RESULTS OF THE MALACOLOGICAL ASSEMBLAGE FROM THE MOAT OF SULTAN SULEIMAN'S TÜRBE AT SZIGETVÁR (SW HUNGARY)

SZULEJMÁN SZULTÁN SZIGETVÁRI TÜRBÉJÉNEK ÁRKÁBÓL SZÁRMAZÓ MALAKOLÓGIAI ANYAG VIZSGÁLATÁNAK EREDMÉNYEI•

SÜMEGI, Pál[1,2]

[1]University of Szeged, Department of Geology and Paleontology, H-6722 Szeged, Egyetem Str. 2-6, Hungary

[2]EötvösLoránd Research Network, Institute for Nuclear Research 4026 Debrecen, Bem Square 18/c, Hungary

*Corresponding author e-mail: sumegi@geo.u-szeged.hu

Abstract

A total of 25 samples were taken from the section of the moat bordering the former türbe of Sultan Suleiman in Szigetvár. Altogether 5 713 identifiable mollusc remains that cover 20 terrestrial snail species were found. Based on the dominance changes of species and palaeoecological groups and the detrended correspondence analysis (DCA), three malacological zones (Türbe Malacological Zone: TMZ) could be separated in the profile of the moat.

In the first malacological zone (between 250 and 140 cm) the high number of Eurosiberian species (hygrophilous and cold resistant species, Succinea: amber snail) were found. Their presence and significant amount are in relation with the colder meso- and microclimate of the 17th century. As a result, it can be assumed that the climate of the Little Ice Age (LIA) in the Carpathian Basin changed according to the micro-topography and vegetation cover, and was not uniform.

In the second malacological zone (between 140 and 50 cm) the number of cold-tolerant and hygrophilous, Eurosiberian fauna elements decreased, and gradually disappeared from the profile. In parallel, mesophilous and thermophilous, open-vegetation favouring Central and South-eastern European taxa became dominant. So, the moat filled up and a dry habitat with more open vegetation, which was no longer favourable for moisture-loving (and shade-loving) species developed.

The third malacological zone (from 50 cm towards the surface) indicated a major transformation in the fauna composition. The ratio of mesophilous species decreased drastically. Central and South-eastern European thermophilous species, favouring open vegetation dominated in this level of the profile. Very likely, the upper 40–50 cm part of the profile was filled up at the end of the 17th century, or at the beginning of the 18th century.

The changes in the malacofauna composition indicate mesoclimatic and microclimatic alterations and strong human impact. Based on our data, we need to treat climate change and its effects on agriculture in the Carpathian Basin in a more differentiated way for the 17th century, and we cannot and should not extend the negative effects of the North Atlantic to the Carpathian Basin. Since, on the basis of former malacological studies, the mosaic-like nature of the Carpathian Basin was able to compensate for the unfavourable climatic changes of the Little Ice Age.

Kivonat

A szigetvári, Szulejmán szultán egykori türbéjét északról határoló árok szelvényéből összesen 25 db mintát sikerült venni. Összesen 20 szárazföldi csigafaj 5 713 határozható egyede (héjtöredéke és héjmaradványa) került elő. Az egyes fajok, a paleoökológiai csoportok dominancia változásai és a DCA statisztikai elemzés alapján három szintet lehetett malakológiai alapon elkülöníteni az árok szelvényében (Türbe Malacological Zone: TMZ).

Az első malakológiai szintben (250–140 cm között) euroszibériai fajok (higrofil és hidegtűrő elemek, Succinea = *borostyánkő csigafélék) kerültek elő viszonylag jelentős arányban. A jelenlétük és jelentősebb arányuk összefüggésben lehet a 17. századi hidegebb időjárásával, hidegebb mezo- és mikroklímával. Ennek nyomán*

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feltételezhető, hogy a Kárpát-medencében a kisjégkorszak (Little Ice Age: LIA) klímája (is) a mikrodomborzati – vegetációs borítottsági adottságoknak megfelelően változott, vagyis nem volt egységes.

A második malakológiai zónában (140–50 cm között) a hidegtűrő, nedves környezetet kedvelő, döntően euroszibériai elterjedésű elemek aránya lecsökkent, illetve fokozatosan eltűntek a szelvényből. Ezzel párhuzamosan a mezofil és termofil, nyitottabb növényzetet kedvelő, közép-európai és délkelet-európai elterjedésű taxonok váltak dominánssá. Ennek nyomán az árok feltöltődött, száraz, nyitottabb vegetációval jellemezhető élőhellyé alakult, amely már nem kedvezett a nedvességkedvelő (és árnyékkedvelő) fajok számára.

A harmadik malakológiai zónában (50 cm-től a felszínig tartó szelvényszakasz) az árok faunája alapvetően átalakult. A mezofil fajok aránya is drasztikusan lecsökkent. Nyílt vegetációt kedvelő termofil, közép- és délkelet európai elterjedésű taxonok domináltak ebben a szelvényszakaszban. Valószínűleg az árok felszínközeli részét, felső 40–50 cm-re már a 17. század végén vagy a 18. század kezdetén töltötték fel. Ennek nyomán az eltérő környezeti jelzőszereppel rendelkező taxonok és paleoökológiai csoportok arányváltozásai mögött a mezoklíma és a mikroklíma átalakulása és erőteljes emberi hatások húzódtak meg. Adataink nyomán jóval differenciáltabban kell kezelnünk a 17. századi éghajlati változásokat és azok hatásait a Kárpát-medence mezőgazdaságára vonatkozóan, nem lehet és nem szabad az észak-atlanti negatív hatásokból kiindulni. Úgy tűnik, hogy a korábban malakológiai vizsgálatok nyomán megfogalmazott mozaikos környezeti adottsága a Kárpát-medencének ellensúlyozni tudta a LIA kedvezőtlen éghajlati változásait.

