

5. The loess environment in Central Europe

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INTRODUCTION

Loess and related deposits have always attracted the attention of geologists owing to their properties and a comparatively uniform development over vast areas. In the voluminous literature on their origin, there is a wide divergence of opinions. Most authors, however, are inclined to the view that not only deposition of eolian dust but also a special, concomitantly acting process called loessification, are responsible for the formation of loess. A comprehensive survey of these problems was presented by V. S. Obruchev, in 1948, in one of his last loess papers (Gerasimov, 1964). Loessification demands the existence of particular environmental conditions at the site of loess deposition, which I shall try to explain.

The character of the environment where loess was formed has so far been inferred mainly from its petrographic properties and the mode of occurrence. Paleontological criteria, if used at all, served particularly mammals, although mollusca were long known to be the most abundant and most typical loess fossils. That little attention was paid to the molluscan fauna can be accounted for by the inconclusive results of the earlier, not sufficiently precise, analyses of loess malacocoenoses (Geyer, 1927). The discussions bearing on cold and warm loesses, for instance, which have reappeared in various modifications in the literature, generally resulted from the use of differing, one-sided criteria (Ambroz, 1947; Obermaier, 1935; Werner, 1949; etc.).

The systematic study of the mollusca of loess complexes which I have carried out during the post-war years has shown an interdependence between the sedimentation and

soil-forming process, on the one hand, and the mollusc assemblages on the other (Lozek, 1964; 1965). The critical analyses proved a specific character of the loess molluscan fauna, which, in correlation with other criteria, can substantially contribute to the knowledge of the natural environment at the time of loess formation. Recently, analogous results have been achieved by means of pollen analysis (Frenzel, 1964; 1965), which helps complete the general picture. It is the objective of this paper to review briefly the results obtained thus far in central European countries.

MOLLUSCAN FAUNA OF LOESS

As mentioned above, molluscs are the most abundant loess fossils. In many regions the shells are so numerous that their distribution is traceable both in vertical and lateral directions. It should be stressed that they are found in the loess itself, while bones are often joined to the horizons of another origin, inserted in the loess complex (Lugn, 1962, p. 23-25). Numerous "loess finds" made by earlier collectors do not originate from pure loess, but from other layers of the loess series. For this reason we must base our investigation only on new finds, recovered from safely determined sediments. The mass collections from the richly differentiated loess complexes, when studied in detail, make it possible to correlate loess assemblages with those which inhabited the same environment during the intervals on non-deposition of loess (Lozek, 1964).

On the basis of quantitative analyses of the molluscan faunas from different parts of central Europe, the following characteristics of the malacocoenoses can be stated:

1. A small number of species is represented by prolific populations.
2. The presence of special species and races is characteristic of loess environment.
3. A special composition of loess assemblages distinguishes them from other recent and fossil malacocoenoses.

4. Species of loess environment are either eurythermic or cold-loving.

5. They live, or are able to live, in open habitats, and the woodland species are missing.

6. The assemblages consist of xerophilous and mesic elements.

7. The loess thanatocoenoses represent monotonous assemblages which preserve a uniform composition over vast areas, extending from France to the Volga River.

This concise outline of the fundamental features of the loess molluscan fauna should be completed by additional data. The loess assemblages, when viewed from the standpoint of the modern ecology of associated species, prove to be a peculiar mixture of elements whose ecological requirements are nowadays occasionally so contradictory as to prevent them from living in the same habitats. Thus, for instance, the prevalently hygrophilous *Succinea oblonga* Drap., the species of lowland steppe *Helicopsis striata* (Müll.) and rocky steppe species of *Pupilla*—*P. sterri* (Vth) and *P. triplicata* (Stud.)—forming closed assemblies in the loess, are found at present in different, frequently far apart, habitats. The penetration of petrophilous elements to the loess habitats is not a sporadic phenomenon. Apart from the above-mentioned Pupillas, this is valid also for *Clausilia dubia* Drap., *Cl. parvula* Fér., and *Orcula dolium* (Drap.), which we would seek in vain in the present-day loess areas. We must, of course, keep in mind that all the above petrophilous elements live today in an intimate contact with a fresh, usually calcareous, substratum. This suggests that their presence in loess was due to the fact that pure loess likewise provided them with an unweathered carbonate environment. Their absence from the fossil soils of loess complexes can be interpreted in the same terms.

