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The Late Pleistocene paleoenvironment and paleoclimate of the Madaras section (South Hungary), based on preliminary records from mollusks

Communication

Júlia Hupuczi*, Pál Sümegi

Department of Geology and Paleontology, University of Szeged, H-6722, Szeged, Egyetem u. 2-6, Hungary

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Abstract: 24 species and 110 506 specimens of mollusks were collected and identified from 250 samples of the loess profile at Madaras, South Hungary. According to changes in the mollusk fauna, six malacological–paleoecological zones can be identified in this profile. The Quaternary malacological data from the Madaras loess section suggest that the Middle and Late Pleniglacial development of the mollusk fauna, and local climatic and environmental conditions in this area differed from other loess regions in Europe.

Keywords: Upper Weichselian • malacothermometer • July paleotemperature • loess plateau

1. Introduction

The investigation was carried out on a 10 m vertical loess profile exposed in a brickyard at Madaras, on the northern edge of Bácska Loess area, South Hungary. The geographic name of this region is the Telecska Hills, and it is a nature reserve area [1] approximately 500 m north of the Hungarian–Serbian border in the Bácska region (Figure 1). Bácska is the southwesternmost region of the Great Hungarian Plain, an extensive area occupying 100 000 km^2 of the Carpathian Basin. Sand movement in the Bácska area began at a relatively high altitude during the drier climatic periods of Late Pleistocene [2, 3], and wind-blown sand had shaped a diverse landscape by the early phase of the last glacial period. All sandy areas were covered by 10–11 m thick loessy horizons during the Middle and Late Pleniglacial phases [3–5].

The aim of this paper is to develop a more reliable paleoecological and paleoclimatological framework for the loess-paleosol sequences in the Bácska area using the remains of Quaternary gastropods.

2. Methods

The 10 m section of loess analyzed in the Madaras brickyard wall was sampled at every 4 cm intervals for Quaternary malacological analyses, following sediment cleaning. Mollusk shells for malacological studies were derived

*E-mail: hupuczi@gmail.com

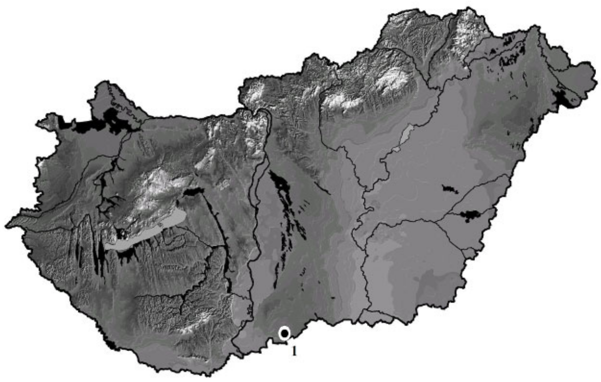

Figure 1. Map showing the location of the study site within Hungary. 1 = The brickyard at Madaras.

from sediment samples of 1 dm^3 in all the profiles in order to gain comparable results regarding the composition of the fauna, and species and specimen numbers. Sampling was carried out according to the methods advocated by Krolopp [6]. Sediment samples were screen-washed using a mesh of 0.5 mm, and the retrieved shells were taxonomically identified using the works of Cameron & Redfern [7], Kerney et al. [8], Liharev & Rammel'meier [9], Ložek [10] and Soós [11, 12].

Once the specimens were taxonomically identified, the abundance and dominance values of individual species were put into tables for every profile. Charts were then prepared to depict, using numbers and percentages of specimens, the distribution of individual species with depth for the whole profile. The dominance values of individual species were also plotted according to depth for those profiles with considerable mollusk material. Afterwards, the individual species were clustered into paleoecological and biogeographical groups based on the works of Krolopp & Sümegi [13–15], Sümegi [16], and Sümegi & Krolopp [5, 17], taking into account their ecological requirements, including such parameters as temperature, humidity, and vegetation cover. This approach can be considered innovative in Quaternary mollusk research internationally [16]. Ecological studies on recent and fossil mollusk faunas [18–20, 34], plus biogeographic distribution maps and data [8–11, 21–23], have been used for sorting. Fluctuations in the abundance and dominance values of individual paleoecological and biogeographical groups according to depth are depicted for each profile using charts and tables prepared with the help of the Psimpoll software package [24].

