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THE SEQUENCE OF REMICOURT (HESBAYE, BELGIUM) : NEW INSIGHTS ON THE PEDO- AND CHRONOSTRATIGRAPHY OF THE ROCOURT SOIL

Paul HAESAERTS, Hans MESTDAGH and Dominique BOSQUET

(14 figures)

Royal Belgian Institute of Natural Sciences, Vautierstraat 29, B-1000 Brussels, Belgium

ABSTRACT. For more than 40 years the Rocourt Soil has stood out as an important pedo-stratigraphic marker in Belgium and north-western Europe. Since the seventies the complexity of this Soil was well illustrated, though its pedological and stratigraphic evolution remained doubtful. Macro-, meso- and micromorphological data gathered along long variable sections in Remicourt finally provided the 'missing link' between the Hesbaye sections and the Haine Basin. Soil characteristics allowed to match the Rocourt Soil with three major soil forming processes belonging to the Eemian and the first half of Saint Germain I (^{18}O-stages 5e and 5c). The overlying humiferous sediments and soils, which also incorporate the Rocourt Tephra, are linked with the second half of Saint-Germain I (^{18}O-stage 5c). The loess, stratified sediments and soil covering the humiferous layer are the equivalent of E.B.1, E.B.2 and Malplaquet Soil in Harmignies and belong to Melisey II and Saint Germain II (^{18}O-stage 5b and 5a).

KEYWORDS: Palaeopedological record, loess, Last Interglacial-Early Glacial, north-western Europe

1. The Rocourt Soil: a concept

The Rocourt Soil was defined in 1954 by Gullentops at the Gritten sand pit, located to the NW of Liège along the Meuse-Geer interfluve on the eastern edge of the Hesbaye plateau (Fig. 1). According to the author, it consisted of a thick red brown clayey loam horizon overlain by a 10 cm whitish horizon, the whole being ascribed to illuviated (B2t) and eluviated (E) horizons of a leached soil developed during the Last Interglacial in a climate slightly warmer than the present day one (Gullentops, 1954, p. 163). A humiferous horizon present between the Rocourt Soil and the upper loess cover was ascribed to a more continental episode heralding the Last Glaciation (Gullentops, 1954, pp. 163-164), with occurrence of a volcanic ash characterised by enstatite; the latter will be further called Tephra of Rocourt by Juvigné (1977) and used as a stratigraphic marker associated with the Rocourt Soil.

During the sixties, the Rocourt Soil concept, as pedostratigraphic marker of the Last Interglacial, was widely applied to the Upper Pleistocene loess sequence of Belgium (Paepe and Vanhoorne, 1967), and later to the whole loess sequence of north-western Europe (Zagwijn and Paepe, 1968; Sommé *et al.*, 1980). This scheme relied notably on a stratigraphic relation between the Rocourt Soil and marine sediments with *Tapes senescens var. eemiensis* observed by Paepe (1967) at Zelzate near Ghent, but also on the ascription of the Rocourt humiferous horizon to the Warneton Soil, which seemingly recorded the Amersfoort and Brörup Interstadials (Paepe and Vanhoorne, 1967). This correlation was at that time in good accordance with the palynological interpretation proposed by Bastin (1969, 1971)

2. The Rocourt Soil in the type locality

From 1973 on, the interdisciplinary study of the loess cover of the Gritten sand pit carried out by Haesaerts, Van Vliet and Juvigné demonstrated the complexity of the Rocourt Soil and questioned the ascription of this soil to the Eemian Interglacial *sensu stricto* (Haesaerts, 1978). This new approach, based notably on a micromorphological study of the sequence, enabled Van Vliet-Lanoë (1985, 1986; Van Vliet, 1975) to recognise a succession of three pedogeneses, whose evidences were partly obliterated by an intense down-bending movement affecting the upper horizons of the Rocourt Soil

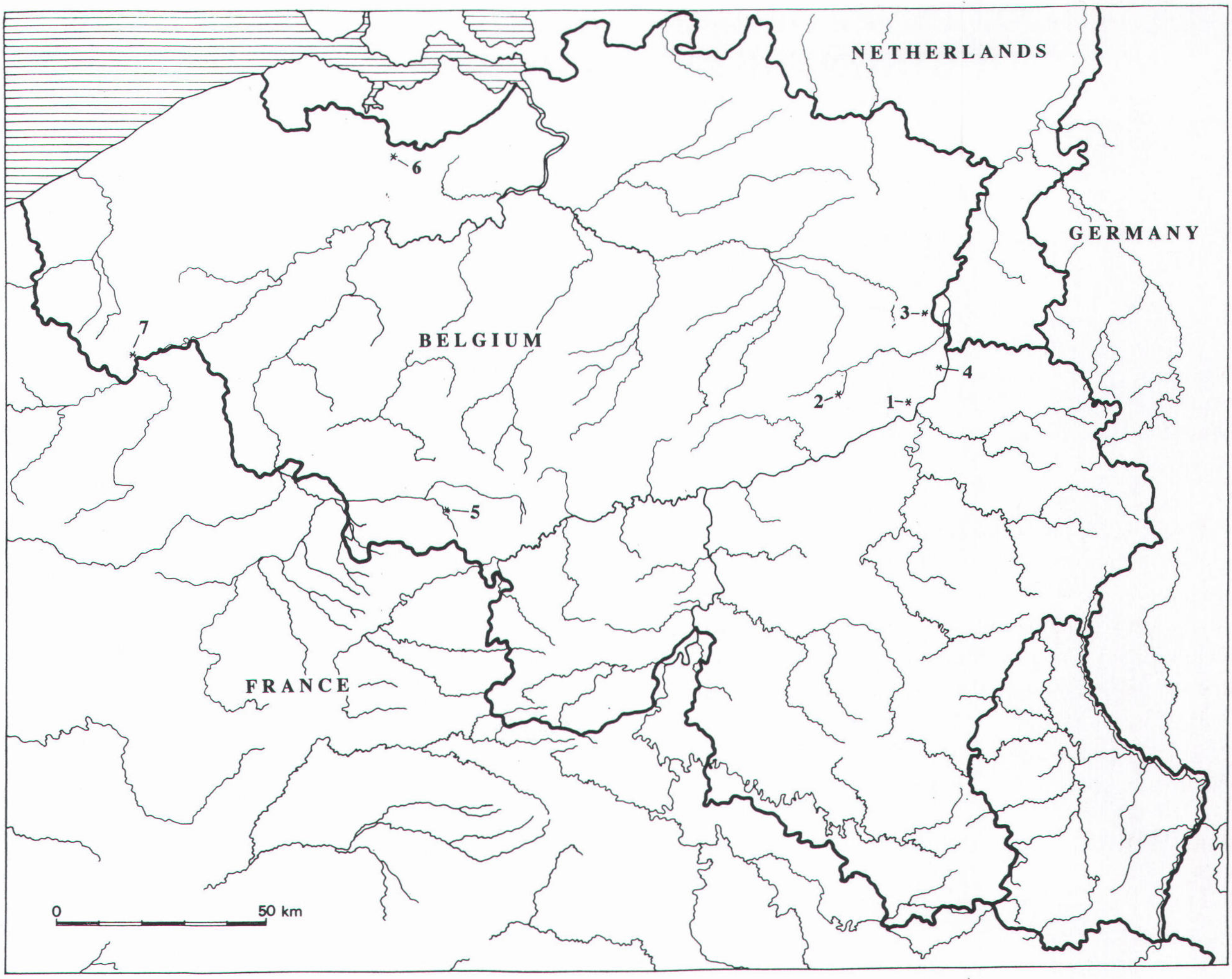

Figure 1. Location map of the sites. 1: Rocourt; 2: Remicourt (and Bia Flo); 3: Kesselt; 4: Lixhe; 5: Cuesta of Harmignies; 6: Zelzate; 7: Warneton.

and the lower part of the overlying humiferous horizon (Haesaerts and Van Vliet-Lanoë, 1981).

At first (Haesaerts, 1978; Haesaerts and Van Vliet-Lanoë, 1981), using the polycyclic character of the Rocourt Soil as an argument, this soil was suggestively correlated with the sequence of the Harmignies Cuesta, where the complexity of the pedostratigraphic record for the Last Interglacial and Early Glacial was well-established and expressed by three individualised soils, each time separated by loamy colluvium (Haesaerts, 1974; Haesaerts and Van Vliet, 1974). According to this scheme, the Rocourt Soil was thus considered as an equivalent of the Harmignies, Villers-Saint-Ghislain and Malplaquet Soil sequence correlated by Haesaerts and Van Vliet (1974) with the Eemian, Saint-Germain I and Saint-Germain II climatic episodes, recognised at Grande Pile by Woillard (1974, 1975).

Subsequently, new stratigraphic records and complementary studies, carried out at Rocourt from 1977 on, led to a better approach of the chronostratigraphic context of the local loess sequence (Haesaerts *et al.*, 1981). The diagnosis of the upper part of the Rocourt Soil however remained questionable due to the telescoping of the different pedological features and their subsequent disturbance by creep and frost action (Fig. 2). Such a complexity and the absence of new detailed studies are probably at the origin of slightly differing and sometimes far-fetched interpretations (Haesaerts and Van Vliet-Lanoë, 1983; Van Vliet-Lanoë, 1986; 1990; Van Vliet-Lanoë *et al.*, 1993), the argumentation of which is often based on the identification of ephemeral soil forming processes.

In such a context, a better understanding of the Rocourt Soil complexity was only possible recently thanks to

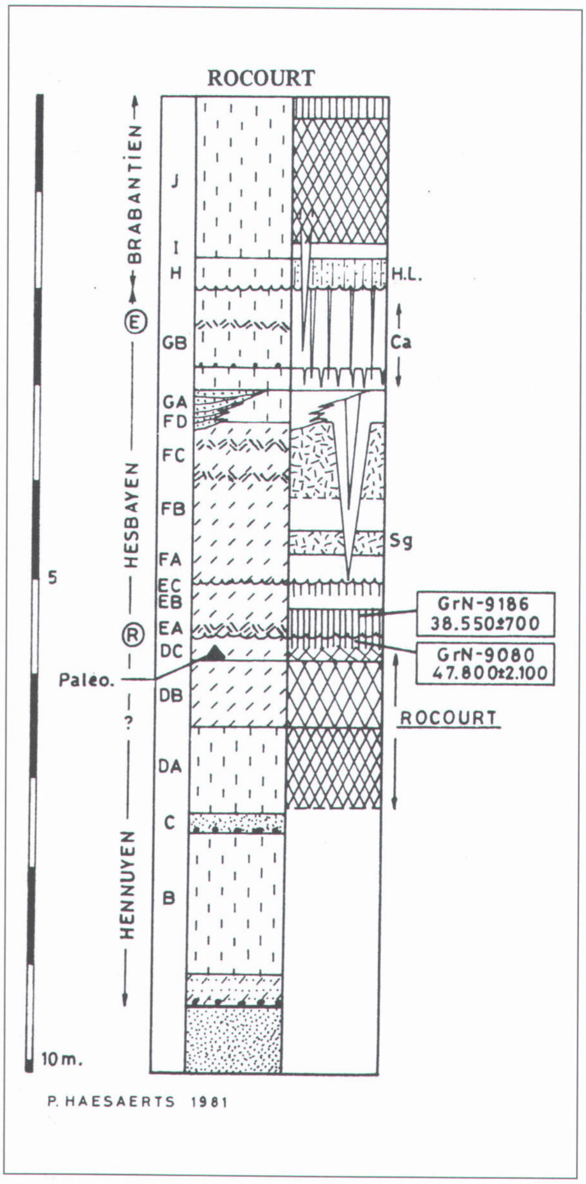

Figure 2. The Rocourt section in the type locality (1981). Legend: see "La stratigraphie des loess d'Europe", suppl. Bulletin de l'Association Française pour l'Etude du Quaternaire, 1969, p. 7. Other symbols: E: Eltviller Tephra; R: Rocourt Tephra; Sg: ice segregation; Ca: carbonated sediment; H.L.: tongued horizon.

original observations gathered by the authors in the locus typicus, at Kesselt (Juvigné *et al.*, 1996), at Remicourt (Haesaerts *et al.*, 1997) and at Harmignies. Particularly, the sequence of Remicourt (about 10 km west of Rocourt) turned out to be the most informative one. It allowed for the first time the integration of all the Hesbaye and Haine Basin sequences into a single coherent regional pedostratigraphic system.

