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Morphology and genesis of mor from a pine-heath stand

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Studia Forestalia Suecica
No. 164 · 1983

ISSN 0039-3150
ISBN 91-576-1398-2

Abstract

Olsson, M. 1983. *Morphology and genesis of mor from a pine-heath stand.* Studia Forestalia Suecica 164, 14 pp. ISSN 0039-3150, ISBN 91-576-1398-2.

Morphological studies of mor of different ages were carried out with the purposes of describing and elucidating biological activity on the basis of morphological properties, and deducing the rate of genesis. The site was characterized by a quartz-rich sand deposit, low ground-water table, poor vegetation and orthic podzol. In the morphological analyses the mor was separated into different horizons. Micromorphological studies showed that fungi were very important in the decomposition process. Soil animals were of less significance. The formation of the fermentation horizon was a fast process. After a period of 20 years a fermentation horizon had developed although it was characterized by a low content of altered organic matter. The formation of a humus-substance horizon was a much slower process.

Key words: mor, soil micromorphology, soil biology.
ODC 114.355:114.69; 114.355:114.6

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MS. accepted 26 November 1982

Tofters tryckeri ab, Östervåla 1983

Introduction

Much attention has been paid to the humus forms since their concept was introduced by Müller (1879). In the case of forestry the quality as well as the quantity of humus play very important roles in the usually coarsely textured forest soils. Although this fact has long been known, the importance of humus has only been brought up to date during recent years due to strong demands upon the long-term timber production. Major questions are which circumstances are behind the development of different humus forms and their consequences on soil fertility. Of the utmost importance in this respect is the type and speed of organic matter turnover in the soil. A fast turnover favours the vegetation due to a good supplial of plant nutrients.

Although we know a lot about the genesis of different humus forms there still are many questions left to be answered. In Sweden the most common humus forms in coniferous stands are mor and sometimes intermediate types between mor and mull. It is, thus, important not to regard mor as a uniform humus form but to separate it into different subgroups and to evaluate their ecological significances. Moreover, the humus forms are never in a permanent state. The type of humus form depends on several site properties, of which some will successively change with time. For instance, when a forest stand grows older and denser, or after clear-cutting, there will be changes in litter supply as well as in decomposition processes which will influence the humus form. To get an idea of these natural changes it is important to deduce the rate of genesis of the humus forms.

In order to study the morphology of mor and its formation over time a 80-year-old pine stand (Pinus sylvestris) was studied. The stand is characterized by widely scattered and slowly growing pines and a ground vegetation of mainly lichens and sometimes mosses and dwarf shrubs. The mineral soil was a quartz-rich sand. During the 1800's, forest fires occurred several times in the studied area (Troedsson et al., 1965). These repeated fires partly burnt up the mor. The decrease in humus quantity which followed the fires was especially disadvantageous as the sand itself had a very low cation and water retention capacity. The fires in combination with the poor sand are considered as the main reasons for the low soil fertility.

After the last fire in the end of the 1800's the mor was devastated. The area was reforested in about 1900 and today there is a new mor above a charcoal layer. This new mor originates from the new stand and consequently has an age of about 80 years, thus providing an unique possibility to study the development. The charcoal is lying directly on the mineral soil indicating that the old mor was devastated by the fire or that it was completely decomposed later on (see also page 9).

In part of the area of study, a 10 mm deep layer of montmorillonite-rich Rhaetic-Liassic clay was laid out covering the mor and the ground vegetation. The experiment was part of a series of long-term experiments carried out by the Royal College of Forestry. Today the clay is covered by a new and thin mor, but the clay layer was too thin to change the humus form or the ground vegetation. The newly established vegetation has the same composition of species as the area not covered with clay. The pines seem to by very little or unaffected by the clay. Although the purpose of the experiment originally was to improve forest production it also provided the possibility to study mor development during a period of 20 years. Thus, in the studied area it was possible to estimate the development of mor during 80 and 20 years.

The investigation was financed with funds from The Swedish Council for Forestry and Agricultural Research.

The concept of mor

The humus form mor, toghether with synonymous concepts as rawhumus and trockentorf, has been described or defined by a great number of authors. Originally, mor as well as mull were defined by Müller (1879). He used these types to characterize in which way the turn-over of organic matter takes place in forest soils. However, sometimes these terms have been used with another sense, that is to characterize the humus in itself. In this report the term mor is used with Müller's (op.cit.) intention. The definition from Müller (op.cit.) is applied by among others, Romell (1935), Kubiena (1953), Handley (1954), Scheffer & Ulrich (1960), Jongerius & Schelling (1960), Barratt (1964), Jongerius & Rutherford (1979) and Klinka et al. (1981). Hesselman (1926) introduced a more detailed system for humus forms characterization by distinguishing litter horizon (L), fermentation horizon (F) and humus-substance horizon (H). On the basis of the classification of Hesselman (op.cit.), Babel (1971) and Klinka et al. (1981) proposed more exhaustive separations of mor into several horizons.

