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GEOCHRONOLOGIC AND PALEOCLIMATIC CHARACTERIZATION OF QUATERNARY SEDIMENTS IN THE GREAT HUNGARIAN PLAIN

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ABSTRACT. We reconstructed the climate of the Great Hungarian Plain between the years, 7–32 ka BP using a malacothermometer method. The reconstruction is based on seven Gastropoda taxa, for which optimal temperature and tolerance ranges have been determined. The temporal scales of the malacofaunal levels were calibrated with radiocarbon data. We compared our paleotemperature values with the temperature values of existing climatic curves and found the same climatic periods.

INTRODUCTION

Terrestrial gastropods have generally been treated as microclimatic indicators. Tolerant taxa, spread over large areas, were considered mostly useless for climatic reconstruction due to the large temperature range typical of these species. However, as micro- and macroclimatic differences within lowland regions covered by open vegetation are very small, they consequently might not hinder the reconstruction of climatic changes of the relevant region if carefully selected Gastropoda species are studied. These species are active only during certain times of the year with given temperature and humidity. During this active time, they are consuming food and constructing their organic-non-organic biomineralizate snail shells. As the individuals survive the period unfavorable for them in an anabiotic state, our paleoclimatic deductions are necessarily valid only for the vegetation period. On the basis of these considerations, the paleoecological characteristics of several terrestrial Gastropoda species, persisting from the Upper Pleistocene to the present, have been analyzed, with special regard to the quality of the soil, humidity and the role of vegetation. From mesoclimatic research stations, information has been obtained on optimum climate conditions for several taxa, including the maximal and minimal temperatures these taxa tolerate, or their resistance range. From the resistance range, we computed the vegetation climatic optimum identified with the July mean temperature. When dealing with a composite malacofauna, using the equation of Skoflek (1990),

$$t = \frac{m_1 a_1 + m_2 a_2 + \dots + m_n a_n}{m_1 + m_2 + \dots\dots + m_n} \qquad (1)$$

we can calculate the July mean temperature of the investigated level (a_n is the optimum temperature of the Gastropoda species, and m_n is the percent ratio of the given species in the sample). By testing the mathematical validity of our hypothesis on recent samples, we are able to reconstruct paleoclimatic periods characterized numerically by the July mean temperature.

Temperature is the most important but not the only causative control on gastropod parameters. Humidity, vegetation and pH of the soil are also relevant. Thus, gastropods may provide information on paleohumidity.

Methods

We investigated in detail several stratigraphic profiles formed during the Upper Pleistocene – Holocene in the Great Hungarian Plain. Figure 1 shows the location of the profiles. Table 1 shows the radiocarbon age of the layers measured with a high-precision radiocarbon dating system (Hertelendi *et al.* 1989). We dated carbonate sections of *Succinea oblonga, Trichia hispida, Pupilla muscorum, Vallonia tenuilabris, Helicigona arbostrum* and *Granaria frumentum*. We used the following cleaning procedure: drying (105°C), then washing twice with water (40°C) through a 0.8-mm sieve; manual separation of the shells, leaching in 1% H_2O_2 (20°C 24 h), washing with distilled water through an 0.8-mm sieve, drying (105°C), crushing of the shells, washing (40°C), drying (105°C), and again, manual separation. The CO_2 was obtained from the clean shells by acid evolution.

Dating gastropods involves many sources of error. Thus, for several layers, we compared our ^{14}C dates of gastropod shells with ages of charcoal from the same layer. We found that the difference in the ages did not exceed 1 ka in the range between 8 and 30 ka BP. Thus, we did not correct for the gastropod dates. We also carried out stable isotope measurements (Fig. 2) on mollusk shells, and found similar trends in the change of $\delta^{18}O$ values and temperatures determined by malacothermometry. We calculated the quantitative paleoclimatic values using seven Gastropoda taxa, for which Sümegi (1989) determined the optimum temperatures and resistance ranges (Table 2).

