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DIFFERENTIATION OF THE INTENSITY OF ACCUMULATION OF THE VISTULIAN LOESSES IN POLAND AND HUNGARY

Abstract

Indices of the intensity of accumulation of the basic stratigraphical units of the Vistulian loesses have been determined on the basis of dating with the thermoluminescence method. The intensity of accumulation in the upper pleniglacial, preceded by the interpleniglacial amelioration of climate was 10 times stronger than at the early glacial and about 5 times greater than in the lower pleniglacial. The rhythm of changes of the accumulation intensity was similar in the both areas compared, that is, was conditioned by the factors determining general evolutional rhythm in the glacial cycle. The intensity of loess accumulation in the Danubian areas in central Hungary was much better pronounced than in southern Poland due to the fact that the Danube carried off great quantities of the source material for loess formation from other regions of Europe.

A more precise determination of the rate of loess accumulation became possible in the sixties, when the dating of the younger lithostratigraphical units of these formations was based on the ^{14}C method. One of the first attempt of presentation of the numerical values of the rate of accumulation was made by A. A. VELIČKO (1968) for the loesses of the Valdai (Vistulian) glaciation in the area of the Russian Lowland. It was, however, an exploratory and very simplified study. It has raised various doubts, especially concerning: (1) recognition of the Middle Holocene as the end of accumulation of the Vistulian loesses, and (2) tracing on the curve the Older Holocene as the maximum intensity of accumulation of the loess dust. In further papers respective corrections were introduced. The beginning of the Vistulian loess accumulation on the Russian Lowland was estimated as about 70,000 years BP and its end was dated back to the turn of the Pleistocene and the Holocene. The rate of accumulation was established from below 0.1 mm in the initial phases, to 0.6 mm per year ca. 15,000 years BP (VELIČKO, 1977).

In the seventies, the possibilities of determination of the intensity of loess accumulation increased due to application of the thermoluminescence analyses (TL) for the dating of sediments, because the compass of time of this method is far larger than of the ^{14}C method. This quality is fundamental and from some point of view unrivalled, although the results obtained with TL are criticized among others on account of the methodical error much higher than in ^{14}C method.

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However, it should be stressed that the typical loesses belong to the formation most receptive to dating by the TL method, due to their grain size and especially because of the kind of subaerial transport that they underwent (ŠELKOPLYAS and MOROZOV, 1981; WINTLE and HUNTLEY, 1982).

While considering the problem of intensity of the loess accumulation the essential confinements may result from the state of knowledge on loesses. Regularity occurring in distribution as well as in changes of thickness can be more precisely defined in the younger (Vistulian) loesses only. The older loesses are in this respect less known, because among others being buried under the younger ones are decidedly less accessible. Besides, before burying they were eroded. Hence the older loesses often display remarkable stratigraphical gaps which afford more difficulties in defining them than in the case of the younger ones.

In the present paper there are discussed only the results obtained from the investigations dealing with the younger loesses dated back by the ^{14}C method and in the first place by the TL method. There were only taken into consideration profiles of the proper, typical loesses: (a) accumulated on the uplands and mountain foreland in southern Poland in the presence of permafrost and (b) accumulated on the lowlands and uplands in central Hungary beyond the range of permafrost. Dating of the loesses by the TL method was made in the only one laboratory of the Department of Physical Geography in the University of Maria Curie-Skłodowska in Lublin (BUTRYM, 1983). The results obtained in this laboratory are fully coincident with the ones obtained by somewhat different procedure and analytic apparates in Hungary (BORSY, *et al.*, 1980) and in the Soviet Union (ŠELKOPYAS, MOROZOV, 1981).