The humus form mor refers to the humus formation as a whole, i.e. it includes specific chemical and physical characteristics as well as a specific profile development with all its horizons, their internal structure and the totality of their life (Kubiena, 1953). Mor is comprised of litter-, fermentation- and humus-substance horizons as well as an upper mineral horizon, characterized by a significant accumulation of organic matter. Although organic matter may also be found in B- and C-horizons this organic matter should not be considered as a component of the humus form (Barratt, 1964; Babel, 1975).

Generally speaking, mor is a terrestrial humus form consisting predominately of well-preserved though often fragmented plant remains with few faecal pellets (Jongerius & Rutherford, 1979). It occurs first and foremost in coniferous forests at poor site properties, where the litter is disintegrated in situ on the ground and where large digging soil animals are absent. The litter is altered during the decomposition process and finally accumulated as a humus-substance horizon. According to Romell (1935), this horizon consists of material which only slowly decomposes and which contains decomposing organisms. Romell (op.cit.) also claims that the loss in dry weight might be considerable also when the plant remains still could be recongnized. Probably, he referred first and foremost to macromorphologically recognizable remains. A micromorphological study would reveal that important changes had taken place, for instance that a large number of cavities occur.

Babel (1975) discussed morphological properties of different horizons in the mor. The litter horizon (L) consists of macroscopically slightly changed, only browned, loose-lying plant litter. In the fermentation horizon (F) residues of fine roots occur in addition to fragments of leaves and needles. Most of the tissues in the upper part of the fermentation horizon are still readily recognized microscopically and, as a rule, easily interpreted. Their structures, however, are somewhat distorted. In the lower part of the fermentation horizon most of the parenchymatous and the lignified tissues have been destroyed and phlobaphene-containing tissues are enriched. Droppings and dropping residues increase towards the lower part of the horizon.

Handley (1954) demonstrated the presence of masked cellulose in mor. He claimed that the masking material was a precipitate of proteins from cytoplasm and materials in leaf extracts. The masking material was resistent to decomposing and thus protecting the cellulose from breakdown.

The humus-substance horizon is macroscopically black-brown to nearly black. Plant residues become rarer, being mainly residues of roots, bark and of leaf stalks Babel (op.cit.). The mineral-humus horizon is usually very dark black grey or black brown. When the mineral matter is sand, it contains the same organic constituents as the disintegrated material in the humus-substance horizon. The grains are without coatings.

Methods and materials

Macromorphological study

In the areas covered and not covered by clay 15 and 30 samples respectively were taken. These were studied regarding their total thickness as well as the thickness of different horizons, i.e., fermentation-, humus-substance- and mineral-humus horizons. The structure in the horizons was described.

Micromorphological study

For micromorphological studies, one typical sample for thin section preparation was taken from each of the two areas with and without clay. In order to maintain the soil material in such an undisturbed condition as possible, i.e. not affected by the sampling procedure, a cylindrical core sampler was very carefully pressed and screwed down to a depth of 70 mm. The inner diameter of the sampler was 73 mm. The sampler thus contained the entire humus form including the upper humus-mixed mineral soil. As regards the sample procedure and horizon separations for macro- and micromorphological studies, the mor should by definition include a litter horizon. At this site, however, the litter occurred on and in the vegetation layer of mosses and lichens. This vegetation layer was not sampled. Below the vegetation layer decomposing needles were found. Although these needles were very little affected by decomposition and had their original structure partially intact they were very clearly matted and were considered to belong to the fermentation horizon. Consequently, no litter horizon was studied in this investigation.

The samples were dried and impregnated with resin. Vertical thin sections, were prepared, mainly following standard methods (Avery & Bascomb, 1974). The thin sections, 70 × 30 mm and 30 μm thick, were prepared from the central part of the sample where the structure was supposed to be least affected by the sampling procedure. The resin used was Crystic Resin 17449, manufactured by B. & K. Resins Ltd., London (Swedish agent, AB Syntes. Nol).

The thin sections were analysed according to structure and thickness in the different horizons. Voids, mineral grains and different types of organic matter were quantified by image analysis as described in Jongerius et al. (1972), Ismail (1975) and Murphy et al. (1977).

At quantifications, the organic matter was considered to consist of four groups; tissue remains, altered organic matter, charcoal and living roots. The theory behind this classification is that the ratio between tissue remnants and altered organic matter might reflect the degree of decomposition.

Tissue remains were defined as tissue complexes or tissue fragments without any apparent visible attack of animals or microorganisms (magnification 200). Living organisms such as roots were excluded from this group.

Altered organic matter includes strongly disintegrated or decomposed material without any cellular structure. In large droppings from soil animals, however, tissue fragments with some cellular structure might occur.