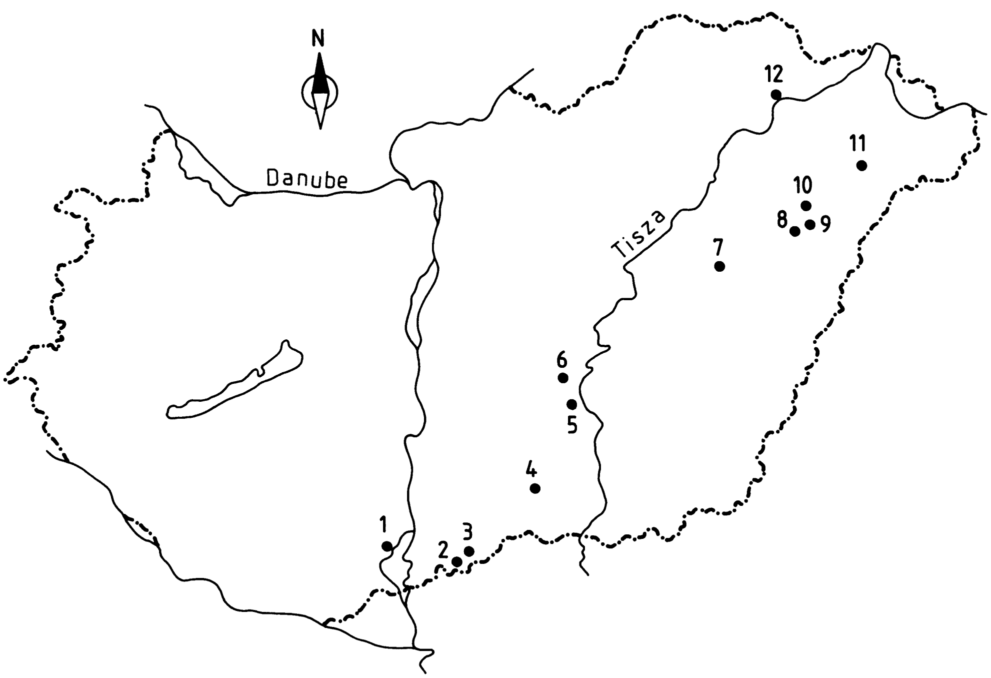

Fig. 1. Locations of the stratigraphic profiles used for paleoclimatic reconstruction: 1. Dunaszekcsö; 2. Katymár; 3. Madaras; 4. Csólyospálos; 5. Tiszaalpár; 6. Lakitelek; 7. Kócsújfalu; 8. Látókép; 9. Debrecen; 10. Józsa; 11. Kállósemjén; 12. Bodrogkeresztúr

TABLE 1. ^{14}C Ages of Molluskan Faunal Levels

Location	Depth (m)	$\delta^{13}C$(‰) (PDB)	^{14}C age (yr BP)	Lab no.
*Dunaszekcsö			21,740 ± 320	HV -4189
*Madaras			18,080 ± 409	HV -1619
*Csólyospálos	(0.75–1)	−6.59	8040 ± 200	DEB-1067
*Tiszaalpár—1	(2.5–2.7)	−7.23	15,310 ± 350	DEB-1080
*Tiszaalpár—2	(3.7–4.0)	−8.01	17,860 ± 350	DEB-1078
*Lakitelek—1	(0.6–0.8)	−6.05	11,700 ± 250	DEB-1092
*Lakitelek—2	(1.4–1.6)	−8.41	14,840 ± 300	DEB-1075
*Lakitelek—3	(2.2–2.4)	−7.45	16,820 ± 200	DEB-1536
*Lakitelek—4	(3.0–3.2)	−7.99	22,110 ± 300	DEB-1562
*Lakitelek—5	(5.8–6.0)	−8.49	29,980 ± 550	DEB-1095
*Kócsújfalu	(1.4–1.5)	−7.66	15,800 ± 200	DEB-1546
*Látókép—1	(3.2–3.5)	−10.74	25,020 ± 500	DEB-1077
*Debrecen I—2	(0.5–0.7)	−8.53	8750 ± 200	DEB-1091
*Debrecen I—3	(0.7–1)	−9.49	10,010 ± 200	DEB-1277
*Debrecen I—4	(1.2–1.5)	−7.68	13,380 ± 200	DEB-1547
*Debrecen I—5	(2–2.25)	−8.88	15,740 ± 200	DEB-1565
*Debrecen I—6	(2.5–2.7)	−7.47	18,090 ± 200	DEB-1537
*Debrecen I—7	(3.5–3.7)	−8.09	22,800 ± 300	DEB-1561
*Debrecen II—1	(0.2–0.5)	−8.55	7130 ± 200	DEB-1276
*Bodrogkeresztúr	(1.1–1.2)		17,680 ± 300	DEB-1614
*Kállósemjén	(1.1–1.2)	−6.65	8010 ± 100	DEB-1564
**Hortobágy—1	(1.9–2.0)	−8.67	13,000 ± 300	DEB-1082
**Hortobágy—3	(4.5–4.7)	−7.65	18,770 ± 200	DEB-1570
**Hortobágy—4	(3.7–4.0)	−9.10	14,560 ± 300	DEB-1068
**Nagyhegyes—1	(1–1.25)	−10.77	25,520 ± 500	DEB-1066
**Derecske—1	(4–4.25)	−8.93	9500 ± 200	DEB-1302
**Abony—1	(1.9–2)	−8.58	20,970 ± 400	DEB-1064
**Tószeg—1		−8.41	11,700 ± 250	DEB-1079
**Császárszállás	(2–2.2)	−8.08	31,300 ± 300	DEB-1484
**Szeged		−8.16	16,080 ± 150	DEB-1486
**Sárszentmihály	(1.7–2)	+3.81	8200 ± 100	DEB-1067
**Pocsaj		−9.67	19,600 ± 200	DEB-1582