3. The Rocourt Soil and the Early Glacial deposits at Remicourt

The loess sequence of Remicourt was uncovered at the beginning of March 1997 along the E40 Liège-Brussels highway (Fig. 1). There, archaeological prospecting along the high-speed train track intersected a NS-oriented loess ridge, delimited by two asymmetrical dry valleys (Fig. 3). As usual in Hesbaye, the loess cover was lying on the Upper Cretaceous chalk with a thick residual flint layer in between. An exceptional composite record of about 20 m thickness, including the upper part of the Middle Pleistocene loess, the Rocourt Soil and a long Upper Pleistocene loess sequence (Haesaerts et al, 1997), was thus reconstructed here.

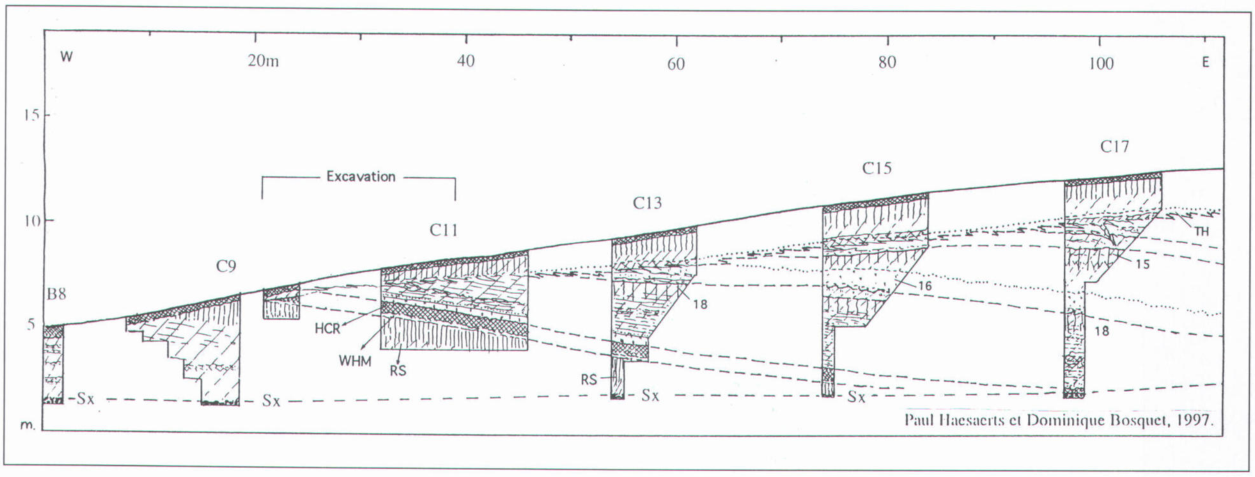

Figure 3. Remicourt : cross section of the loess ridge (western edge).
Legend: TH: Tongued Horizon; HCR: Humiferous Complex of Remicourt; WHM: Whitish Horizon of Momalle; RS: Rocourt Soil; Sx: residual gravel (flint).

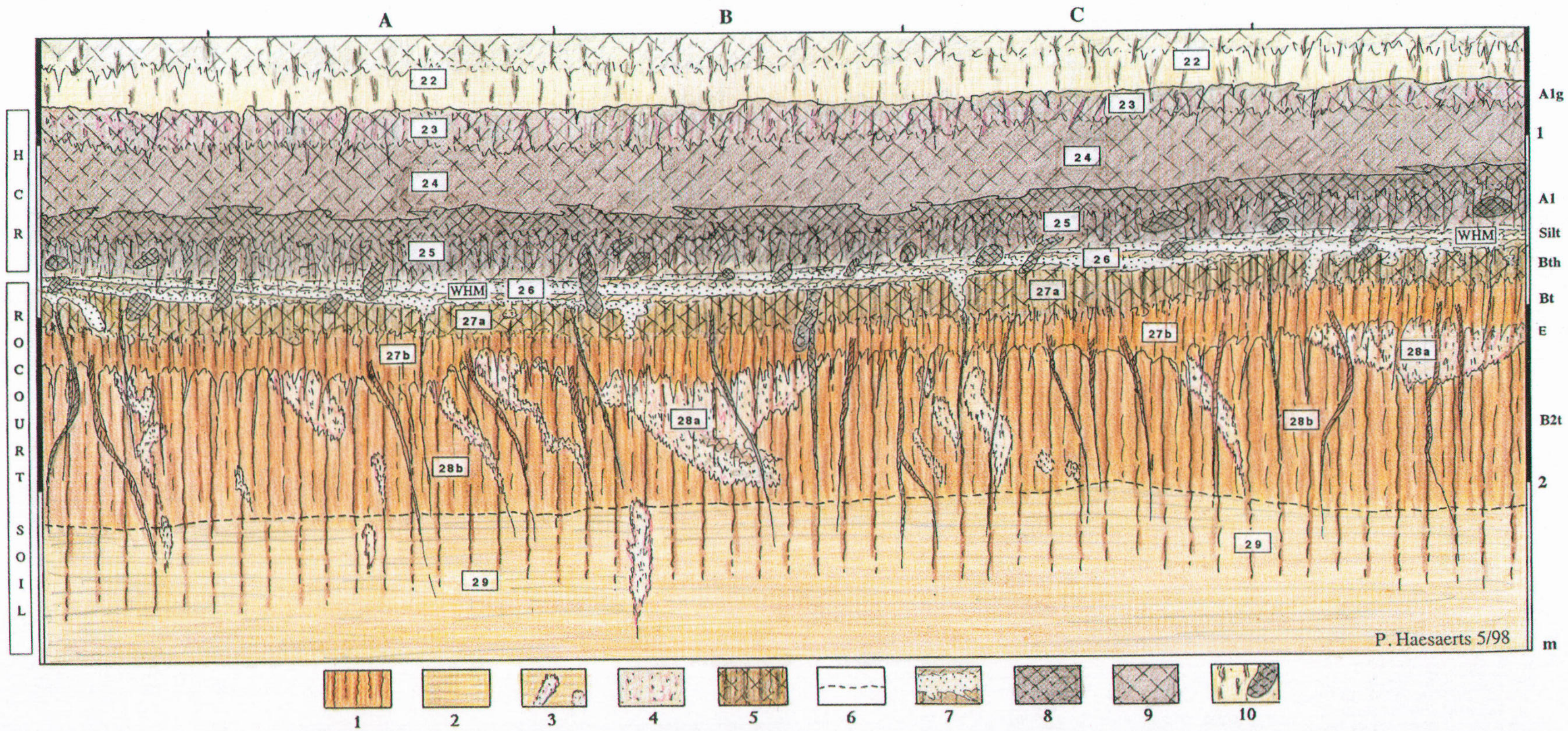

Figure 4. Remicourt: longitudinal section of the Rocourt Soil and the overlying H.C.R. Graphic symbols: 1: illuviated horizon; 2: banded B horizon; 3: grey patches with iron staining; 4: bleached sediment; 5: platy pedality; 6: lower limit of platy pedality; 7: whitish silt (W.H.M.); 8: dark brown humiferous sediment; 9: light brown humiferous sediment; 10: biogaleries and krotovina.

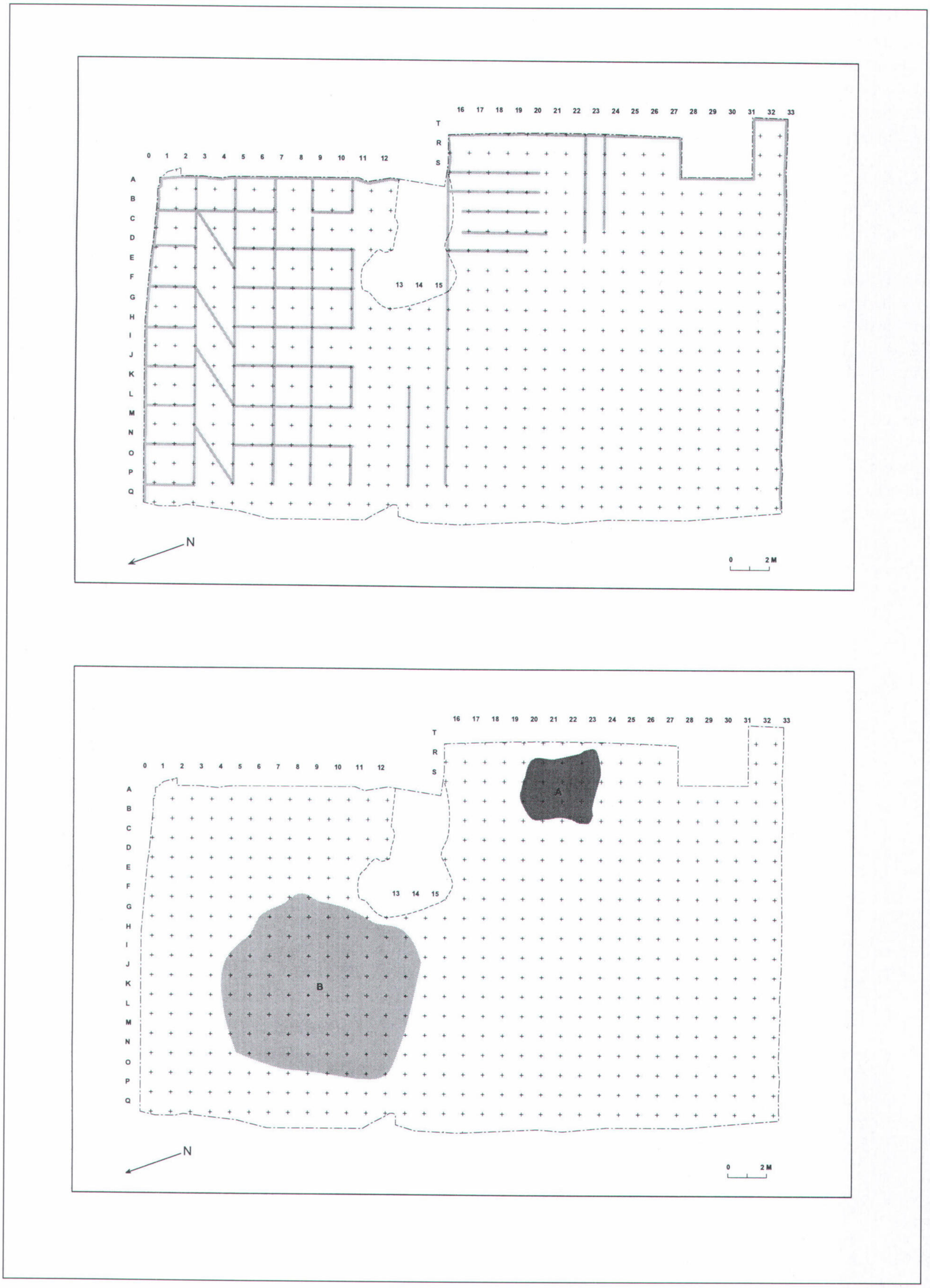

Figure 5. Remicourt: location of profiles and archaeological concentrations.

