THIRD INTERNATIONAL WORKING-MEETING ON SOIL MICROMORPHOLOGY
WROCŁAW, 1969

ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1972 z. 123

A comparative micromorphological study of light and medium textured podzols

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1. INTRODUCTION

Micromorphological studies have shown that the A_2 horizon of typical sandy podzols is characterized by a bleached sand fabric whilst in the B_2 a chlamydomorphic fabric is present and occasionally agglomeratic and intertextic types are observed [1, 4, 7, 8, 11-13]. Most of these micromorphological studies have been confined to the typical Podzols developed on sandy materials. Conry, de Coninck and Bouma [3] have studied the micromorphological properties of medium textured podzols (with less than 20% clay and 25 to 45% silt). These studies showed distinct macro- and micromorphological differences in the characteristics of the eluvial and illuvial horizons.

The present study discusses the micromorphological differences between some medium-textured podzols from Ireland and light-textured podzols from Belgium, and endeavours to correlate field properties with micromorphological observations.

2. TERMINOLOGY

To facilitate the study, some new terms were added to Brewer's [2] terminology to explain the specific features observed. Brewer proposed four terms — granular, intertextic, agglomeroplasmic and porphyroskelic — to describe the specific arrangements in the basic structure of the s-matrix. Two new types have been introduced to describe the related distribution pattern.

(a) *Phyric related distribution. The randomly distributed sand-sized skeleton grains occur in a dense, compact matrix of silt-sized skeleton grains with small amounts of plasma.*

The matrix formed by the silt-sized skeleton grains interspersed with the coarser skeleton gives a prophyroskelic aspect to the related distribution. However, plasma is not recognizable even though granulometric analysis indicates the presence of small but significant quantities of clay and so the related distribution could be considered as granular [2]. In thin-sections, such an s-matrix has a compact appearance which is primarily due to the close packing of the inequigranular skeleton grains. Simple packing voids are only recognizable under high magnifications. These horizons have a firm consistence in the field.

(b) *Chlamydomorphic related distribution. The plasma occurs as uniform coatings covering the skeleton grains or pedological features* [7].

This type of related distribution is frequent in spodic horizons. In Brewer's [2] terminology, these could be described as free grain cutans but the term chlamydomorphic related distribution is considered more descriptive for the arrangement pattern in these s-matrices.

In well developed spodic horizons, the chlamydomorphic related distribution can grade to a porphyroskelic type. The following sequence: granular → chlamydomorphic → intertextic → porphyroskelic — is possible with increasing plasmic material. In the field such a sequence will be characterized by an increasing firmness in the consistence. As a thin-section may show one or more related distribution patterns, the convention adopted is to express the dominant last e.g. "agglomeroplasmic-chlamydomorphic", where the chlamydomorphic is predominating with smaller amounts of agglomeroplasmic.

Cutans:

Brewer's concept of cutans incorporates both separations and concentrations and this is often confusing to the field pedologists. Consequently, cutans here only refer to plasma-concentration features and are defined as:

> *Modifications of the texture, structure or fabric at natural surfaces in soil materials due to the concentration of a particular soil constituent.*

Lithopedorelicts:

This term was introduced by Laruelle [10] and defined by Stoops (1968) as:

> *A rock or mineral fragment which shows simultaneously the rock structure and also evidences of pedogenetical transformations or additions.*

Plasmafication:

> *Process by which the mineral or organic matter is converted to plasma.*

3. PROFILE DESCRIPTIONS AND MICROMORPHOLOGICAL OBSERVATIONS

The present study compares the morphological, physico-chemical and micromorphological properties of two uncultivated medium textured podzols (Typic Orthods) from the south-west of Ireland with two uncultivated typical light-textured podzols (Orthod and Humod) from the Province of Antwerp, Belgium. The physico-chemical analysis of the medium textured podzols (profiles 1 and 2) were carried out at Johnstown Castle, Wexford and the light-textured podzols (profiles 3 and 4) were analyzed at Ghent University (Table 1). Each horizon was sampled in the field using Kubiëna boxes and thin-sections prepared by the method of Laruelle [9]. Thin-sections were studied under a polarising microscope and the micromorphological features were described according to Brewer's

Table 1. Physico-chemical analyses of profiles 1, 2, 3 and 4

Profile number and horizons	Granulometric composition (%)				pH	Free Fe_2O_3 (%)	Organic fraction	
	clay	silt	fine sand	coarse sand			C%	N%
Profile 1								
02	7	27	31	35	4.7	0.1	7.0	0.48
A2	11	25	27	37	4.6	0.2	1.1	0.05
B21irh	—	—	—	—	5.0	3.9	4.6	0.18
B22irh	9	23	28	40	5.1	3.2	1.3	—
C	6	17	34	43	5.6	0.3	0.0	—
Profile 2								
01	—	—	—	—	4.3	0.1	30.0	1.15
A2	6	24	30	40	4.4	0.2	0.8	—
B21irh	—	—	—	—	4.5	—	6.0	—
B22irh	7	32	25	36	4.6	4.7	2.5	0.11
C	5	25	26	44	5.1	0.3	0.8	—
Profile 3								
01	0.8	9.6	72.3	16.3	3.7	—	—	—
A2	0.8	13.2	71.2	14.9	4.2	—	0.4	—
B21h	2.9	8.7	70.3	18.2	4.3	0.1	2.5	—
B22irh	2.2	9.8	72.2	17.1	4.6	0.5	2.9	—
B3ir	1.7	16.2	71.5	9.7	4.8	0.9	0.4	—
C	1.0	12.3	76.1	10.7	4.9	0.4	—	—
B'2t	3.1	14.9	68.4	12.7	4.8	0.7	—	—
IIB'2t	12.3	29.3	45.0	13.6	4.2	0.3	—	—
Profile 4								
01	2.2	14.9	78.8	6.3	4.6	0.2	—	—
A2	1.5	16.0	78.6	5.4	4.6	0.1	0.1	—
B21h	0.9	12.6	85.0	2.5	4.6	0.1	1.3	—
B22h	1.6	16.5	77.3	6.3	4.6	0.1	1.7	—
B3h	3.5	18.5	76.3	5.2	4.6	0.1	0.4	—
A'2	2.6	24.6	69.2	6.2	4.9	0.2	0.2	—
B'2t	9.5	27.8	66.3	6.0	4.4	0.3	—	—

Table 2. Areal measurements of micromorphological features (expressed as percentage of area of thin section)

