MICROMORPHOLOGICAL ASPECTS OF SOME PODZOLS IN THE PARIS BASIN (France)

A.M. Robin[(1)] et F. de Coninck[(2)]

I. INTRODUCTION

The podzols of two typical forests have been described in this study : the Fontainebleau Forest and the Villers Cotterets Forest. All of these podzols have been developed in a sandy parent material : Stampian (marine deposits of Oligocene age) or recent windblown sands at Fontainebleau, sands of Beauchamps (marine deposits of Eocene age), Stampian and windblown sands at Villers Cotterets. In each forest several stages of soil development have been recognized, forming a continuous evolution sequence and belonging to two groups of soils : podzols of "broad-leaved forests" with friable B horizons (podzols de feuillus) and podzols with cemented B horizons (podzols aliotiques) (ROBIN, 1970).

In the field, those two forms of podzols are distinguished by the nature of the accumulation horizons : the first have a very friable consistence without cementation and with light colors (5YR 4,5/12,5) and an even distribution of the roots, gradually decreasing with depth. In the second case, the consistence of the B horizons is much firmer and cemented, colors are darker (5YR 2.5/1); the roots stop abruptly in the upper part of the horizon but

(1) Laboratoire de Geologie Dynamique, Université Pierre et Marie Curie4 Place Jussieu, 75230 PARIS Cedex 05 -France.

(2) Laboratory of Pedology, Geological Institute, Ghent State University, Rozier 44, 9000 GENT - Belgium.

may form rootmats. The first soils are always underneath broad-leaved vegetation (oak and beech), sometimes accompanied by a vegetation of fern, and it does not look as if they ever bore a much different vegetation . The typical cemented podzols are now mostly under pine and birch, together with heather and seem to have had this vegetation for a long time. Between these two clearly different types there are intermediary soils with cemented B_h , that must have gone through a stage with a "broad-leaved" B before reaching their present stage of cementation.

2. SOIL DESCRIPTIONS AND MICROMORPHOLOGICAL OBSERVATIONS.

4 soils of Fontainebleau and 6 of Villers Cotterets have been sampled. They have been described following their (increasing) sequence of evolution, not taking into account their place of origin. Some data on particle size, organic carbon, pH and extractable Fe and Al are given in table 1.

2. 1. Podzolic soil without A2 and with very friable B horizons, on windblown sands, under beech forest and Pteridium Aquilinum; Fontainebleau.

This soil has a dark reddish brown to black (5 YR 2. 5/1. 5), very friable Al of 10 cm; a reddish brown (5 YR 4. 5/2, 5)friable Bh of 25 cm with many roots; a brown (7. 5 YR 4/4) B_s with common roots.

Micromorphology *

* The description of the organic substance has been made according to the system of DE CONINCK et al., 1973.

A1 : at the top : numerous transformed and not transformed plant remains, many of which are strongly fragmented; not transformed fecal pellets of variable size, up to 300μ ; many hyphae and sclerotiae; downwards polymorphic amorphous matter forming pellets and simple and complex aggregates; the pellets may have a regular shape and clear boundary, with the typical aspect of polymorphic organic matter, but many are irregular and diffuse and seem to be composed of tiny, black or very dark points on a lighter background; pellets and aggregates have a juxtaposed and agglomerated distribution.

Bh: few, transformed plant remains; the rest of the o. m.* forms numerous polymorphic pellets and simple and complex aggregates, containing many silt particles, and complex, partial and irregular coatings, that increase with depth; the distribution is mainly linked, sometimes agglomerated and coated.

Bs : is similar to the Bh, but the organic units are less numerous.

Conclusion : the pedological features, visible in thin sections, are units composed mostly of fresh plant remains at the top, and of polymorphic units lower in the profile, the last ones clearly due to transformation of the first ones.

2.2. Podzolic soil without A2 and with very friable B horizons, on sands of Beauchamps, with oak-beech forest and Pteridium Aquilinum; Villers Cotterets.

The profile has a dark to very dark gray (5YR 3.5/1), very friable Al of 8 cm; a dark reddish gray (5YR 4/2), friable Bh of 30 cm with many roots; a brown to dark brown

* o.m. : organic matter.

(7.5 YR 4/4), friable Bs of 10 cm with some roots; a yellowish brown (10YR 5/4), friable C.

Micromorphology.

Bh : comparable to Bh of profile 2.1; with polymorphic o.m. present as accumulations and coatings, with a lighter, more uniform color than in 2.1, forming a linked and coated distribution; only few plant remains.

Bs : many, strongly transformed plant remains; few complex accumulations, composed of pellets, some of which have a clear plant structure; partial, irregular and mostly thin, polymorphic coatings; where they are thicker, they are dark reddish brown and may be birefringent; the distribution is essentially coated.

Conclusions

Both horizons have the same basic constituants but their repartition into units is different, the Bh having mostly accumulations, the Bs more coatings. This difference in micromorphology corresponds with a difference in color in the field.

The vegetal structure recognizable in some pellets proves that pellets can be formed by direct transformation of plant remains.

The Bh is very similar to the Bh of profile 2.1, even as regards the field characteristics.

