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A tribute to Ložek (1965): The problem of loess formation and the loess molluscs

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When addressing the nature and origin of loess deposits and the associated environment as deduced from the terrestrial mollusc faunas, Ložek produced a synthetic review of the state of the art at that time. This synthesis was one among several papers he published the same year in English about ”The loess environment in Central Europe” (Lozek, 1965b) or ”Problems of analysis of the Quaternary nonmarine molluscan fauna in Europe”(Lozek, 1965a). It was mainly based on his own experience of investigating terrestrial molluscs in Czechoslovakian Quaternary deposits.

In his seminal paper, Ložek addresses key issues, which remain valid and are still relevant nowadays - 56 years later! Ložek noticed the problem, “that it is surprising how little attention has been paid to the mollusc fauna, which occurs so frequently in loess that it can rightly be considered one of the main characteristics of this sediment”. Such key statement still prevails today by comparison with other proxies which appear much more popular. This leads Ložek to conclude that ”we still see that this goes far beyond the framework of the loess problem”. On a personal aspect, reaching the end of my academic career, I strongly agree with Ložek.

Ložek initially addresses the critical question of the loess formation, indicating that at that time there were two schools: soil scientists and bio-geoscientists. Interestingly, such distinction remains until present, however, the differentiation between the two today seems to rather corresponds to a problem of scale at which the relevant processes and mechanisms are analysed. Ložek favours the aeolian hypothesis of loess formation, what he termed ”Richthofenian hypothesis”, by reference to Richthofen who first proposed that loess was aeolian in origin. He adds the critical assumption that "it is clear that the loess is to be regarded as the product of a peculiar environment which has no parallel in present-day Europe”.

With Ložek correct and concrete statement that ”molluscs are best suited, as they are more abundant than the vertebrates in the loess and the related deposits” it is easier to understand the sampling protocol developed by Ložek and his followers. About 10kg of sediment need to be sampled and sieved in order to retrieve the remaining shells. During this procedure, frequently bones or even skull of micromammals, rodent teeth are found among the numerous shells, making vertebrates a sub-product of mollusc studies!

In my 1987 paper (Rousseau, 1987), I have demonstrated that loess mollusc faunas are the end member of a dynamical process opposing glacial mollusc assemblages to temperate ones through numerous intermediary communities representing therefore the complete environmental variability that could prevail during the Quaternary. In contrast to this Ložek states ”molluscs are so widespread and common in loess that the presence of shells has to be seen as one of the main characteristics of loess”. This statement may be biased by his own experience of central European mollusc assemblages, where this finding holds true. However, not noticing shells from an outcrop does not imply the absence of any shells in a loess sample, as they have a great variability in size. Ložek further states that the ”largest number of finds is indisputably known from the loess areas of Germany and Czechoslovakia”. This statement clearly is not precise enough. Is he considering the number of shells, i.e., abundance? The number of species, i.e., richness? There are other more precise ecological indices allowing for a description of mollusc communities, like diversity and equitability, which refers to the ecosystems they live in. Therefore, the conclusion reached can be totally different. Ložek’s vague statement may, however, simply be reflecting the state of the art of terrestrial mollusc studies at that time. Expanding the geographical range of his statement, he acknowledges the lack of useful information from Asia and indicates a kind of parallelism of North American loess mollusc faunas with the ones from Europe, with ”many developmental traits [...] specific to America”. Although loess mollusc faunas have been identified in Chinese loess series, loess mollusc faunas in North America indeed show similar characteristics to Europe but with properties inherited from the biological evolution: different species of the same genus but showing almost similar ecological requirements. Similarly, Ložek refers to the fading of the loess faunas towards the south, concluding that loess had been deposited with its associated mollusc faunas living in the sediment, however, under different climate conditions. This lead Ložek to conclude that there must have been different climate zones in the Quaternary, a concept that had been known since Köppen (1918) for the present-day climate.