Profile number and horizons	Skeleton	Voids	Raw humus	Aggregates	Clusters	Chlamydomorphic coatings	Argillan	Lithorelict
Profile 1								
02	9.6	25.9	59.2	0.0	—	0	0	5.3
A2	66.0	20.1	0.4	1.7	—	0	0.3	11.5
B21irh	18.1	32.0	0.5	42.9	—	2.3	0	4.2
B22irh	29.3	25.2	0.2	21.1	—	4.4	0	19.8
C	61.5	20.5	0.0	0.2	—	0	3.2	14.6
Profile 2								
A2	41.4	10.4	0	0	—	0	0	48.1
B21irh	8.8	30.2	0.4	36.5	—	3.6	0	20.5
B22irh	7.5	26.5	0.6	33.6	—	5.4	0.4	26.0
C	39.0	15.7	0.3	0.2	—	0.4	5.3	39.1
Profile 3								
A01	23.0	40.5	36.5	—	0	0	0	0.5
A2	54.0	35.5	8.0	—	0	0	0	0.5
B21h	42.5	27.4	1.9	—	21.6	6.5	0	0.1
B22irh	35.0	22.5	3.1	—	21.1	17.9	0.4	0
B3ir	61.9	24.5	0		0.7	11.0	2.0	0
B′2t	59.4	35.4	0		0	0	6.0	0
IIB′2t	50.0	25.2	0		0	0	24.8	0
Profile 4								
A2	48.2	44.2	2.8	—	4.6	0.2	0	0
B21h	39.0	38.0	2.0	—	19.6	1.4	0	0
B22h	41.8	29.2	4.0	—	8.4	13.0	2.6	0
B3h	49.0	28.2	3.8	—	4.6	11.2	3.2	0

[2] terminology, with some modifications and additions. Areal measurements of the micromorphological features were made by counting 1,000 points per thin-section, using a point-count analyser [5]. The areas are expressed as percentages (Table 2) and plotted as depth functions (Fig. 1).

MEDIUM-TEXTURED PODZOLS

Profile 1

Location: Ballycasheen Wood, Killarney, Co. Kerry, Ireland (67/1 U1).

Topography: rolling.

Slope: 20°.

Altitude: 61 m.

Precipitation: 1,500 mm.

Vegetation: Oakwood (*Quercus*) and some Beech (*Fagus*) with undergrowth of Holly (*Ilex*) and *Rhododendron* and field layer of *Luzula sylvatica, Erica cinerea* and *Vaccinium myrtillus.*

Drainage class: well drained.

Parent material: glacial till (with some gravel pockets) composed of coarse grained sandstone, shaly sandstone, shales and slate of the Old Red Sandstone Series.

Classification: Typic Orthod.

Horizon	Depth cm	Thickness cm	Description
01	0-5	5	Peaty sandy loam; partly decomposed plant root remains; black to very dark grey (10 YR 2/1-3/1) with abundant bleached quartz grains; clear smooth boundary to:
A2	5-25/43	20-38	Sandy loam; pinkish grey (7.5 YR 7/2-6/2) to yellowish brown (10 YR 6/4) (the former becomes whitish on exposure to weather while the latter becomes bleached); moderate fine granular structure; moist friable to firm in places; plentiful roots; clear tonguing boundary to B21irh and B22irh.
B21irh	—	0-7½	Occurs in upper part of B2 horizon; intermittant horizon — most strongly developed portions of A2 occur particularly beneath tongues of A2; sandy loam; dark reddish brown (5 YR 3/4) to reddish brown (5 YR 4/4); moist very friable; plentiful roots; gradual boundary to:
B22irh	25-69/76	25-51	Sandy loam; strong brown (7.5 YR 5/8) but colour slightly more intense in places; weak fine granular structure; moist very friable; plentiful roots; gradual boundary through B3 to C.
B_3	69-74/91	5-15	Transitional horizon; clear wavy boundary to:
C	74+	—	Stony sandy loam (with some gravelly coarse sandy pockets); olive grey; structureless; moist firm to hard *in situ* (gravel is loose and friable); no roots; non-calcareous.

Micromorphology

The 01 horizon is characterized by raw humus which is in different stages of plasmafication. The plasmafied raw humus is dark brown to opaque and is present as irregular shaped masses in the intergranular spaces. Fragments of organic matter also occur in association with the plasmafied material. The moder humus forms, 20 to 60 μ in size, are very scarce. The basic structure is characterized by a dominance of voids with relatively few skeleton grains which range in size from silt to coarse sand. Lithorelicts are also present.

The most striking feature of the A_2 is its dense, compact appearance. Skeleton predominates with the silt-sized grains forming a matrix in which the coarser sand-sized skeleton grains and lithorelicts are embedded. Voids are relatively scarce and plasma is not easily recognizable. This