*Layers with terrestrial gastropoda used in temperature determination
**Layers used in timescale calibration only

TABLE 2. The Optimum Temperatures and Resistance Ranges of Gastropod Species Used for Climatic Reconstruction

Species	Optimum (°C)	Resistance range (°C)
Vallonia tenuilabris	9 ± 2	4 – 13
Columella columella	10 ± 1	5 – 15
Columella edentula	15 ± 1	10 – 20
Pupilla muscorum	16 ± 1	10 – 22
Succinea oblonga	16 ± 1	13 – 19
Pupilla triplicata	20 ± 2	16 – 24
Cepaea vindobonensis	22 ± 2	18 – 26

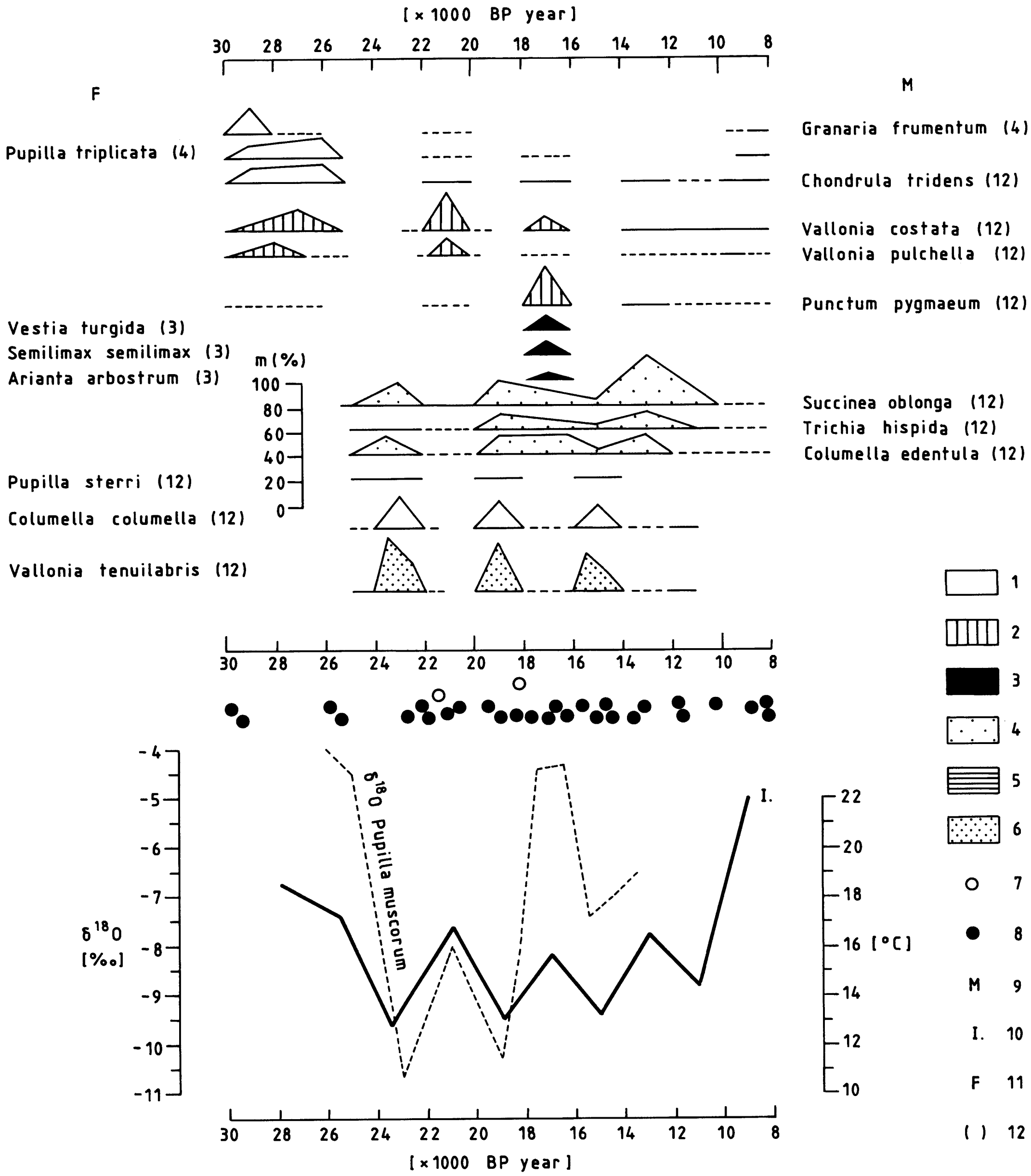

Fig. 2. Paleoclimatic and paleoecological reconstruction of the Great Hungarian Plain based on mollusk fauna and isotope geochemical data. Mean temperatures were obtained from 12 profiles listed in Table 3 and shown in Fig. 1. 1. Thermophilic, steppean species; 2. Mesophilic, steppean species; 3. Forest species; 4. Hygrophilic, cold-resistant, steppean fauna; 5. Hygrophilic, cold-climate, steppean fauna; 6. Cold-climate fauna, resistant to dry climate; 7. Radiocarbon data (from Hannover); 8. Radiocarbon data (from Debrecen); 9. Fossil species of the Great Hungarian Plain; 10. Malacothermometer (Sümegi 1989); 11. Current species of the Great Hungarian Plain; 12. Number of profiles used for the calculation of the mean percent ratio for a given species.

TABLE 3. Paleotemperatures obtained from various profiles in Hungary between 8 and 30 ka BP. The age of the layers were determined by radiocarbon dating (x), or by biostratigraphy.

Location	July mean temperature (°C) Age range (year × 10^3)									
	30–26	26–25	25–22	22–20	20–18	18–16	16–14	14–12	12–10	10–8
Dunaszekcsö	18	17	13	17x	13	16	–	–	–	–
Katymár	19	18	14	17	–	16	14	16	15	–
Madaras	19	18	14	17	–x	16	14	16	15	–
Csólyospálos	–	–	–	–	–	–	–	–	–	22x
Tiszaalpár	18	17	–	17	–	16x	13x	17	–	–
Lakitelek	–x	17	–x	17	–	16x	13x	16	13x	–
Kócsújfalu	–	–	–	–	–	15	13x	–	–	–
Látókép	–	17x	12	16	13	15	13	17	14	–
Debrecen	–	17	12x	16	13	15x	13x	17x	15x	22x
