Comparative stratigraphy of Würm loess deposits in Belgium and Austria,

by R. PAEPE.

1. — INTRODUCTION.

The stratigraphy of the Würm loess deposits exposed on the northern wall of the brickyard « Point du Jour » at Tongrinne (Belgium) (fig. 1), shows a striking resemblance to the succession found at the locus typicus Stillfried (and others) in Austria.

Both sites are located in an area where eolian loess sedimentation was dominant and where relatively dry climatic conditions prevailed (Trockenen Lösslandschaft, J. FINK, 1955). Due to its topographic, high and flat position, the sedimentation pattern at Tongrinne does not show disturbances as may often occur in depressionlike fillings. Therefore the loess morphology at this site can be considered normal and complete and has been chosen as a reference locality. It must

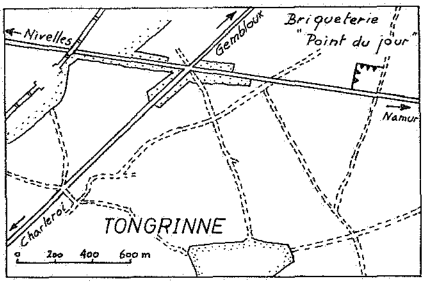

FIG. 1.

be understood that during the following discussion the knowledge of other previous studied sites (R. PAEPE, 1963, 1964, 1965, 1966) influenced the stratigraphical interpretation about the present profile.

The present comparison of loess deposits, deals with the problem of the division of the Würm loess.

One wonders whether such comparison considering the distance between the localities, can be justified, and can contribute to solve the problem. As pointed out by J. BÜDEL (1950), it has become a common property to believe in the tripartition of the Würm loess on the basis of the apparent accordance between moraine deposits, loess successions, river-terraces and astronomical calculations within the area of origin of the tripartitional concept of the Würm (W. Soergel, 1919). It has been shown now that a comparison of the loess stratigraphy with the moraine succession cannot be held any longer. J. Büdel (1950) and J. Fink (1959, 1965) have clearly described the misapprehensions about this concept and how they found their way in literature; furthermore, J. Fink (1959) reports that not less than seven different interpretations of the Würm I appeared to exist at the session of the Commission for Würm stratigraphy of the IV Inqua Congress. Even within the borders of a small country like Belgium, communication on loess, and even on Würm loess stratigraphy only, seems difficult. Amongst those who advocated in favour of a tripartition of the loess R. Tavernier (1946, 1948, 1954), J. de Heinzelin (1957), G. Manil (1949) and R. Paepe (1965) must be cited while F. Gullentops (1954, 1957) pleaded in favour of a bipartition.

The whole problem is in fact situated around the recognition and definition of the so-called Würm I deposits. But we shall come back to this question later.

From this it follows that there is no longer reason to simply apply the W I, W II and W III division for the establishment of the Würm stratigraphy. The latter should be disentangled from its sediment morphology, lithofacies, periglacial features, palaeosoils and their stratigraphical interrelationship. This enables one to elaborate a stratigraphical scheme even in areas where glacial deposits do not occur.

It is then, and only then, possible to compare profiles from different areas and to conclude as to their similar stratigraphical significance if they occur to reveal the same sequence. Consequently, this is a further argument in itself which affirms the general world-spread climatic evolution with which the loess stratigraphy deals. In other words : we start from climatic bounded relicts of the glacial epoch (loess, solifluction and non-glacial river terraces) which we then try to tie up with the glacial controlled phenomena of the same period (J. Büdel, 1950; J. Fink, 1959, 1961 and 1965) and not vice-versa.

2. — TONGRINNE AND NEIGHBOURHOOD.

Localisation : « Briquieterie Point du Jour » at Tongrinne (Prop. M. Michel). Sheet Fleurus 143 W - n° 5 (see fig. 1).

Height : 163 m.

Relief : Ondulating landscape; small plateaus and shallow valley depressions.

Description (figs. 2 and 3).

Ap : A — plow horizon of modern soil, 10 YR 4/3.

B_2t : Textural B horizon; 10 YR 4/4; prismatic structure; « terre à briques ».

LIMON J.B. : Yellowish brown loam 10 YR 5/4 characterised by quickly alternating fine layers of more sandy or more loamy texture.

CRYOT : Cryoturbatic horizon in fine stratified sediment composed of alternating sandy yellowish layers and brownish loam layers. Involutions (congeliturbates) composed of sand. At the top and at the base of these layers tall wedges occur; the top ones are developed inside the lower ones; both are filled with materials of the layer lying immediately above. The cryoturbatic layer is partly gleyified and contains vegetation remnants.