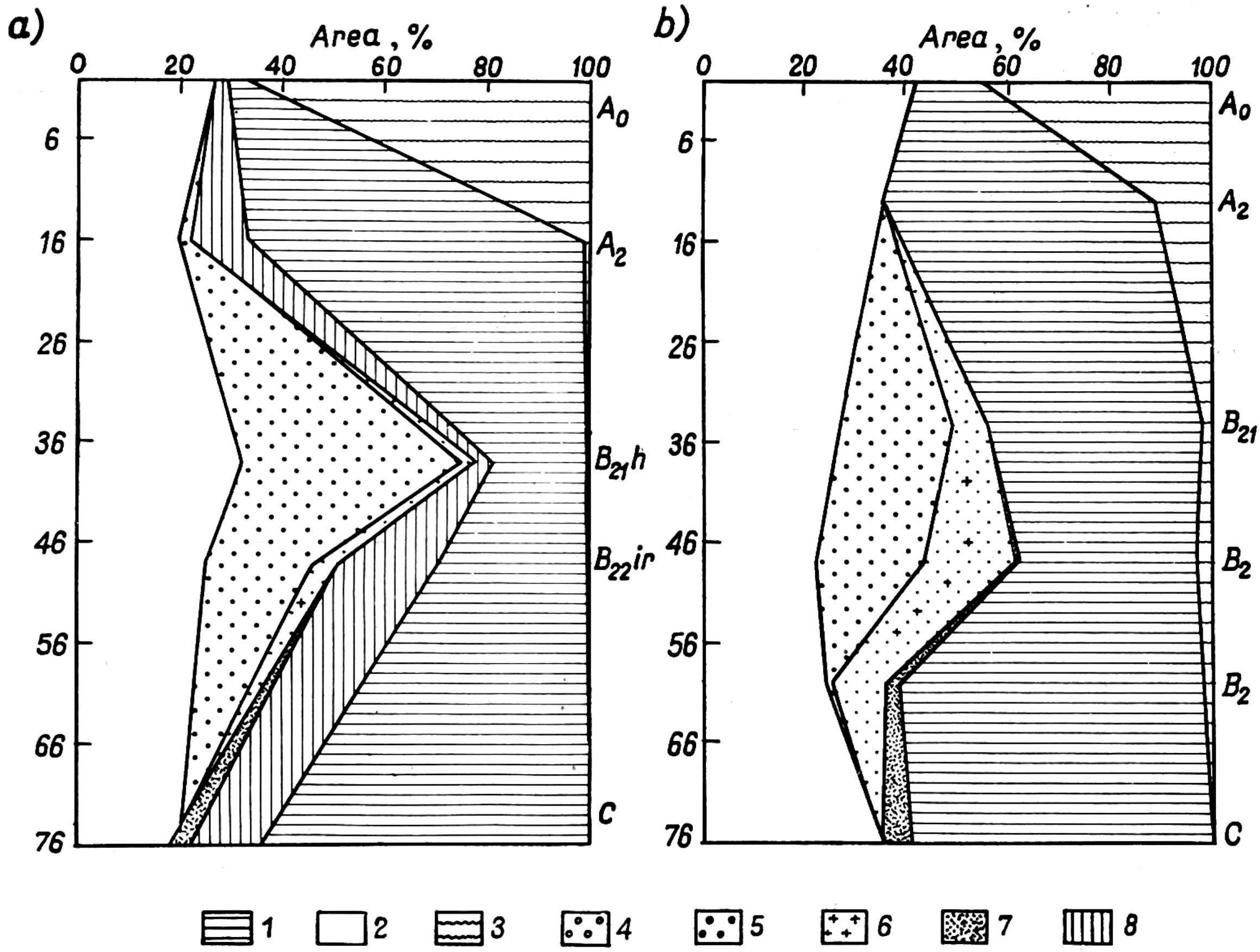
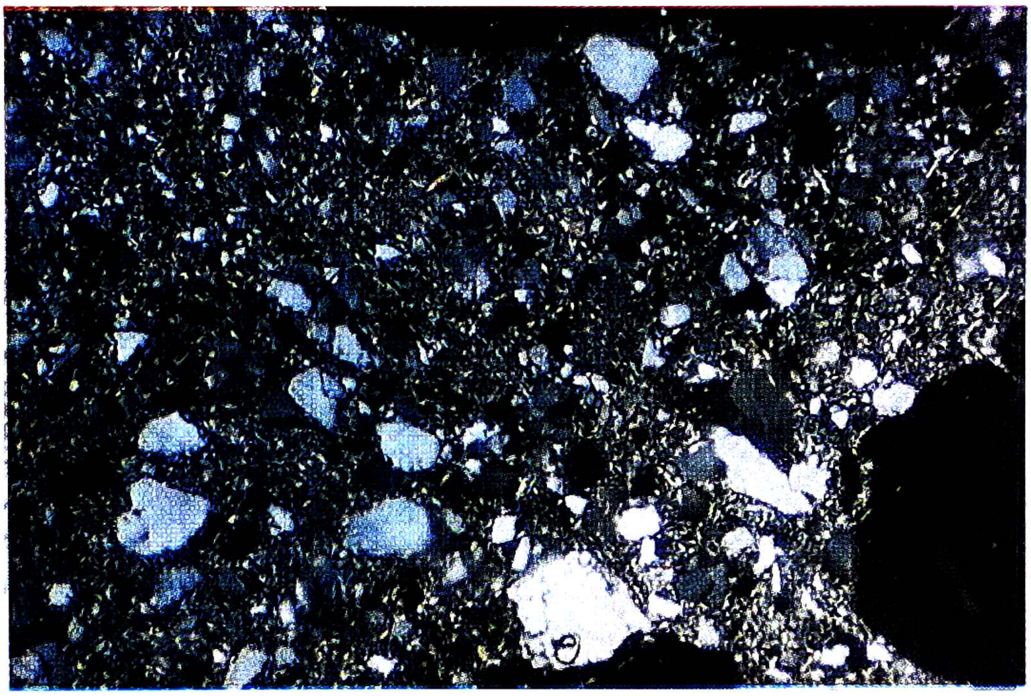


Fig. 1. Distribution of micromorphological features in podzol profiles (data from point-count analysis, Table 2). *a* — distribution of features in profile 1 (medium textured podzol), *b* — distribution of features in profile 3 (light textured podzol); *1* — skeleton, *2* — voids, *3* — raw humus, *4* — aggregates, *5* — clusters, *6* — chlamydomorphic coating, *7* — argillan, *8* — lithorelicts.

type of distribution pattern (Fig. 2) is considered as the central concept of the phyric related distribution. Raw humus shows little evidence of plasmafication. Lithorelicts are common and those containing chlorites and micas have weathered giving rise to lithopedorelicts. Other lithopedorelicts (very few) show the presence of entrapped cutans.

The B_{21irh} horizon is distinctly different from the overlying horizon. The s-matrix appears very loose as a result of the high proportion of packing voids (Fig. 3). In contrast to the pale colours of the A_2, the B_{21irh} is brownish yellow and this is due to the enrichment with plasma. The plasma occurs as aggregates incorporating the silt-sized skeleton grains. These are present as single or welded entities in the packing voids. The coarse skeleton grains and lithorelicts are essentially free of coatings. The related distribution is agglomeroplasmic. The single aggregates are 30 to 100 μ and are generally round. When welded the original form is lost but they usually retain a globular structure and mammilated outline. Fungal hyphae are also present.