Provided with the results from only one laboratory we have to do with the same error. In this paper the results of dating are presented in a simplified version, without determination of the error, i.e. of the degree of exactitude. In the basic elaboration quoted in this text, the value of error is mentioned, it amounts to about 15%. It exclusively comprises the accuracy of indications of the apparatus, the dispersion of sensitivity of the radiation dosimeter and the dispersion of the results of about 30 measurements which constituted the basis of calculation of the mean values. The errors resulting from the essential assumption of the method that the loess grain being deposited was deprived of the TL properties cannot receive a univocal determination (BUTRYM, 1983). Thus the datings should be treated as approximative. It seems, however, that for consideration of our problem they are sufficiently "exact". It must be born in mind that the intensity of the loess accumulation varied in time and space. Significant changes in space confirmed among others by remarkable differences in the thickness of particular stratigraphical horizons of the loesses occurring side by side on various relief elements. These differences are especially characteristic of southern Poland where the loesses appear in numerous, often distinctly isolated patches (MARUSZCZAK, 1972, 1980).

VISTULIAN LOESSES IN SOUTHERN POLAND

The indices of intensity of accumulation of the Vistulian loesses generally resulted from the determination of thickness of the particular chronostratigraphical units distinguished by some authors at the beginning of the seventies (JERSAK, 1970, 1973; MARUSZCZAK, 1972). They were described quantitatively and graphically presented by MARUSZCZAK (1980). As it issues from that paper, the mean rate of accumulation of the loesses in the particular stratigraphical horizons oscillated from below 0.1 mm to 0.8 mm per year. The datings with the TL method made in last years permit to determine the changes of rate of the loess accumulation in more precise way (BUTRYM, MARUSZCZAK, 1984; MARUSZCZAK, BUTRYM, 1983; MARUSZCZAK, *et al.*, 1983).

In this region of Europe the formations so far considered as the younger loesses are classed among the Vistulian glaciation. As results from the TL datings the beginning of their accumulation should be estimated as about 110,000 years BP,

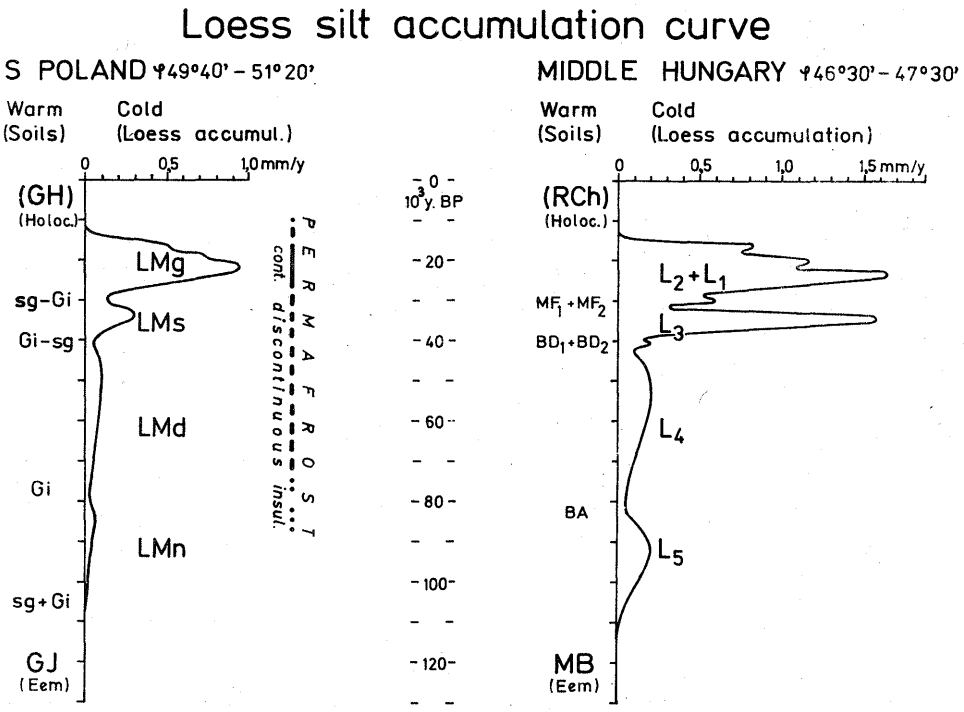

Fig. 1. Diagram of the intensity of accumulation of the Vistulian loesses in southern Poland and central Hungary