2.3. "Broad-leaved" podzol with A2 and very friable B horizons, on windblown sands, under beech forest and Pteridium Aquilinum; Fontainebleau

The profile has a black (5 YR 2.5/1), very friable A of 6 cm; a lighter, dark reddish brown (5 YR 2.5/2)

A12 of 20 cm; a pinkish gray (5 YR 6/2), loose A2 of 20 cm, with subhorizontal, irregular, darker, firmer lamellae of <3 mm thick, and with few roots; a dark reddish brown (5 YR 3/3.5), friable Bh of 10 cm with few, darker lamellae like in A2 and with common roots; a dark brown (7.5 YR 4/4), very friable Bs of 5 cm, with roots like in Bh.

Micromorphology.

A1: shows a gradual transition of fresh plant remains at the top, into pellets and aggregates with juxtaposed and agglomerated distribution, then into accumulations with linked and agglomerated distribution and at the bottom into accumulations with coated and agglomerated distribution.

A2: very little o.m.; the o.m. present is polymorphic, composed of tiny, black points with almost uncolored background; this punctuation is present in groups which form partial coatings or bridges; in the darker lamellae, monomorphic o.m. with a similar punctuation covers birefringent coatings and bridges.

Bh: polymorphic coatings with few mineral particles give an essentially coated distribution: in the lamellae the coatings are darker and birefringent.

Bs: similar to Bh.

Conclusions

The lamellae seem to be due to an accumulation of monomorphic organic matter on clay lamellae.

The o.m. is different in the A2 and in the B horizons: in the A2 it is composed predominantly out of groups of black points, with an almost uncolored back—

ground, giving a strong contrast in these groups (punctuation); downwards, in the Bh the punctuation becomes less evident, due to the presence of a colored background. The A2 being a leached horizon, the punctuation may be the residue of o. m. after its partial solubilization and leaching. This phenomenon seems to be active also on the monomorphic o. m. present on the clay lamellae.

- The Bh and Bs horizons are similar, like in profile 2. 1.
- The coated distribution in the Bh may be due to a redistribution of aggregates and accumulations as a result of mechanical forces (pressure and contraction of the menisci of the soil water around the skeleton grains on drying).

2. 4. "Broad-leaved" podzol with A2 and very friable B horizons, on sands of Beauchamps, under oak-beech forest and much Pteridium Aquilinum; Villers Cotterets

The profile has a very friable A1 of 6 cm, with a dark gray to very dark gray (5 YR 3. 5/1) matrix, but with lighter and darker spots; a pinkish gray (5 YR 5.5/2), loose A2 of 25 cm with some darker spots and a few medium and thick roots; a dark reddish brown (5 YR 3.5/2), friable Bh of 10 cm with common, fine and medium roots; a dark brown (7. 5 YR 3/2), friable Bs of 10 cm with roots like in Bh; a yellowish gray (2. 5 Y 5. 5/3) C.

Micromorphology

Bh: only polymorphic o. m. forming partial, irregular, but mostly thin, dark coatings, locally birefringent, and few accumulations, with a distribution that is essentially coated, locally linked or agglomerated.

Bs: similar to Bh, but the coatings are thinner, and the distribution is nowhere agglomerated.

General conclusions

- The local birefringence points to the presence of clay.
- The general aspect of the Bh and Bs horizons in the 4 preceding profiles is rather similar, with polymorphic organic matter forming coatings or complex aggregates in some horizons, especially when the material contains some silt. These horizons are always friable and light-colored.
- The two last profiles have an A2 horizon with a lighter color than the C horizon; this indicates a leaching. However, the Bh and Bs horizons of these profiles are very similar to the Bh and Bs horizons of the two first profiles without A2. This means that the features of the B horizons of profiles 2.3 and 2.4 do not allow to find indications of an illuviation.
- The monomorphic coatings - always considered as a typical expression of illuviation of organic matter - are found in the lamellae of one podzol.

2.5 Podzol with A2 and friable and weakly cemented B horizons, on sands of Beauchamps, with young Pinus Silvestris and Calluna; Villers Cotterets.

The profile has a very dark gray to black (10 YR 2.5/1), very friable A11 of 10 cm; a very dark gray to very dark brown (5 YR 2.5/1.5) A12 of 15 cm; a pinkish gray (7.5 YR 6/2), loose A2 of 35 cm; a dark reddish brown to black (5 YR 3/1.5), friable but locally firm Bh of 10 cm, with few roots; a reddish brown to dark reddish brown (5 YR 3 /4), friable and locally firmBs of 5 cm with some roots; a dark yellowish brown (10 YR 4/4)C.

Micromorphology

Bh: two clearly distinct forms of o. m. are present :

1) typical polymorphic o. m. forming rather complete, but irregular coatings, giving a coated distribution.

2) o. m. with a more uniform aspect, giving the impression to be close to a monomorphic form; in a few places it presents an irregular pattern of polyedric surfaces - due to cracking - which is a typical feature of monomorphic o. m. . However, its more grainy aspect and a less regular cracking pattern point to a transition form between typical monomorphic and typical polymorphic o. m.

Bs: has almost exclusively the typical polymorphic o. m. similar to the Bh; very little of the monomorphic form as in the Bh.

Conclusion

The appearance of the monomorphic form in the Bh coincides with the presence in the field of weakly cemented zones that are darker than in the preceding profiles.