Climatic reconstructions were conducted on the Madaras fossils using the malacothermometer method [16, 25, 26, 35], based on the recent biogeographic patterns of 11 dominant gastropod species from a composite malacofauna [16, 26, 35]. For the selected gastropod species, optimal climatic conditions were determined, along with the minimum and maximum temperature tolerances (i.e. the gastropods' activity range), based on meteorological station data [16, 25, 26, 35].

The stratigraphic position of different sedimentological layers in the Madaras brickyard's loess wall were identified using the methods of Marković et al. [27, 28], but based on a local stratigraphic system. Previous chronostratigraphic investigations of the Bácska Loess area indicated that the loess and paleosol horizons formed during the final phases of the last glacial period [3, 29]. Based on this data and the work of Marković-Kukla [30], local stratigraphical units were assigned following Chinese loess stratigraphic nomenclature schemes [31], with the unit prefix "K" referring to the standard section at the nearby Katymár brickyard site [29].

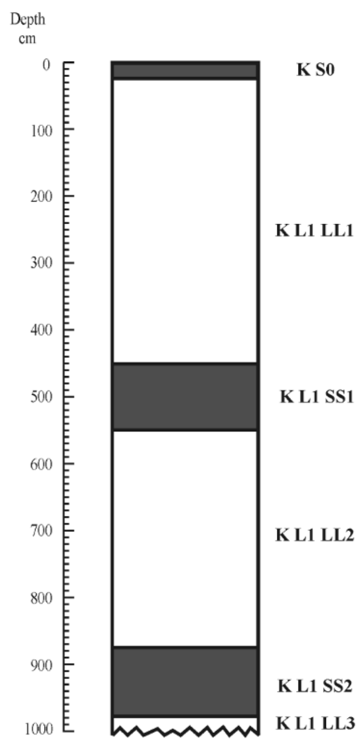

Figure 2. Lithological profile of the Madaras brickyard outcrop.

3. Study profile

The Madaras brickyard is located at 46° 02′ 14.39″ N and 19° 17′ 15.01″ E, at 131.8 m ASL. Based on sedimentological parameters, eight sedimentary layers were distinguished within the 10 m profile exposed (Figure 2).

Between the depths of 10.0 and 9.9 m, there are moderately sorted, yellowish-brown (10 YR 6/4), coarse sandy silts (eolian loess with high sand content) with a significant carbonate content, which contain minor carbonate concretions of 1–1.5 cm and a mass of crotovinas. This sandy loess layer is porous, loosely cemented and, in some parts, finely laminated, often developing thin beds of fine sand. The startigraphic position of this layer is K L1LL3, with this loess layer developed during the Middle Pleniglacial.

There is a significant decrease in carbonate content, and the amount and size (0.1–0.5 cm) of carbonate concretions between 9.9 and 8.7 m, with a concomitant rise in the clay and fine-silt fractions when compared to the bedrock. This intensively brunified paleosol (K L1 SS2) is made up of pale brown (10 YR 6/3), clayey silt, with a few small burnt charcoal fragments of Scots pine (*Pinus sylvestris*). The stratigraphic position of this paleosol suggests that it formed during the second phase of the Middle Pleniglacial.

A light pale brown (10 YR 7/3), weakly brunified layer is developed on top of this paleosol, between 8.7 and 8.0 m. A typical interfingering zone is observable at the boundary of the paleosol and overlying loess layers. There was likely an alternatation of weathering and dust accumulation during this period, creating a gradual transition between the two units with the progressive cessation of pedogenesis.