LIMON B : Grayish brown (10 YR 4/4) loam, homogeneous.

LIMON G : Grayish (10 YR 5/4 - 2.5 Y) heterogenuous loam with irregular stratification (limon à doublets). Locally small wedges may occur. At the base and in the middle, oxydation bands are present; at the base of the lower oxydation band larger wedges are observed. Sporadically, pebbles deriving from primary rocks occur within the body of the loam.

LIMON B.H. : Homogeneous yellowish brown (10 YR 4/4) loam with slight irregular stratification.

SOL. HUM. : Grayish yellow (10 YR 5/4) sandy loam; the upper part is humiferous (10 YR 4/3), dark brown while the lower part, much lighter and grayer in colour, contains numerous spots of Fe/Mn concretions. Vegetation remnants are common; slight (irregular) stratification is visible. Crotovines are numerous. The upper limit of the deposit is characterised by a pebble pavement (stone line) composed of green phyllades; at this level little wedges may occur. The lower, diffuse limit shows, however, ravinations of different forms (holes, wedges) and of different sizes.

SOL ROUGE : Clayey loam dark brown (7.5 YR 4/4) in colour. The most clayey part (B_2t) is even more reddish. This horizon is impregnated with irregular fine cracks filled up with red heavy clay. Crotovines also occur in this layer and are filled with material from the layer above; lighter in colour and loamy and sandy in texture.

LIMON ARG. : Brown (10 YR 5/4) clayey loam with yellowish sandy bands.

Similar observations in the loess deposits at Tongrinne and in its neighbourhood have been made by G. MANIL (1949, 1952). His descriptions permit correlation with the above described profile. In the following interpretative discussion we shall refer to them.

The lower soil horizon (SOL ROUGE) shows a degree of development which is much stronger than any other soil horizon represented in the profile. Even the textural B horizon of the upper recent soil (« Terre à briques »; Gray brown Podzolic), does not attain the strong weathering of the clay minerals as is shown by the heaviness and the more reddish colouring of the structural B horizon of the SOL ROUGE. Also the red clay cracks are completely lacking in the upper soil. Since both are subgroups of the same great (soil) group, the SOL ROUGE has obviously been subdued to a longer and climatically more intensive evolution than could have ever existed in post-glacial times. It is the B Horizon of a Red Yellow Podzolic. An interglacial age is thus avident. The question now rises whether a Riss/Würm or older interglacial age should be attributed. G. MANIL (1952, 1958) describes at the « Pont d'Agasse » apparently the same horizon. There his « limon rougeâtre et fendillé typique » lies on a brown clayey loam and is overlain by a gray sandy loam with a diffuse but ondulating contact. After hesitating whether his « fendillé » should be attributed to the lower part of the Würm or as in France (V. COMMONT, 1909; F. BORDES, 1952) to the Riss/Würm interglacial, he finally choses for the latter interpretation (1958). By doing this he also assumed that the grayish dark lower part of the overlying loess (our SOL HUM. at Tongrinne) represented the A horizon of the SOL ROUGE (fendillé). The whole pedological profile is then developed in Riss loess deposits. At other localities the same author reports : « lehm brun rougeâtre, fendillé » (Briqueterie Laubain, Gembloux) called lower loess (ancient loess) (1949) and attributed to the lower Würm (1952); « horizon limoniteux » (Briqueterie Vigneron, Sombreffe) which he considers as due to fluctuations of the waterlevel rather than to weathering processes. The latter horizon, however, occupies the same stratigraphical position of the already mentioned reddish horizons. It is a common feature that soil horizons do not attain an equal (maximum) degree of intensity everywhere because of prevailing local conditions even when climatic conditions are equal.

In such case the stratigraphical boundaries and position of the faintly developed paleosols permit correlation with the already recognised ones. We therefore think that the above mentioned reddish horizons all belong to the same stratigraphical unit and that