While calculating the accumulation rate of loess silt in Poland the average thickness of particular stratigraphical units were taken into account, and in Hungary the thickness established for the representative loess profile at Mende. Stratigraphy of Polish loesses after H. MARUSZCZAK (1980) and Hungarian loesses after M. PÉCSI (1982). Letter symbols and stratigraphical index of loesses and fossil soils are explained in the text

provided that the products of accumulation from the initial phases of superimposing of the meadow soil horizons on the Eemian horizon of forest soil are included into them. This dating is confirmed by the results of the former paleomagnetic investigations. The end of a more intensive accumulation should be dated at 15,000 years BP. Later, most probably 12,000 years BP the intensity of accumulation became very weak. This dating of the upper limit is consistent with the results obtained in the previous studies on the relief of the area of loesses (MARUSZCZAK, 1972; MARUSZCZAK, BUTRYM, 1983).

In the time interval 110,000 – 12,000 years BP, the intensity of loess accumulation changed in great range. It has been determined for the basic stratigraphical units of the younger loesses distinguished accordingly to the latest MARUSZCZAK'S scheme (1980). The results of paleocryological studies have proved that the younger loesses were accumulated under the conditions of permafrost which was initially seasonal, strongly developed freezing, later insular permafrost, then discontinuous and finally continuous one (Fig. 1). Out of three age-differing interstadial soils distinguished in these loesses two younger ones developed within the periglacial environment. They are brown subarctic or gley-swampy soils with distinct pseudomorphoses of the permafrost microstructures.

THE YOUNGER LOWEST LOESS LMn
(110/100 – 80/75 t.y. BP)

It was accumulated since 110,000 years BP, initially in some places only, chiefly on slopes of N exposure. The oldest layers, usually very thin, are rather indistinct being composed within the humus-meadow horizons (sg + Gi, Fig. 1) overlying the profile of forest soil of the Eemian Interglacial (GJ). In the majority of exposures the well distinguishable layers are those accumulated in the time interval 100 – 80/75 thousands of years BP. They are clayey loesses, in places without any content of carbonates (decalcified?). Their average thickness, including the top layers with the interstadial pedogenesis (Gi), amounts to 0.5 – 1.0 m, only in extreme cases reaching up to 1.5 – 2.0 m. Thus the mean rate of accumulation of the loess silt was in that period below 0.04 mm per year, while for the phases of maximum intensity it may be estimated as 0.06 – 0.08 mm/year.

THE YOUNGER LOWER LOESS LMd
(75 – 40 t.y. BP)

It is less clayey and shows a content of carbonates up to several percents. In some profiles it is not well distinguishable because the top strata are deprived of interstadial soils, replaced by soil sediments (sg – loess layers with the symptoms of initial pedogenesis), if not – these horizons display stratigraphical gaps. Its average thickness, including the layers with pedogenesis (Gi-sg), amounts to

2.0 – 3.0 m and only in extreme cases it reaches up to 4.0 m. The mean rate of accumulation of the loess thus amounted to 0.06 – 0.1 mm per year, and in phases of maximum intensity it was most probably about 0.12 mm/year.

THE YOUNGER MIDDLE LOESS LMs
(40 – 30 t.y. BP)

The features of this loess are similar to those of LMd but it usually contains a little more carbonates and shows better developed signs of pedogenesis in the top layers (Gi). Its average thickness together with the interstadial soil is ca. 2.0 m, reaching 3.0 m in extreme cases. Thus the mean range of its accumulation amounted to ca. 0.2 mm/year, and in the phases of maximum intensity to 0.3 mm/year.

THE YOUNGER UPPER LOESS LMg
(30/28 – 15/12 t.y. BP)

It displays the features of most typical loess. It is the lightest, contains more carbonates, up to several percents, and usually constitutes predominant part of the Vistulian profiles. Within its layers two (1 – 3) horizons of gleization have been distinguished; they attest to a change of the rate of accumulation. The average thickness with the layers showing the symptoms of the Holocene pedogenesis (GH) amounts to 6.0 – 7.0 m. It usually oscillates in limits between 2 – 3 m and 11 – 12 m; only in the individual profiles non-investigated more accurately so far, the thickness reaching up to 14.0 m has been noticed in some places. As the loess in question was accumulated in the time interval 28.000 – 15.000 BP, the mean rate of accumulation should be estimated as about 0.5 mm/year, and for the phases of maximum intensity: 0.8 – 1.0 mm/year.