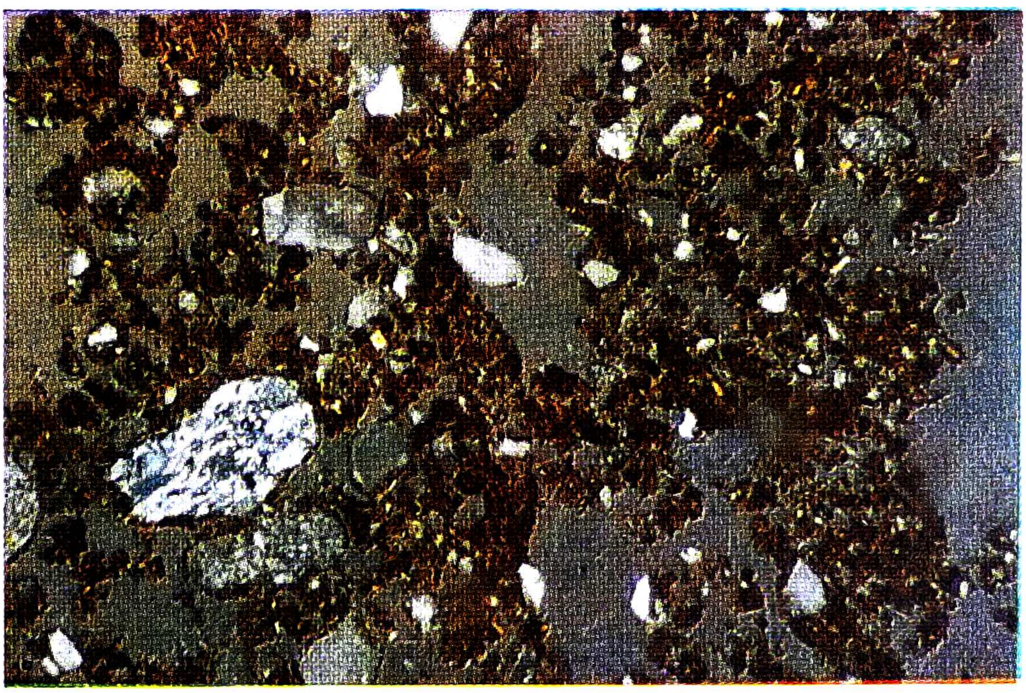


Fig. 2. Phyric related distribution. Note the very dense packing of the skeleton grains. A2 horizon of profile 1; thin-section under crossed polarizers. Magnif. ×4.

Fig. 3. Agglomeroplasmic-chlamydomorphic related distribution. The plasma occurs dominantly as aggregates incorporating silt-sized skeleton grains in the interregular voids with some present cutanically on the coarser skeleton. Note the rather loose packing. B21irh horizon of profile 2; polarizers crossed at 15°. Magnif. ×8.

The B_{22irh} differs in some respects from the B_{21irh}. The colours are less intense and there are more free silt-sized skeleton grains in the s-matrix. This apparent increase in the free silt-sized skeleton grains can be related to the decrease in the number of aggregates in this horizon. The coarse skeleton grains and lithorelicts show some coatings. A few of the coatings are weakly birefringent. The related distribution is chlamydomorphic-agglomeroplasmic.

The C horizon has a similar phyric related distribution as the A_2. The lithorelicts are relatively unweathered with only the chlorite showing any degree of alteration. Moderately oriented channel and vugh argillans are common. Some of the voids also show fine silt-sized skeleton grains occurring cutanically; these are possibly skeletons.

Profile 2-Type 3

Location: Derrycunnihy, Killarney, Co. Kerry, Ireland.

Topography: Broken rolling.

Slope: 6°.

Altitude: 43 m.

Precipitation: 2,250-2,500 mm.

Vegetation: *Quercus*, with second storey of *Sorbus* and *Betula* with some *Ulex* and field layer of *Calluna vulgaris, Vaccinium myrtillum* and *Pteridium.*

Drainage Class: Well drained.

Parent material: Very shallow cover of rubbly glacial till composed of coarse-grained sandstone, shaly sandstone shales and slates of Old Red Sandstone Series.

Classification: Typic Orthod.

Horizon	Depth cm	Thickness cm	Description
01	0-2	2	Partly decomposed litter and root remains.
02	2-10	8	Mostly decomposed plant root remains; black to dark reddish brown (5 YR 2/1 2/2); abrupt smooth boundary to:
A2	10-38/43	28-33	Stony sandy loam; light grey (10 YR 7/2); moderate fine granular tending towards massive structure; moist firm *in situ*; plentiful roots; abrupt boundary to:
B22 irh	38-79	46-51	Sandy loam; yellowish red (5 YR 5/8) with portions of B21irh, having a dark reddish brown (5 YR 3/4) colour; particularly found at base of A2; weak fine granular structure; moist very friable; plentiful tree roots; gradual boundary to:
C	79-86	0-7	Sandy loam; olive brown; structureless; friable or firm; occurs in packets between rocks; abrupt boundary to:
11C	79+	—	Shattered bedrock.

Micromorphology

This profile, compared to profile 1, has a greater number of larger lithorelicts which are more pelitic in composition.

The skeleton dominates the A_2 horizon; there are few voids and plasma is not recognizable. The A_2 has a phyric related distribution and the whole structure has a compact appearance. Several types of lithopedorelicts are present but they do not show the presence of entrapped cutans. Fragments of raw humus are the only forms of organic matter present.

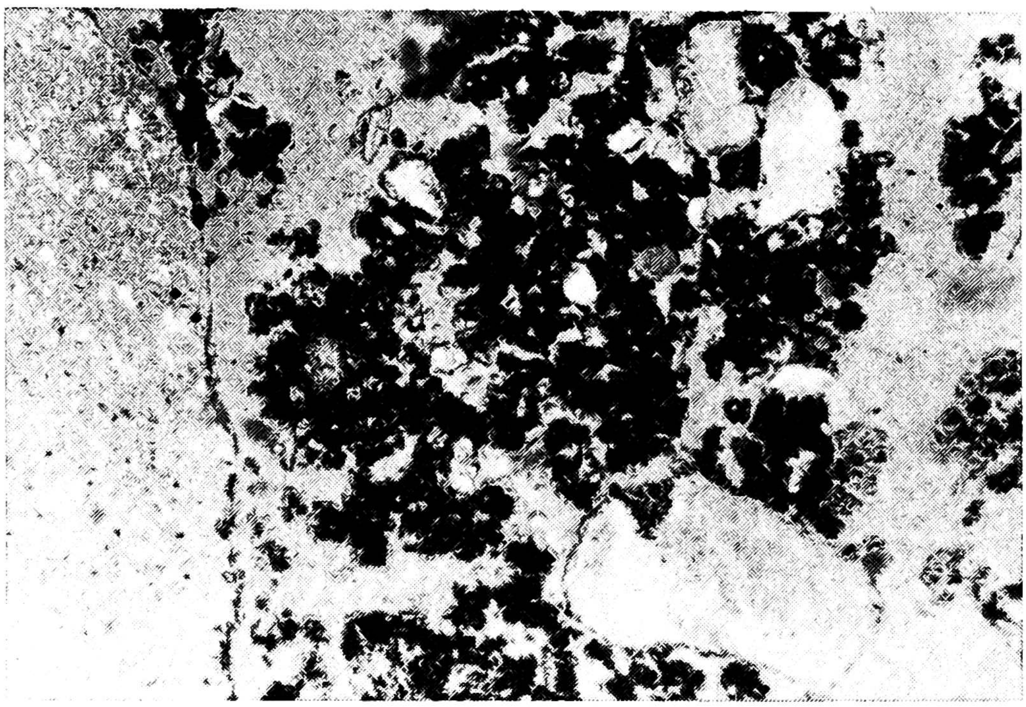


Fig. 4. The organic matter rich plasma is present as aggregates incorporating silt-sized skeleton grains in the inter-granular voids. The lithorelict on the left shows some thin coatings. B21irh horizon of profile 2; polarizers crossed at 15°. Magnif. ×120.