To explain the lack of efficient comparison with other regions Ložek lists four reasons, which are still relevant and valid today. He emphasises the very need for a careful observation of the shells and determination of the species. The identification at the species level is not always easy, and some variability exists in the shape and ornamentation of the shell of a single species. Careless and surficial investigations of the shells can significantly change the interpretation of a mollusc assemblages, which Ložek pointed out. This resulted in the identification of mollusc assemblages, named after key species, basically the *Pupilla* and the *Columella* faunas with variations in their composition resulting from the environmental conditions and geographical locations. Ložek summarised this interpretation which is commented in Table 1.

Making a turn to Asian loess Ložek states that it “could perhaps be argued that loess in Asia formed under different conditions […] and that the term mentioned should refer primarily to this environment”. Over the last decades it has been demonstrated that one ought to remove the “perhaps”, i.e. indeed Asian loess formed under different conditions with different sources than those for European loess.

Defining subzones among the loess landscapes, Ložek indicates that loess deposits mainly occurred in dry and low elevated areas. Indeed, recent studies (e.g. Rousseau et al., 2014) have demonstrated that at least in Europe loess deposited at lower elevation in relation to the dust transport dynamics, and that the source of the transported material is mostly regional or local.

Therefore, Ložek correctly speaks of fairly uniform faunas from a fairly uniform environment. However, he reconciles with the soil hypothesis by stating that the ”fauna of the loess phases thus clearly testifies to peculiar soil conditions, and confirms that the loess is to be regarded not only as a product of wind sedimentation but also of a specific soil-forming process”.

Ložek further tries to summarise the complexity of the loessification process, still referring to the presence of molluscs as a key indicator: ”The mollusc analyses showed that the soil and environmental conditions were really quite peculiar and that the assumption of a special loessification process seems completely justified”. Such a statement could be given nowadays without relying on the mollusc analyses, especially from sequences or deposits where there are no snails reported. However, the peculiarity of the mollusc assemblages was the key to characterise the loess environments. From that, Ložek drew four general conclusions that are still valid even if the third one needs to be discussed a little more.

1. ” […] the particular chemistry of loess deposits and weathering products allows the appearance and proliferation of some steppe molluscs and apparently also characteristic vegetation." Mollusc individuals and species would grow and develop because environmental conditions allow them to do so: vegetation to feed on, but also to hide from temperature and precipitation variations. Moreover, the occurrence of carbonate in the dust or the soil would also favour the development of mollusc populations. However, it is possible to observe modern terrestrial snails living in a more acid environment, but under such condition, they often show very thin and fragile shells that would not be preserved after the death of the animal.
2. “the formation of loess is not only due to the accumulation of dust”. This is a correct statement! This assumption, however, was only expressed years later by Pecsi in his paper “Loess in not just the accumulation of dust” (Pecsi, 1990)
3. ” […] the particular chemistry of loess deposits and weathering products allow the appearance and proliferation of some steppe molluscs and apparently also characteristic vegetation”. I would rather reverse the arguments: The particular vegetation allows the appearance and proliferation of mollusc populations. Moreover, later Ložek states “the loess environment is especially favourable for snails but the species richness is quite limited due to harsh climate and aridity”. Loess environment will be favourable for snails if there is enough carbonate available to build their shells. In addition, the harsh climate appears rather vague, as it is less precise. Apparently, Ložek refers to temperature, but as this is a limiting factor in general, some species can endure various temperature minimums allowing them to be observed at very high latitudes or elevation. As a complement to these points, one should refer to the main limiting factors that constrain the growth of terrestrial molluscs found in the loess deposits. The first factor is the impact of temperature: i) eggs endure less extreme temperatures than adults, ii) most of the identified species have at least a bi-annual growth imposing them to face winter conditions, iii) their thermic sensitivity is determined for decreasing temperatures by the beginning of the freezing of the tissues, and for rising temperatures by the beginning of cell coagulation. The second factor is the impact of hibernation: i) when the cold season arrives, terrestrial molluscs ”sleep” between four to five months retracted in their shell, ii) respiratory and cardiac rhythms, oxygen consumption decrease, but not cease, iii) the total water loss can reach 20%, and iv) growth stops and wastes (water, CO_2) are concentrated in the kidneys. Other factors like precipitation, moisture, and dust can impact also the growth of the terrestrial molluscs. Knowing these limitations allow us to understand the low number of species able