General site description

Locality

Lövkullaslätten, Hökensås häradsallmänning.
Latitude 58,0°. Altitude 230 m above sea level.

Parent material

Glacifluvial quartz-rich sand deposit. Base mineral index, on average 1.2 (Troedsson et al., 1965).

Climate

Mean temperature, year 5°C. July 16°C.
Mean precipitation, year 600 mm.
Humidity index, year 200 mm (Tamm, 1959).

Hydrology

Plane surface. Ground water table below 2 m.

Vegetation

Tree layer. Widely scattered and low productive 80-year-old Scots pine (Pinus sylvestris).

Field layer: Sparse dwarf shrubs of Vaccinium myrtillus, V. vitae-idea and Calluna vulgaris.

Bottom layer: Lichen, mainly Cladonia sp. and mosses.

Soil profile

Orthic podzol (FAO-system):
0–3 cm: F/H horizons
3–4 cm: Ah/E horizon (humus-mixed albic horizon)
4–9 cm: E horizon (albic horizon)
9–15 cm: B horizon (spodic horizon)
15–35 cm: B/C horizon
Below 35 cm: C horizon (mainly unaltered parent soil material).

Results and discussions

Macromorphological properties

The mor was composed of a L-horizon, mixed in and at the surface of the ground vegetation, a F-horizon, a H-horizon and a thin horizon of humus-mixed mineral soil. The study comprised all parts of the humus form below the ground vegetation and consequently the L-horizon was excluded from the study.

In the 80-year mor the F/H-horizons together amounted to approximately 30 mm (Table 1) while in the youngest mor they were not thicker than 13 mm. This very significant difference in thickness is caused by the difference in ages. The humus formation during 60 years resulted in a 18 mm thicker mor. Besides, decomposition processes during a longer time in the older mor have formed a humus-substance horizon of about equal thickness to the fermentation horizon. In the 20-year old mor, on the other hand, there was no humus-substance horizon at all or only such a thin horizon that it could not be separated in the field. In conclusion the most significant difference between the younger and the older mor was not the thickness but the absence of a humus-substance horizon.

Between different sites and stands there is a great variety of humus-substance horizons as regards the proportions of structureless material and tissue fragments. The studied mor was characterized by having a weakly developed humus-substance horizon, i.e., it contained a relatively large amount of only partially disintegrated material with the tissue structures still preserved. This could be explained by the young age of the mor as well as the poor site and low biological activity.

The tissue remains were mainly composed of pine needles or fragments of pine needles. In the lower F-horizon and in the H-horizon roots and root remnants also occurred.

Table 1. *Thickness in mm of different horizons in the 80 years, 20 years and buried mor. Average of 30 and 15 measurements respectively*

80-year mor	mm	20-year mor and buried mor	mm
Fermentation-horizon (F)	18	Fermentation- and humus-substance horizons (F/H)	13
Humus-substance horizon (H)	13	Clay layer	9
Humus-mixed mineral soil (Ah/E)	10	Covered old mor	9
		Humus-mixed mineral soil (Ah/E)	10

The altered organic matter was very dark brown and gave an amorphous impression. It often occurred as dark clusters at the surfaces of the needles and together with fine roots and fungal hyphae it gave a certain coherence to the mor (Fig. 1). These clusters are considered to be droppings, probably enchytraeid droppings.

Fig. 1. Hand specimen of a pine needle covered with dark altered organic matter. Frame length 3 mm.

Micromorphological properties of the 80-year mor

The organic matter in the studied mor showed a number of different stages of decomposition (Figs. 2 and 11). Close to the surface there were mainly undecomposed but to some extent partially fragmented pine needles, twigs, bark, lichens and mosses. This material is classified as tissue remains. In deeper levels, especially in the humus-substance horizon, the tissue remains succesively became more disintegrated but also more rare. In lower F-horizon and in the H-horizon roots and root remnants occurred.

The fragmentation first and foremost took place from inside the litter either by faunal grazing or by microbiological activity. Faunal activity created cavities which sometimes were empty but which more often contained droppings of the animals. Microbiological activity seemed to result in a successive dissolution of the tissues without any cavities with sharp boundaries or droppings.