Between the depths of 8.0 and 5.5 m, there are moderately sorted, yellowish-brown (10 YR 6/4), coarse sandy silts (eolian loess), developed in the terminal phase of the Middle Pleniglacial (K L1 LL2). No cryogenic sedimentary features have been observed in this loess layer at Madaras.

From 5.5 to 4.5 m and on top of this eolian loess layer is a light pale brown (10 YR 7/2) weakly brunified layer with slim fossil carbonate-filled roots, and small carbonated noodles (K L1 SS1).

Between the depths of 4.5 and 1.5 m exists moderately sorted, yellowish-brown (10 YR 6/4), coarse sandy silts (eolian loess). This loess layer probably developed in the terminal phase of the Late Pleniglacial (K L1 LL1). No cryogenic sedimentary indicators have been found in this Madaras loess layer.

On top of this Late Pleniglacial eolian loess is a layer of pale brown (10 YR 7/3), weakly brunified sediment (1.5–0.25 m), and pale brown (10 YR 6/3) clayey, fine silt (the recent soil horizon, from 0.25 m to the surface; K S0 layer). Many spherical, relatively soft carbonate nodules and humus infiltrations in old root channels can be found in this layer near the contact with the modern soil surface (S0).

4. Results

24 species and 110 506 specimens were collected and identified from 250 samples of loess profile at Madaras. According to changes in the mollusk fauna, six malacological–paleoecological zones can be identified in the loess profile (Figures 3, 4).

Between 10.0 and 9.9 m, freshwater gastropods and termophilous and mesophilous terrestrial gastropods can be found. The malacofauna composition suggests that temperate grasslands with short periodic pools formed during this phase. The July paleotemperature would have reached 18–20°C.

Soon after, freshwater species disappear from the profile and the xerothermophilous *Granaria frumentum* (10%) and *Pupilla triplicata* (70%) reached their maximum dominance between 9.9 and 8.5 m. The collective presence of *Pupilla triplicata*, *Chondrula tridens*, *Granaria frumentum*, and *Pupilla muscorum* in this zone, as well as the general composition of the fauna, refers to the emergence of a steppe under mild, dry conditions of vegetation seasons with mean July paleotemperatures of 18–20°C.

The next malacological horizon can be found between 8.5 and 6.0 m. In this section, *Granaria frumentum* disappears, and the dominance of the thermophilous species declines to be replaced by a number of cold-resistant and cryophilous species, such as the Boreo–alpine *Columella columella* [10], which prefers tundra-like environments, and north Asian xeromontan *Vallonia tenuilabris*. Also increasing in this section is the dominance of mesophilous species. The fauna in this zone indicates the development of a cold climatic phase and typical loess fauna in the analyzed region. The faunal composition of this zone is not homogenous, with some short dominance changes of species with different ecological tolerances suggesting dynamic climatic changes in the analyzed area during the terminal phase of the Middle Pleniglacial and beginning of the Late Pleniglacial. The malacothermometer data shows the July paleotemperature changed between 19 and 12°C.

Between 6.0 and 4.4 m, all thermophilous species disappear, the dominance of cold-resistant and cryophilous species declines, with an increase in the number of shade-loving forest species, such as *Orcula dolium* and *Discus ruderatus*. *Punctum pygmaeum* reached its maximum