The total average thickness of all stratigraphical horizons of younger loess is thus about 12.0 m as they were accumulated in the time interval 100 – 15 thousands of years BP, the mean rate of accumulation of the Vistulian loesses in southern Poland should be estimated as 0.14 mm/year.

THE VISTULIAN LOESSES IN CENTRAL HUNGARY

The indices of intensity of their accumulation were determined by M. PÉCSI (1972) ten years ago. On the basis of datings with the ^{14}C method concerning only upper layers, he calculated that the mean rate of accumulation was: (a) for the typical loess 1 m/1000 years (= 1.0 mm/year); (b) for the stratified slope loess 1 m/2000 years (= 0.5 mm/year); (c) for the inter-loess fossil soils 1 m/3 – 5000 years (= 0.3 – 0.2 mm/year). He did not pay attention to the differentiation of the

accumulation rate in time. As the result, the indices of intensity of the loess accumulation, established in such a way, were used among others in the attempts of estimative determination of the age of older interstadial soils ill-fitted for dating by means of the ^{14}C method. Thus the age of chernozem soil BA was dated back at 60 – 64,000 years BP (PÉCSI, *et al.*, 1979). The datings executed by the TL method showed that it is probably some 20,000 years older. The recent results of the TL datings may serve as the basis for defining the differentiation of accumulation rate of the Hungarian loesses during the Vistula glaciation (BORSY, *et al.*, 1980; BUTRYM, MARUSZCZAK, 1984; MARUSZCZAK, *et al.*, 1983).

In this region of Europe the formations determined by PÉCSI as young loesses are ranked with the Vistulian. The TL datings prove that the accumulation of these loesses began and ended in central Hungary earlier than in southern Poland. Their oldest layers are about 115,000 years in the Mende profile, while the youngest ones are most probably about 15,000 years. More intensive accumulation started about 100,000 years BP and ended about 18,000 years BP (MARUSZCZAK, *et al.*, 1983).

Among the Vistulian loesses occurring on lowlands and uplands of central Hungary there were not encountered any typical structures attesting to the presence of permafrost. In stratigraphical respect they are divided by three age-differing interstadial soils which are considered as associated with arid steppe, or with slightly more humid forest-steppe environment (PÉCSI, 1982).

PÉCSI'S division and denotations of stratigraphical units of the Hungarian loesses (PÉCSI, 1982) have been adopted in this paper. Because the literature does not afford data defining the mean values of thickness, they were assumed according to the determinations the Mende profile. It is treated as representative and typical from the lithological and chronostratigraphical point of view (PÉCSI, *et al.*, 1979). The general thickness of young loesses in the Mende profile is 27.0 m, i.e. slightly more than 25.0 m determined as representative thickness (PÉCSI, 1972). It should be, however, stressed that it is representative only for the Danubian areas on the southern foreland of Middle Hungarian mountains. In other regions of Hungary the loesses are decidedly less thick. The results of the analysis of accumulation rate in the Mende profile are presented in figure 1.

THE LOESS L_5 CORRESPONDING TO THE POLISH LMn (115/110 – 85/78 t.y. BP)

This loess is more conspicuous and univocal than in Poland. It is developed typically enough and rich in carbonates. Its great upper part was transformed into well developed chernozem BA. The thickness of this loess including chernozem amounts up to 4.5 m. Assuming that it was deposited within the period of 110 – 80 thousands of years BP the mean rate of accumulation may be estimated as 0.15 mm per year, in the phases of maximum intensity reaching up at least to 0.2 mm/year.

THE LOESS L_4 CORRESPONDING TO LMd IN POLAND
(78 – 38 t.y. BP)

This loess also is well distinguishable and typical enough. Its upper part is transformed into double chernozem BD which developed chiefly in the time interval 42 – 38 thousands of years BP. Lower, better developed chernozem BD_1 is separated from the upper BD_2 by a layer of typical loess 0.5 – 1.0 m thick. It proves that in the course of the soil development there was a longer epizode of such an intensive accumulation of the loess silt that the pedogenetic processes distinctly played a second-rate role. As total thickness of the loess, including soil BD, is 5.0 m, the mean rate of accumulation is estimated as 0.13 mm/year, in the phases of greatest intensity it probably reached up to 0.2 mm/year.