In Remicourt the Rocourt Soil overlain by a thick humiferous horizon was met halfway up the eastern slope of the western dry valley; it showed a classical facies consisting of an ochre, yellow-brown complex clay horizon with a whitish well-expressed horizon on top, named by us the "Whitish Horizon of Momalle" (Figs. 3 and 6). The whole presented thus a reverse geometry with regard to the present topography and pinched out at short distance towards the east at the top of the residual flint gravel. The thick humiferous horizon called here "Humiferous Complex of Remicourt" was followed up by a continuous loess layer of about 50 cm, overlain by a thick stratified loamy complex preserved in a bottom slope position underneath the Lower Pleniglacial carbonated loess (Fig. 3). As in Rocourt, the whitish horizon of the Rocourt Soil contained lithic evidences of a Palaeo-lithic occupation, which were excavated from January till April 1998 over 500 m². Thus it was possible to check over long distances the development of the Rocourt Soil and to recognise there the superimposition of 5 distinct horizons with a clear continuity (Figs. 4 and 5).

3.1. The lithostratigraphic sequence (Figs. 4 and 7)

We will focuse here on the lower third of the Remicourt sequence, located between the residual flint gravel and the base of the Lower Pleniglacial calcareous loess (Haesaerts *et al.*, 1997). All the deposits considered are decalcified.

3.1.1. The Lower Loess (units 35 to 29)

About 3 m thick light brown yellow loess, characterised by three greyish sub-horizontal tundra gleys (units 34, 32, and 30); occurs only in the lower part of the eastern side of the dry valley where it sustains the Rocourt Soil. In the upper two metres, the loess is very compact and shows a clear zonation marked by textural banding. The textural bands are parallel to the slightly oblique geometry of the Rocourt Soil and extend somewhat towards the top in the overlying unit 28b.

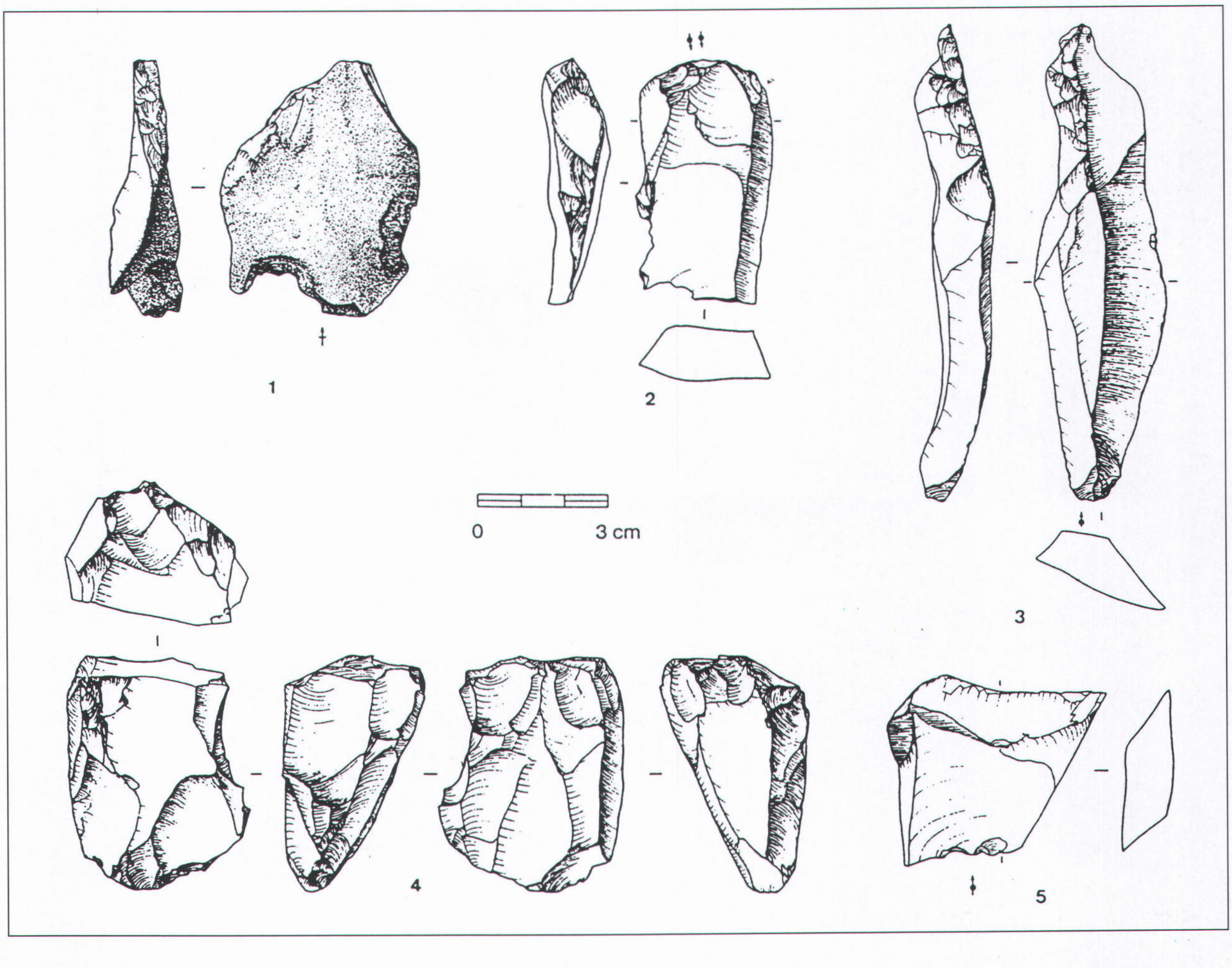

Figure 6. Remicourt: artefacts. 1: bifacial tool (concentr. B); 2, 3 and 4: blades (concentr. A); 5: convergent side-scraper (related to concentr. B).

3.1.2. The Rocourt Soil (units 28 to 26)

Unit 28b
About 60 cm thick ochre brown yellow clayey loam horizon with strong platy to sub-angular blocky structure, which stops at the top of unit 29. In voids and on structural plans, quite numerous ochre brown clay coatings are present. They are overlain by a second generation of greyish brown coatings on the platy structure in the upper part of the horizon. Unit 28b is furthermore characterised by large grey oblong patches with ferruginous rims also affected by the platy structure. These patches also extend in the upper part of loess unit 29 where they intersect the textural banding.

Unit 28a
Large pocket-like structures with an asymmetrical profile up to 40 cm deep, opening locally at the top of unit 28b. They are filled with light-ochre yellow loam also intersected by a strong platy structure; usually the grey patches in unit 28b are more abundant around these pocket-like structures.

Unit 27b
Brown ochre clayey loam horizon with strong platy to sub-angular blocky structure and dark brown clay coatings; occurs in slight discordance at the top of units 28a and 28b with a variable thickness of 10 to 15 cm, going up to 25 cm on top of the pocket-like structures. The base of this horizon is sharp and generally underlined by small wedges and numerous biogalleries with clay coatings. The lower part of unit 27b shows a system of large sub-vertical wedges a few cm wide and more than one metre deep with an ochre brown clay infilling. They form a quite regular polygonal pattern of about 60 cm diameter and intersect indistinctly the underlying units 28a and 28b as well as the associated grey patches. In the lower half of unit 28b, the platy structure and wedges are clearly associated since the ochre brown clay that fills the wedges diffuses laterally over the structural surfaces (Fig. 7c). However, in the upper half of the profile, a second generation of platy structure with dark brown coatings starting from above (top of unit 27a), crosses the whole sequence and intersects also the ochre brown clay infilling of the polygonal pattern's wedges (Fig. 7b).

Unit 27a
Greyish ochre loamy continuous horizon, 10 to 15 cm thick, with a gradual lower limit disturbed by biogalleries and a sharp upper limit. It is affected by a strong subangular to blocky structure with well-developed dark brown coatings. This horizon is also characterised by numerous small pupal chamber-like cavities with dark brown clay infilling shaped in thin pellets often covered by silty coatings, which extends from above and diffuses laterally along the structural plans. These pupal chambers also occur downwards in unit 27b.

3.1.3. The whitish horizon of Momalle (unit 26)

Decimetrical, almost continuous pale yellowish grey horizon in close connection with the underlying grey brown horizon (unit 27a). Its lower limit, marked by small wedges and biogalleries filled with pale silt, is very sharp and truncates locally the large biogalleries developed in unit 27a. The internal structure of the whitish layer is particular because of the occurrence of thin bands of greyish brown loam connected to the upper part of unit 27a that seem in a way "injected" into the pale yellow grey loam (Fig. 4 and Fig. 7a). On high landscape position, these bands are sub-horizontal slightly upturned and clearly discordant with regard to the slope of the whole system, while in the bottom part of the site, they bend towards the slope's direction. The upper limit of the bands is linear and generally underlined by a thin film of light silt, whereas the lower limit of the band is most often irregular as it has been stretched out.

3.1.4. The humiferous complex of Remicourt (units 25 to 23)

Unit 25
Grey loam layer of about 25 cm thick with a geometry parallel to that of the Whitish Horizon of Momalle. It is characterised by abundant bioturbations, mainly subvertical galleries with dark grey and light ochre yellow infillings, but also by large dark grey galleries (krotovinas), both penetrating also into the underlying layers. The lower limit of unit 25, though hidden by the bioturbations, is underlined by a scattered gravel and probably truncates the top of the Whitish Horizon of Momalle. Towards the top, the bioturbations fade and give way to a dark brown grey homogeneous loam whose upper limit is clearly undulated.

Unit 24
Homogeneous brown grey loam layer of about 30 cm thick, with some scattered pebbles at its base; abundant small bioturbations spread out through the mass of the loam.

Unit 23
Decimetric layer of greyer colour with diffuse lower limit, developed in the upper part of layer 24. Numerous small ferruginous patches are associated with biogalleries and follow a polygonal pattern of thin wedges of about 20 cm diameter, which is intersected by a thin platy structure that developed from the top of the layer.