Józsa	–	17	12	16	13	15	13	16	14	–
Bodrogkeresztúr	–	–	–	17	13	16x	13	–	–	–
Kállósemjén	–	–	–	–	–	–	–	–	–	22x
Average	18.5	17.2	12.8	16.7	13.0	15.6	13.2	16.4	14.3	22.0

RESULTS AND DISCUSSION

Figure 2 and Table 3 show the results of the paleoclimatic and paleoecological reconstruction, as well as the results of ^{14}C dating and stable isotope ratio analysis. On the basis of a detailed ecostatistical analysis of the Upper Pleistocene–Holocene malacofauna of the Great Hungarian Plain, the following paleoclimatic outline can be documented:

30–26 ka BP – temperate humid climate. This period is generally characterized by fossil soil zones (Stillfried B, Kesselt, Mende Upper Horizon) in Europe. Malacothermometry indicated a July mean temperature exceeding 18°C for this period.

26–25 ka BP – dry and warm climate (end of the interstadial) indicated by xerophilus elements, such as *Pupilla triplicata, Chondrula tridens* and *Vallonia costata*.

25–22 ka BP – cold, dry climate on the Great Hungarian Plain with July temperatures about 12–14°C. The malacofauna is dominated by *Vallonia tenuilabris* resistant to cold and dry weather.

22–20 ka BP – a warming period, with July mean temperatures of 16–17°C, indicated by the dominance of *Pupilla muscorum* and *Vallonia costata.*

20–18 ka BP – significant deterioration of the climate, with 13°C July mean tem-peratures, indicated by the extremely high ratio of *Columella columella* and *Vallonia tenuilabris.*

18–16 ka BP – more humid, temperate climate, indicated by the presence of *Vestia turgida* and *Punctum pygmaeum.* This short, humid phase was followed by a gradual improvement of the climate. We have to stress the dominance of *Punctum pygmaeum,* dated at 18–16 ka BP. This period, in Hungary, is associated with Upper Paleolithic (Gravettian) archaeological sites (Dobosi *et al.* 1983). The interstadial period typical of this phase can be observed both locally and globally.