The B_{21irh}, unlike the pale coloured A_2, is dark brownish in colour. The plasma is combined with the silt-sized skeleton grains to give single or welded aggregates (Fig. 4). The coarse skeleton grains are in general devoid of coatings. There is a significant increase in the amount of voids in this horizon (Table 2). Related distribution is agglomeroplasmic with chlamydomorphic very locally developed. Few roots and fungal hyphae are also present.

In the B_{22irh}, the s-matrix appears slightly more compact than in the B_{21irh} but is still considerably looser than in the A_2. Similar phenomena are observed in profile 1 (Table 2 and Fig. 1). Coatings on the coarser skeleton and lithorelicts are more common. The related distribution is chlamydomorphic — agglomeroplasmic. Few roots and fungal hyphae are present.

The C horizon has a phyric related distribution. Few void argillans are present and the amount of skeleton grains are less obvious than in profile 1. The lithorelicts which are large and common, show all gradations from coarse grained quartzitic sandstones to fine grained pelitic slates. In this horizon, only the chlorites show any degree of alteration.

Discussion

In the field, the A_2 horizons have a friable to firm consistence. This was distinctly different from the very friable, fluffy consistence of the B_2 horizons. These features were reflected in the micromorphological properties. The point-count analysis (Table 2 and Fig. 1), shows the dominance of skeletal material in the A_2 and the increase in voids in the B horizons. The B_{21irh} had more voids than the B_{22irh}.

The phyric related distribution with the inequigranular composition and close packing of the skeletal material, gives rise to a very compact s-matrix in the A_2 horizon which correlates well with field observations. The simple packing voids were only visible under high magnifications; channels contribute to the void system. Lithopedorelicts were frequent but only profile 1 had these features with entrapped cutans. Similar distinct properties have been recognised in the A_2 horizons of medium textured brown Podzolic soils in South-west Ireland [3]. The direct relationship between field properties and micromorphological features is evident from Table 2 and Fig. 1. In profile 1 the A_2 with a friable to firm consistence in the field has 20% voids in thin-sections, while the A_2 of profile 2 with a firm consistence has only 10% voids.

The aggregates in the B horizons, which consist of plasma with the silt-sized skeleton grains, occur as single or welded entities in the packing voids. Coatings were also present on some of the coarser skeleton grains and lithorelicts — with more in the B_{22irh} — but these coatings do not form intergranular braces. As a result the s-matrix appears very loose with the different components separated from each other by the interconnected packing voids. This explains the very friable, fluffy consistence of such horizons in the field.

The C horizon is characterised by the phyric related distribution as in the A_2 horizon. In both profiles, the C horizon had significant amounts of illuviation argillans and possibly some skeletons. The argillans in both cases showed little enrichment with iron. In contrast to the surface horizons, the lithorelicts are not subject to any degree of alteration.

LIGHT TEXTURED PODZOLS

Profile 3

Locality: Sheet of Hoogstraten, municipality of Meer, Belgium.
Relief: Subnormal. Microrelief strongly developed.
Slope: 1%.
Altitude: 15 m.
Precipitation: 800-850 mm.

Vegetation: *Calluna vulgaris, Molinia caerulea, Oak, Birch,* Pinus *silvestris,* little *Erica tetralix,* little *Genista* and mosses.

Drainage: Excessively drained.

Parent material: Cover sand, with silty layers in the subsoil.

Classification: Orthod.

Horizon	Depth cm	Description
01	1-0	Slightly altered plant remains and many bleached sand grains.
A2	0-25/30	Dark gray to very dark gray (10 YR 4/ 4/1-31)* sand, humic; structureless, massive; loose; with very dark gray (10 YR 3/1), common distinct, diffuse, medium and coarse patches and strips; abrupt, smooth boundary.
B21 h	25-30/40	Very dark gray (5 YR 3/1) sand, very humic; many bleached sand grains; structureless, massive; firm; with few, bleached A2 horizon patches; abrupt, irregular boundary, coinciding with a very hard, reddish-brown (5 YR 2/2), thin iron pan, underlying a distinct rootmat.
B22 irh	30/40-50	Sand, variegated; matrix very dark brown (7.5 YR 2/2); with yellowish-red (5 YR 4/6) little spots and horizontal strips just underneath the iron pan and dark yellowish-brown (10 YR 3/4) brown (10 YR 5/3) and dark brown to very dark gray (7.5 YR 3/3) patches; structureless, massive; friable (dark parts), loose to very friable (light parts); gradual, wavy boundary.
B3 ir	50-75	Mottled sand: matrix yellowish-brown (10 YR 2.5 Y 5/4); structureless, massive; friable; non-stratified; with many, distinct, medium and coarse, diffuse to clear, very hard mottles, reddish-brown (7.5-5 YR 4/4), with many black spots and faint stratification; clear, irregular to broken boundary. Remark: mottles form a discontinuous B2ir hor.
C	75-80	Yellowish brown (10 YR-2.5 Y 5/4) sand; structureless, massive; friable; nonstratified; with (1) brown to dark brown (10 YR 3/3-3/4) humic patches; (2) common, faint, little to coarse, diffuse, firm, dark yellowish-brown (10 YR 4/4) stratified patches; abrupt, wavy boundary.
B′2t	80-90/95	Pale brown (10 YR 6/3) sand; structureless, massive; loose; with many, prominent, medium and coarse, sharp, firm, strong brown (7.5 YR 5/6), stratified patches locally occupying the largest part of the horizon; the strong brown patches form the remnants of a former continuous B2t-hor.; abrupt, smooth boundary.
II B′2t	90/95-100/105	Variegated light sandy loam; light gray (2.5 Y 7/2) (type 1); light brownish-gray (2.5 Y 6/2; type 2); strong brown (7.5 YR 5/8) (type 3); structureless and massive; composition and consistence: (1) friable, nonsticky and non-plastic; (2) more clayey because of thin irregular clayey channels, friable to firm, slightly sticky and slightly plastic, with many dead roots; (3) friable to firm, nonsticky and non-plastic; abrupt, smooth boundary, accentuated by a very hard iron pan.

* Colours are given in wet conditions.