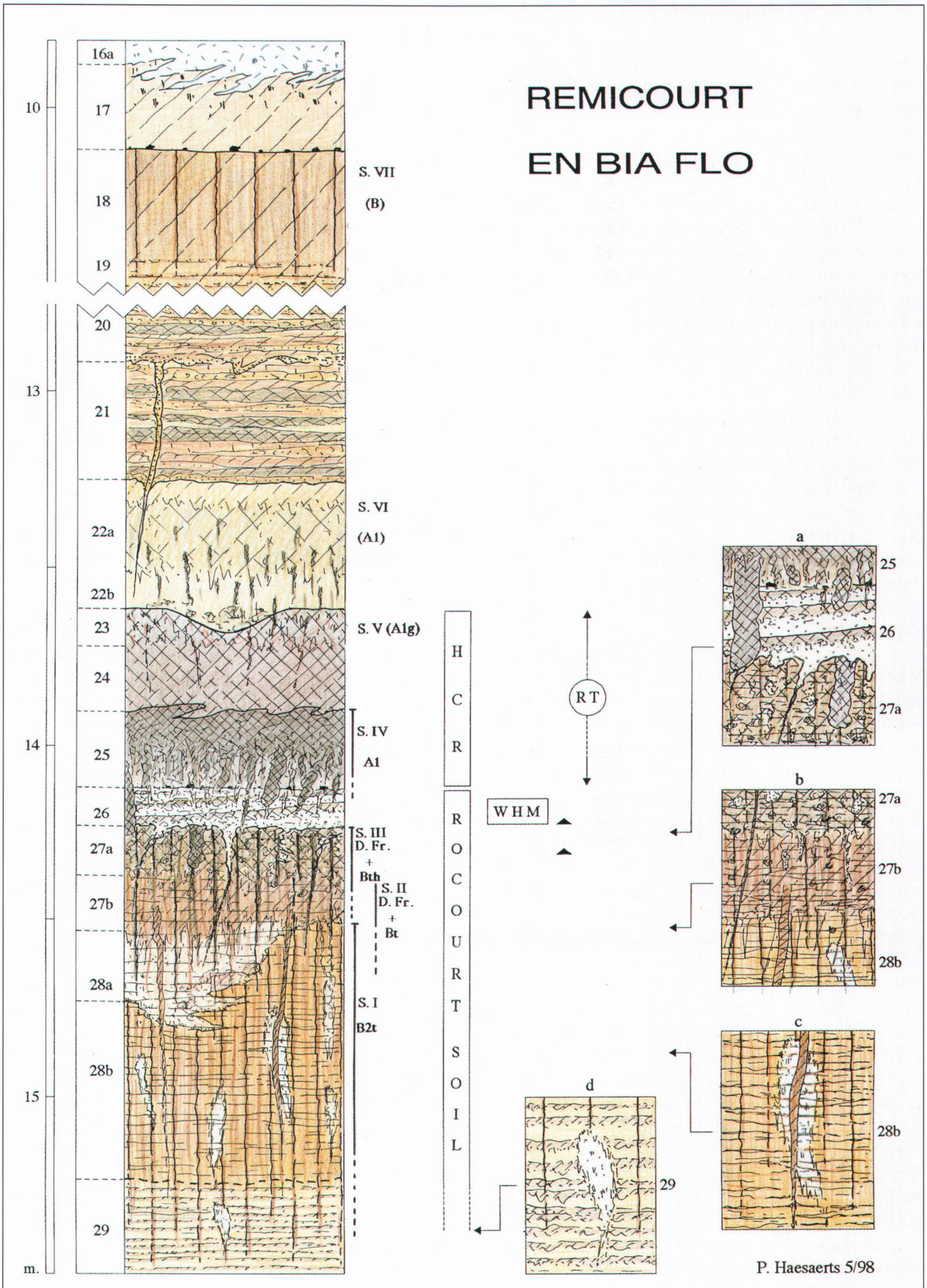

Figure 7. Remicourt : pedostratigraphic record. See Fig. 4 for legend

The mineralogical analysis led by E. Juvigné (Haesaerts *et al.*, 1997) demonstrated the presence of abundant volcanic ash in all units of the Remicourt Humiferous Complex, with notably occurrence of enstatite, a mineral which constitutes in a way the signature of the Rocourt Tephra (Juvigné, 1977).

3.1.5. The cover deposits (units 22 to 17)

Unit 22
Continuous greenish yellow homogeneous loess layer about 40 cm thick resting in accordance with the Remicourt Humiferous Complex, except in the bottom part of the excavation site where its base slightly ravines unit 23. In its lower third the loess is penetrated by a set of dark brown earthworm galleries, whereas the two upper thirds, intersected by a platy structure, show a more greyish colour and small abundant biogalleries and contain calcareous encrustings around small rootlet tracks.

Units 21 to 18
Thick stratified ochre brown loamy deposit, reaching about 3 m in thickness, which consists mostly of thin clayey sand, loamy and silty laminations alternating with dark grey bands, mainly in the middle part (units 21 to 19). In the lower third of this complex opens a system of wedges of about 5 cm wide and 2 m deep developing a polygonal pattern of about 15 m in diameter. Towards the top, the stratified deposits turn into a more ochre homogeneous loam (layer 18), showing a granular to sub-angular blocky structure with seldom brown grey coatings on the structural plans.

Unit 17
Greyish brown loam layer (about 25 cm thick) with a scattered gravel at the base. In the upper part shows abundant ferrugious patches related to the base of an above lying light grey layer which marks the base of the Upper Pleniglacial carbonated loess cover (unit 16).

3.2. Pedosedimentary evolution (Figs. 7 to 10)

The combination of the macro-, meso- and micromorphological observations about the sequence variability over long distances made it possible to reconstruct the pedosedimentary evolution in 14 phases. The odd figures of this evolution (phase 1, 3, …) are related to erosion and sedimentation processes, while the even figures (phase 2,4,...) indicate periods with surface stability and pedogenesis.

3.2.1. Phase 1 : Loess deposition (units 35 to 29)

The sequence starts with the deposition of calcareous loess. Its facies and mineralogical composition are similar to the lower cover in Kesselt (Juvigné *et al.*, 1996) and belong to the Late Saalian Glaciation.

3.2.2. Phase 2 : Pedogenesis of soil I : "Luvisol" (units 28b and 28a)

The characteristics of unit 28b, which developed on top of the textural banding in unit 29, are indicative of a textural B-horizon. This textural B-horizon is marked by clay illuviation, which is mainly visible in thin sections (Fig. 8a). The dark yellowish brown (10 YR 4/6) clay coatings are thick and grey under oblique incident light. Locally the coatings may be rich in iron and/or skeletal grains. The soil forming processes (decalcification and clay illuviation) are the result of favourable leaching conditions. The soil formed during this period seems to correspond to the present-day one. Although the application of present-day soil classification to palaeosols is problematic, Soil I resembles a Luvisol.

The bleached patches with ferruginous rims and pocket-like structures (unit 28a) are an additional feature. Their morphology is characteristic of the presence of a rooting system and wind-throw (Langohr, 1993). They indicate an increasing acidification of the soil near the end of phase 2. The skeletal grains covering the clay coatings on the other hand mark a period with several freeze - thaw cycles, corresponding to the onset of phase 3.

3.2.3. Phase 3 : Slight soil erosion; cryo-dessication cracks; ice segregation

At first the upper most part of Soil I is eroded. Apart from the presence of a platy pedality in units 28b and 28a, the polygonal pattern (50 to 60 cm ø) points to cryo-desiccation cracks penetrating the erosion surface. They are related to very cold climatic conditions. Locally these cracks cross the bleached patches of Soil I as well as the wind-throw structures. The induration of the lower part of the B-horizon is related to this phase and corresponds to a fragipan. Textural pedofeatures belonging to phase 2, such as clay coatings, are further broken and churned within the remaining *in situ* soil profile (unit 28b). The cold phase 3 is further characterised by a period with deep seasonal freezing and more likely permafrost.

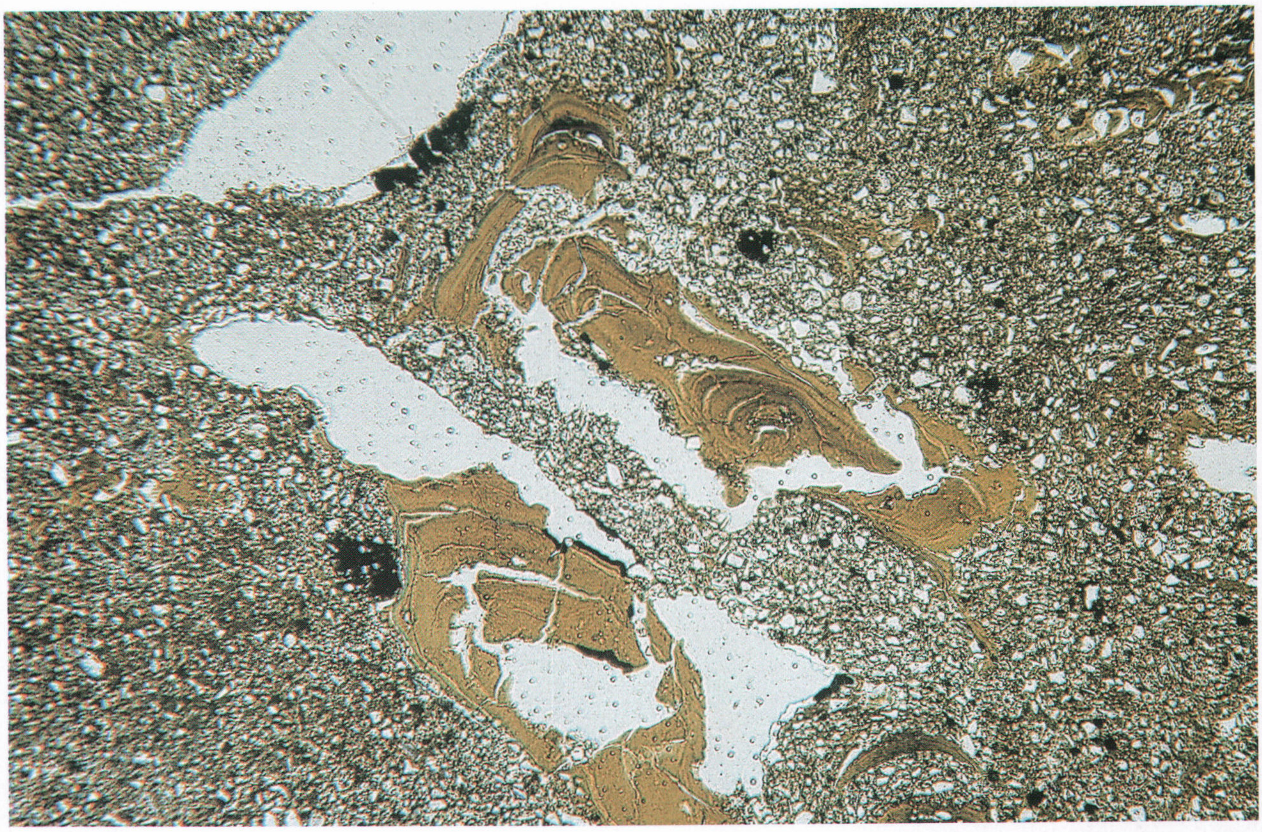

Figure 8a. Soil I (unit 28b): *in situ* clay coating and compound coating.

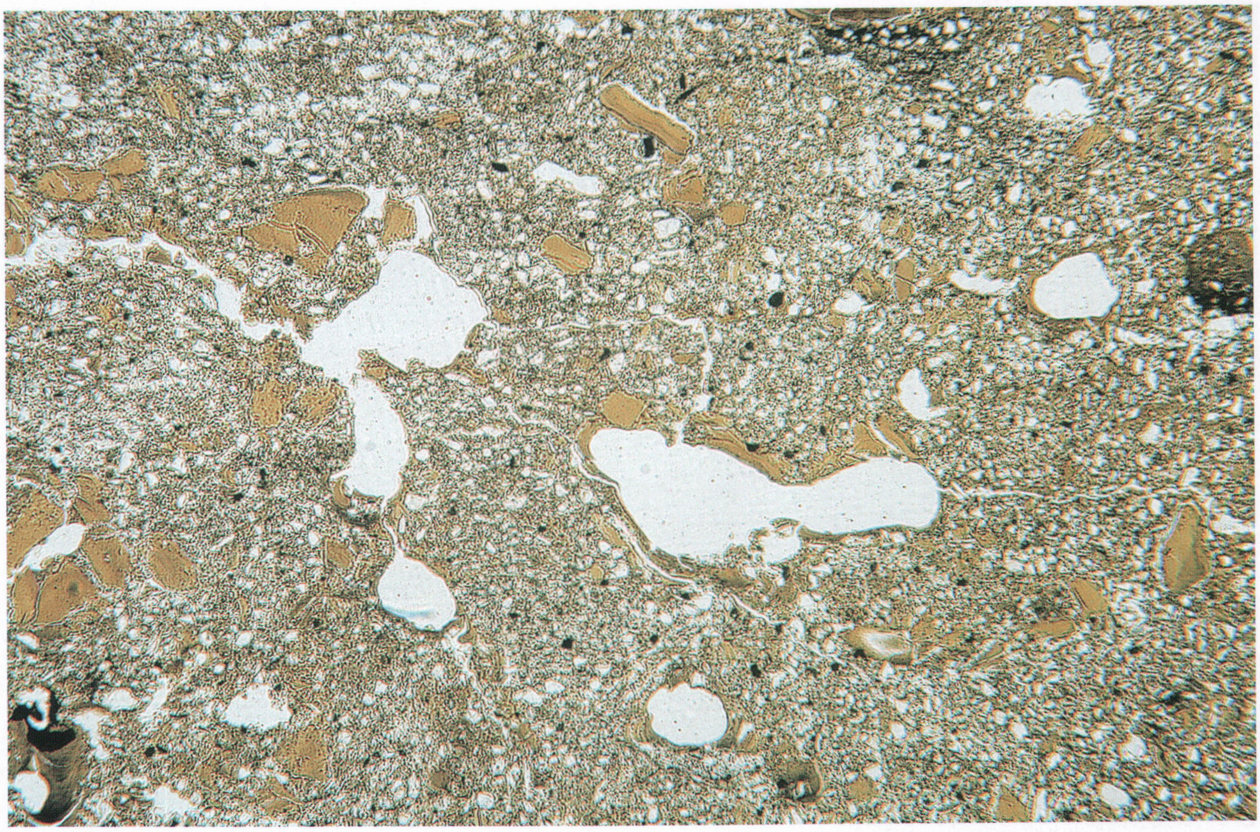

Figure 8b. Soil II (unit 27b): fragmented clay coating in the matrix and *in situ* clay coating along biogalleries; locally coating of organomineral substances related to Soil III.

