analyses.

## 4. EXAMINATION OF FRACTIONAL COMPOSITION

We had, first of all, to more accurately characterize the organic matter contained in the tested muck soil samples regarding its physico-chemical properties, and to find out probable qualitative differences in the chemical structure which might have resulted from the prevalence of respective decomposition degrees. For this purpose we analysed the fractional composition of humus with the Aleksandrova method, using 0.1 m $Na_4P_2O_7$ of pH brought up to 8.4, and soluble humus compounds additionally extracted with use of 0.1 n NaOH. The results are shown in Table 4.

As seen in the Table 4, the content of bitumens is increasing in deeper horizons of profile I, and decreasing in profile II. A higher amount of bitumens appears in the sample containing less humified organic matter.

The amount of carbon extracted by means of 0.1 m $Na_4P_2O_7$ in profile I is higher in horizon $M_1$ and decreases in horizons T; in profile II it in-

*Table 4. Fractional composition of humus of the examined muck soils*

| Profile | Horizon | Sampling depth, cm | Bitumens | C evolved in 0.1 m $Na_4P_2O_7$ | C in the residue after extraction | C of humic acids | $C_h/C_f$ | Extraction in 0.1 n NaOH | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | % of total carbon | | | | C evolved in % C total | C : N |
| I | $M_1$ | 5-15 | 10.4 | 34.9 | 51.9 | 20.4 | 1.41 | 43.2 | 4.12 |
| | $T_1$ | 30-40 | 12.3 | 12.0 | 73.1 | 5.4 | 0.81 | 33.4 | 5.48 |
| | $T_2$ | 70-80 | 15.9 | 12.2 | 76.5 | 5.8 | 0.89 | 37.2 | 5.42 |
| II | $M_1$ | 5-15 | 17.8 | 35.3 | 52.2 | 22.2 | 1.69 | 51.1 | 5.40 |
| | $T_1$ | 35-45 | 15.7 | 48.0 | 42.3 | 30.7 | 1.76 | 84.0 | 12.91 |

creases in horizon $T_2$. Similar is the content of C-humic acids and ratio $C_h/C_f$, what suggests a differentiation of the humification degree in the soil profiles under investigation.

The amount of carbon extracted by means of 0.1 n NaOH in both the examined profiles is much higher than C extracted with 0.1 m $Na_4P_2O_7$, although the tendency to a profile arrangement is alike. The ratio C/N in humus compounds extracted with 0.1 n NaOH is distinctly differentiated in profile II, being broadest in horizon $T_2$.

Irrespective of the above given results, the humus compounds soluble in 0.1 n NaOH were additionally resolved on a chromatographic column filled with cation exchanger, using different eluting solutions. Eluats were extracted with ether and chloroform, and then analysed by means of an UR-10 spectrophotometre for infra-red in the range from 400 to 4,200 $cm^{-1}$ (25-2.38 $\mu$).

Despite of considerable differences in the decomposition degrees, per cent content of respective components, genesis and botanical composition of the tested samples, the spectra in infra-red showed far-reaching qualitative likeness concerning the occurrence of definite groups of organic compounds. This allows the supposition that structural elements of the organic compounds of different origin, being in different stages of decomposition, are all alike. Then, the decomposition degree seems to express the spatial arrangement of these smallest substituents.

## 5. CONCLUSIONS

The results of macro- and micromorphological as well as chemical and physicochemical analyses of the tested muck soil samples allow to draw following final conclusions:

1. There has been stated general qualitative conformance in estimation of the tendency of the decomposition degree of organic matter, determined by different methods, although the numerical values obtained with respective research methods considerably differ between themselves.

2. The truest picture of the processes of organic matter decomposition is obtained with the micromorphological method; this method allows qualitative determination of different stages of decomposition and humification of organic soil matter as well as of the forms of humus.

3. Classic methods of micromorphological examination of humus in thin sections appear to be insufficient for highly disintegrated, no more showing a cellular structure, organic matter of strongly silted up muck soils. In these cases there should be used methods of high resolving power, supplemented with other chemical and physicochemical ones.

4. Chemical determination of the fractional composition of humus considerably helps to identify the humification degree of organic matter in muck soils.

5. The infra-red spectra of extracted organic matter, differing by plant composition and decomposition degrees, showed high qualitative similarity. This allows a supposition that the structural elements of organic compounds, appearing in the tested samples, are alike. Now, the decomposition degree seems to be the resultant of the spatial arrangement of substituents.

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