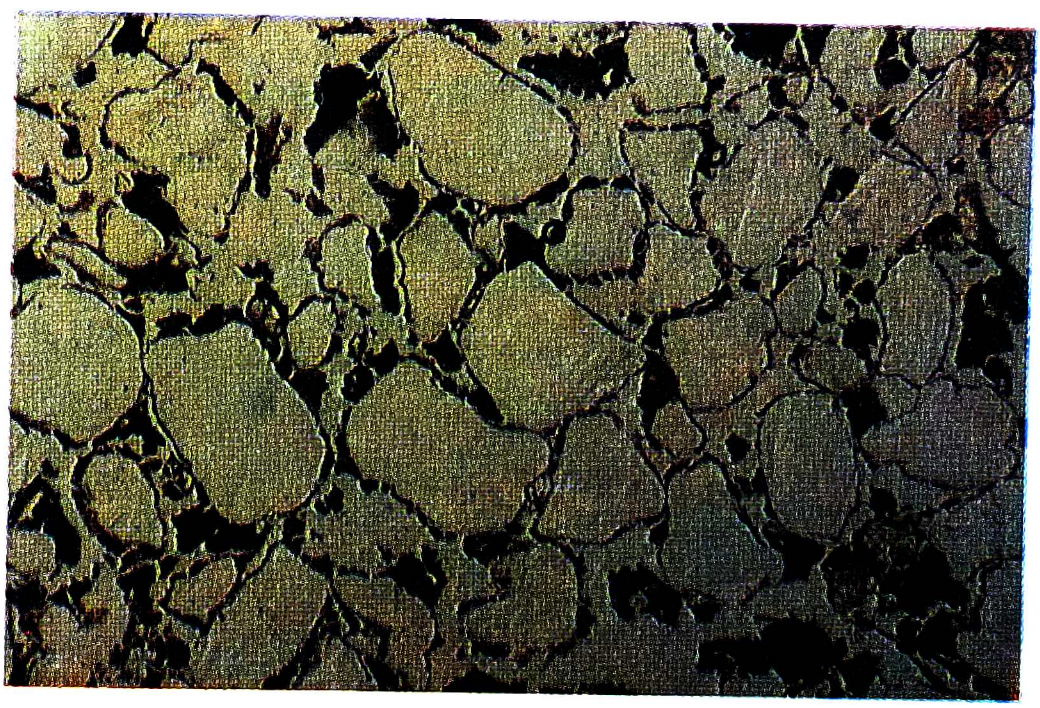


Fig. 5. Discontinuous coatings on skeleton grains and clusters of plasmafied organic matter adhering to skeleton grains. B22irh horizon of profile 3; thin-section in plain light. Magnif. ×10.

Horizon	Depth cm	
III C	100+	Yellowish-brown (10 YR 5/4) sand, stratified, structureless, massive, very friable; with irregular strong brown (7.5 YR 5/8) argillic bands.

Micromorphology

The sparsely distributed skeleton in the 0_1 is composed mainly of quartz with some plagioclase and microcline. The intergranular voids contain fragments of raw humus particles which are in various stages of plasmafication. Clusters of plasmafied organic matter often with a moder humus aspect are also present. Some of the plasmafied material adheres to the skeleton grains. The moder form of humus is very locally represented and usually confined to channels.

In the A_2, the s-matrix is very loose with plenty of simple packing voids. Clusters of plasmafied organic matter are fewer and darker in colour than the 0_1 horizon and usually adhere to the skeleton grains. Related distribution is typically granular.

The simple packing voids of the B_{21h} are partly filled with irregular shaped clusters of plasmafied organic matter. A few, however, are rounded and appear like moder humus. The skeletal material is not incorporated in these clusters. The clusters, which range in size from 20 to 60 μ, often adhere to the skeleton grains and consequently many of the skeleton grains show discontinuous coatings. The related distribution is in general agglomeroplasmic. Chlamydomorphic, weakly intertextic and even granular related distribution are locally present.

The colour of the plasma in the B_{22irh} is more reddish than the dark brown to opaque B_{21h}. The skeleton grains are almost completely coated by the plasma and these coatings frequently show shrinkage cracks (Fig. 5). The coatings of adjoining grains often form intergranular braces. Clusters of the plasmafied organic matter are locally present in the s-matrix. The binding of the skeleton grains by the intergranular braces gives a decrease in the quantity of simple packing voids and hence a more compact appearance to this horizon. Related distribution is intertextic-chlamydomorphic with little agglomeroplasmic.

The colour of the plasma in the B_{3ir} is pale reddish yellow and is essentially isotropic. The plasma occurs as continuous coatings on the skeleton grains and these often show compound cutanic features. In the compound cutans, the inner layer is birefringent whilst the outer sesquioxidic rich layer is isotropic but in the latter layer a weak birefringence may sometimes be observed under high magnifications. Related distribution is chlamydomorphic but in some parts intergranular braces give an intertextic type.

The C horizon resembles the A_2 except that the skeleton grains have a very thin coating of birefringent clay. In the deeper horizons — B'_{2t} and IIB'_{2t} — all the skeleton grains have illuviation-free grain argillans and some have intergranular braces. This feature is similar to the plectoamitic elementary fabric of Kubiëna [7]. In the IIB'_{2t}, bands of such illuviation features are found and also this horizon is characterised by a greater amount of fine skeleton grains. The related distribution in these bands is typically porphyroskelic. These bands are highly enriched with iron, giving dark red colours, whilst the zones above and below are iron deficient.

Profile 4

Location: Sheet of GEEL, Municipality of GEEL (Southern Campine).

Topography: Low ridge, along a depression, about 1 m above the bottom of this depression.

Slope: ±5%.

Altitude: 17 m.

Precipitation: ±800 mm.

Vegetation: Plantation of *Pinus laricio corsicana,* with *Genista, Calluna vulgaris, Molinia caerulea.*

Drainage class: Excessively drained.

Parent material: Cover-sand with greenish colour, and few glauconite grains.

Classification: Humod.