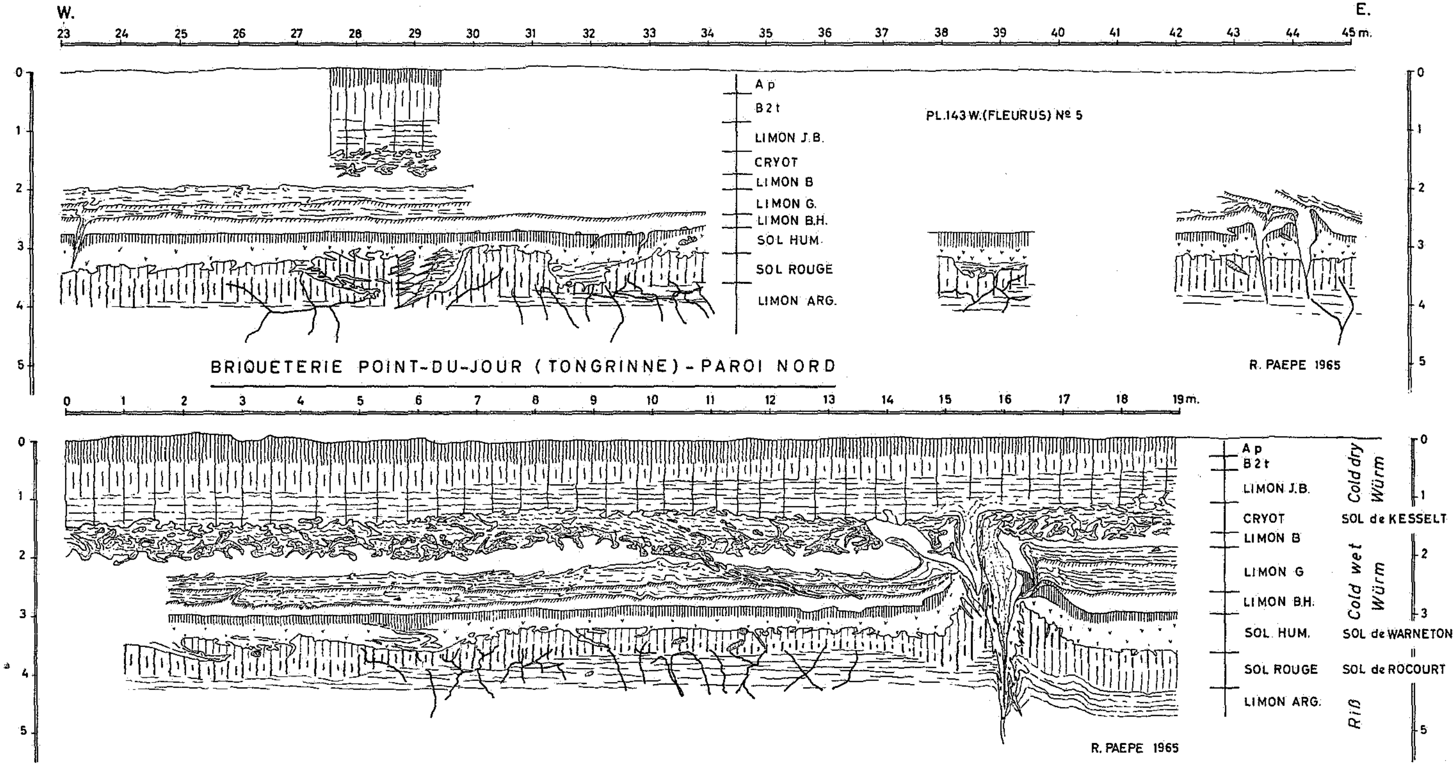
W.
E.
23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 m.
A p
B2t
LIMON J.B.
CRYOT
LIMON B
LIMON G.
LIMON B.H.
SOL HUM.
SOL ROUGE
LIMON ARG.
PL.143 W.(FLEURUS) Nº 5
BRIQUETERIE POINT-DU-JOUR (TONGRINNE) - PAROI NORD
R. PAEPE 1965
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 m.
Ap
B2t
LIMON J.B.
CRYOT
LIMON B
LIMON G
LIMON B.H.
SOL. HUM.
SOL ROUGE
LIMON ARG.
Cold dry Würm
SOL de KESSELT
Cold wet Würm
SOL de WARNETON
SOL de ROCOURT
Riß
R. PAEPE 1965

FIG. 2.

the SOL ROUGE of Tongrinne extends as a constant stratigraphical level within the area around Gembloux. As already assumed by G. MANIL (1952), according to their high topographic position, erosion has little or not at all affected these sites which all occur on the Meuse-Scheldt divide. In fact, no traces of important destruction of the SOL ROUGE is noticed. The ravinations occurring at the diffuse contact between the SOL ROUGE and the SOL. HUM. are minor processes which cannot be the result of an important erosion cycle. The constancy of the stratigraphical sequence and the lack of important erosion let us assume that there is no stratigraphical (chrono-geological) hiatus between the SOL ROUGE and the deposits immediately above. Therefore, we conclude that the SOL ROUGE is Riss/Würm interglacial in age. F. GULLENTOPS (1954) described at Rocourt (northwest of Liège) the same pedological horizon to which he attributed also a Riss/Würm interglacial age. To avoid confusion with the so called « fendillés » of other warm periods, GULLENTOPS proposed to name this particular horizon SOL DE ROCOURT. Contrary to G. MANIL, GULLENTOPS separates the SOL DE ROCOURT pedologically from the humic horizon lying immediately above. Chrono-geologically, the latter author attribute a late Riss/Würm age both for the humic layers and for the sediments in which they developed.