Figure 9a. Soil III (unit 27a): Abundant organomineral coating *in situ* along voids and pores; fragmented clay coating in the matrix.

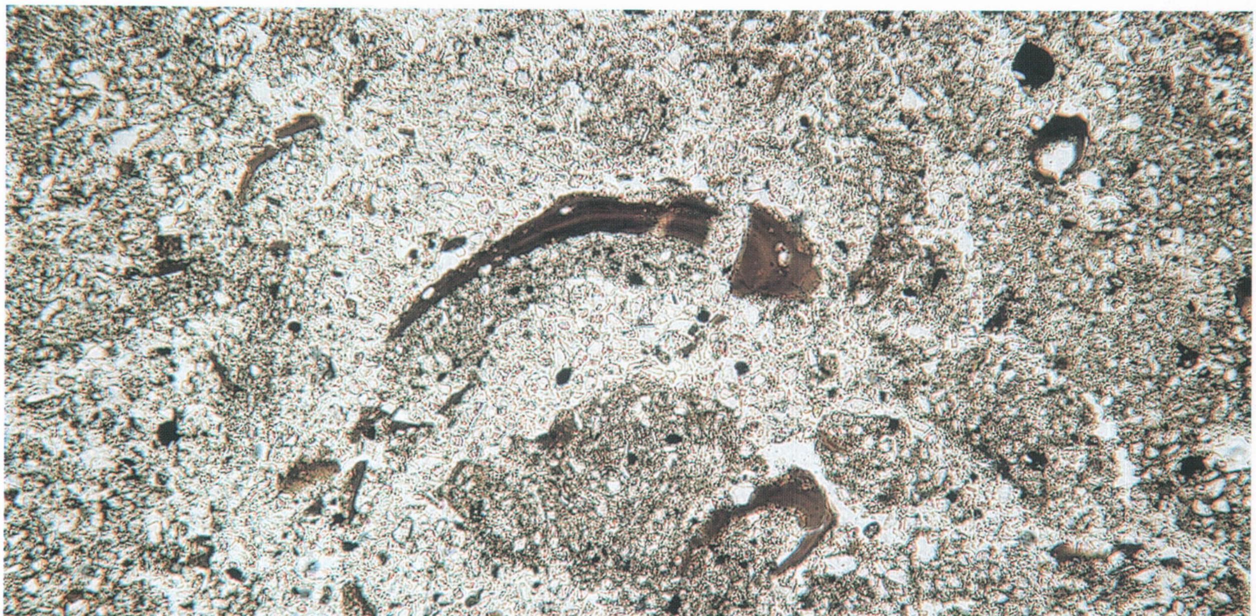

Figure 9b. Whitish Horizon of Momalle (unit 26): fragmented mineral coating in the silty matrix; *in situ* organomineral coating in soil fragment (light yellowish brown bands).

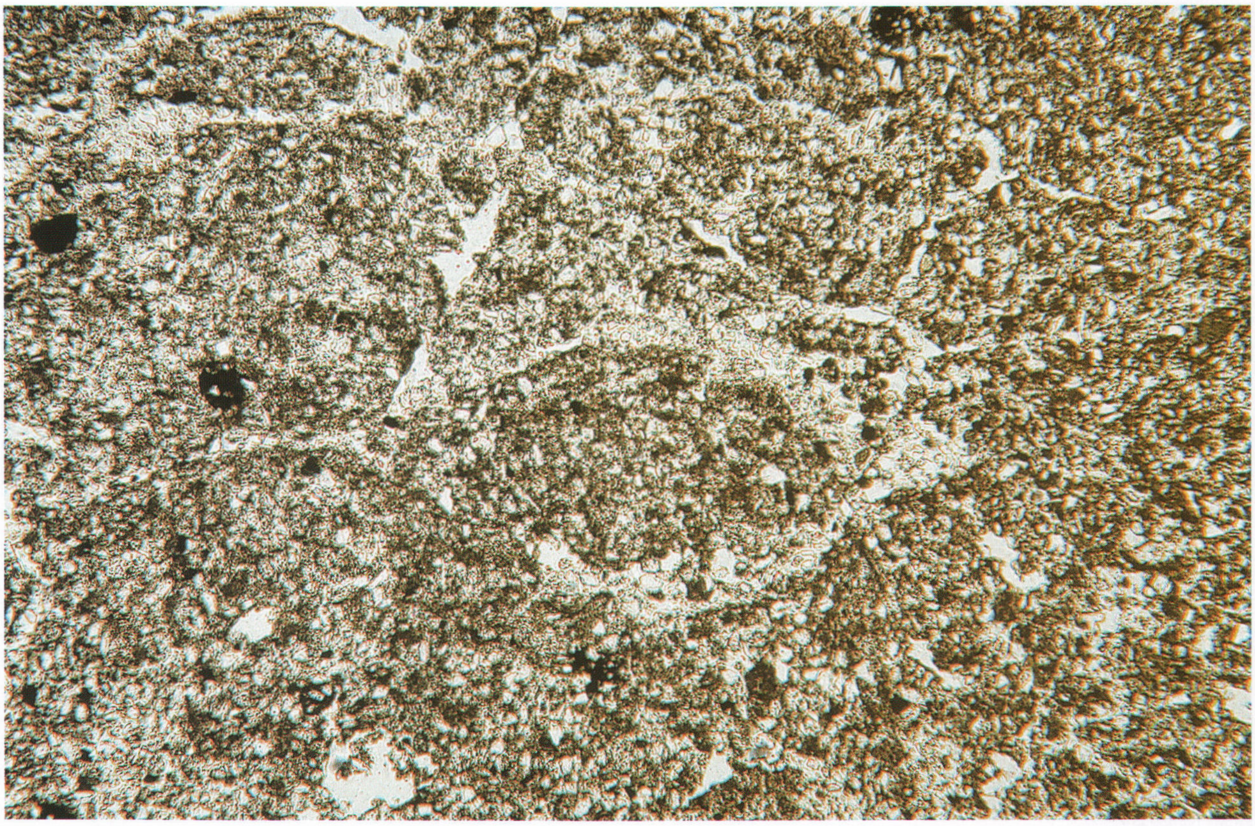

Figure 10a. Soil IV (unit 25): plastically deformed platy pedality with silt capping on humiferous horizon; well sorted matrix with very few soil fragments.

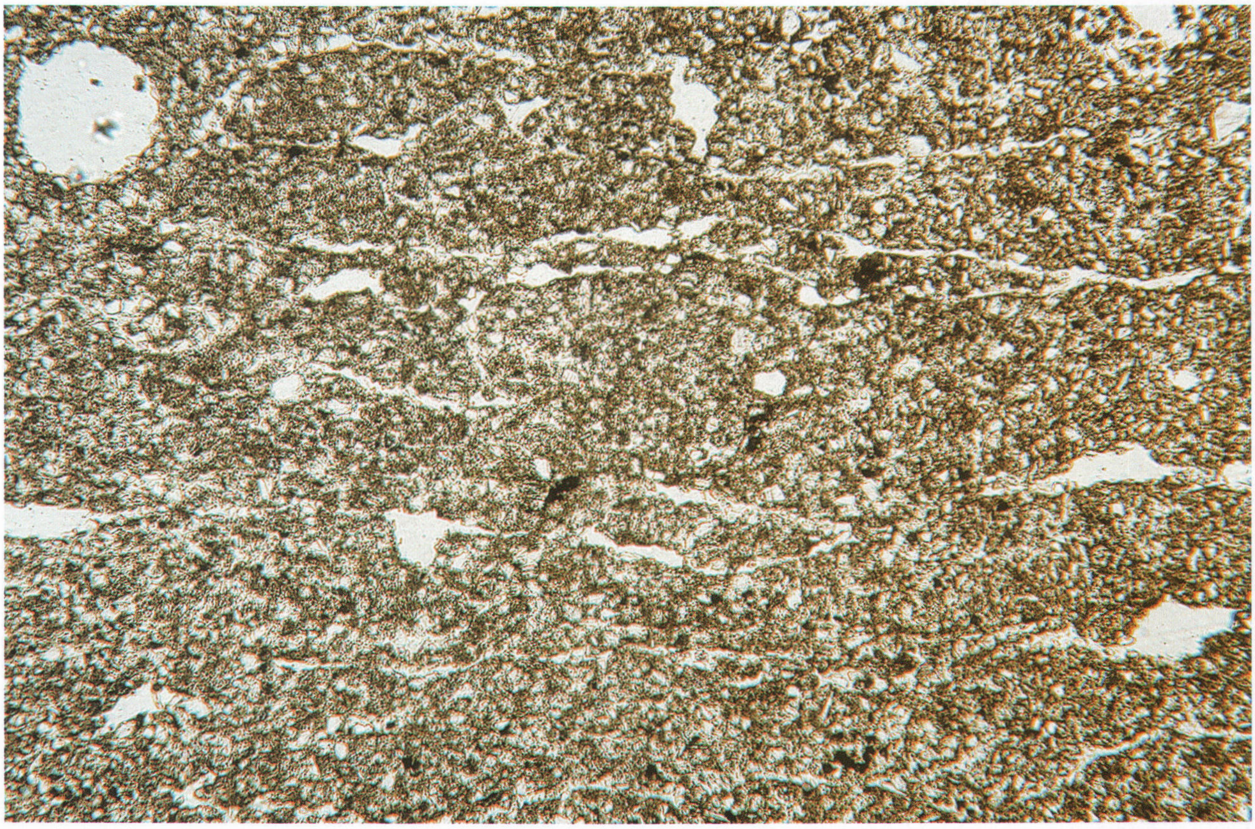

Figure 10b. Unit 24: undisturbed platy pedality in well sorted humiferous sediment

3.2.4. Phase 4 : Pedogenesis of soil II : "Luvisol" (unit 27b)

The strong brown horizon 27b is related to clay illuviation, which penetrates the cryo-desiccation crack pseudomorphs and coats the platy peds formed during phase 3. The common presence of fragmented clay coatings within the matrix, which belong to phase 2, is in sharp contrast with the "fresh" clay coatings belonging to phase 4 along biogalleries (Fig. 8b). The illuviation of this strong brown clay (7,5 YR 5/6) results from favourable leaching conditions and is indicative of the formation of Luvisol.

3.2.5. Phase 5 : Colluvium, deep seasonal freezing (unit 27a pp)

This phase starts with the erosion of the upper horizon of Soil II and continues with the deposition of unit 27a. The micromorphological analysis of this unit proves the presence of soil fragments coming from the reworked underlying textural B-horizons. The capped fragments are rounded and suggest a colluvial origin. This process may well be due to solifluction and suggests cold climatic conditions. The platy pedality of the light yellowish brown horizon 27a continues through unit 28 and crosses the crack pseudomorphs. This pedality is characteristic of a period of deep seasonal freezing following or during the deposition of unit 27a.

3.2.6. Phase 6 : Pedogenesis of soil III : "Greyzem" (unit 27a pp)

Evidence of pedogenesis associated with unit 27a are the translocation of organomineral compounds found along pores, in krotovinas and pupal chambers formed during phase 6 (Fig. 9a). These organomineral compounds also cover the platy structure affecting the underlying horizons, and cutting through the wedge pseudomorphs of phase 3 filled with dark brown clay during phase 4. All these features suggest the development of a Greyzem in a continental climate with cold snowy winters and warm summers.