2. 6 Podzol with A2 and weakly cemented B horizons, on sands of Beauchamps, under Pinus Laricio and Pteridium Aquilinum ; Villers Cotterets

The profile has a very dark gray (5 YR 3/1), very friable A1 of 30 cm, with lighter and darker spots , a pinkish gray (7. 5 YR 5. 5/2), loose A2 of 35 cm with subhorizontal, dark, undulating, fine lamellae, and in the lower part dark reddish brown to gray (5 YR 3. 5/2) spots; a black to very dark gray (5 YR 2. 5/1. 5) firm and cemented

Bh with more friable, lighter spots at the top, without roots except few, small ones in the more friable spots; a friable Bs, varying from very dark gray (5 YR 3/1), to strong brown (7.5 YR 5/6) with locally firmer spots and without roots; a dark yellowish brown (10 YR 4/4) C.

Micromorphology.

Bh: a small fraction of the o.m. forms very dark, polymorphic pellets and aggregates of varying shape, rarely complex; the rest is comparable to the monomorphic form of the Bh of profile 2.5 with a grainy constitution and showing a cracking pattern with irregular edges; many units show a gradual transition between a polymorphic part and a monomorphic part; the distribution is essentially coated.

Bs: the o.m. is similar to the Bh, with thinner and lighter colored coatings.

Conclusions

Profiles 2.5 and 2.6 represent the profiles of transition between the podzols with friable, not cemented B horizons, and the podzols with firm and cemented B horizons. Part of the o.m. in the B horizons of these profiles has the same aspect, intermediate between typical monomorphic and polymorphic, with a grainy aspect and irregular cracking pattern, which suggests the possibility of a transformation in place of the polymorphic into the monomorphic state. This transition form coincides with the beginning cementation. This coincidence is very evident in the two Bs horizons : the Bs of 2.5 is not cemented and does not have the monomorphic features; the Bs of 2.6 is cemented and has the monomorphic form.

2.7 Podzol with A2 and cemented B horizons, on sands of

Beauchamps, locally under Pinus Silvestris; Villers Cotterets.

The profile has a very dark gray to black (5 YR 2.5/1) A1 of 15 cm; a reddish gray (5 YR 5/2), loose A2 of 30 cm with some darker spots, especially at the top and the bottom, with few, subhorizontal, undulating, brown, fine lamellae, without roots; a very dark gray to dark reddish brown (5 YR 3/1.5), firm and cemented Bh of 3 to 15 cm, forming tongues downwards, with few, fine roots; a dark reddish brown (5 YR 3/2), friable Bs of 15 cm with few, fine roots; a yellowish brown (10 YR 5/4) C.

Micromorphology

Bh: different units of o.m. are present :

1) rather thick and dark monomorphic coatings, locally showing a fine layering, and having clear cracking patterns, giving a coated and linked distribution.

2) polymorphic, very dark to black pellets and mostly complex accumulations or aggregates, in a linked and juxtaposed distribution. The pellets are locally found in or on the monomorphic coatings.

3) Sever al root fragments, strongly transformed and fragmentes, with dark color masking the vegetal structure, and having many sclerotiae; there is a great number of polymorphic units (pellets and aggregates)around these fragments, suggesting that they have been formed from them; small root fragments are incorporated in the monomorphic coatings and in the aggregates and accumulations.

Bs: the o.m. is almost exclusively polymorphic in irregular, rather complete coatings, with some pellets and complex accumulations, giving a coated and linked distribution; a small amount of monomorphic o.m. locally forms a thin coating at the top of the horizon in channels throughout the horizon along a large root fragment.

Conclusions

The presence of the cemented Bh coincides with a strong development of the monomorphic units. In the Bs the location of the monomorphic units is connected to the presence of migration zones or of a root fragment, suggesting that the monomorphic o.m. may directly originate from it.

2.8 Podzol with A2 and cemented B horizons, on wind blown (Stampian) sands, with birch and heather; Fontainebleau

The profile has a very dark gray to black (5 YR 2.5/1) A1 of 20 cm; a very dark gray (5 YR 3/1), very friable A2 of 10 cm with some roots; a very dark gray to dark reddish brown (5 YR 3/1.5), firm and cemented Bh of 20 cm tongueing downwards, with few, fine roots; a dark brown (7.5 YR 3/2), friable Bs of 10 cm, with darker, undulating lamellae and few, fine roots; a yellowish brown (10 YR 5/4) C with dark, undulating lamellae.

Micromorphology

Bh: 1) upper part : two different zones : one including thin, regular, complete, cracked, monomorphic coatings, locally covering complex polymorphic accumulations : one including monomorphic units similar to the first zone, many root fragments, and a great amount of polymorphic units : numerous, dark brown aggregates composed of rounded, regu lar pellets, which may be present even in the center of the root fragments.

2) strongly cemented spot : dark, thick, regular, cracked, monomorphic coatings give a predominantly coated distribution; locally black, polymorphic pellets and accumulations.

Bs: mostly rather complete, polymorphic coatings, as well as complex aggregates and accumulations, giving a coated and linked distribution.

Dark lamellae in C : dark, monomorphic coating and concentrations cover birefringent argillans.

Conclusions

The most important feature is the presence of 2 different zones in the Bh, with in the one a predominance of monomorphic units, in the other a predominance of polymorphic units in connection with - and even in the center of - root fragments, clearly suggesting that they have been formed from these plant remains by faunal activity.