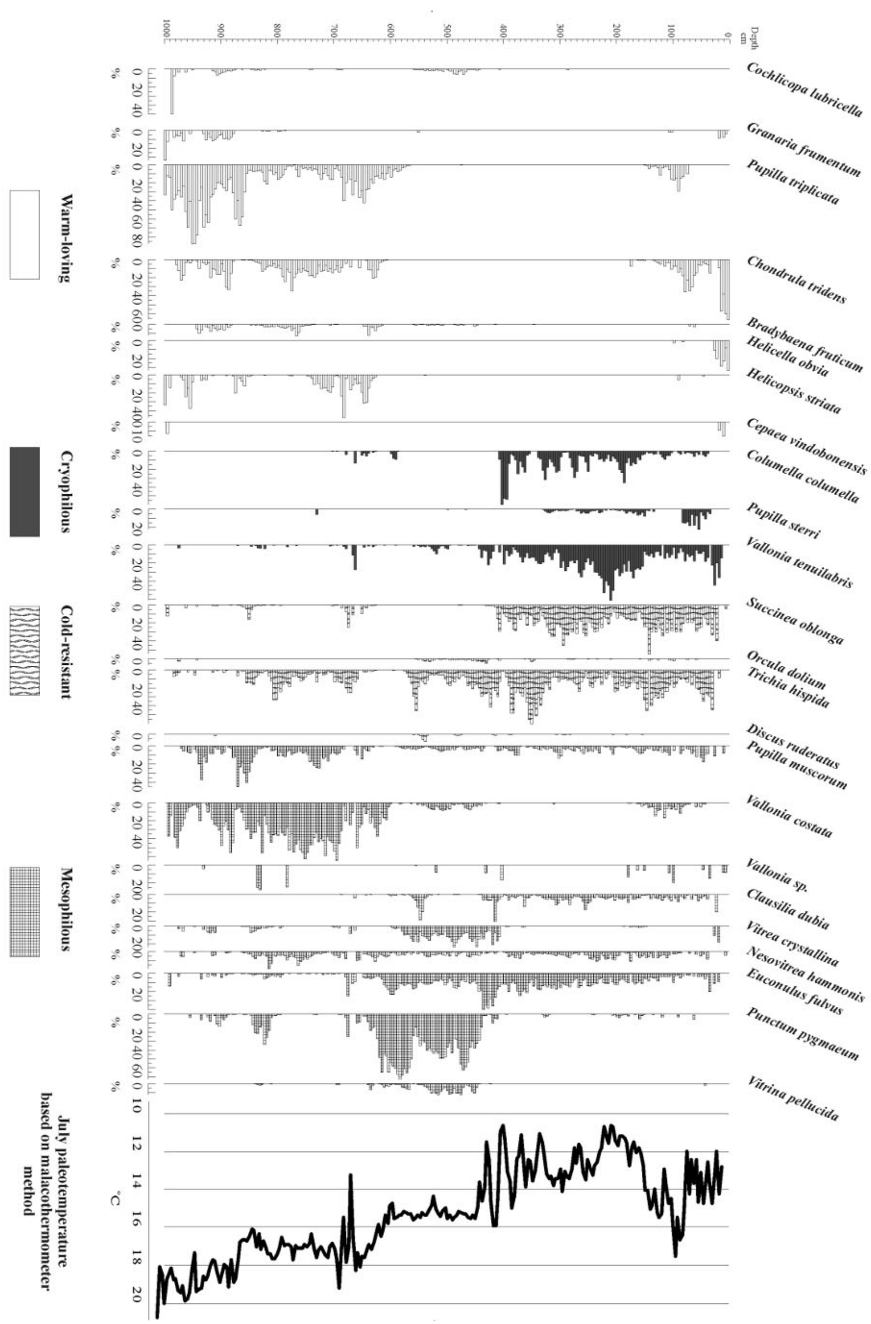

Figure 3. Malacofauna compositional changes, and malacothermometer results for the loess section of the Madaras brickyard.

dominance (40–70%) in this zone, and it, plus some other shade-loving species, such as *Clausilia dubia*, *Vitrina pellucida*, and *Vitrea crystallina*, suggest that the open forest environment developed and expanded in the analyzed region. The appearance of *Orcula dolium* and *Discus ruderatus*, and the maximum dominance of the aforementioned *Punctum pygmaeum, Clausilia dubia*, *Vitrina pellucida* and *Vitrea crystallina*, suggests that a relatively milder climate must have emerged in this horizon, characterized by mean July paleotemperatures of about 15±1°C. It is likely that the weathering process increased during this period and a weathering layer formed on the loess surface.