3.2.7. Phase 7 : Solifluction, gravel and sedimenta-tion (units 26 and 25 pp)

In Remicourt several arguments assert that the so-called Whitish Horizon of Momalle in the upper part of the Rocourt Soil (unit 26) is no longer completely *in situ*. Apart from the rounded soil fragments, giving an almost granular pedality, this horizon clearly shows bands. The light yellowish brown bands consist of rounded fragments containing the humiferous clay coatings of phase 6 (Fig. 9b). The whitish silty bands on the other hand contain skeletal grains and fragmented clay coatings of different origin. Pores and voids of theses bleached bands are never coated by humiferous clay coatings. These bands can be traced over long distances (more than 1 m) and are discordant with the underlying B-horizon. Additionally small cryo-desiccation crack pseudomorphs with a silty infilling are observed at the contact between the so-called E-horizon (unit 26) and the B-horizon of Soil III (unit 27a). Also the krotovinas formed during this pedogenesis are systematically truncated.

We further assume that a subsequent process disrupted the A-1, E- and part of the B-horizon of Soil III in cold climatic conditions. This process is most probable as the bands show characteristics of solifluction lobes.

The presence of gravel at the top of unit 26 is indicative of an erosion process which occurred before the aeolian deposition of unit 25. The silty accumulation of unit 26, which is probably related to percolating melt water, and the loess-like texture of unit 25 are most indicative of continental climatic conditions.

3.2.8. Phase 8 : Pedogenesis of soil IV : "Chernozem" (unit 25 pp)

The lower half of the Humiferous Complex of Remicourt consists of a very dark grey (10 YR 3/1,5) horizon (unit 25) characterised by a high biological activity. Krotovinas and biogalleries, commonly filled with earthworm excrement, are frequently observed. At the level of the so-called "Whitish Horizon of Momalle" all the observed krotovinas cross the bleached and light yellowish brown bands. Therefore they are clearly posterior to the formation of the bands and bleaching in this horizon.

We ascribe this lower half of the humiferous complex to a stable surface during humid continental conditions with a steppe or forest-steppe vegetation. The soil resembles a Chernozem.

3.2.9. Phase 9 : Creep; sedimentation (unit 24)

The horizons of the Chernozem-like soil are characterised by a blady pedality with a high amount of skeletal grains. The peds are plastically deformed and rounded (Fig. 10a). The fabric therefore resembles an initial frostcreep or frostcreep fabric (Van Vliet-Lanoë, 1985), which suggests a slight movement of Soil IV along the slope during cold climatic conditions.

Soil IV is covered by a dark greyish brown to very dark greyish brown (10 YR 3,5/2) sediment (unit 24). Although a probable increasing importance of aeolian sediment does not seem negligible, one has to stress the persistence of small fragments of local elements in the matrix (Fig. 10b). Also the matrix remains humiferous. We are dealing most likely with an aeolian sediment of nearby origin deposited under grassy vegetation.

3.2.10. Phase 10 : Pedogenesis of soil V : "Sub Arctic Soil" (unit 23)

The top of the Humiferous Complex of Remicourt is marked by a very dark greyish brown (10 YR 3/2) horizon (unit 23). The horizon has a faint bluish appearance and a homogeneous humification. About 10 cm under the upper boundary of the humiferous complex thin pale yellowish clay coatings are very locally observed in the biogalleries under crossed polarised light. The top of the horizon is characterised by a superficial gley. The ferruginous patches are particularly obvious along the small pseudomorphs of wedges, which form a polygonal pattern of about 10 to 15 cm in diameter. Blady peds cross an initial micro granular structure. The blady peds are seldom plastically deformed. The pedality is therefore characteristic of a soil surface after a limited number of freeze-thaw cycles.

The pedofeatures are intermediate to a ranker or Arctic/Sub Arctic humiferous soil, as described by Van Vliet-Lanoë (1990). The oxido-reduction features suggest humid (seasonal) conditions. The polygonal pattern and platy pedality indicate cold (seasonal) conditions.

3.2.11. Phase 11 : Loess (unit 22 pp)

This phase coincides with local erosion of the Sub Arctic Soil and subsequently with a new aeolian deposition (unit 22).

3.2.12. Phase 12 : Pedogenesis of soil VI (unit 22 pp)

Earthworm galleries can be traced within the yellowish brown (10 YR 5/6) loess layer of phase 11. These galleries seem to be related to a homogeneous brown (10 YR 5/3) horizon (unit 22a). This unit commonly contains biogalleries, which are filled with humiferous material. At this level we assume the presence of a stable period with humiferous surface building and intense biological activity. The vegetation during this phase may well be grassland or steppe.

Contemporary or subsequently to this phase occurs a period of seasonal freezing and thawing which is well-illustrated by the platy pedality starting at this level.

3.2.13. Phase 13 : Stratified sediments (units 21 to 18 pp)

A thick non-calcareous micro granular layer covers Soil VI (units 21 to 19). This unit consists of numerous thinly stratified layers, which are locally interrupted by ice wedge pseudomorphs. Micro morphologically this unit is characterised by fine capping of rounded soil fragments. This fabric corresponds to gelifluction. Such a pedisediment results from numerous freeze-thaw cycles and rapid displacement of the sediment due to the steep slope or high water saturation. The well-sorted matrix on top of the stratified sediment suggests the input of aeolian sediments near the end of phase 13.

3.2.14. Phase 14 : Pedogenesis of soil VII (unit 18 pp)

On top of the sediment of phase 13 a new stable surface occurs. The homogeneous brown (10 YR 5/7) horizon (unit 18) is characterised by numerous channels of biological origin and a micro granular pedality. This horizon is associated with very few clay coatings. No traces of an important humiferous surface building are to be found. Thus many diagnostic features and analytical data are lacking to appreciate the pedogenesis during phase 12.

3.3. Pedological overview (Fig. 11)

In Remicourt the Rocourt Soil embraces the phases 2 up to 7 *pro parte*. of the local pedostratigraphic sequence. These phases encompass three soil forming processes, which are separated by subsequent cold periods. Soil I and Soil II are characterised by two individualised clay illuviations and resemble Luvisols. Soil III on the other hand is attested by common pupal chambers and translocation of organomineral substances and resembles a Greyzem. The cold phase separating Soil I and Soil II is characterised by slight erosion, deep seasonal freezing and most probably permafrost, whilst Soil II and Soil III are divided by colluvial sedimentation and deep seasonal freezing. Finally the whitish horizon indicates a reworking of the upper part of the Greyzem (Soil III) during cold climatic conditions, while the whitish colour and accumulation of skeletal grains is mainly due to percolating melt water prior to the development of a chernozem (Soil IV), which is present in the lower half of the Humiferous Complex of Remicourt (HCR).

The HCR, which contains the Rocourt Tephra (Haesaerts *et al.*, 1997), is represented by two soil forming processes, separated by frostcreep and aeolian sedimentation (phases 7 *pro parte* to 10). These soils resemble a chernozem (Soil IV) and Sub Arctic Soil (Soil V).

The cover deposits (units 22 up to 17) correspond to phases 11 up to 14. On top of the loess-like sediment covering the HCR a weak humiferous soil is formed. This soil is covered by a stratified thick loamy sediment which was deposited by gelifluction and subsequent aeolian sedimentation. Soil VII with faint clay illuviation finally closes the Early Glacial sequence in Remicourt.

3.4. Palaeolithic occupation in Remicourt

The excavations carried out at Remicourt from January until April 1998 have uncovered about 580 m^2 and have enabled the recognition of two main concentrations (Fig. 5, areas A and B).

The concentration A (16 m^2) provided some 170 average-sized artefacts (from a few mm up to 7-8 cm) made by blade and bladelet flaking out of fine-grained black-grey flint. The majority of the artefacts laid in a horizontal position within the Whitish Horizon of Momalle (unit 26); they were scattered throughout the light yellowish brown and silty bands. Most often the small- or large-sized artefacts presented a light silty coating, which generally covered the totality of their surface.

Besides, 16 pieces from concentration A were collected *in situ* in the light yellowish brown horizon (unit 27a) lying underneath the Whitish Horizon of Momalle. The majority of these artefacts laid in a horizontal position and presented clayey dark brown coatings. The refits between pieces from both layers (27a and 26) demonstrate that they belong to a single assemblage. It can therefore be concluded that the occupation from which concentration A originated, occurred during the sedimentary phase preceding the formation of the Greyzem (Fig. 14). After the pedogenesis, the artefacts present in the upper part of this soil were slightly displaced by solifluction processes and incorporated into the Whitish Horizon of Momalle, while the underlying artefacts remained *in situ* in the light yellowish brown horizon.

The concentration B, (about 80 m^2) located at a distant of ca. 20 m (Fig. 5), provided some 200 artefacts which were all scattered throughout and collected from the Whitish Horizon of Momalle. These artefacts were made out of flint of different qualities and include Levallois, laminar (Figs. 6.2, 6.3 and 6.4) and bifacial (Fig. 6.1) reduction patterns. The first refits realised on the material from this concentration associate pieces found at various depths of the Whitish Horizon of Momalle. Without any refitting between concentrations A and B and in the absence of material within the light yellowish brown horizon under the concentration B, it could not be excluded that this concentration should be somewhat posterior to concentration A. In such a case the occupation related to concentration B would date to the solifluction phase associated with the settling of the Whitish Horizon of Momalle.

4. The Rocourt Soil with regard to the Last Interglacial-Early Glacial cycle in the Belgian Loess Belt (Figs. 11 to 14)

For the first time, the sequence of Remicourt embraces a detailed reconstruction and interpretation of the Rocourt Soil, preserved in a 20 m thick loess record . This record integrates the known sections of Hesbaye (Rocourt, Lixhe and Kesselt) and of the Haine Basin in SW Belgium (Harmignies), since it contains all the pedological, sedimentary and tephrostratigraphic markers of the Upper Pleistocene in the Belgian loess belt (Fig. 12).

4.1. Remicourt - Rocourt sections (Fig. 11)

The new insights given by the Remicourt section match perfectly with the complexity of the classic Rocourt Soil (Fig. 11) which was recently re-examined at its locus typicus by the authors. The textural B-horizon and the textural banding at the base of the Rocourt sequence is characterised by thick clay coatings and suffered minor periglacial turbation. This horizon with its bleached spots matches with Soil I of Remicourt.

The strongly turbated upper part of the textural B-horizon indicates periglacial churning and corresponds to phase 3 of Remicourt. Clay illuviation along relict periglacial structures within the upper half of the textural B-horizon resembles Soil II of Remicourt.

In Rocourt, a yellowish brown horizon of 10 to 15 cm thick was locally recognised below the whitish horizon. Within this new horizon the translocation of organomineral substances is attested and its characteristics are similar to those of unit 27a of Soil III in Remicourt.