2.9 Podzol on Stampian sands under pine, birch and heather; Fontainebleau.

The studied profile is buried under a reworked sand layer in which a more recent podzol has developed. It has: an A1 of 20 cm; a pinkish gray (5 YR 6/2), loose A2 of up to 50 cm with subhorizontal, undulating to irregular, very contrasting, firm, dark lamellae; a Bh of varying thickness, firm and very cemented, except at the top, where it is friable, composed of successive, horizontal, black or very dark gray (5 YR 2.5/1) and dark reddish brown (5 YR 2.5/2) layers, and locally tongueing downwards, without roots; a thin Bs with several, dark, fine, irregu lar lamellae without roots; a white to light gray (5 YR 8/1 to 10 YR 7/1) C.

Micromorphology.

Bh: has very thick, dark, cracked, monomorphic coatings and concentrations, giving a coated, linked and locally filled distribution.

Conclusions

The very cemented consistence corresponds with a linked and filled distribution due to monomorphic units.

2. 10. Podzol with A2 and strongly cemented B horizons, on sands of Beauchamps, with pine and Calluna heather; Villers Cotterets

The profile has a very dark gray to black (5 YR 2.5/1) A11 of 5 cm; a very dark gray (5 YR 3/1) A12 of 25 cm; a dark gray to very dark gray (5 YR 3. 5/1), loose A2 of 15 cm with very thin, brown, subhorizontal lamellae ; a black (5 YR 2.5/1), very firm and strongly cemented Bh of 10 cm with few roots; a firm and cemented Bs of 15 cm composed of very dark gray (5 YR 3/1) spots or subhorizontal, irregular lamellae, without roots; a brown (10 YR 5. 5/3.C.

Micromorphology

A1 horizons: at the top many plant remains as well as many hyphae and fresh fecal pellets often situated inside the plant remains, as well as black pellets and aggregates; downwards mostly pellets and accumulations, formed by a partial welding together of pellets with ill-defined shape and punctuated with tiny, black points.

Transition A2 - Bh: at the top only polymorphic units composed of groups of tiny, black points on a light background in a linked and some coated distribution. Towards the bottom these punctuated units gradually pass into aggregates and accumulations composed of black, dense pellets.

Bh: dark, dense, polymorphic units are covered by dark, thick, cracked, monomorphic coatings and concentrations, giving a linked and filled distribution; locally a big, strongly transformed root fragment is surrounded by very dark aggregates; no monomorphic coatings are present in this place.

Bs: mostly complete and irregular, light brown, polymorphic coatings giving a coated distribution; in a horizontal lamella and in vertical channels typical, cracked, monomorphic coatings.

Conclusions

The A horizons, especially the A2, show again the punctuated polymorphic o.m. similar to the A2 horizons of the other profiles.

In the Bh it is evident that some polymorphic units are anterior to the monomorphic units, being covered by the latter. Around a root, the preexisting monomorphic coatings have disappeared and aggregates have been formed. These aggregates must be posterior to the monomorphic coatings. In the Bs, the polymorphic units are covered or replaced by monomorphic ones both in the lamellae and in vertical channels, clearly proving the illuvial origin of the monomorphic o.m.

3. DISCUSSION AND CONCLUSIONS

3. 1 Composition of the units of organic matter

The processes responsible for the evolution in the studied soil profiles are :

1) The more or less advanced weathering of the minerals present in the parent materials. This process is responsible for the release of the constituting elements of these minerals and especially for the presence ot the Fe and Al in "free" form, this being one of the characteristics of the podzolic soils and of the podzols.

2) The destruction of the plant remains, producing different organic compounds. From the micromorphological point of view we can distinguish three important basic constituents

1. Vegetal residues, which may either form isolated units or be incorporated into units with the other basic constituents.
2. Polymorphic organic matter, in pellets, aggregates, accumulations and coatings. (Picture I).
3. Monomorphic organic matter, in coatings and concentrations. (Picture 2) Sometimes, the distinction between the form 2 and 3 is delicate, since the o. m. can present intermediate characteristics, like in the weakly cemented B horizons. Moreover, these forms seem to pass from one into the other, a feature present in a strongly cemented B horizon.

The basic constituants may be assembled into two groups of units.

a. The units with polymorphic o. m. : pellets, aggregates, accumulations, coatings, always including more or less important amounts of plant remains as well as silt particles, if present.

b. The units with monomorphic o. m. : monomorphic coatings and concentrations with polygonal cracking pattern.

3.2. Formation of the two groups of units

3.2.1. In the genesis of polymorphic o. m. two factors intervene.

1. A mechanical phenomenon (fragmentation of plant remains or uptake of monomorphic units).

2. A biochemical phenomenon, transforming the recognizable plant remains into an amorphous substance, in which theoriginal structure cannot be recognized any more, and which is indicated by the name "polymorphic". This transformation is typical around dead roots.

The composition of the polymorphic o. m. depends on the position in the profile : the "typical polymorphic" o. m. of the not cemented B horizons is present in units of globular form, mostly of $> 20 \mu$ diameter, in which zones with different color and density may be distinguished; their overall aspect is however rather homogeneous. In the A 2 horizons the polymorphic o. m. is composed of groups of numerous and very small black points ($< 5 \mu$) on a light background, indicated as polymorphic o. m. " in punctuation " . The presence of this punctuation in all the A2 horizons shows that it is a residue of partly dissolved and leached organic compounds. (Pictures 3, 4, 5 and 6).