After 4.4 m, the fauna changes very dynamically. The

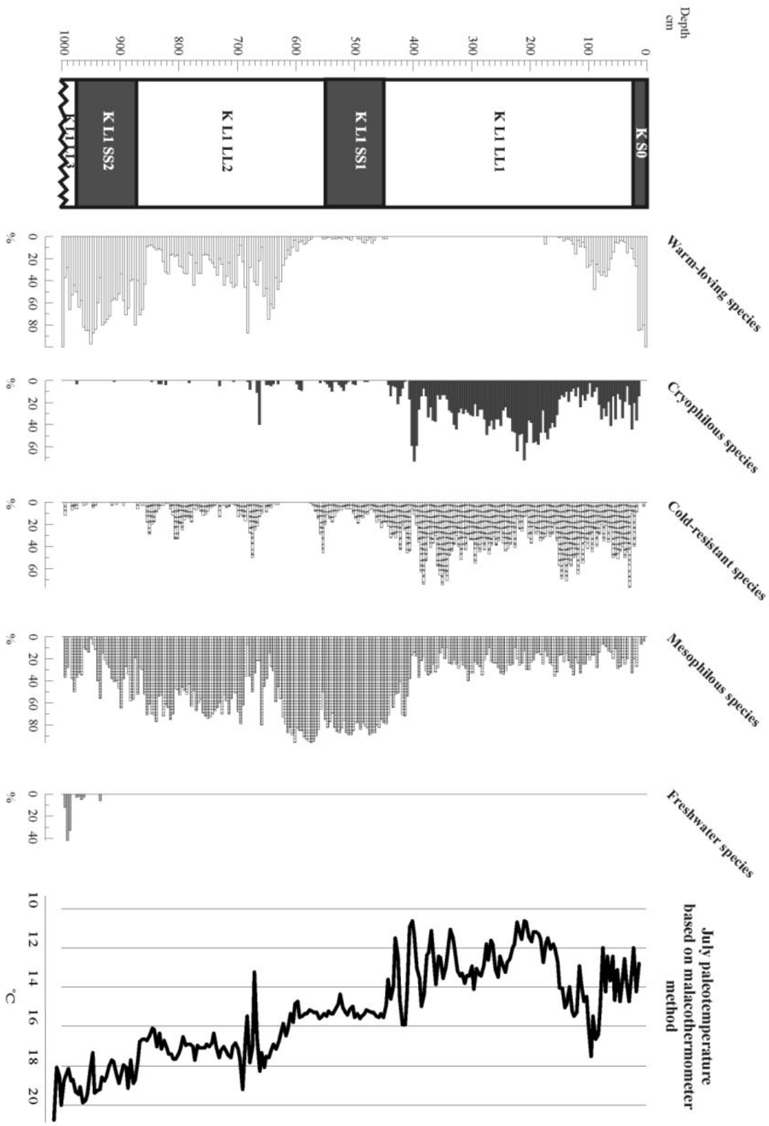

Figure 4. Dominance relations of mollusk groups with different ecological preferences, based on malacothermometer results, for the Madaras profile.

dominance of the mesophilous species declines, and cold-resistant and cryophilous species such as *Trichia hispida, Columella columella, Vallonia tenuilabris* and *Pupilla sterri* dominates in their place. The July paleotemperature decreased and stabilized between 11 and 14°C. Cold and humid growing seasons developed in this climatic phase, with a mosaic of vegetation within tundra-like, steppe-like, and scrub- and tree-covered environments formed in the studied area.

The next malacological phase formed between 1.5 and 0.7 m. The thermophilous species reappear and the dominance of cryophilous species declines. The cold-resistant and mesophilous species that favor steppe-like environments dominate. Based on the malacofaunal composition, a transitional climatic and environmental phase developed during the last loess-forming period, with increased weathering processes and a leaching layer forming on the loess surface prior to Holocene soil-forming processes.