The humiferous complex and the so-called E-horizon in the Rocourt section give a similar pedo-stratigraphic picture as the Whitish Horizon of Momalle and the HCR (units 26 to 24) of Remicourt. Consequently the

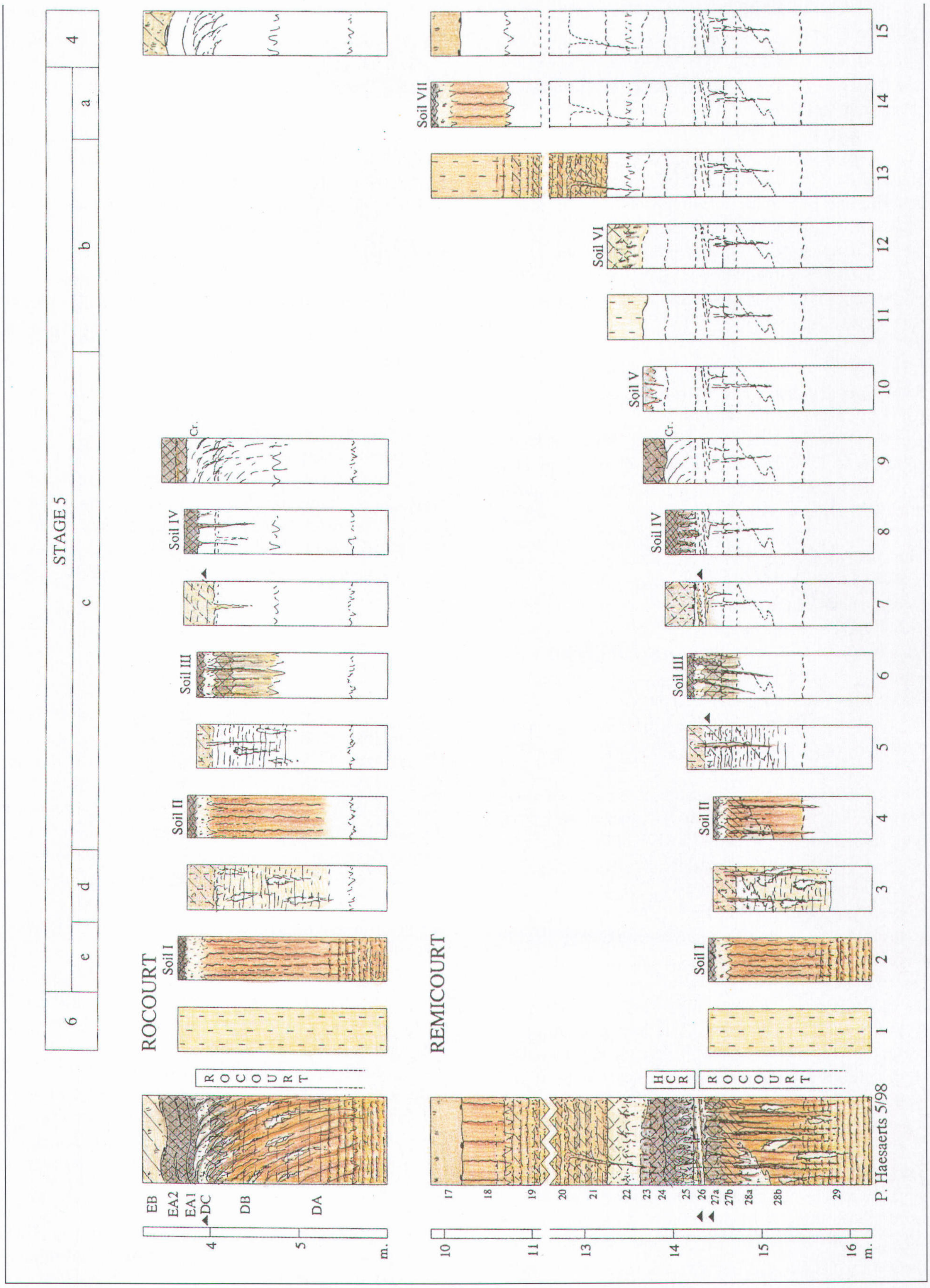

Figure 11. Pedostratigraphic reconstruction of the Rocourt Soil in the type locality and in Remicourt. See Fig. 4 for legend.

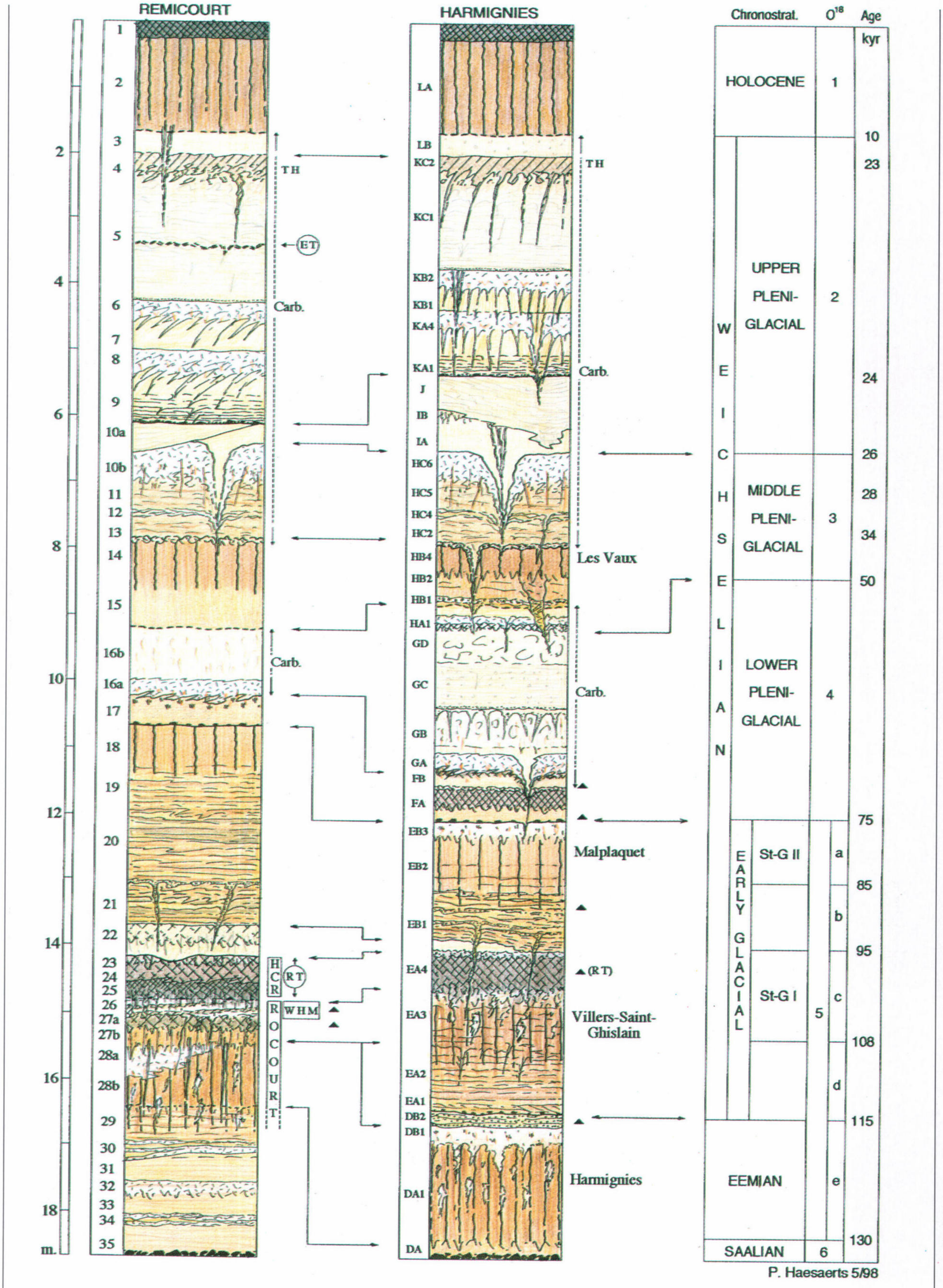

Figure 12. The Remicourt - Harmignies sequences. See Fig. 4 for legend.

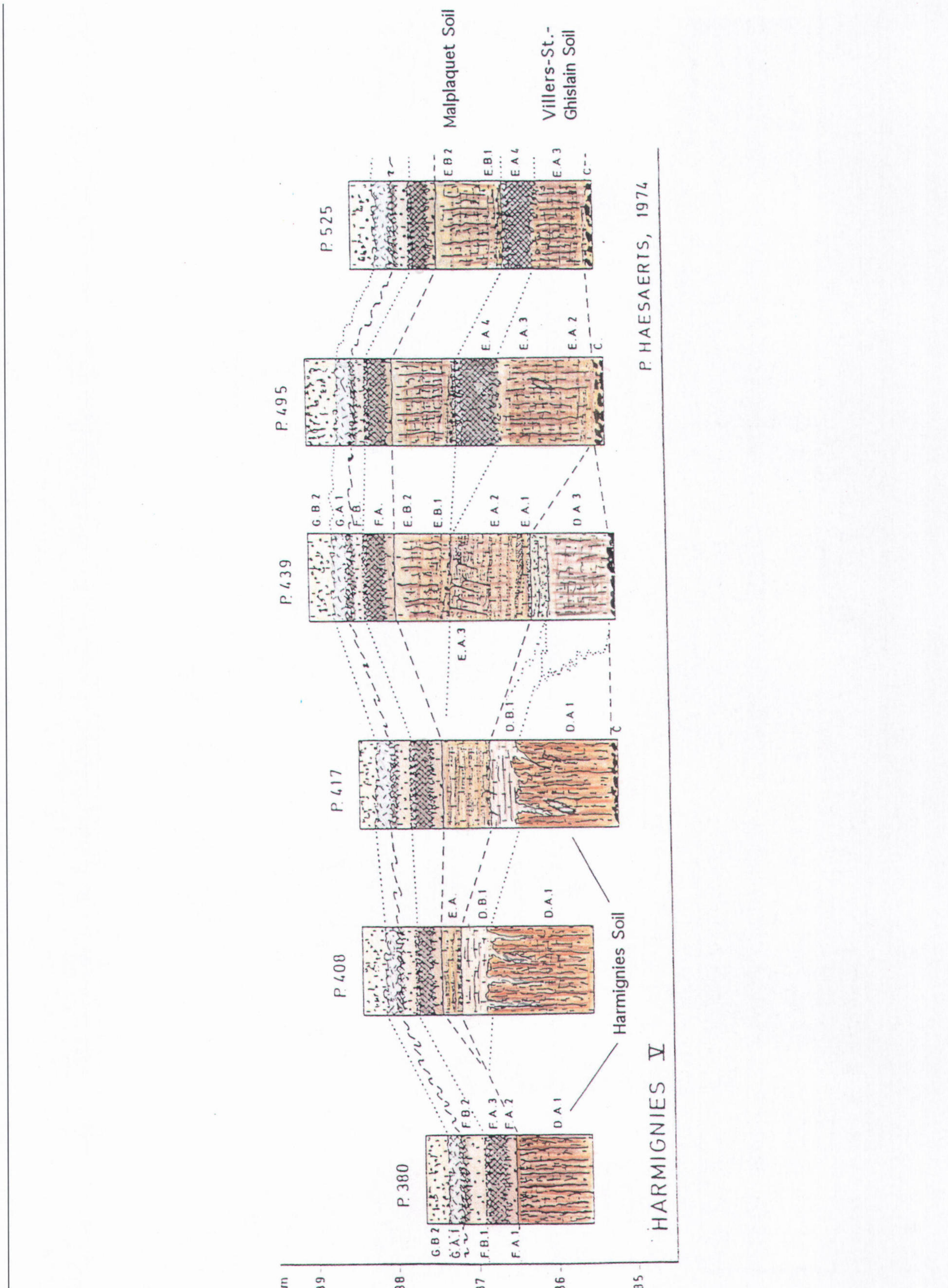

Figure 13. Cuesta of Harmignies: pedostratigraphic sequence. See Fig. 4 for legend (after Haesaerts, 1974).