We are convinced that the biological activity has a remarkable importance in the formation of the polymorphic o. m. (DE CONINCK et al., 1973). Many arguments support this concept.

1) If the fractionation by the fauna would not exist, the destruction of the dead roots would have to be done only by direct microbiological activity. The bacteria, fungi and

actinomycetes would then leave the roots more or less transformed but complete while in reality they are mostly fragmented, the fragments being present even in the pellets. Moreover, the small amount of dead roots, compared to the number of living roots (e.g. in the not cemented B horizons) proves the activity of the fauna (Picture 7).

2) The presence of small recognizable root fragments and of silt particles within numerous units excludes the hypothesis of formation of these units by sole precipitation of organic substances.

3) The study of 14 C in two of the studied profiles (GUILLET et ROBIN, 1972) gives an apparent age of 2100 years for a cemented B (profile 2.8) and of only 180 years for a not cemented B (profile 2.3). This shows that the genesis of these 2 horizons is fundamentally different : in the not cemented Bh, the "turn-over" of the o.m. is much faster than in the cemented Bh, which may be considered as fossilized. This can be explained only by a higher biological activity in the not cemented Bh, while the accumulation of the monomorphic o.m. brings about a decrease of the biological activity.

4) Since in the cemented Bh the age of the organic substances is much higher than in the not cemented Bh, the pedogenetic activity has gone on for a much longer period in the last horizons. Notwithstanding this much longer period, the amounts of aluminium and iron accumulated in the not cemented horizons are much smaller than in the cemented ones. This means that in the first ones the migration and accumulation of these elements - or the podzolisation - has reached only a weak intensity, compared to this of the profiles with cemented Bh. The units of polymorphic o.m. of the not cemented Bh cannot be due directly to a phenomenon of podzolisation, for in

that case their contents of aluminum and iron would have to be much higher than in those of the cemented Bh horizons, since their formation has lasted about 2000 years longer. The only possible explanation for the existence of the polymorphic units then is their formation through faunal activity.

3.2.2. The formation of the monomorphic o.m. is due to physio-chemical phenomena : a fraction of the organic substance is solubilized, transported and precipitated again, giving rise to monomorphic coatings and concentrations. These mobilized substances may proceed from different levels. However, the gradual transtition between the typical polymorphic o.m. in the B horizons and the punctuated one in the A2 horizons clearly indicates that polymorphic o.m. undergoes a dissolution and may be an important source of monomorphic o.m.

3.2.3. Transition between polymorphic and monomorphic o.m. (Pict. 8, 9 and 10)

The two forms of o.m. are often present in nearby surroundings, suggesting a kinship between one another.

- Some coatings in the Bh show, on the perimeter of the same grain, the monomorphic state at one side and the polymorphic state at the other side.
- In a cemented Bh, complex polymorphic units are often covered, rather abruptly, by monomorphic deposits.
- At other places polymorphic units become gradually uniform towards the outside and acquire some features of the monomorphic state (Bh horizons of the transition podzols with beginning cementation).
- In horizons with predominantly monomorphic units, these units may be replaced by pellets and aggregates around a root.

These exemples prove that the processes responsible for the genesis of the states of amorphous o.m. may go on simultaneously or sucessively and inverse themselves.

3.3. Distribution of different basic units in the studied soils

3.3.1. The two first profiles (2.1 and 2.2) do no have an A2 but an A1 resting on a Bh-Bs. These two horizons have a very similar micromorphology : the o.m. is present in the form of few, recognizable plant remains, but mostly as pellets as well as aggregates and coatings polymorphic o.m., containing variable amounts of silt. The very friable consistence is clearly expressed by the high porosity. The formation of these units with polymorphic o.m. is due to a process including a mechanical fragmentation by the fauna and a biochemical transformation of the plant remains.

3.3.2. The Bh-Bs of the profiles with A2 and friable B horizons (2.3 - 2.4). are identical to those without A2 : the units of these horizons seem to be due to a faunal activity and a biochemical transformation. However, the presence of the A2 implies an eluviation andanilluviation, and the chemical analyses clearly show an accumulation of iron and aluminum in the B horizons. Since the o.m. in the B horizons is only polymorphic, it must be admitted that the monomorphic o.m. responsible for the leaching, has been taken up by the faunal activity and incorporated into units with polymorphic o.m. The reality of the migration of the o.m. in monomorphic form also in these profiles is shown by the presence of monomorphic o.m. in the dark lamellae in these soils.

3.3.3. In the two first profiles of the intermediate pod—

zols (2. 5 and 2. 6) the monomorphic o. m. appears weakly, and a faint cracking pattern develops at the surface of the polymorphic units. Fine, uniform monomorphic coatings develop locally on the skeleton grains.

In profile 2. 7, the Bh is predominantly monomorphic, covering the skeleton grains and polymorphic units with continuous coatings. In the Bs, the polymorphic o. m. is dominant.

Profile 2. 8 is differentiated by the appearance, especially at the surfece of the Bh, of polymorphic units (brown globular pellets, with clear boundary) as well as fractionated, but distinctly recognizable plant remains. These units are in direct contact with monomorphic units, which predominate in the lower part of the Bh.