The mixture of ecologically very different species gives evidence that the loess habitats were of such a special character that they complied with apparently contrary require-

ments of associated molluscs. The methods of detailed quantitative research rule out the possibility that the faunas concerned could have been secondarily mixed up (Lozek, 1964).

The broadly monotonous complex of loess faunas bears signs of local distributional effects, resulting in the local occurrence of some species, e.g., *Orcula dolium* (Drap.) in the Carpathian Basin, and *Clausilia parvula* Fér. in the Rhône valley (in southwest Germany), and in the Jizera Valley in Bohemia. On the basis of representation of the index species, we can distinguish pronouncedly cold *Columella* faunas, the medium-tolerant *Pupilla* faunas, and the *Striata* fauna, which represents the warmest facies of the loess molluscan fauna. This differentiation indicated temperature differences which, between the *Columella* and *Striata* faunas could have attained 3–4°C. in the annual mean. The *Striata* assemblages, even if designated "warm loess fauna," correspond to climatic conditions with a mean annual temperature about 0°C. but relatively warm summers. Within the whole of the climatic cycle, the above conditions are indeed glacial, but, within the scope of loess phases, they represent the warmest interval. Because of this, undoubtedly, the *Striata* faunas are commonly restricted to thin, often-contaminated loess interlayers inside the soil complexes which are matched with the minor cold fluctuations—as, for instance the Early Würm cold interval that separated the Last Interglacial from the Early Würm interstadials.

The so-called marshy loesses were distinguished by faunas of periodic marshes. Although their occurrences within the complexes with terrestrial faunas were conditioned mainly by topogenic relations, as is shown by their deposition in subhorizontal loess layers in the proximity of the flood plains of major streams, they give clear evidence that the loess "steppe" was not a scorched desert but an area with at least temporarily wet grounds. The retaining of water was probably due to the frozen ground conditions.

Before we proceed to the correlation of the results of loess paleontological investigation with other data, it is necessary to mention briefly the zonation of loess formations, which cannot be omitted in solving the problem discussed.

ZONATION OF LOESSES

In central Europe the true calcareous loesses are confined to the low-lying areas. The upper limit of their occurrence is drawn at an altitude of about 300–400 m., which in the driest areas is scarcely surpassed. In more humid regions, on the windward sides of the mountain ranges or in the intramontane depressions, the limit drops to 200 m. or less (the Ostrava area, the Tisa Plain). The loess zone can be divided into subzones which at a first sight differ in the development of fossil soils (Fink, 1956). In general, the loess zone is divisible into the dry subzone, with fossil Chernozems and richly differentiated soil complexes that are intercalated with loess beds that contain the *Striata* fauna, and into the humid subzone, where the sectors corresponding to Chernozems and loess interlayers usually consist of wash and solifluction complexes or weakly developed Brown soils. Between them, a transition subzone intervenes, which under favorable conditions can be fairly large in extent.

It is noteworthy that this difference also is reflected in the composition of fauna of the loess itself. Whereas in the dry subzone the species *Helicopsis striata* (Müll.) is a common component not only of the *Striata* faunas but also of the drier facies of the *Pupilla* faunas, in the humid subzone prolific *Trichia hispida* (L.) and *Arianta arbustorum* (L.) are characteristic, and *H. striata* (Müll.)—as well as the *Striata* fauna—are lacking. A common feature of the humid subzone is poor assemblages, composed of one to three *Pupilla* species and *Succinea oblonga* (Drap.).

The problem of the loess equivalents in the more elevated or moist areas is most relevant. The loess zone passes into the zone of dust loams (*Staublehm*); i.e., loams of eolian

origin which show an analogous mode of deposition and granular composition as true loesses. They lack, however, calcium carbonate—to a large extent or completely—so that their texture is altogether unaffected by it. The calcium carbonate is replaced by the iron compounds. The pseudogley process occurs currently, and is often observable throughout the thickness of these deposits as at least moderately developed.