R. TAVERNIER and J. DE HEINZELIN (1957) thought that the upward extension of GULLENTOPS' « Sol de Rocourt » was too large. These authors rather considered the humic facies above the sol de Rocourt as the lower part of the Würm I. The « Sol de Clypot » of the same authors represents then an upper lehmification zone of the Würm I.

It is clear now that the geological and pedological interpretation of the SOL. HUM. of Tongrinne has a threefold importance :

— the litho-stratigraphic boundary between Riss and Würm loess deposits,
— the time-stratigraphic boundary between the Eem and Würm periods,
— the bipartition or tripartition of the Würm.

The SOL. HUM. zone with its cryoturbatic irregularities at the bottom and the solifluidal structure of the sediment itself, gives proof not only of a new sedimentation but also of climatic conditions which were different from those prevailing during the previous interglacial. It is a solifluction deposit typical for the periglacial area of the Würm period to which J. BÜDEL (1959) has given the name of « episodic solifluction ». Under such circumstances, locally reworked sediments can easily be taken up within the mass of the loess sediment and explain the unpure lithological character of the latter. The humic horizon which occupies the very upper part of the solifluidal deposit is the A horizon of a steppe soil. The crotovines in the lower part of the SOL. HUM. and in the SOL ROUGE show that this steppe soil is still in situ and also that the soil development started only after the solifluidal processes had come to an end. The numerous Fe/Mn concretions in the gray lower part, however, prove that the watertable remained high after the solifluction period and probably also during the steppe soil formation. Saturation with water of this horizon is a consequence of the impermeability of the SOL ROUGE, the fossil landscape morphology and the wet nature of the climate combined.

The afore, reveals the cold-humid climatic conditions which controlled the sedimentation and the soil development of the SOL. HUM. The above mentioned authors also came to this conclusion notwithstanding the fact that they incorporated this formation in widely seperated periods. Even G. MANIL, in earlier publication (1949), had described this SOL. HUM. as an independant soil formation and described the coarse Fe/Mn concretions as due to a high waterlevel.

R. PAEPE (1963, 1964) observed this soil in western Belgium and in nothern France. Sometimes instead of one simple humic horizon, three such layers seperated by cryoturbatic phenomena were visible. Lateral convergence of the threefold bandering to one single humic band was well expressed at Warneton. The name SOL DE WARNETON was given after this locality to this complex. The present author recognised recently the same complex at Zelzate and Antwerp (west bank of the Scheldt) (R. PAEPE, 1966). At that time R. PAEPE considered the sol de Warneton complex as incorporated in the base of the Würm I. He explained the recurrences as due to repeated fluctuations of relatively warm-humid and cold-dry periods.

Above the SOL. HUM. layer lies a pure eolian deposit (LIMON B.H.). The deflation horizon (pebble band) and the frost wedges at the bottom mark the coming of a cold-dry period favourising the loess deposition. The cold character held on after the loess sedimentation so that frost wedges could develop again at the upper limit of the deposit. We believe that such eolian sedimentation is a minor oscillation, since the size of the wedges are small (T. L. PÉWÉ, 1962). The moreover, except for the frost wedges, no other periglacial feature lines out the contact with the heterogeneous loam (LIMON G) that follows upwards. The latter mixed layered loam (Wechsellagerung?) reveals again a solifluidal image : all the irregularities of the stratification are inclined in a same eastern direction and so are the numerous little frostwedges. The small size of the frost wedges within the body of a sediment which was undoubtedly controlled by high moisture conditions, permits the statement that given a saturation with water, the degree of decrease in temperature must have been small. On this solifluidal deposit (LIMON G) lies another eolian loess (LIMON B). As for the LIMON B.H., the boundaries with the solifluidal deposits are astonishingly sharp and reflect only the irregularities of the solifluction. But this time no frost wedges were formed eventhough the temperature had dropped considerably. As a consequence these changes in the nature of the sedimentation (from solifluction to eolian activity) proceeded apparently quickly and are thought to reflect the unstable prevailing climatic conditions. Nevertheless the weak stratification of the LIMON B show that solifluidal conditions slightly remained even during the eolian sedimentation of this period. After a suggestion by V. VAN STRAELEN, R. TAVERNIER (1946) introduced the term « niveo-eolian » for such sediments. J. BÜDEL (1959) reports the building of eolian deposits in a area where solifluidal processes under the present climate dominate : the Moldloess of Iceland. It is certainly not under such climatic conditions that the maximum glaciation and therefore a stable climatic « high » was reached.