3. 3. 4. In the podzols with dark and cemented B horizons

(2. 9 and 2. 10), the monomorphic o. m. predominates completely forming thick coatings and concentrations with clear, polyedric cracking patterns. However, there are always polymorphic units, often complex, covered or completely included in the monomorphic o. m. (fossilizing process of the polymorphic o. m.).

At the surface of the Bh of profile 2. 10 we find polymorphic units like in profile 2. 8 - but more explicitely so- forming a transition horizon of a few cm. This corresponds with the important enrichment of roots at this level, due to the blocking effect of the cemented Bh.

3. 3. 5. Table of recapitulation

The clear relation existing between the consistence of the B horizons and the nature of the o. m. is shown in the following table.

		Friable B horizons		Intermediate B horizons		Cemented B horizons
		without A2	with A2			
		2.1 2.2	2.3 2.4	2.5 2.6	2.7 2.8	2.9 2.10
Bh	field	friable		→ progressive cementat.		cemented
	microm.	polym.		polym. + monom.	monom. + polym.	monom.
Bs	field	friable		friable		friable + cemented
	micron.	polym.		polym.		polym. + locally monom.

3.4. Evolution processes of the podzolisation

Two opposing processes may take place during the evolution of these soils, which are all freely drained.

1) A mechanical fragmentation by the soil fauna and a biochemical transformation of the plant remains of the litter and of dead roots at all levels of the solum, forming pellets and simple or complex aggregates and accumulations. This brings about a loosening of the horizon and it must be the only process taking place in the podzolic soils.

2) A gradual solubilization of plant remains and polymorphic units, forming mobile organic compounds. These compounds migrate down into the soil and after having fixed some iron and aluminium, precipitate and form the monomorphic units, bringing about a cementation.

This last process is responsible for the leaching of the upper zone of the profile, resulting in the A2 horizon, and occurs in all podzols.

These two processes have an opposite result on the consistence of the accumulation horizons, process 1 tending to loosen the horizons and to increase the porosity, process 2 cementing the horizons and decreasing the porosity.

As long as the first process predominates, no real cementation occurs. Once the second process becomes important compared to the first one, the cementation of the B horizons may become too strong for the roots to penetrate into them. Consequently the loosening effect of the first process cannot take place anymore and a continuing supply of monomorphic o.m. brings about a strong cementation of the horizon.

The impossibility for the roots to penetrate into the ce mented B horizon makes them accumulate at its top, and their destruction again forms polymorphic units.

The existence of two successive stages in the formation of the cemented B horizons is shown by the complex polymorphic units, now included and fossilized in the monomorphic units. These polymorphic units are equivalent to the polymorphic units present in the friable B horizons.

The presence of the monomorphic o.m. in the lamellae, even when the B horizons have only polymorphic o.m., is interesting. The evolution of these lamellae in space and in time is difficult to assess. Their preservation may be due to the fact that they are still functioning, i.e. that monomorphic organic matter is still accumulating.

Most of these lamellae have argillans with a brown color, even in the A2 horizons. This suggests that the lamellae in the A2 have been formed at a moment when the clay still contained free iron - i.e. before the formation of the A2 - and that they are not destroyed by the podzolisation.

The podzols with friable B and those with cemented B seem to be completely different profiles. However, the intermediate profiles, with a gradually increasing amount of monomorphic o.m. and increasing cementation, clearly show the connection between the two extreme forms. Moreover, the ratio of free aluminium and iron in A2 and B horizons, which is an expression of the intensity of the podzolisation, decreases in the same way.

The study of a sequence of soils with impeded drainage (low humic hydromorphic soils to hydromorphic podzols) (RIGHI & DE CONINCK, in print) shows the same evolution and the same relation between the nature of the organic matter and the amount of aluminum accumulated in the B horizons.

This similarity suggests that the processes described here, are of general importance.

Table 1 - Particle size, organic carbon (O.C) %; Fe_2O_3 and Al_2O_3 extractable in oxalic acid(Fe_{ox} Al_{ox}) in ‰, pH H_2O *

Profile	Horizon	Particle size < 2 μ	2-50 μ	> 50 μ	O.C %	Fe_{ox} ‰	Al_{ox} ‰	pH H_2O
Z.1 **	A1	1.1	5.0	93.9	2.7	n.d. ***	0.18	4.1
	Bh	0.5	4.0	95.5	0.5	n.d.	0.55	4.2
	Bs	2.5	5.0	92.5	n.d.	n.d.	0.46	4.5
Z.2	A1	1.0	2.7	96.3	2.5	0.26	0.12	[illegible]
	Bh	1.0	2.4	96.6	0.85	0.64	0.12	4.1
	Bs	0.9	1.4	97.3	0.35	0.66	0.36	4.7
	C	0.9	0.3	98.8	n.d.	0.44	0.18	4.6
Z.3	A11	[illegible]	3.8	94.9	4.7	0.28	0.02	[illegible]
	A12	1.0	3.3	95.7	1.35	0.16	0.06	n.d.
	A2	[illegible]	2.6	94.6	0.15	0.12	0.04	3.9
	Bh	1.9	2.1	96.0	0.55	1.52	0.44	4.1
	Bs	1.5	2.1	96.6	0.30	1.18	0.44	4.5
	C	0.9	2.0	97.1	0.15	0.38	0.52	4.4
Z.4	A1	0.7	2.4	96.9	2.3	0.16	0.008	4.2
	A2	0.6	2.8	96.6	0.2	0.16	0.04	4.0
	Bh	1.0	2.0	97.0	0.15	1.16	0.74	4.3
	Bs	0.7	1.3	98.0	0.35	0.72	0.92	4.7
	C	0.7	0.3	99.0	0.05	0.12	0.16	4.4