In general, the mor was characterized by having

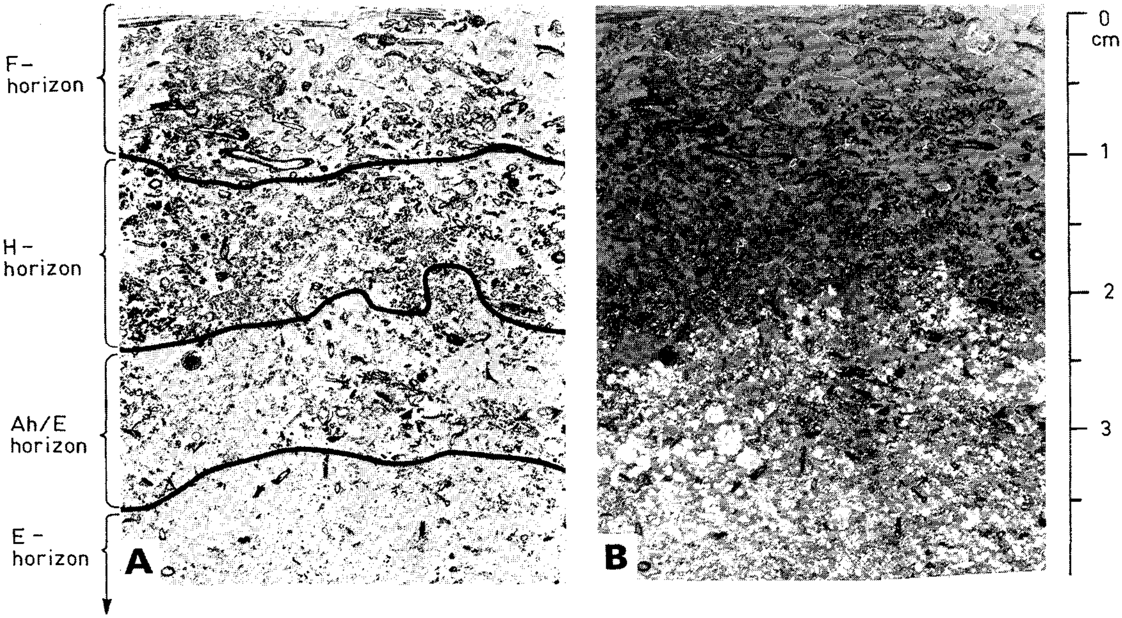

Fig. 2. Vertical thin section from the 80-year mor. Picture A in plain transmitted light and B under crossed polarizers.

the tissue remains distintegrated mainly by microorganisms and not by soil animals. Some parts of the tissue remnants had a very intense black colour, which was always combined with a rich occurrence of hyphae (Fig. 3). Bal (1973) considered the black area to be accumulation of organic plasma as a result of fungal activity and described the process of their formation as melanosis. Plasma includes material of colloid sizes smaller than 2 μm (Bal, op. cit.). Such black material frequently occurs in the thin sections which Hartmann (1965) used to illustrate Pilzhumus, e.g., a kind of humus form in which fungi play an active role. Some of the intensively black-coloured roots were hollow and it is proposed that these were partially decomposed mycorrhizal roots. Babel (1975) similarly demonstrates mycorrhiza mantles to be irregular dark rings.

In addition to plant remains there also occurred decomposed organic material with completely or partially destroyed cellular structure. This soil constituent is classified as altered organic matter and occurred frequently in the humus-substance horizon but also in the fermentation horizon.

In the fermentation horizon the main part of the altered organic matter was light-brown to dark-brown with irregular contours and sometimes attached as large (100–1 000 μm) clusters to needles (Figs. 4 and 5). These clusters were droppings from

Fig. 3. Mycorrhiza root in strongly decomposed condition. The black area is a result of intensive fungal activity. Thin section in plain transmitted light. Frame length 1.6 mm.

Fig. 4. A pine needle with a large cavity and arthropod droppings. Outside the needle there are enchytraeid faeces and fungal hyphae. Thin section in plain transmitted light. Frame length 1.0 mm.

Fig. 5. Enchytraeid faeces. Thin section in plain transmitted light. Frame length 1.0 mm.

enchytraeids or springtails. A complementary study of fresh unimpregnated soil showed that macerated fresh excrements from extracted worms mainly contained the same material as the clusters in thin sections, e.g. mostly fungal hyphae and to a lesser extent small pieces of tissue fragments. The occurrence and distribution of excrements from enchytraeids are discussed by Zachariae (1964) and Babel (1968).

Small egg-shaped pellets (50 mm) of fine fragmented light-brown organic matter sometimes occurred in cavities in needles, bark and roots (Fig. 6). In some cases these droppings from arthropods were considerably aged and clustered together. Typically the pettets had the same light-brown colour as the surrounding tissues on which the animals had grazed. This indicated that the microbiological decomposition in the pellets might be low as otherwise their colour would have been darker. This type of altered organic matter, with very few exceptions, could be found inside the tissues. It is supposed that when the droppings are released they very soon are consumed by animals or become subjected to microbiological decomposition or disintegration through physical conditions. Finally, they are washed down by percolating water water. The amount of these pellets inside tissues is much lower than the amount of enchytraeid clusters outside the tissue residues.

In the humus-substance horizon the altered organic matter principally resembled enchytraeid droppings while fresh excrements from arthropods were absent. However, the altered material was much more predominant compared to the fermentation horizon. It was also darker and occurred as very loose clusters with numerous microaggregates and a granular structure (Fig. 7). The genesis of this kind of altered organic matter is not known with certainty but it is supposed that it consists of aged disintegrated droppings from enchytraeids or springtails or that it is fresh droppings, composed of consumed and strongly decomposed arthropod droppings.