The cryoturbatic horizon (CRYOT.) is the next important diagnostic layer. G. MANIL mentions this horizon in all his profiles : « horizon rougeâtre ou orangé avec disturbations (solifluction) ». The solifluction character is largely affected by cryoturbations at Tongrinne. The congeliturbates are composed of sand derived from the sand layers within the complex. The dark colour, the vegetation remnants and the gley also indicate that at this level a weak soil development occurs. G. MANIL even mentions a dark polyedric horizon. To all these characteristics, the presence of large, deep frost wedges must be added. They start in the upper part of the solifluction-cryoturbation layer. Their size especially their width (more than 1 m), is an index that they grew over a long period (see also T. L. PÉWÉ, 1962). Furthermore the superposition of two such wedges reveals that there were two periods of wedge formation interrupted by a warmer (solifluction) period. Indeed we can observe that the lower wedge is filled with the same sandy material as the congeliturbates whereas the upper one contains sands and loams from the loam deposit above (LIMON J.B.). Between the two wedges solifluidal material from the top of the CRYOT. layer occurs. The vertical stratification of the wedge fillings is similar to the ones described by T.L. PÉWÉ at the Mc Murdo Sound (Antarctica) and in Alaska; he considered them as caused by the formation of seasonal recurring thermal contraction cracks in the perennially frozen ground (cold season) and seasonal filling of the cracks (warm season). We admit that the same processes are at the origin of the wedges at Tongrinne. Therefore we used the term frost wedge rather than ice wedge; but if one considers the lithological composition than it would even better to speak of loess wedge (Loess Keile, G. SELZER, 1936) rather than of PÉWÉ's sand wedge and the « fentes à remplissage » of P. MACAR and W. VAN LECKWIJCK (1958). Accordingly to J. BÜDEL (1959) the effect of this repeated thaw and freeze was extremely important during a warm/cold transitional period : interglacial or interstadial and contributed highly to the growth of such wedges.

From the above, it follows that the loess wedges of the CRYOT. layer were formed at the end of an interstadial. The weak soil that developed during the interstadial has in turn been disturbed (cryoturbations) as soon as the first severe cold peaks controlled the climate. With increase of the cold conditions, loess wedges developed. In other words the CRYOT. horizon holds the complete succession of the transition from cold/humid to cold/dry climatic conditions.

The maximum of the cold was reached with the sedimentation of the yellowish brown loam (LIMON J.B.) which is dominantly an eolian deposit. Since solifluidal layers still occur at the bottom of this deposit (above the wedges), it shows that also at the beginning of the maximum phase of the cold, transition to severe cold/dry conditions grew only gradually.

F. GULLENTOPS describes cryoturbatic layers similar to our CRYOT. horizon at Kesselt, Rocourt, Ans and Kessel-Lo (1954). R. PAEPE, in a previous work, also observed (1963, 1965) these cryoturbations and wedges in several outcrops : Rumbeke, Poperinge, Zonnebeke, Frélinghien, Quesnoy. To the soil under or/and mixed with this horizon, F. GULLENTOPS has given the connotation SOL DE KESSELT.

The stratigraphy of Tongrinne can be summarised as follows : above the Riss/Würm interglacial soil (SOL ROUGE) only two important diagnostic horizons, the SOL. HUM. and the CRYOT. layers, can be observed in the Würm loess cover. The loess deposits below the CRYOT. layer show a dominance of solifluidal processes. Transition between solifluction and eolian deposits belonging to this solifluidal phase are so abrupt that both are to be considered as oscillations of one and the same period. The latter can be parallelised with the « solifluction period » of J. BÜDEL, or « loess-toundra » during which cold-humid climatic conditions prevailed. At the base of this loess-toundra, lies the SOL DE WARNETON complex (SOL. HUM.). The eolian loess deposits above the CRYOT. layer then deals with the cold-dry phase or « loess steppe » (J. BÜDEL). The soil mixed with the CRYOT. layer occurs at the same stratigraphical level as the SOL DE KESSELT. There is no evidence of the SOL DE CLYPOT.