Horizon	Depth cm	Description
01	-3-0	Slightly and non-decayed needles, over a thin layer of more decomposed plant remains; weak platy structure; abrupt, wavy boundary.
A2	0-10/15	Grey (10 YR 6-5/1, dry) dark grey to very dark grey (10 YR 4-3/1, wet) fine sand; structureless, massive; loose; clear, wavy boundary.
B21 h	10-20/25	Very dark brown (10 YR 2/2, dry), black to very dark brown (10 YR 2/1-2, wet), fine sand; structureless, massive; friable, with many bleached sand grains; with common, distinct, diffuse, coarse spots, filled with A2 material; many roots, especially in the A2 spots; gradual, irregular to broken boundary, with few tongues down to the bottom of the B_{22h}.
B22 h	25-40	Yellowish brown (10 YR 5/6, dry), dark brown (7.5 YR 3/4, wet) fine sand; structureless, massive, to thin platy, very weak; friable; with many, distinct, medium, diffuse, white to very pale brown (10 YR 8/2-3, dry), yellowish brown (10 YR 5/6, wet) and brown (10 YR 5/3, dry) dark brown (10 YR 3/3, wet) loose spots; most roots in the loose spots; diffuse, smooth boundary.
B3 h	40-55	Light yellowish brown (10 YR 6/4, dry), dark yellowish brown (10 YR 4/4, wet) fine sand; structureless, massive; friable; with

Horizon	Depth cm	
		common, distinct, medium, diffuse, white to very pale brown (10 YR 8/2-3), dry), yellowish brown (10 YR 5/6, wet) and brown (10 YR 5/3, dry), dark brown (10 YR 3/3, wet), loose spots; more roots than in B_{22h}; diffuse, wavy boundary.
A'2	55-70	Pale yellow (2.5 Y 8-7/4, dry), light olive brown (2.5 Y 5/6, wet) fine sand; structureless, massive; with (1) locally, few, faint, 3 to 4 mm thick, sharp, light yellowish brown to light olive brown (2.5 Y 6/4-5/6, wet) firm clayey bands; (2) common, faint, fine and coarse, clear, light olive brown (2.5 Y 5/6, dry) (2.5 Y 5/6; wet) clayey spots with faint mottling; abrupt, irregular to broken boundary.
B'2t	70-90/100	Clayey sand, mottled: (1) brownish yellow (10 YR 6/8, moist), yellowish brown (10 YR 5/8, wet); (2) pale yellow (5 Y 7/4, moist and wet); (3) white (5 Y 8/1, moist), pale olive (5 Y 6/3, wet); structureless, massive; very firm; no roots, except in rootmats; gradual, wavy boundary.
C	+90	Pale yellow (5 YR 7/4, moist), pale olive (5 Y 6/4, wet), loamy sand; structureless, massive; friable.

Micromorphology

The A_2 is characterised by a typical granular related distribution. Plasmafied organic matter is scarce and occurs as irregular shaped clusters adhering to skeleton grains.

The dark brownish yellow to opaque plasmafied organic matter which is present in large quantities in the B_{21h} has a more regular shape than that in the B_{21h} of profile 3. The pellet-like structures vary in size from 20 to 50 μ. The distribution of the plasmafied organic matter in the s-matrix is random but there is a tendency for it to accumulate in channels which have a horizontal to subhorizontal referred distribution pattern (Fig. 6). The plasmafied organic matter also tends to occur as discontinuous coatings on some skeleton grains. Related distribution is agglomeroplasmic.

The pellet-like plasmafied organic matter seen in the B_{21h} is almost completely absent in the B_{22h}. The plasma, which is also almost entirely organic, occurs as coatings on skeleton grains resulting in a typical chlamydomorphic related distribution. On some grains, however, there is a difference in the colour of the coatings — the outer part is dark, sometimes opaque whilst the inner is light yellow to brownish yellow and frequently shows weak birefringence. This suggests that the plasmafied organic matter is coating and invading former free-grain argillans. Coatings of adjoining skeleton sometimes form inter-granular braces.

In the B_{3h} horizon, the coatings are almost completely of illuviated clay with some enrichment of organic matter giving brownish colours.

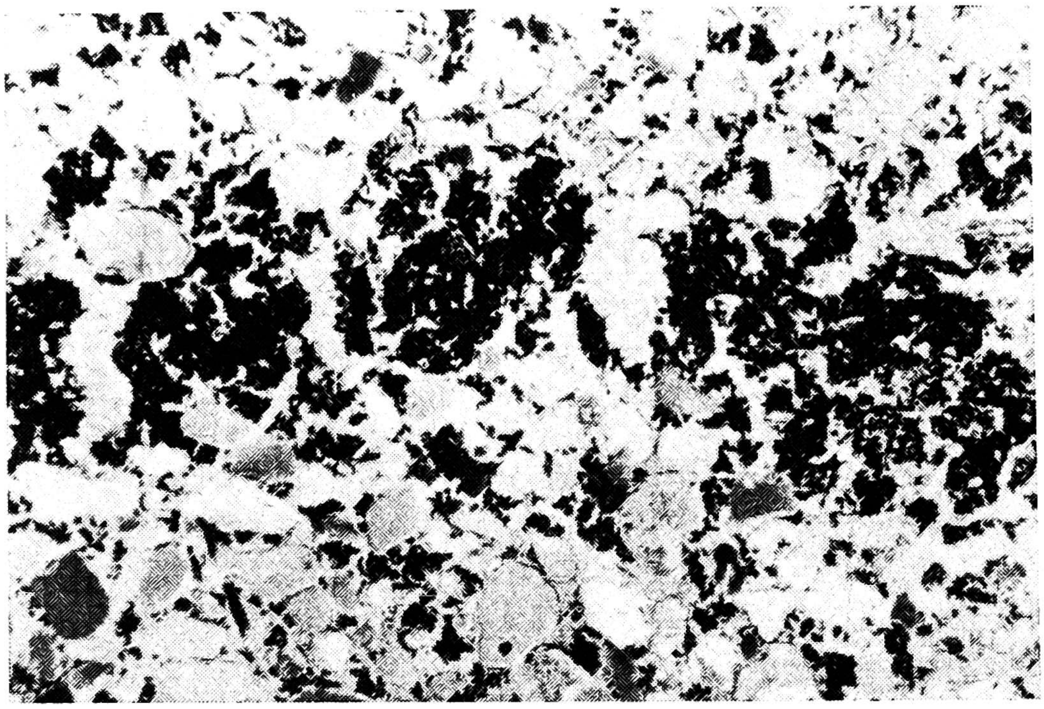


Fig. 6. Clusters of plasmafied organic matter in horizontal channels. B21h horizon of profile 4; thin-section under plain light. Magnif. ×120.

The amorphous organic matter frequently forms a distinct layer on the argillan resulting in a compound cutanic feature. The simple illuviation-free grain argillans have strong birefringence indicating that the enrichment with organic matter and iron is not intense.

Discussion

Field observations indicated that the A_2 was structureless and had a loose consistence whilst the B_2 was friable to firm in general. The micromorphological study and the point count analysis (Fig. 1) showed that the A_2 has a granular related distribution, little plasma and an equal quantity of voids and skeleton grains. The loose basic structure was very evident in thin-sections and correlates well with the loose consistence observed in the field.