Fig. 6. Mite droppings in a root cavity. Thin section in plain transmitted light. Frame length 0.15 cm.

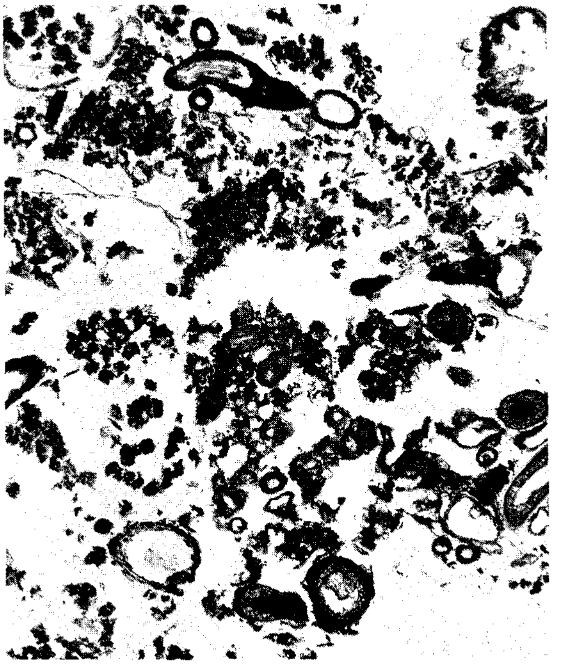

Fig. 7. Microaggregate fabric in the humus-substance horizon. Thin section in plain transmitted light. Frame length 6 mm.

The humus-substance horizon also contained a small number of minor and evenly distributed mineral grains. They were never larger than 300 μm in diameter but mostly within the range of 20–50 μm. It is proposed that they were wind-blown from roads and other areas with exposed mineral soil and that they were finally deposited on the topsoil and enriched in the lower part of the mor.

The distribution pattern in the F- and H-horizons was characterized by relatively large voids and few contacts between the coarse particles (Fig. 2). However, the fine material of altered organic matter sometimes formed bridges between the coarse particles, thus giving the mor a certain coherence (Fig. 8). Within the altered organic material very fine voids occurred. The fabric was enaulic according to Stoops & Jongerius (1975). Referring to Bullock & Murphy (1976), the structure could be characterized as a granular or single-grain structure.

In the humus-mixed mineral soil the tissue remains were composed of root and bark residues. Charcoal frequently occurred in a relatively narrow zone between the humus-substance horizon and the mineral soil (Fig. 9). This was very important as practically no charcoal at all could be found in the F- or H-horizons. The only possible explanation is that the charcoal originates from old forest fires and that the old mor was completely devastated by the fire or that it has decomposed later on. The organic matter above the charcoal consequently has to be dated to the time after the fires. This explanation is of a very great significance when humus formation over time is discussed.

The main parts in the humus-mixed mineral soil were altered organic matter and mineral grains. The former was closely related to the loose clusters in the humus-substance horizon but could be described as still more loose or disintegrated. However, organic microaggregates were observable. In this granular structure, mineral particles occurred as single grains or in a loose association with organic matter resulting in kinds of organic bridges between mineral grains (Fig. 10).

The quantification revealed substantial differences between the horizons (Table 1). The fermentation horizon was characterized by a large proportion of tissue remains, no mineral grains and high porosity. In the humus-substance horizon the amount of tissue remnants was lower while the amount of altered organic matter was higher. Very few mineral grains and charcoal pieces occurred, the latter only in the lower part of the horizon. The humus-mixed mineral horizon contained only a small amount but strongly altered organic matter. The pore area was much lower compared to the F-and H-horizons.

The proportion of altered organic matter compared to total organic matter (charcoal and living roots excluded) varied between the horizons. In the fermentation horizon the proportion was 43% while in the humus-substance and humus-mixed mineral horizons it was 67 and 87% respectively. It could thus be concluded that the proportion became higher with