Above 0.7 m, the numbers of mollusk species decline and a special fauna develops where the shells of extinct and Late Holocene migratory species can be found together in the recent soil layer. This taphocoenosis is characterized by different ecological groups, and must have formed as a result of the bioturbation related to soil formation. The zone of modern soil on top of the loess sequence is not complete, and may have been eroded as a result of either natural or artificial processes.

5. Discussion

Changes in the Quaternary malacofauna, observed within the brickyard loess wall at Madaras, suggest a number of dynamic climatic and local environmental changes in the Bácska loess area during the Middle and Upper Pleniglacial periods. In the lower loessy horizon (K L1 LL3) and paleosol layers (K L1 SS2), which developed on top of the deepest loess deposits during the interstadials, the proportions of xerophilous and xerothermophilous mollusks (*Pupilla triplicata, Chondrula tridens, Helicopsis striata*) were the highest in this part of the country [16]. Thermophilous immigrant forms from the Balkans (e.g. *Granaria frumentum*) also intruded into the central parts of Great Hungarian Plain, corresponding to their northernmost distribution boundary for this period. On the other hand, due to its relatively low topography, this region is geographically open towards the south, likely enabling the rapid expansion of thermophilous elements into the area from refugia located along the northern margin of the Balkans (e.g. around the Fruska Gora Hills) during the interstadials and terminal phase of the Middle Pleniglacial [16].

During the terminal phase of the Middle Pleniglacial and beginning of the Late Pleniglacial, the composistion of the mollusk fauna changed drastically. In this phase (K L1 LL2 loess zone), thermophilous species disappeared, cold-resistant and cryophilous elements were uncommon, and the mesophilous species, such as *Vallonia costata* and *Pupilla muscorum*, dominated.

The layers corresponding to this cold maximum are overlain by loess sequences containing a highly unique mollusk fauna. Here there is a peak in the dominance of the mesophilous, Holarctic species *Punctum pygmaeum* (40–70%), which prefers larger vegetation cover [32]. Nevertheless, woodland elements such as the Central European *Clausilia dubia, Vitrea crystallina* and *Nesovitrea hammonis*, and Holarctic *Vitrina pellucida* [33], plus the Boreo-alpine *Discus ruderatus* are also present in the fauna in considerable numbers. Thanks to the cooler and more humid conditions, an expansion of open forest vegetation initiated concomitant pedogenesis in the southern part of the Carpathian Basin during this time (K L1 SS1 horizon).

This short period of relatively mild and humid climate was followed by another strong cooling, a period characterized by the expansion of cold-loving (cryophilous) and cold-resistant elements, primarily the Boreo-alpine *Columella columella*, north Asian *Vallonia tenuilabris*, Eurosiberian *Succinea oblonga* and European *Trichia hispida*, as well as the complete decline of mesophilous elements from the accessory fauna. This change marks the emergence of another cold maximum within the last phase of Late Pleniglacial (K L1 LL1).

After this cold peak, the cold-loving (cryophilous) elements underwent a gradual retreat and finally completely disappeared from the Hungarian loess deposits. In their place, some thermophilous species reappeared and there was a peak in the dominance of cold-resistant, hygrophilous elements (*Succinea oblonga* and *Trichia hispida*). These latter taxa appear in large numbers in the profiles, sometimes representing 90% of the total fauna. This period, which could have developed in Late Glacial phase, is characterized by somewhat milder and more humid conditions as well as the last appearance of the loess fauna in the Carpathian Basin. Above this Late Glacial loess is a black soil layer formed during the Holocene.

Therefore, the malacological data from the loess section of Madaras shows that the Middle and Late Pleniglacial development of the fauna and the local environments in this area differed from the other loess regions of Hungary [16].

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