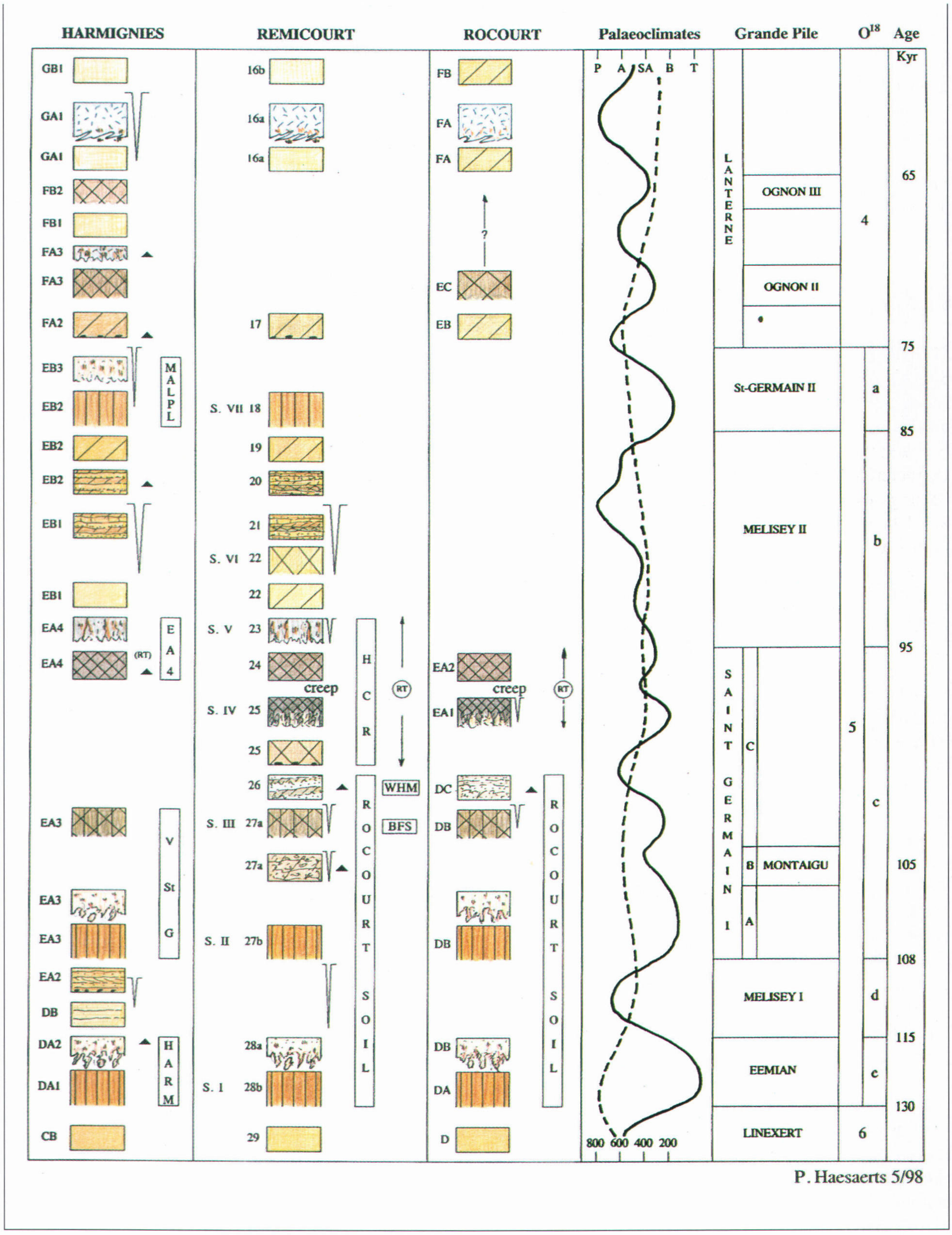

Figure 14. Chronostratigraphic background.

See Fig. 4 for legend. Other symbols: MALPL.: Malplaquet Soil; V. St. G.: Villers-Saint-Ghislain Soil; HARM.: Harmignies Soil; R.T.: Rocourt Tephra; H.C.R.: Humiferous Complex of Remicourt; W.H.M.: Whitish Horizon of Momalle; B.F.S.: Bia Flo Soil. Palaeoclimates: full line: P: periglacial with active permafrost; A: arctic; SA: sub-arctic; B: boreal; T: temperate); dashed line: mean annual precipitation.

human occupation related to the workshop with the laminar reduction pattern at Rocourt (Otte *et al.*, 1990) may be considered as contemporaneous of the deposition of the Whitish Horizon of Momalle (phase 7). In contrast, the cold phase 9 of Remicourt just posterior to the development of Soil IV, provoked a stronger turbation in Rocourt. As a result, the frostcreep during this phase hinders a correct interpretation of the pedostratigraphical and climatological picture at Rocourt.

4.2. Remicourt - Harmignies sections (Figs. 12 to 14)

The recognised soil forming processes of the Rocourt Soil in Remicourt correspond perfectly to the Harmignies Soil and the Villers-Saint-Ghislain Soil in the Haine Basin (Haesaerts and Van Vliet, 1974; Haesaerts and Van Vliet-Lanoë, 1981). Indeed, the soil characteristics of Soil I are similar to those of the Harmignies Soil while the characteristics of Soil II and Soil III correspond to those recognised in the Villers-Saint-Ghislain Soil (Figs. 12 and 13). The re-examination of the latter soil in February 1997 illustrated a first illuviation characterised by well-oriented clay coatings and a second illuviation which appears in the faunal pedoturbations as humiferous clay coatings (organomineral translocation). It is now undoubtedly clear that the Villers-Saint-Ghislain Soil in Harmignies does not correspond to a single and unique soil (Haesaerts and Van Vliet-Lanoë, 1981), but to a pedocomplex.

As a matter of convenience we will keep the name "Villers-Saint-Ghislain Soil" for Soil II in Remicourt, since it corresponds best to the known descriptions of this soil in Harmignies (e.g. Haesaerts and Van Vliet 1974; Haesaerts and Van Vliet-Lanoë, 1981). On the other hand, Soil III, which resembles a Greyzem and was first individualised in Remicourt, is named here "Bia Flo Soil".

The correlation between the Remicourt and Harmignies sequences is also well-illustrated by the presence of the thick humiferous layer covering the Rocourt Soil. The occurrence of few volcanic mineral grains, which most probably belong to the Rocourt Tephra in a lateral equivalent of the humiferous unit E.A.4 in Harmignies (Juvigné, 1977) strengthens this stratigraphic correlation. Similar relations between the Rocourt Soil, the overlying humiferous layer and the Rocourt Tephra have also been recorded in Rocourt (Juvigné, 1977) and Kesselt (Juvigné *et al.*, 1996).

The soil characteristics and the palynological investigation of E.A.4 in Harmignies (Haesaerts and Van Vliet, 1974), which corresponds to a taiga or forest steppe, agrees with the interpretation of Soil IV of the HCR in Remicourt as a chernozem. On the other hand, Soil V developed on top of HCR, is clearly related to a Sub Arctic Soil. As a similar soil occurs on top of the humiferous layer E.A.4 in Harmignies and in Kesselt, Soil V most probably records a drastic cooling of the climate announcing the following marker loess (unit 22) which is only locally preserved on top of E.A.4 in Harmignies (Fig. 13).

Although Soil VI, with its remarkable earthworm activity, is not present in Harmignies, the stratified loamy sediments with small ice wedges pseudomorphs (E.B.1 and E.B.2), which correspond to phase 13, are clearly identified above E.A.4 and are capped by the Malplaquet Soil. In Remicourt, equal stratigraphic conditions are present, since these stratified sediments are covered by Soil VII with faint clay illuviation which was identified as the "Malplaquet Soil". In Harmignies as well as in Remicourt this soil was truncated by erosion, this process being marked by a continuous gravel at the base of the Lower Pleniglacial loess cover (Figs. 12 and 13).

5. Conclusions

The sequence of Remicourt allows to make for the first time a complete diagnosis of the Rocourt Soil under its classic facies, revealing a succession of three soil forming processes separated by two cold episodes. Soils I and II resemble Luvisols, while Soil III could be ascribed to a Greyzem. The whole is capped by a thick humiferous body containing the Rocourt Tephra. Further, in Remicourt, the Rocourt Soil occurred within a long loess sequence that constitutes the link between the Hesbaye classic records and the Cuesta of Harmignies in the Haine Basin.

On this basis, the equivalence between the three pedogeneses forming the Rocourt Soil and the succession of the Harmignies Soil and the two folded Villers Saint-Ghislain Soil could be demonstrated, using the HCR with the Rocourt Tephra as stratigraphic marker (Figs. 12 and 14). Since the parallelism between the Harmignies sequence and La Grande Pile is well established (Haesaerts and Van Vliet, 1974; Van Vliet-Lanoë, 1986), the Rocourt Soil as defined in Hesbaye can therefore be ascribed to the Eemian - Melisey I - Saint-Germain I succession, thus to isotopic substages 5e to 5c* (Woillard, 1975).

*) A comparable ascription has already been proposed by B. Van Vliet-Lanoë *et al.* (1993) as part of a study of the Riencourt-les-Bapaume site; although the argumentation was rather confused and partly based on incomplete data, their intuition turns out to be correct.

An essential aspect of the Remicourt sequence also concerns the high degree of resolution of the upper horizons of the Rocourt Soil and the overlying humiferous complex, which enables their precise positioning according to the different climatic episodes recognised within Saint-Germain I by Woillard (1975).

In fact, the climatic environment of Soils II and III (Luvisol and Greyzem) is consistent with Saint-Germain IA and the first half of Saint-Germain IC, both represented by a vegetation still dominated by thermophile species, the cold episode that separates these soils at Remicourt being therefore the expression of the cold Saint-Germain IB (Montaigu). In contrast, the HCR and its E.A.4 equivalent which involve a more continental and cool environment, are conform with the upper part of Saint-Germain IC characterised by a taiga vegetation.

This interpretation is also in accordance with the further evolution of the climatic sequence at Remicourt where the stratified deposits (units 21 to 19) associated to a cold episode with permafrost (phase 13) are ascribed to Melisey II, whereas Soil VII developed on top of these deposits appears as an equivalent of the Malplaquet Soil contemporaneous to Saint-Germain II. Finally, at Harmignies as well as at Remicourt, the erosion basis of the loess cover represents a major morpho-stratigraphic boundary that marks the lower limit of isotopic Stage 4 in the loess sequence of north-western Europe. The doublets of isohumic soils generally present at this level (Van Vliet-Lanoë, 1986; 1990) were not recorded at Remicourt.

The soil characteristics in Remicourt prove a general trend of increasing continentalisation or increasing desiccation of the climate. The Rocourt Soil however stands out as a clear physical signal, which corresponds to Atlantic and moist continental climates (Fig. 14). Its upper boundary, notably the Whitish Horizon of Momalle, is the onset of more continental and dry climatic conditions, which announce the Pleniglacial. The cold phases probably follow the same trend but the temperature witnesses variable intensities. Two cold phases are definitely extremely severe. These phases (3 and 13) correspond to permafrost and are clearly individualised. Phase 3 is characterised by cryo-desiccation cracks and the formation of fragipan. Phase 13 corresponds to a period of severe erosion with at least one generation of small ice wedges.

Finally, the integration of the Remicourt data into a chronostratigraphic sequence for north-western Europe leads to the ascription of the formation of the Rocourt Soil to a period of about 30 kyr, extending from the beginning of the Eemian (substage 5e) around 130 kyr up to the second third of Saint-Germain I (substage 5c) around 100 kyr (Fig. 14). In such a context, the Whitish Horizon of Momalle, which contains a workshop with laminar reduction pattern at Rocourt, as well as the HCR containing the Rocourt Tephra, record the upper part of Saint-Germain I and can thus be dated between ± 100 and ± 95 kyr. As for the workshop with the laminar reduction pattern from concentration A at Remicourt, it is surely more ancient for it is ascribed to the cold Saint-Germain IB (Montaigu) episode; its age is probably close to 105 kyr. Further, it is worth mentioning that the chronological background proposed here for the Rocourt Soil perfectly fits with the TL ages around 90 kyr obtained on humiferous deposits equivalent to the HCR at Metternich and Tönchesberg in the Middle Rhine Basin (Frechen *et al.*, 1994), while humiferous soils at the base of the Lower Pleniglacial loess cover in the same sites were TL dated between 75 and 65 kyr.

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