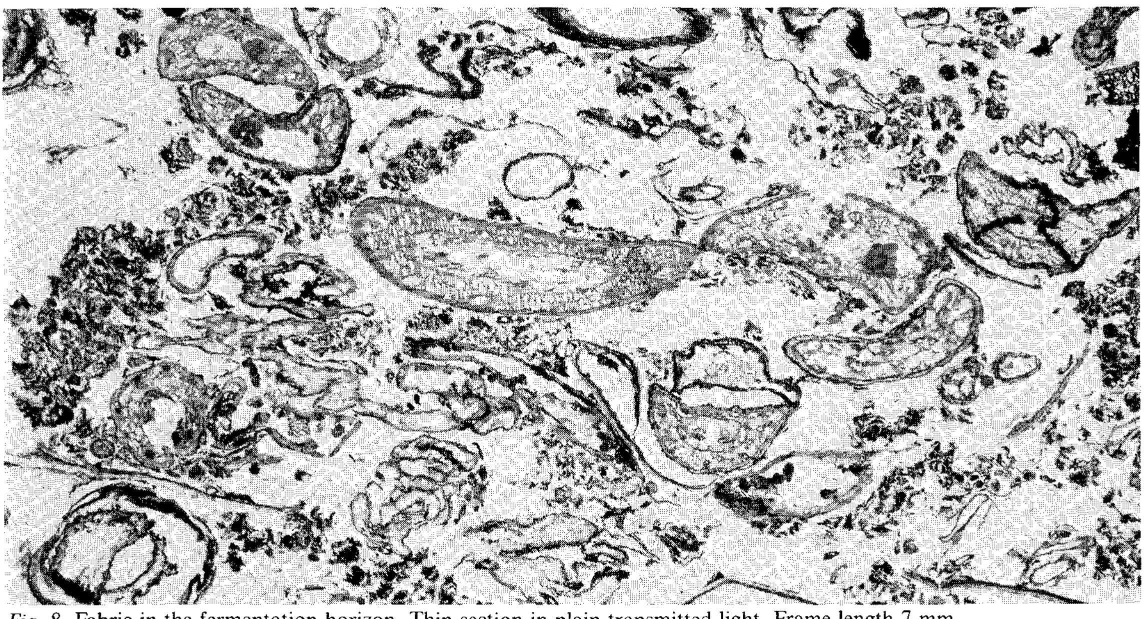

Fig. 8. Fabric in the fermentation horizon. Thin section in plain transmitted light. Frame length 7 mm.

Fig. 9. Charcoal in the humus-mixed mineral soil. Thin section in plain transmitted light. Frame length 1.6 mm.

the depth in the soil. This result is in accordance with the well-known fact that the proportion of structureless organic matter is higher at deeper levels.

The characteristic distribution of tissue remains and altered organic matter originates from the more complete decomposition in deeper soil levels as a result of longer residence time in the soil as well as more favourable humidity conditions. However, the

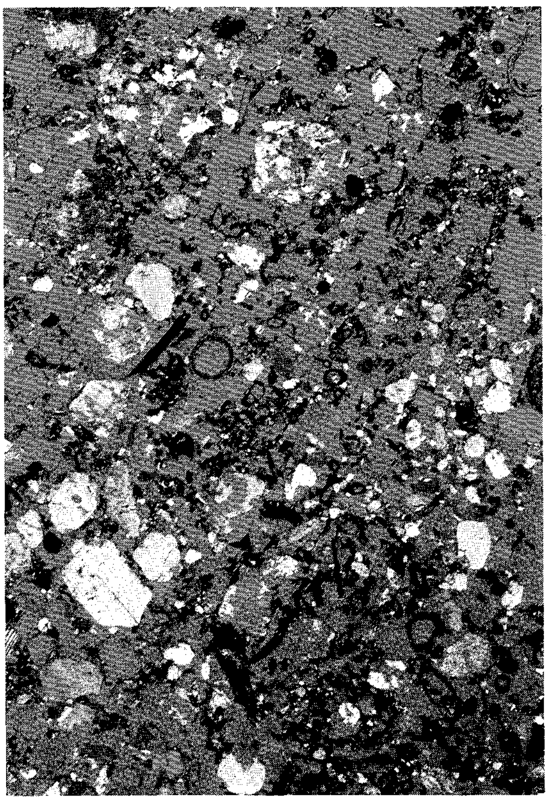

Fig. 10. Fabric in the humus-mixed mineral soil. Thin section in transmitted light under partly crossed polarizers. Frame length 12 mm.

Table 2. *Thickness (mm) and areas of soil constituents (percentage of total area) in different horizons. Analyses of one thin section from the 80-year mor*

	Fermentation horizon (F), mm	Humus-substance horizon (H), mm	Humus-mixed mineral soil, mm
Thickness, mm	12	11	–
Tissue remains, %	17	10	1
Altered organic matter, %	13	20	6
Charcoal, %	0	1	4
Mineral grains, %	1	1	40
Voids and living roots, %	70	69	49
Total, %	100	100	100

micromorphological analysis also revealed that the tissue remains in the fermentation horizon mainly were composed of needle fragments but in the humus-substance horizon and particularly in the humus-mixed soil they mainly were root remnants. Due to the supply of different kinds of litter, the horizons in the mor cannot uncritically be compared to each other regarding properties and genesis. This is especially important regarding conclusions from chemical analyses.

The results indicated that it might be possible in an objective way to estimate the degree of biological activity in soil with micromorphological analyses. It is assumed that a high activity involves a thin fermentation horizon in combination with high proportions of altered organic matter. It is necessary also to take the type of activity into consideration, i.e., what kind of organisms occur.