* Analyses carried out by the "Centre de Pédologie Biologique," C.N.R.S., Vandoeuvre - Nancy, Director : Prof. B. SOUCHIER

Table 1 - (Continued)

2.6	A1	0.6	2.5	97.1	1.8	0.110 .	0.009	4
	A2	0.3	1.4	98.3	0.7	0.035	0.001	4
	Bh	1.0	0.9	98.1	1.3	2.900	0.110	4
	Bs	0.9	0.9	98.2	0.8	1.830	0.120	4.2
2.8**	A1	2.5	5.5	92.0				
	A2	[illegible]	4.2	93.6				
	Bh	5.4	6.3	88.3				
	Bs	1.6	1.5	96.9				
	C	0.8	1.6	97.6				
2.9	A2	0.1	0.5	99.4	0.1	0.024	0.640	n.d.
	Bh	1.1	0.5	98.4	1.7	0.640	1.920	4.5
	C	0.6	0.5	98.9	0.0	0.012	0.040	n.d.
2.10	A11	0.9	3.5	95.6	4.0	0.320	0.520	4
	A2	0.5	2.0	97.5	1.6	0.190	0.040	[illegible]
	Bh	1.4	3.7	94.9	7.3	1.920	[illegible]	[illegible]
	Bs	1.7	5.6	92.6	1.6	0.680	3.400	4.2
	C	0.3	0.8	98.9	0.05	0.020	0.160	4.2

** The data given for profiles 2.1 and 2.8 are taken from these profiles

*** n.d. not determined

LIST OF FIGURES

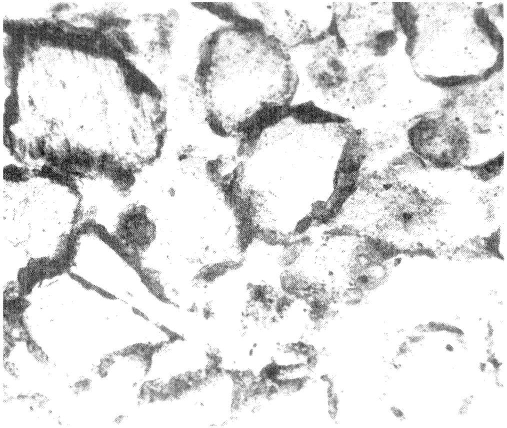


Fig. 1

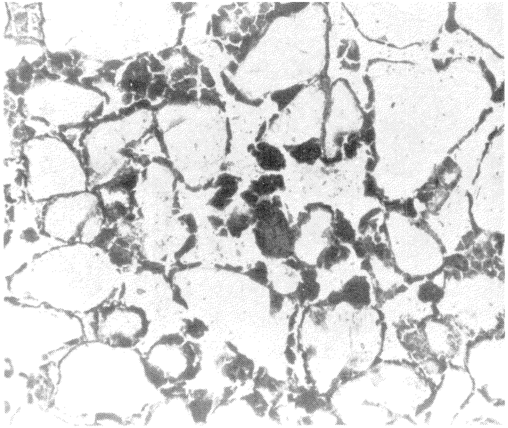


Fig. 2

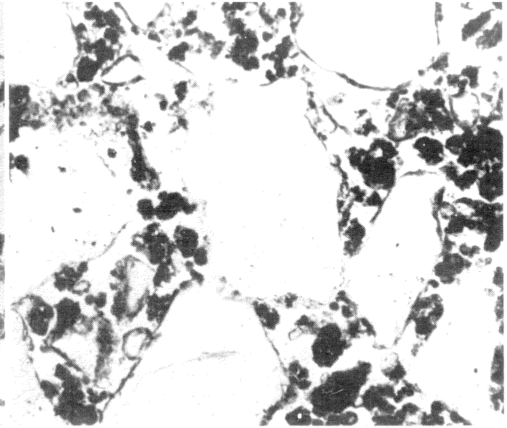


Fig. 3

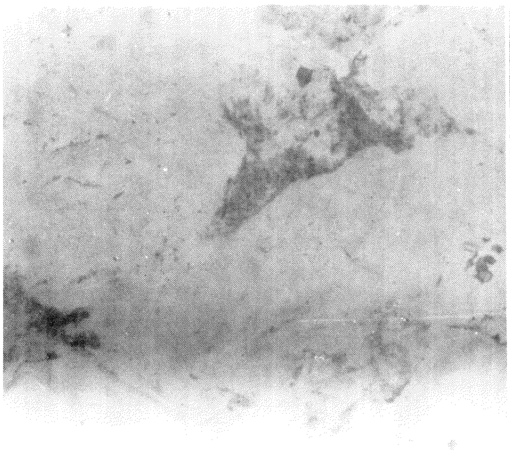
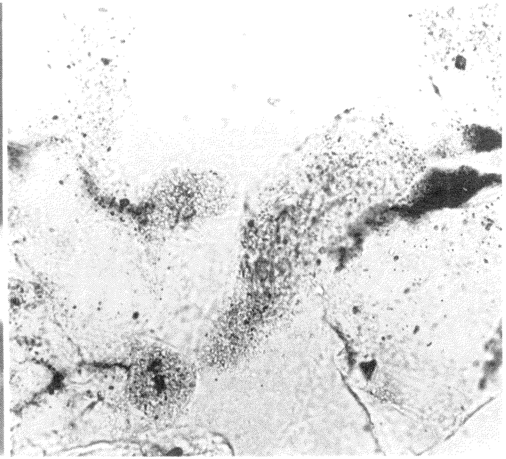