The character of the dust loams reveals that they represent a loess facies from the more humid environment. The boundary between the loess zone and the dust loam zone was not constant. Its slight oscillations can be inferred from the presence of both calcareous loess and dust loam layers in some sections. The maximum extent of loesses falls into the phase of maximum loess deposition within the loess zone. Therefore, the sector corresponding to the loess maximum is not unfrequently developed as calcareous loess, whereas other parts of the complex are already formed of lime-deficient dust loam. Such loess "islands" within the dust loam areas have been established, for instance, southeast of Prague (between Ríčany, Davle, and Zbraslav), in the Sázava Valley, and along the middle course of the Vltava (Cholín) River.

Because of the lime-deficient environment, the area of dust loams yields only scarce paleontological finds. In the above loess "islands," only poor *Pupilla* faunas are preserved, which, moreover, are not decisive for the reconstruction of the environmental conditions. Because they derive from the intervals and sites of loess formation, they reflect the state of the loess zone.

The zone of dust loams passed upward into a zone which is distinguished by the lack of extensive sheets of sorted, wind-blown loams. These are replaced by slope deposits containing a variable admixture of loamy matrix whose nature corresponds to that of dust loam. The amount of the admixture is not uniform; it is largest on the leeward hillsides, which, within the zones of loess and dust loam, would be

most suitable for the deposition of eolian material. Under favorable conditions, the eolian component can predominate, giving rise to patches of dust loam which grade continuously into deposits with a prevalence of slope material. This zone, which can most conveniently be termed as the zone of mixed slope sediments, is followed upward by the zone of montane slope deposits—with coarse blocks of solid rocks—where the eolian component recedes to the background.

For completeness' sake it should be added that, in the dissected rocky areas, the mixed sediments consisting of coarse slope material and the matrix of loess nature can also be found within the loess zone. This suggests that the zonation (in textural [stoniness], not chemical composition!) is not only controlled by climatic conditions but is also affected by the relief configuration and the parent material, whose effects are marked only at particularly suitable places. They are, however, most important in connection with the paleontological considerations.

The paleontological evidence for the zones of dust loam and mixed and montane slope deposits is everywhere hindered by the lack of calcareous sediments that are derived safely from the loess phase. The distribution of loesses and dust loams is independent of the parent material, as can be easily proved by the presence of loess in areas built up of carbonate-free rocks and, on the other hand, by the absence of loess from the areas which are composed of pure carbonate rocks but lie outside the loess zone (e.g., the Nitrica Valley). The paleontological evidence thus is afforded only by pollen analysis, which so far has been carried out only in the foreland of the Alps (Frenzel, 1964; 1965). Although the existing data are far from complete, they indicate that the zone of dust loams was substantially more humid than the loess zone, allowing a sparse growth of tolerant shrubs and trees (relictual forests). Faunal remains can be found only in places where, in the loess phase, mixed sediments with a large component of local carbonate material were laid down, i.e.,

chiefly under the limestone scarps or in the cave entrances. It is, of course, very difficult to attest that the respective sediments actually correspond in time to the true loess or dust loams. This question is most relevant because the interrelationship between the loesses and slope deposits shows that—at the time of loess optimum—the slope deposition was very limited, even where coarse scree rapidly accumulated during other phases (e.g., in the warm Postglacial [Lozek, 1963]).

It follows from the above that only fauna, provided its composition corresponds to the fauna of the loess zone, remains as a main evidence. Slope deposits with a loess admixture and the corresponding fauna were found, for example, in the Upper Hron Valley (Farkašovo) or in the south Slovak Karst (Hrhov, Jasov). A few differences that have been ascertained, such as the occurrence of *Vertigo alpestris* Ald., which is absent from the true loess, are in fact meaningless. Otherwise, those finds proved that the fauna of the zones of dust loam and mixed slope deposits was very similar in composition to that of the loess zone, not exceeding the framework of loess habitats.