The B_{21} horizons had plasmafied organic matter which often adhered to skeletal surfaces. Plasmafied organic matter forms weak inter-granular braces in these horizons. The B_{22} horizons, however, have a typical chlamydomorphic related distribution with frequent formation of inter-granular braces. The point count analysis showed a decrease in voids in this horizon and as a result of all these features, the s-matrix has a compact appearance. The friable to firm consistence of this horizon in the field is attributed to the related distribution patterns observed in thin-sections.

Both profiles studied are bisequa with textural B horizon in the lower sequum. It was also noted that in the B_{22} and B_3 horizons, the chlamydomorphic related distribution was largely due to enrichment of free grain argillans with organic matter or sometimes iron and these frequently result in compound cutanic features.

4. GENERAL DISCUSSION

The two groups of profiles showed distinct differences in the field. The A of the medium textured profiles were firm or firm to friable whilst those of the light textured profiles were loose and structureless. The B_2 horizons of the medium textured profiles were loose and fluffy whilst in the case of the light textured profiles they were firm to friable.

These distinct differences in consistence have been attributed to the related distribution pattern of the basic structure i.e. the relationship between the plasma, skeleton and voids. The A_2 and C horizons with a phyric related distribution exhibit a firm or firm to friable consistence in the field. This results from the dense packing of the inequigranular skeleton grains. When the sand-sized skeleton grains dominate the skeletal composition of the s-matrix with considerably less silt-sized fractions as in the sandy podzols, these horizons have a loose consistence in the field. The dominant voids in the phyric type consist of channels whilst in the granular type simple packing voids predominate.

In the B_2 horizons of the medium textured Podzols, the aggregates, composed of plasma with silt-sized skeleton grains, and the coarser skeletal materials exist as separate entities in the s-matrix. The s-matrix has a loose appearance because the plasma does not bind these entities together; these horizons have a very friable to fluffy consistence in the field.

The B_{21h} of the light textured profiles had clusters of plasmafied organic matter in the intergranular voids with a very weak development of intertextic related distribution. The B_{22irh} and B_{22h} had essentially chlamydormophic related distribution with intertextic less strongly developed. The degree of development of the intertextic related distribution is related to the firmness of these horizons in the field. In contrast to the medium textured profiles, there is a decrease in the quantity of voids in the B horizons with respect to the A_2, of the light textured profile (Fig. 1).

The origin of the aggregates in the medium textured profiles and the clusters of plasmafied organic matter in the light textured is not very clear. Several features indicate that biological activity could play an important role in the formation of these B horizons. The field observations indicate a greater quantity of roots in the B horizons in contrast to the A_2 and C horizons. In thin-sections, decaying roots, some with root moder, fungal hyphae and some discrete moder humus are present. These indicate that the horizon is conducive to biological activity. Further, the clusters of plasmafied organic matter in the light textured profiles showed a tendency to accumulate in horizontal to subhorizontal channels; in addition, the aggregates in the medium textured Podzols had the general morphology of moder humus which had been subject to several cycles of formation. The increase in voids of the B horizons when compared to the A_2 (Table 2 and Fig. 1) in the medium textured profiles could be attributed to a biological loosening of the s-matrix. Hence there is strong evidence that the aggregates and clusters may be of biological origin. Jongerius [6], de Coninck and Laruelle [4], Righi and de Coninck [14], Conry, de Coninck and Bouma [3], have also attributed a biological origin to similar features.

The formation of organic and sesquioxidic cutanic and compound cutanic features especially in the B_{22h} and B_{22irh} suggests a physico-chemical process. These illuvial coatings are in some instances invasions of former argillans as also observed by Altemüller [1] and Eswaran [5]. Hence a chlamydomorphic related distribution is dominant in the B_{22ir} of the light textured podzols with a bisequal profile; in the medium textured profiles, where illuviation argillans were in insignificant quantities, the chlamydomorphic is poorly expressed and only developed locally.

From the present evidence, it appears that aggregates in the medium textured podzols and clusters of plasmafied organic matter in the light textured podzols are largely due to biological activity. In the lower B_2 horizons, especially in the light textured profiles, the micromorphological properties can be attributed to physico-chemical processes. In this respect, the medium textured podzols are considered to be less intensely podzolised.

SUMMARY

Field studies of some free-draining podzols in Ireland (medium textured) and Belgium (light textured) indicated a difference in the morphology of the various horizons. The A_2 horizons of both groups of profiles were well developed and bleached but the Irish podzols showed a dense compact consistence which was distinctly different from the loose consistence of the typical sandy podzols in Belgium. The B_2 horizons of the Irish podzols were fluffy and more friable than the overlying A_2 whilst the Belgian profiles had a firmer B_2.

To facilitate the study some new terms were added to Brewer's [2] terminology to explain the specific features observed. These are:

Phyric related distribution: the randomly distributed sand-sized skeleton grains occur in a dense compact matrix of silt-sized skeleton grains with small amounts of plasma.

Chlamydomorphic related distribution: the plasma occurs as uniform coatings covering the skeleton grains or pedological features [7].

The compact consistence of the A_2 horizons of the medium textured podzols was attributed to the dense matrix formed mainly by the silt-sized skeleton grains in which the coarser sand-sized skeleton grains and lithorelicts were embedded giving the basic structure a porphyroskelic appearance. The salient features are the inequigranular composition and the

compact nature; such a related distribution has been described as phyric. In contrast, the A_2 of the light textured profiles showed the typical, granular related distribution.

The B_2 horizons in both cases were also strikingly different. The light textured profiles had a typical chlamydomorphic related distribution, with aggregates of organic matter in the simple packing voids of the B_{21h}. In the B_{22irh} the aggregates were lacking and the related distribution was dominantly chalmydomorphic with intertextic locally developed. In contrast, the chlamydormorphic related distribution, in the medium textured profiles, was poorly developed and in many cases the skeleton had only partial coatings. The plasma of the illuvial horizons in these latter profiles occurred in the form of aggregates in which the silt-sized skeleton grains were embedded. The related distribution was agglomeroplasmic. The plasma had the appearance of faecal pellets which occurred singly or as welded aggregates. The B_2 of the medium textured profiles showed a greater degree of biological activity in the form of faecal pellets and fungal hyphae. The origin of these aggregates is not clear but has been attributed largely to biological activity though illuvial organic matter and sesquioxides may also play an important role.

Acknowledgement. We would like to thank Dr. G. Stoops, of Ghent University for helpfull discussions.

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