16–14 ka BP – average July temperatures could be about 13–14°C. *Pupilla sterri* can be identified for the last time on the Great Hungarian Plain. Typical for this period, we note the dominance of elements preferring a cold climate (*Columella columella* and *Vallonia tenuilabris*). It is well known that the extent of the inland ice cover was fairly large at this time. This phase was identified as the Dryas I period. From the year, 14 ka BP on, we observe oscillations of climatic conditions, and a general rise in temperature.

14–12 ka BP – withdrawal of the taxa preferring cold climate, accompanied by the gradual dominance of hygrophilous species resistant to cool climate. In our opinion, this period can be associated with the Bølling interstadial.

12–10 ka BP – the dominance peak of the species, *Succinea oblonga*, is characteristic for this period. The July mean temperature, determined from malacothermometry, was 14°C.

10–8.5 ka BP – the July mean temperature reached 22°C. *Cepaea vindobonensis* had already appeared, and from 8.5–7 ka BP, the climate was warmer and drier than at present. This climatic optimum is evidenced on the Great Hungarian Plain by the dominance of *Granaria frumentum, Pupilla triplicata* and *Helicopsis striata*. During this period, the youngest freshwater lime silt (limestone) beds, Balaton and Sárrét Basins, were formed.

We compared our climatic curve with those of other authors (Fig. 3.). The general trend of our temperature curve agrees very well with that of Heusser (1973), based on palynology and calibration with ^{14}C dates. The warming attributed to the beginning of the Holocene and the Upper Pleistocene peaks of maxima and minima can be followed very well. The different temperatures can be explained, at least partly, by the fact that Heusser's palynothermometer was designed for the State of Washington (USA) environs of inland ice cover.

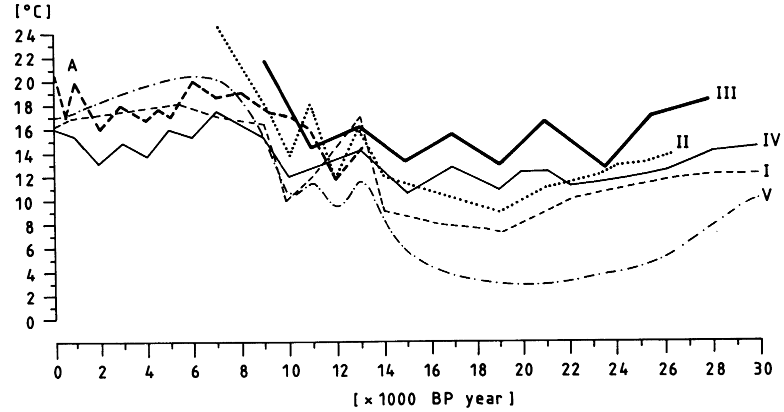

Fig. 3. Comparison of our paleoclimatic curve (malacothermometer) with results of other authors (all these curves show July mean temperatures.) A. Vole thermometer (Kretzoi 1957; Kordos 1977); I. *Coleoptera* thermometer (Coope 1971); II. Pollen thermometer (Járai–Komlódi 1969); III. Malacothermometer (Sümegi 1989); IV. Pollen thermometer (Heusser 1973); V. Pollen thermometer (Zagwijn & Paepe 1968)

Our malacothermometer can be compared in its full range with the climatic curve of Coope, Morgan and Osborne (1971), based on *Coleoptera* remains from Britain, the trend of which is very similar to the palynological curve of Hungary. This can probably be explained by the fact that both studies were based on the comparative investigation of marshes and marshy biotopes. From 30–14 ka BP, these sites were refugia, and supply data on a special environment. Thus, they are not suitable for documenting finer changes in climate. Lower temperatures can be explained by the more temperate, cooler climate and, in the case of Britain, by the neighboring ice sheet as well.

We consider uncertain the 26–14 ka phase of the climatic curve calibrated with ^{14}C dates and constructed for The Netherlands (Zagwijn & Paepe 1968), which shows only a single period of cooling. We are more comfortable with the hypothesis that the climate changed more frequently on the Great Hungarian Plain, a part of the Carpathian Basin.

The data of our malacothermometer can be compared to those of the "vole thermometer" based on vertebrate succession of small mammal remains of the Mid-Mountain range (Kretzoi 1957; Kordos 1977), tested for the period between 13 and 7 ka BP with ^{14}C dates and a chronology of fossil bones (Szöör 1982). During this phase, the trends of the two curves agree very well. The differences in actual temperatures reflect mesoclimatic differences between lowlands and hills. In our opinion, the above evaluation validates the paleoclimatic picture based on malacofauna, and also supports the paleoclimatic reconstruction of the Great Hungarian Plain.

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