to face the drastic environmental and climatic conditions under which the loess deposited. In fact, loess faunas are composed theoretically of mollusc species, which are either eurytherm (large temperature range tolerance) or stenothermic (limited and specific temperature range tolerance). However, precipitation has been a second important limiting factor. This has been demonstrated by comparing loess faunas over Europe, showing a strong reduction in the richness westwards. Therefore, one ought to speak in terms of seasonality, especially of the interval from spring to fall when the molluscs have some metabolic activity.

4. ” […] the formation of loess and loess-like formations is thus closely linked to specific climatic and vegetation conditions”. This ought to be more precise. In fact, only during cold and glacial conditions deflations areas are created, which is a prerequisite for the production of aeolian material. In general, those areas are outwashes of glaciers or ice sheets, moraines, and riverbeds. The vegetation is important in the deposition area to trap the aeolian dust, but also in the deflation area, in the emission process. Modelling studies (Sima et al., 2013) have demonstrated that if the vegetation is too high, later in spring, the aeolian material cannot be emitted, and therefore transported. Conversely, if the vegetation has not grown enough, but the ground is still frozen, the aeolian material cannot, irrespective of wind speed, be emitted.

In addition, Ložek discusses the hypothesis of interglacial loess, which is misleading as loess is typically a glacial sediment. He also states ”It is equally misleading to compare the present conditions in the alpine region of Central Europe mountains with the conditions of other areas during the loess phases”. This is only true with regard to the average annual temperature but does not apply to the humidity, which is very high in the mountains, while the loess climate must have been noticeably arid. Although such statement may be appropriate concerning temperature, the degree of aridity must be questioned. Indeed, there must have been some seasonality allowing the vegetation to grow in spring and thus to trap the aeolian material. Recent studies have added to this, claiming that aridity should have been seasonal and rather located in Eastern Europe (Sima et al., 2013) .

Ložek discusses further what is called the loess interlayers, mostly corresponding to odd marine isotope stages (Kukla, 1977), and highlights the importance of the precise observation of the outcrop stratigraphy. This could be considered a misleading interpretation of the interglacial loess hypothesis. Indeed, some of these particular units have been named ”markers” by Kukla (1977) and correspond to specific climate conditions. The best example is given from the Dolni Vestonice record of the last climate cycle where several of these units have been described (Kukla and Ložek, 1961; Rousseau et al., 2013). In fact, when Ložek’s paper got published, interglacials were still interpreted as a single temperate episode, while later investigations demonstrated a much more complex history marked by the occurrence of stadials.

Ložek further points out the aeolian activity should ”not being underestimated”. We know now that this is very basic as aeolian material is the source of the deposited material. This is indeed best evidenced when among the transported material elements, fossils or particular grains or granules, characteristics of the source region can be found, supporting therefore the regional origin of the transported material.

Ložek also noted the bedding of some loess units. They are mostly related to slope deposits but may also be related to dust deposits on snow, resulting in such facies after the snow had melted. He states that “at the time of loess accumulation at the

foot of a slope, slope transport and the formation of coarser debris were limited to the lowest degree". This appears logical because of the drier conditions of the dust deposition, but also the substratum frozen during most of the year preventing major sediment movement. On the contrary, the soil complexes show units corresponding to slope deposits that were described by Kukla (1977) as pellet sands representing the erosion by heavy rains of sedimentary units deposited or developed on the slope itself. Other form of laminations occurs in western and eastern loess sequences, named "limon à doublets", which are mostly post-sedimentary in origin.

Intense calcareous precipitation at the end of the cold periods is another misleading assumption by Ložek. In fact, the carbonate precipitation marks the lower limit of a soil formation and development. The pedogenesis actually started at the top of the aeolian unit, after the dust accumulation had stopped, and produced large carbonate concretions at the base of the palaeosols by leaching of the loess sediment. Therefore, precipitation of carbonates occurred during the interglacials and not at the end of cold periods.