3. — STILLFRIED AND NEIGHBOURHOOD, CORRELATION WITH TONGRINNE.

Stillfried an der March is the type locality of the sequence of fossil soils which J. FINK (1954) has called the « Stillfried Complex » (fig. 3). At the base lies a B horizon of a Gray Brown Podzolic (Braunerde) which has been developed in the underlying loess deposits and which has been correlated with the Göttweig paleosoil. The top is eroded and buried under several superposed humic soil horizons developed in original solifluidal deposits. The presence of crotovines pleads for the in situ character of the soil and its formation after solifluction had stopped. The humic horizons are seperated by loess layers the most important of which is the one occurring between the lowest

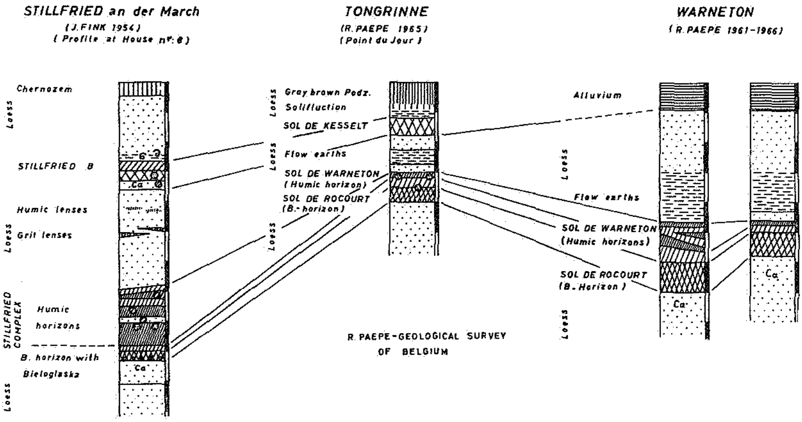

FIG. 3.

humic layer and the B horizon. It is a matter of course to consider the humic horizons as seperate buildings of chernozemlike soils dating from the beginning of the Würm glacial period while the B horizon was formed during the previous Riss/Würm interglacial period. This stratigraphical interpretation is supported by the fact

AUTHOR'S NOTICE : on fig. 3, the upper division line starting at the bottom of the SOL DE KESSELT must be traced downwards to the top of the flow earths of the WARNETON profile.

that the basal part of the Stillfried Complex at Stillfried falls together with a Riss erosion terrace. The same is true at Göttweig (Hollweg Furth) where the B horizon developed partly in the underlying High terrace of Riss age. So the Würm stratigraphy could be related to the terrace system of Lower Austria.

At other localities the humic horizons can lie directly on the B horizon (Oberfellabrunn) and can even be reduced to one single humic horizon (Hollabrunn).

Palynological results were obtained from the humic horizons of textural B horizon and from the Stillfried Complex by B. FRENZEL 1964). This investigation also leads to the division in a Riss/Würm interglacial formation for the B-horizon and an Amersfoort and Brörup age for the two humic horizons.

We refer the reader to the rich literature cited at the end of this paper rather than to repeat what has been described earlier with great care.

It now can be stated that according to the environment, detail morphology may change but the main stratigraphical units remain the same. Then morphological similar profiles may be correlated with each other on basis of the field geological evidence (fig. 3). With this in mind lateral correlation of the SOL ROUGE of Tongrinne with the B horizon at the base of the Stillfried complex and lateral correlation of the SOL. HUM. with the chernozemic humic layers of the upper part of the Stillfried Complex, are justified. Hence, our SOL DE WARNETON is the upper humic part of the Stillfried Complex.

Besides the already mentioned sites it is noteworthy that a similar stratigraphy is represented at the section of Unsterwisternitz (Dolní Vêstonice) (Checoslovakia). The radiocarbon dates, from this locality reapprove the correlation. In the latter area, the humic layers and the B horizon were also for a long time considered as belonging to one and the same pedological profile. This recalls the discussion about the SOL. HUM. horizon around and at Tongrinne.

Above the Stillfried Complex follows a loess formation, which is sometimes interrupted by gravelly layers and small weak humic intercalations. At the upper limit of the loess lies a weakly developed brownish soil horizon the top zone of which is humic and characterized by solifluidal disturbances. The latter horizon has been called Stillfried B (J. FINK, 1955) (1) and was correlated with the

(1) Radiocarbon datings for this level are 28.120 ± 200 and 27.990 ± 300 y. B.P. (J. FINK, 1962).