As concerns the reconstruction of general environmental conditions, it can be objected, of course, that—as the fauna was preserved only on the calcareous material—it must have been affected by this factor. It provides evidence solely of the general character of climate, but not of soil conditions on the deposits of dust loams and slope sediments, which can be reasonably inferred as originally lime-deficient or lime-free. From this it may be deduced that, while the process of loessification occurred in the loess zone, in the dust-loam and higher zones processes of decalcification and weak pseudogley formation took place. On the other hand, the interpretation of the lack of carbonate as a secondary phenomenon; i.e., that the dust-loams were decalcified, should also be taken into consideration.

The relics of calcareous loesses support this latter alternative with marked faunas which are preserved in travertine

fissures within the zone of dust loam or mixed slope deposits (Bojnice, Bešenová), and do not differ either in composition or paleontological content from the common loess. The carbonate parent material in the surroundings enabled their preservation but did not cause their origin.

The process of dust loam formation requires further detailed study, based on additional criteria. Generally it can be said that the environmental conditions in the zones of dust loam and mixed slope deposits were similar to those of the zone of calcareous loess. These monotonous relations, existing over vast areas during the loess phase, will be examined below.

LOESS ENVIRONMENT

In restoring the loess habitats, we shall proceed from the correlation of the paleontological and sedimentological data.

From the analysis of molluscan fauna completed by the mammalian finds and from the results of pollen analysis, the following characteristic features were deduced.

1. Open country;
2. Low temperature;
3. Relatively rich biocoenoses, composed, however, of a small number of tolerant species; and
4. Striking diversity of loess biocoenoses from the contemporaneous fauna and flora.

These points should be considered in relation to the sedimentological statements mentioned below:

A. Loess forms sheets and drifts that are composed mainly of sorted eolian material that is independent of the underlying rocks.

B. It also occurs in those places where, in other periods, deposition of quite a different type prevailed (e.g., coarse scree in warm periods).

C. Some features of the loess—the texture and form of calcium and iron compounds in particular—cannot be explained as due to sedimentation factors but to a special process called loessification.

The correlation of these individual items leads to the following considerations.

An open country (1 [above]) provides very favorable conditions for the accumulation of dust (A) that is blown in from places where the deflation is not hindered by a dense vegetation cover—not even a steppe with a continuous sod mat. The loessification process (C) is conceivable only in open steppe conditions, where long periods of drought and freezing prevent strong weathering and favor precipitation of salts in the surficial layers. A low temperature (2) is attested by the presence of cold-loving molluscs and mammals, as well as by pollen analyses. The absence of thermophiles serves as indirect evidence of this. This conclusion is consistent with the assumption that the eolian activity (A) could have developed when large areas were deprived of a continuous vegetation cover or buried under fresh aggradation that was susceptible to deflation. In European conditions, such a state is plausible mainly as a result of glacial climatic effects—at the time of a strong deterioration of climate. The formation of deserts under a warm climate is—in Europe—hardly conceivable.

The range of temperature at which loesses originated, as evidenced by the differences in the molluscan assemblages, plays only a subordinate role. The *Striata* fauna, which pronouncedly lacks cold-loving species and consists of elements that—up to the present—live on the xerothermic habitats of central Europe, differs from similar contemporaneous malacocoenoses in the absence of true thermophiles (Smolíková and Lozek, 1964). It suggests a mean temperature of about 0°C., thanks to comparatively warm summers.

It can therefore be concluded that central-European loesses universally originated under glacial conditions, with long, severe winters and relatively warm, dry summers. This climatic pattern is also suggested by the mixture of cold-loving and steppe elements in the faunal assemblages.

A rich malacofauna (3) points to a densely inhabited

surface of the generating loess, which in turn implies a well-developed vegetation cover (Frenzel, 1964; 1965). The terrain could not have been a barren, arid steppe but, on the contrary, must have been overgrown with vegetation which enabled the existence of assemblages with a strong component of mesic, relatively moisture-loving species. This assumption is in keeping with the presumed character of areas where the wind-blown dust (*A*) accumulated, and with the repression of other types of sedimentation (*B*) at the time of loess deposition. The relatively slow accretion of eolian dust did not impede the evolution of the respective biocoenoses; on the contrary, it supported those plants and molluscs which preferred raw soils that were well supplied with salts (Frenzel, 1964; 1965).