THE LOESS L_3 CORRESPONDING TO LMs IN POLAND
(38 – 29 t.y. BP)

In the Mende profile it bears all features of most typical loess with the greatest content of carbonates. In its top parts the double chernozem MF also occurs. Lower, well developed chernozem MF_1 is separated from the upper, weakly developed MF_2 by a thin layer of loess. In the course of formation of this soil the rate of the loess dust accumulation also epizodically increased. The thickness of the loess with the soil MF is 7.5 m. The mean rate of accumulation was thus about 0.8 mm/year and in the phases of the maximum intensity it was probably 1.5 – 1.6 mm/year.

THE LOESS $L_2 + L_1$ CORRESPONDING TO LMg IN POLAND
(29 – 18 t.y. BP)

In the Mende profile as well as in others, examined in the region of central Hungary it is less typical than L_3, because its middle and upper parts pass into distinctly sandy loesses, distinguishable by a small content of carbonates. In the middle-upper parts there are two horizons enriched with humus (embryonic soils) attesting most likely to an epizodic decrease of the rate of loess accumulation. The top layers are transformed into a contemporary chernozem soil (RCh) or into a brown forest soil. In the Mende profile the thickness of $L_2 + L_1$ together with the contemporary soil is below 10 m. The mean rate of accumulation was about 0.9 mm per year, while in the phases of maximum intensity it was probably 1.6 – 1.7 mm/year.

As it has already been mentioned, the representative total thickness of the Vistulian loesses in the discussed region of Hungary is admitted as 25.0 m. Assuming that they were accumulated in the time interval 110 – 18,000 years BP, the mean rate of accumulation may be estimated as 0.27 mm/year.

It should be stressed that the value estimated above is only representative of a relatively small Danubian region of the southern foreland of Middle Hungarian

mountains. The loess accumulation was extremely intensive there due to the occurrence of very abundant initial source of silt in the shape of alluvial material carried off by the Danube from a vast area of Europe. To calculate a comparable index for Poland there should be taken into consideration only the thickest profiles of the Vistulian loesses. As a representative value for such profiles might be assumed the thickness of 17 – 18 m. A mean yearly rate of accumulation would have amounted to 0.2 mm, i.e. it would have been by a quarter lower than the one estimated for the region of central Hungary.

Thus, an exceptionally great intensity of "glacial" loess accumulation occurred in the Danubian areas of southern foreland of Middle Hungarian mountains which during the Vistulian was beyond the compass of proper periglacial zone. It is evidenced by the occurrence of abundant source of alimentation with the Danubian alluvia containing large quantities of the allochtonous material.

CONCLUSIONS

1. The intensity of accumulation of the Vistulian loesses greatly oscillated. In the upper pleniglacial (28 – 15 t.y. BP) that followed the interpleniglacial warmings (42 – 28 t.y. BP) it was ten times stronger than at the early glacial and about 5 times stronger than in the lower pleniglacial (75 – 42 t.y. BP). The rhythm of changes of the accumulation intensity was, however, similar in Poland and in Hungary. It was conditioned by general factors determining the rhythm of development of phenomena in the glacial cycle.

2. In southern Poland, i.e. within the extent of permafrost, during the last glaciation (Vistulian) the rate of loess accumulation was weaker by about a quarter than in central Hungary. It resulted from the fact that in this region of Europe the silt forming the loess covers was predominantly of autochthonic origin and was blown off from the local sources. The source areas of silt were scattered within the loess zone itself or in its close vicinity.

3. In the Danubian areas of southern foreland of Middle Hungarian mountains, i.e. beyond the extent of permafrost, the intensity of accumulation of the "glacial" loesses was the greatest in the whole area of Hungary. It was promoted by the occurrence of rich sources of silt mainly supplied: (a) by the Danube carrying alluvia deriving from the far-off parts of Europe and (b) by the local rivers flowing out from the Hungarian mountains which in the Vistulian was in the vertical range of permafrost. In the former source the allochtonous material was most probably predominant.

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