With respect to loess deposition Ložek claims that "the entire environmental conditions at that time were very peculiar and that they have no equivalent in present day Europe". He goes further by stating that loess characterises the late phases of highly glacial periods in the Pleistocene of Europe. We should amend this statement by saying that in general, loess is noticed and observed in deposits corresponding to glacial (odd marine isotope stages) or stadial conditions.

Some final reservation should be raised for one major point of Ložek's work: He claims that the mollusc fauna "differs sharply from all other cold and warm period communities, which is undoubtedly due to the condition of the substrate". According to present analyses and from the ecological requirement of the modern representatives of the identified species, this is not certain.

In conclusion, the present paper appeared one year after the release of Ložek's doctoral thesis "Quartärmollusken der Tschechoslowakei" (Ložek, 1964), in which he had developed many more points compared to what he addresses here. In his paper he chose to make his vision and the ones Czechoslovakian loess researchers had at that time visible to the international community. Ložek represented a detailed and complete state of the art loess and mollusc study. This paper represents therefore an extraordinarily synthetic review, with still a modern flavour, as many of the aspects addressed remain relevant today. I am proud to have met Vojen Lozek in person several time and have conducted fieldwork with him around Prague and in Moravia

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Table 1. Comments on Ložek 's original statements about the loess molluc faunas

Original Statement	Validity	Comment
1 - ”The loess faunas represent closed autochthonous populations, which have no analogy in the present”.	Partly yes	The *Pupilla* fauna fits with this statement, especially because of the particular association of the various *Pupilla* species, while the *Columella* fauna does not, as similar communities could partly be found presently in Europe.
2 - ”They consist of a relatively small number of cold-hardy species, which indicate open, largely wood-free formations (and can live today in cold steppes, tundra as well as in the high mountains)”.	Yes	This statement refers to a longitudinal and latitudinal knowledge and interpretation of the modern distribution of the species at that time which evolved since then and that I used later in proposing reconstructing quantitative estimates of past temperatures and precipitation.
3 - ”The mollusc fauna is characterised by a few special species that occur almost exclusively in loess; species common elsewhere are also represented by special races and forms and often have different ecological requirements compared to the present”.	Yes	In fact, using biometry, I have demonstrated the occurrence of ecophenotypism in modern populations of *Pupilla muscorum*, but also in fossil ones, especially in loess series with higher shells present in glacial deposits or more continental conditions while shorter ones prevailed in interglacial units or in western environments (Rousseau, 1997). Similar variations have been also noticed with other eurytherm species like *Trochulus hispidus* (former *Trichia hispida*) or *Succinea oblonga*, present also in loess mollusc fauna through the *S. oblonga* elongate form in layers corresponding to the coldest conditions.
4 - ”On the basis of detailed analyses of loess faunas, a whole series of mollusc communities have been distinguished, some of which are bound to certain areas, other to certain biotopes (e.g. through different relief conditions)”.	Roughly speaking yes	This is correct and one can follow the time evolution of the ecosystems in time from interglacial to glacial ones (Rousseau, 1987). Among the latter,”the loess fauna forms a closed monotonous unit that is clearly distinguishable from all other Quaternary mollusc communities”. Rather than monotonous, I would rather qualify the loess fauna as particular as one could immediately refer to particular environmental conditions.
5 - ”A loess fauna with the described characteristics is distributed in a huge area, in which currently very diverse mollusc communities live, which indicates a far-reaching leveling of the environmental conditions, which has no analogy in other sections of the Quaternary”.	Yes	Loess deposits are capping worldwide areas, especially in the Northern Hemisphere corresponding to glacial open landscapes with very little vegetation. Such general environmental characteristics induce biomes relatively homogenous with slight local or regional adaptations, what Ložek calls”loess biotopes or loess environment”. This is far different from environmental conditions mostly corresponding to interglacial conditions during which the local and regional specificities took over, and which are expressed by more specialised and diverse biomes (here the association of vegetation and fauna).