Fig. 4

Fig. 5



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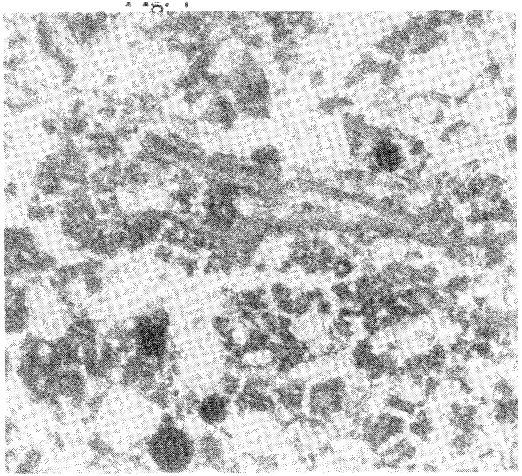


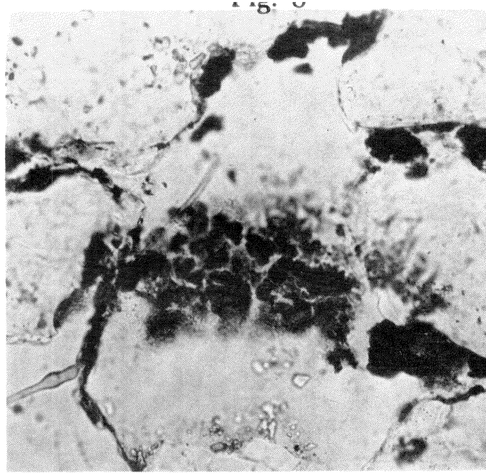


Fig. 9

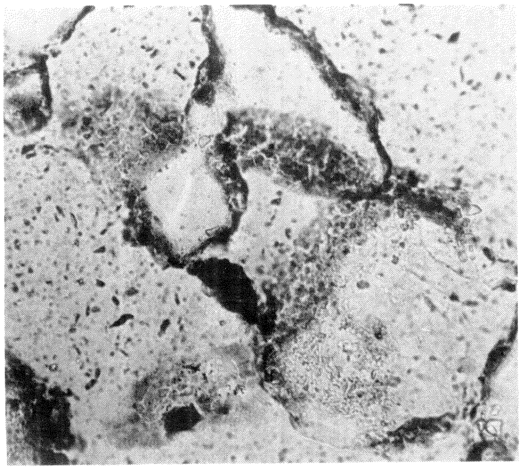
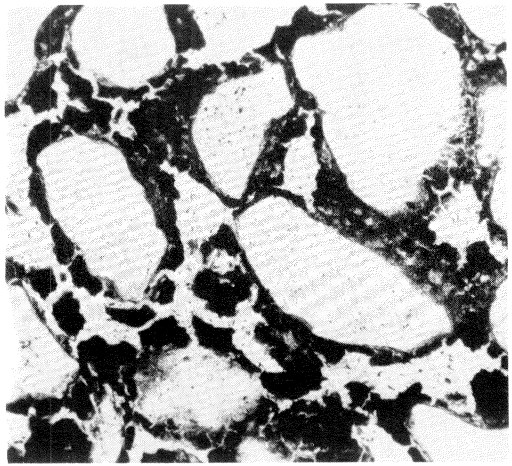


Fig. 10



A.M. ROBIN et F. CONINCK

RESUME

Des dépôts sableux d'âge oligocène et éocène dans les forêts de Fontainebleau et de Villers Cotterets (Bassin Parisien, France), partiellement remaniés par action éolienne, montrent des stades différents de développement : Sols podzoliques sans A_2, podzols à A_2 et horizons B friables; podzols a A_2 et horizons B faiblement cimentés; podzols à A_2 et horizons B fortement cimentés.

Al et Fe extractibles à l'oxalate montrent une accumulation croissante dans les horizons B avec une cimentation croissante.

L'aspect micromorphologique des A_2 est similaire dans tous les sols : la m.o. polymorphe est composée de points noirs très fins (piquetis) indiquant que cette forme est due à une dissolution et un lessivage.

La micromorphologie présente une conformité frappante avec la consistance sur le terrain; les horizons B friables ont exclusivement des unités polymorphes (granules, agrégats, accumulations); dans les B_h faiblement cimentés, les unités polymorphes sont transformées graduellement en m.o. monomorphe; les B_h fortement cimentés ont surtout des unités monomorphes, qui ont couvert et fossilisé des unités polymorphes préexistantes.

La pédogenèse semble due à deux processus opposés :

1) une activité faunique, responsable de la formation des unités polymorphes et de la consistance friable des B_h ;

2) une illuviation de composés organiques mobiles, ayant de l'Al et du Fe complexés; ces composés forment les unités monomorphes et sont responsables de la cimentation.

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