The studied mor was characterized by a relatively low proportion of altered organic matter even in the humus-substance horizon. Besides, the tissue remains mainly were needle fragments. It is concluded that the biological activity was low and predominantly of fungal nature. Few animals were directly feeding on plant remnants. There was evidence of some but only few arthropods feeding inside roots and needles. Fungal hyphae on which enchytraeids or springtails were feeding frequently occurred.

The total pore area was 70% in the fermentation and humus-substance horizons and approximately 50% in the humus-mixed mineral soil. These figures only include voids larger than about 30 μm, i.e., the thickness of the thin section. Smaller voids could not possibly be detected. Some of the voids, particularly in the fermentation horizon, were cell luminas in tissue remains. Although these cell luminas were empty, the cell walls often were intact whereby this kind of void could only take part in gas and water exchange to a small extent. Consequently, it is questionable whether cell luminas should be regarded as voids.

Micromorphological properties of the 20-year mor and the clay-covered old mor

The organic matter in the 20-year mor showed, in similarity with the 80-year mor, a number of different stages in decomposition (Fig. 11). The types of processes or kinds of organisms involved seemed to be the same as in the 80-year mor. In the upper part of the mor there was evidence of small arthropods feeding inside needles. But this kind of activity was low and not of any great significance for the properties of the mor. Fungal hyphae frequently occurred and their activity caused a successive dissolution of plant remnants without leaving any cavities with sharp boundaries or droppings. In general, the mor was characterized by having the tissue remains disintegrated mainly by microorganisms and not by soil animals. Between the tissue remains, altered organic matter in the form of excrements from enchytraeids or springtails could be found. These excrements were, as in the 80-year mor, mainly composed of fungal hyphae.

Although the processes were the same in the old and in the young mor there was a difference in the degree of decomposition or alteration. The main characteristic property of the young mor was first and foremost that the humus-substance horizon was missing and secondly a low proportion of altered organic matter compared to tissue remains (Table 3). The proportion of altered organic matter was only 33% of the total organic matter (living roots excluded). The corresponding values in fermentation and humus-substance horizons in the old mor were 43% and 67% respectively. From this it could be concluded that the degree of alteration was lower in the fermentation horizon in the young mor compared to the old mor. Other important differences between the 80- and the 20-year mors were that the latter had a smaller thickness and a higher porosity (Table 3). In conclusion, the total amount of organic matter and particularly the altered fraction was much lower in the young profile compared to the old.

These results indicate that transformation of plant remnants to altered organic matter is a slow process. During a period of 20 years the litterfall gave rise to a thin mor composed exclusively of a fermentation horizon which was also characterized by a low degree of alteration. After a period of 60 additional years a humus-substance horizon was developed.

In the clay-covered profile the total thickness of the buried horizon of mor and mosses and lichens had