Paudorf paleosoil of the transitional region At other localities this horizon is only represented by a hydromorphic soil : « Gley-flecken zone » of the Alpen Vorland. Inside Lower Austria, the paleosoil can thus show very different outlooks, of which no present analogue is known. It can now easily be observed that the CRYOT. horizon of Tongrinne is the Stillfried B horizon and that the complex of loesses and solifluidal deposits are similar to the loess below the Stillfried B. Hence the latter horizon tallies with the SOL DE KESSELT.

Above the Stillfried B horizon lies a second loess which, as at Tongrinne, carries the present soil.

4. — CONCLUSION.

The correlation between Stillfried and Tongrinne is visualized in the following table :

	AUSTRIA			BELGIUM
	Dry area	Transitional area	Humid area	Loam area
Recent soil	Chernosem	Braunerde	Parabraunerde	Gray Brown Podzolic
Eolian sedimentation (Cold dry Würm phase)	Loess			Loess
Interstadial	Stillfried B	Paudorf	Gleyflecken zone	CRYOT. horizon with weak brown soil at Tongrinne = SOL DE KESSELT.
Solifluction period (only in wet areas) (cold wet Würm phase)	Loess Humic horizons of the Stillfried Complex		Loess-loam solifluction material.	Loess and solifluidal deposits. SOL. HUM. at Tongrinne = SOL DE WARNETON
Riss/Würm Interglacial	Göttweig soil		Subsoil of Parabraunerde	SOL ROUGE at Tongrinne = SOL DE ROCOURT
Riss	Loess			Loess

The stratigraphy of Tongrinne shall be chosen as a point of departure for correlation with other sites in Belgium. The revision of earlier interpretations is in progress (R. PAEPE et al., 1967).

BIBLIOGRAPHY.

1. Bordes, F., Stratigraphie des Loess et évolution des industries paléolithiques dans l'Ouest du Bassin de Paris. (*L'Anthropologie*, 56, pp. 1-30, 1952.)
2. Bryan, K., Cryopedology. The Study of frozen ground and intensive frost-action with suggestions on nomenclature. (*American Journal of Science*, vol. 244, sept. 1946, pp. 622-642.)
3. — The geologic implications of cryopedology. (*Journal of Geology*, Chicago, 1949, vol. 57, nr 2, pp. 101-104.)
4. — The erroneous use of Tjaele as the equivalent of perennially frozen ground. (*Ibid.*, vol. 59, jan. 1951, pp. 69-71.)
5. Büdel, J., Eiszeitliche und rezente Verwitterung und Abtragung im ehemals nicht vereisten Teil Mitteleuropas. (*The Geographical Journal*, London, 1938, vol. 91, no 1, pp. 62 and 63.)
6. — Die klimaphasen der Würmeiszeit. (*Die Naturwissenschaften*, XIX, 1950, pp. 438-449.)
7. — Klima-morphologische Beobachtungen in Süditalien. (*Erdkunde*, Band V, Lfg. 1, 1951, Bonn.)
8. — Periodische und episodische Solifluktion im Rahmen der klimatischen Solifluktionstypen. (*Ibid.*, Band XIII, Lfg. 4, 1959, Bonn.)
9. Commont, V., La Chronologie et la Stratigraphie des dépôts quaternaires dans la vallée de la Somme. (*Ann. Soc. géol. de Belgique*, 39, pp. 156-170, 1911.)
10. Fink, J., Studien zur absoluten und relativen chronologie der fossilen Böden in Österreich. I. Oberfellabrun. (*Archaeologia Austriaca*, 25, 1959, S. 35-73.)
11. — Studien zur absoluten und relativen Chronologie der fossilen Böden in Österreich. II : Wetzleinsdorf und Stillfried. (*Ibid.*, 31, 1962, S. 1-18.)
12. — Die Böden Niederösterreichs. (*Jahrbuch für Landeskunde von Niederösterreich*, folge XXXVI, 1964.)
13. — Die Gliederung der Würmeiszeit in Österreich. (*Report on the VIth international Congress on Quaternary*, Warsau, 1961, vol .IV : Symposium on Loess, 1964.)
14. — Die Subkommission für Lössstratigraphie der Internationalen Quartärvereinigung. (*Eiszeitalter und Gegenwart*, Band 15, S. 229-235, 1964.)
15. — The Pleistocene in Eastern Australia. (*The Geological Society of America*, Special paper 84, 1965.)
16. Frenzel, B., Über die offene Vegetation der letzten Eiszeit am Ostrande der Alpen. (*Verhandlungen der Zöologisch-Botanischen Gesellschaft in Wien*, Band 103 und 104, 1964.)
17. — Zur Pollenanalyse von Lössen. (*Eiszeitalter und Gegenwart*, Band 15, S. 5-39, 1964.)
18. Gullentops, F., Contributions à la chronologie du Pléistocène et des formes du relief en Belgique. (*Mém. Inst. géol. Univ. de Louvain*, t. XVIII, pp. 125-252, 1954.)
19. — Stratigraphie du Pléistocène supérieur en Belgique. (*Geologie en Mijnbouw*, nr 7, nieuwe serie, XIXe Jaargang, p. 305, 1957.)