The conditions enabling the development of relatively rich vegetation and mollusc populations (3) are somewhat at variance with the character of loess as a soil type (*C*). It should be stressed again that the loess must be considered as soil, and the loessification as a soil-forming process, because the organisms living on its accruing surface affected its properties and composition. Thus, for instance, the roots of steppe vegetation undoubtedly took part in the development of the loess structure and concretions; and shells, when present in a sufficient amount, controlled the CaCO_3 percentage. The loess also lie near the present-day desert soils (Gerasimov, 1964) whose habitats differ widely from those suggested by the paleontological content of loesses, both in climatic and vegetation conditions. The deserts comparable to the Pleistocene loess areas exist nowadays in central Asia, whereas in Europe no modern analogies can be found. From this discrepancy it can be inferred that, at least within the European loess zone, loessification was a rather particular process, conditioned by a special environment in one phase of the glacial stages, whose designation as the loess phase is fully warranted (Lozek, 1965).

Although the annual climatic cycle cannot yet be recon-

structed precisely, a few fundamental data have been recognized. The climate of the loess phase was continental and cold, with the annual temperature mean between -3 and 0°C —the loess optimum being nearer to -3°C . Winters were long and severe, and the summer season short but relatively warm. In addition, an intervening humid and fairly warm phase is to be presumed, which would enable a rich plant life on the loess steppe, fading out gradually during a dry period in the late summer. There were no abrupt changes of the weather, i.e., no abrupt recurrent changes in temperature or alternation of short, dry periods with sudden downpours. The cold period also was dry, so that—in spite of favorable temperature conditions—cryoturbation was of small extent. In our opinion, this tranquil course of climatic cycle is the only reason which can account for the strong limitation of denudation and deposition processes (*B*)—except for the wind activity, so distinctive for the loess phase.

The special character of the loess fauna and flora (4), which is difficult to compare with the present-day assemblages, is closely connected with the above-stated relationships.

CONCLUSION

From our investigation we can conclude that loesses in central Europe originated under continental, cold climatic conditions, at a mean annual temperature of about -3°C . to -2°C .—rising in the warmest phases toward 0°C . The weather had a tranquil annual course. A long, severe, but relatively dry winter was succeeded by a humid and fairly warm period that became summer (July averaged more than 10°C ., probably about 15°C .!); then a dry period persisted until winter.

At this time the loess steppe was covered by a rich steppe vegetation in which species that loved fresh soils, with a sufficient amount of mineral salts, occurred in abundance. The rich molluscan fauna consisted of large populations of highly tolerant species. The soil conditions were very favorable for

the molluscs, but only some species were capable of adapting to the loess climate.

At present, analogies of the loess environment are difficult to find. In the main, there were steppes that passed—into the humid tracts—into tundra formations, which, however, were not identical with the modern tundras of northern Europe or with the Alpine barrens of the high-mountain ranges of central Europe. The special character of the environment is evidenced not only by the composition of the plant and faunal assemblages that were composed of species that differed in ecologic requirements, but also by the species and races of molluscs that adapted to the loess environment. Therefore we are justified in using the term "loessic" in a wider ecologic sense, and in speaking of the loess environment.

The conditions we have described existed in a wide belt, spreading from the Atlantic Ocean to the Volga River, which in the north reached to northern Germany, the southern half of Poland and the U.S.S.R., and in the south to Bulgaria and through the Rhône Valley to the Mediterranean. In the more humid and higher-lying areas, it passed into the zone of non-calcareous dust loams and mixed slope deposits, which, irrespective of a higher humidity, showed very similar environmental conditions.

The task for future research is to follow the fading out of the loesses at the southern and northern boundaries of the loess zone, to identify their facies equivalents in other climatic belts, and to carry out a correlation of European loesses with loesses and related deposits on other continents. Other problems, especially whether there is a warm loess or a modern analogy of the European loesses, also await solution. A closer approach to the solution requires much study, particularly paleontological study, but the results will be invaluable for the recognition of the paleoclimatology and paleogeography of the Quaternary.

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