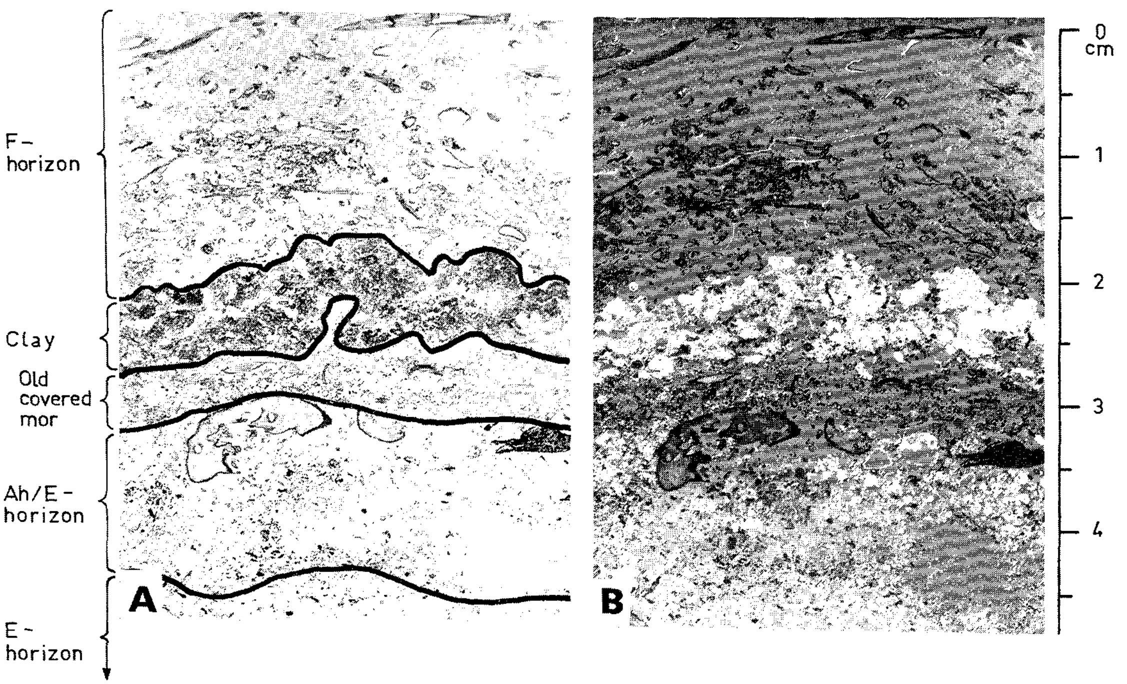

Fig. 11. Vertical thin section from the clay-covered area. Picture A in plain transmitted light and B under crossed polarizers.

Table 3. *Thickness (mm) and areas of soil constituents (percentage of total area) in the 20-year mor and in the clay-covered mor. Analysis of one thin section*

	20-year mor F-horizon, mm	Clay-covered old mor, mm
Thickness, mm	20	5
Tissue remains, %	12	14
Altered organic matter, %	6	29
Charcoal, %	0	1
Mineral grains, %	1	1
Voids and living roots, %	82	56
Total, %	100	100

decreased to about 5 mm. This figure could be compared to a normal total thickness of more than 30 mm in the F- and H-horizons (Table 1). The decrease is caused by reduced supply of litter at the same time as the decomposition processes proceeded. However, only the litterfall was reduced by the clay. Roots were frequently growing in the buried mor and added a substantial amount of litter to the horizon.

The micromorphology of the buried mor was about the same as in the humus-substance horizon with the exception that tissue residues from litterfall, such as needles, were almost completely missing, The reason is that biological activity has transformed plant remnants in the litterfall to altered organic matter without any cellular structure. The proportion of altered organic matter compared to total organic matter (living roots excluded) was 67% (Table 3). Taking the high degree of alteration into consideration, this proportion might seem to be low, but it should be kept in mind that the supply of root litter was rich and that the tissue remains originated from roots.

Some, although very few, pieces of needles could be identified in the buried mor (Fig. 12), which indicated that the needle structure might be preserved for at least 20 years due to the type of biological activity. Bal (1981) gives a short review on this subject and cites some reports which indicate that part of the litter in mor might be recognizable even after 50 years.

Fig. 12. Pine-needles remnants in the old clay-covered mor. Thin section in plain transmitted light. Frame length 8 mm.

Summary

Morphological soil studies of the humus form mor at a pine-heath stand in south Sweden were conducted. The purposes were to describe and to elucidate biological activity on the basis of its morphological properties and to deduce the rate of its genesis. The stand had been exposed to widespread forest fires whereby the existing mor above a charcoal-containing horizon could be age-determined to 80 years. Moreover, in an experiment in 1960 a 10 mm deep layer of clay was laid out covering the soil and ground vegetation. The present new mor above the clay is 20 years old. The study also comprises analyses of this young humus form and of the buried old mor below the clay.

The site was characterized by poor mineral parent material of quartzrich sand, ground-water table below 2 m, ground vegetation mainly of lichens and mosses and finally an orthic podzol.

In macromorphological field analyses the mor was separated into fermetation (F)-, humus-substance (H)- and humus-mixed mineral horizons. During micromorphological studies of thin sections the soil material was separated into different groups and quantified. These groups were tissue remains, altered organic matter, charcoal, mineral grains and voids, and living roots.

The results showed that small arthropods occurred in the F horizon inside plant remnants. Their feeding created cavities in which their droppings could be found. However, this kind of activity was low and not of any great significance for the properites of the mor. Fungal hyphae frequently occurred and their activity caused a successive dissolution of plant remnants without leaving any cavities with sharp boundaries or droppings. The fungal activity often was combined with a black colouration of tissue remnants. In general, the mor was characterized by having the plant remnants disintegrated mainly by microorganisms and not by soil animals. Altered organic matter in the form of excrements from enchytraeids or springtails could be found between tissue remains in the F- and H horizons. These excrements were predominantly composed of fungal hyphae. In the humus-mixed mineral soil the humus and the mineral grains occurred mainly as separate particles but sometimes together in a loose arrangement. The organic matter in this horizon was similar to the altered organic matter in the H horizon but still more disintegrated.

The studies showed that the formation of a fermentation horizon was a rather fast process which took place during less than 20 years although the fermentation horizon did not reach its final thickness during that period. The proportion of altered organic matter was much higher in the 80-year mor compared to the 20-year mor. The formation of a humus-substance horizon was a very slow process and a 20-year period was not enough to develop this horizon.

The buried mor formed a very thin horizon due to the absence of litterfall and proceeding decomposition activity. Some pieces of needles occurred in the horizon, indicating that the needle structure might be preserved at least 20 years due to the type of biological activity.

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