20. MACAR, P. et VAN LECKWIJCK, W., Les fentes à remplissage de la région liégeoise. (*Ann. Soc. géol. de Belgique*, t. LXXXI, pp. B. 359-407, 1957-1958.)
21. MANIL, G., Le Quaternaire des environs de Gembloux. La tranchée de Mazy. (*Bull. Soc. belge de Géol.*, t. LVIII, 1, 1949.)
22. — Quelques considérations générales sur la stratigraphie quaternaire et la pédogénèse à propos de la description de trois coupes de Loess (Hesbaye gembloutoise). (*An. Soc. géol. de Belgique*, t. LXXV, pp. 153-167, 1952.)
23. — Quelques types spéciaux de paléosols et leur importance géomorphologique. (*Ibid.*, t. LXXVIII, pp. 289-296, 1954-1955.)
24. — Observations macromorphologiques, microscopiques et analytiques sur le remplissage des fentes de gel. (*Ibid.*, t. LXXXI, pp. 409-421, 1957-1958.)
25. — Observations sur le remplissage des fentes de gel *in* Le Périglaciaire Préorivinien. (*Congrès et Colloques Univ. de Liège*, vol. 17, Liège, 1960.)
26. PAEPE, R., Invloed van de Niveo-fluviale afzettingen op de bodemtextuur in de Zandleemstreek (met A. LOUIS). (*Pedologie*, t. XI, 1, 1961, pp. 49-60.)
27. — Les dépôts quaternaires de la Plaine de la Lys. (*Bull. Soc. belge de Géol.*, t. LXIII, fasc. 3, 1964, pp. 1-39.)
28. — Stratigraphy of the River Scheldt and Stratigraphy of the Flemish Valley. (IInd *International Conference on Palynology*, Livret-guide, Utrecht, pp. 1-17, 1966.)
29. PÉWÉ, T. L., Sand-wedge polygons (Tesselations) in the McMurdo Sound Region, Antarctica. A Progress Report. (*American Journal of Science*, vol. 257, October 1959, pp. 545-552.)
30. — Age of Moraines in Victoria Land, Antarctica. (*Journal of Glaciology*, vol. 4, n° 31, March 1962.)
31. PIFFL, Ludwig, Die Exkursion von Krems bis Aberlsg. (*Verhandlungen der Geologischen Bunderaustalt*, 1955, Heft D.)
32. — Eine altpleistozäne Scholterflur um Langenlois (*Ibid.*, 1959, Heft 1.)
33. — Der Wagram des Tullner Beckens. (*Ibid.*, 1964, Heft 2.)
34. TAVERNIER, R., Géologie de terrains récents. (*Bull. Soc. belge de Géol.*, pp. 452-478, 1946.)
35. — L'évolution du Bas-Escaut au Pléistocène supérieur. (*Ibid.*, t. LV, fasc. 1, 1946.)
36. — Les formations quaternaires de la Belgique en rapport avec l'évolution morphologique du pays. (*Ibid.*, t. LVII, fasc. 3, 1948.)
37. TAVERNIER, R. and SMITH, G. D., The concept of Braunerde (Brown Forest Soil) in Europe and the United States. (*Advances in Agronomy*, vol. IX, 1955.)
38. TAVERNIER, R. et DE HEINZELIN, J., Chronologie du Pléistocène supérieur, plus particulièrement en Belgique. (*Geologie en Mijnbouw*, nieuwe serie, nr 7, pp. 306-309, 1957.)
39. SELZER, G., Diluviale Lösskeile und Lösskeilnetze aus der Umgebung Göttingens. (*Geol. Rundsch.* 27, pp. 275-293, 1936.)
40. SOERGEL, W., Lösse, Eiszeiten und Paläolithische Kulturen. Eine Gliederung und Alterbestimmung der Lösse. Jena, 1919, p. 177.