KEYWORDS: MALACOLOGY, TERRESTRIAL SNAIL FAUNA, PALEOECOLOGY, LITTLE ICE AGE (LIA)

KULCSSZAVAK: MALAKOLÓGIA, SZÁRAZFÖLDICSIGA FAUNA, PALEOÖKOLÓGIA, KISJÉGKORSZAK (LIA)

Introduction

In the second half of the 16th century, an Ottoman *türbe* was built on the site of the death of Sultan Suleiman I, who died in 1566 in Szigetvár, where his internal organs were buried. The burial place was built in 1575 (Pap et al. 2023) and was an active memorial and pilgrimage site for decades. The türbe was protected by a palisade and a moat system from the north (Pap et al. 2023: figs. 1, 2.). However, after the recapture of the fortress of Szigetvár and the expulsion of the Ottoman army at the end of the 17th century, it disappeared over time, its exact location was forgotten and the area became a site of agricultural production. In the 2010s, a systematic search for the site of the former türbe was launched, which was crowned with success in 2015, as not only the remains of the memorial site and its associated buildings were excavated (Pap et al. 2023), but also the moat that bounded and protected the memorial site from the north (Torma et al. 2023). During the discovery and excavation of the moat (Pap et al. 2023), multi-purpose sampling and environmental historical analysis were carried out (Torma et al. 2023, Tugya 2023).

It is well-known that terrestrial snail species are very sensitive to local environmental change (Boycott 1934; Sparks 1961; Ložek 1964; Evans 1972; Krolopp & Sümegi 1995) and species sensitive to the different environmental factors are excellent for the reconstruction of the local development of a site, in this case, the moat. Through malacological analysis, we aimed to reconstruct the environmental history of the site, i.e. the wet and dry phases of the moat by the dominance analysis of the species occurring. The site is located in an archaeologically well-explored area that was previously unknown from a malacological point of view. Only sporadic data is available on the environmental changes in fauna during the late 17th century. In addition, since the memorial place and moat system could be dated to the 17th century (Gulyás et al. 2022), our data provide information on the climate of a specific period, the Little Ice Age (LIA). So, we are also looking for an answer to the question, of whether the cooling period of the Little Ice Age (LIA) is reflected in the malacofauna at this southern Hungarian site.

Materials and methods

Mollusk shells were collected at 15 cm intervals (5.7 kg/samples) throughout the profile of the moat, and 10 cm intervals (5.7 kg/samples) from the uppermost 50 cm of the profile.

The aquatic malacofauna was divided into two groups following the palaeoecological classifications of Boycott (1934), Sparks (1961), Ložek (1964), and Krolopp & Sümegi (1995): 1./species demanding steady water inundation (moat group), 2./species tolerant to periodic water supply (slum group). The terrestrial fauna was grouped as follows: hygrophilous, mesophilous, xerophilous, cold-resistant, intermediate, thermophilous, open habitat preferring, ecotone habitat preferring, and woodland habitat preferring species (Sümegi & Krolopp 2002; Sümegi 2005). The malacological record was also classified according to the recent geographical distribution of the species (Kerney et al. 1983; Horsák et al. 2013; Evans 1972; Soós 1943; Krolopp 1983; Alexandrowicz 2004; Welter-Schultes 2012), and on the basis of palaeoclimatological indicator roles

(Sümegi & Krolopp 2002; Sümegi 2005; Sümegi et al. 2011, 2013). Statistical methods were used for the zonation of the data. Detrended correspondence components (DCA) analysis computed on correlation matrices was performed after arc sine transformation (Rousseau 1987, 1990, 1991, 2001; Zar 1990) of the malacological data. Detrended correspondence analysis was used for mollusc-based pale ecological reconstructions (Rousseau 1987, 1990; Limondin & Rousseau 1991; Dong et al. 2020). The dominance values of certain Mollusc species and those of the given palaeoecological groups are of crucial importance regarding the reconstruction of the prevailing environmental factors. Dominance values are based on the calculation of percentages from the specimen numbers of species collected from the sample (Krolopp 1973, 1983; Ložek 1964; Sparks 1961).

Results

During the malacological analysis, 5 713 individuals belonging to 20 terrestrial snail species were identified from the sediment series of the moat (**Fig. 1.**).

The following species turned up in the profile, according to their dominance: *Vallonia costata*, *Vallonia puclhela*, *Chondrula tridens*, *Pupilla triplicate*, *Limacidae* (the aragonite and calcite internal shell of slugs get fossilized well), *Pupilla muscorum*, *Vallonia enniensis*, *Zebrina detrita*, *Succinea putris*, *Vertigo antivertigo*, *Cochlico palubrica*, *Succinella oblonga*, *Fruticicola fruticum*, *Aegopinella ressmanni*, *Caucasotachea vindobonensis*, *Helix pomatia*, *Granaria frumentum*, *Clausilia pumila*, *Xerolenta obvia* and *Helicopsis striata*.

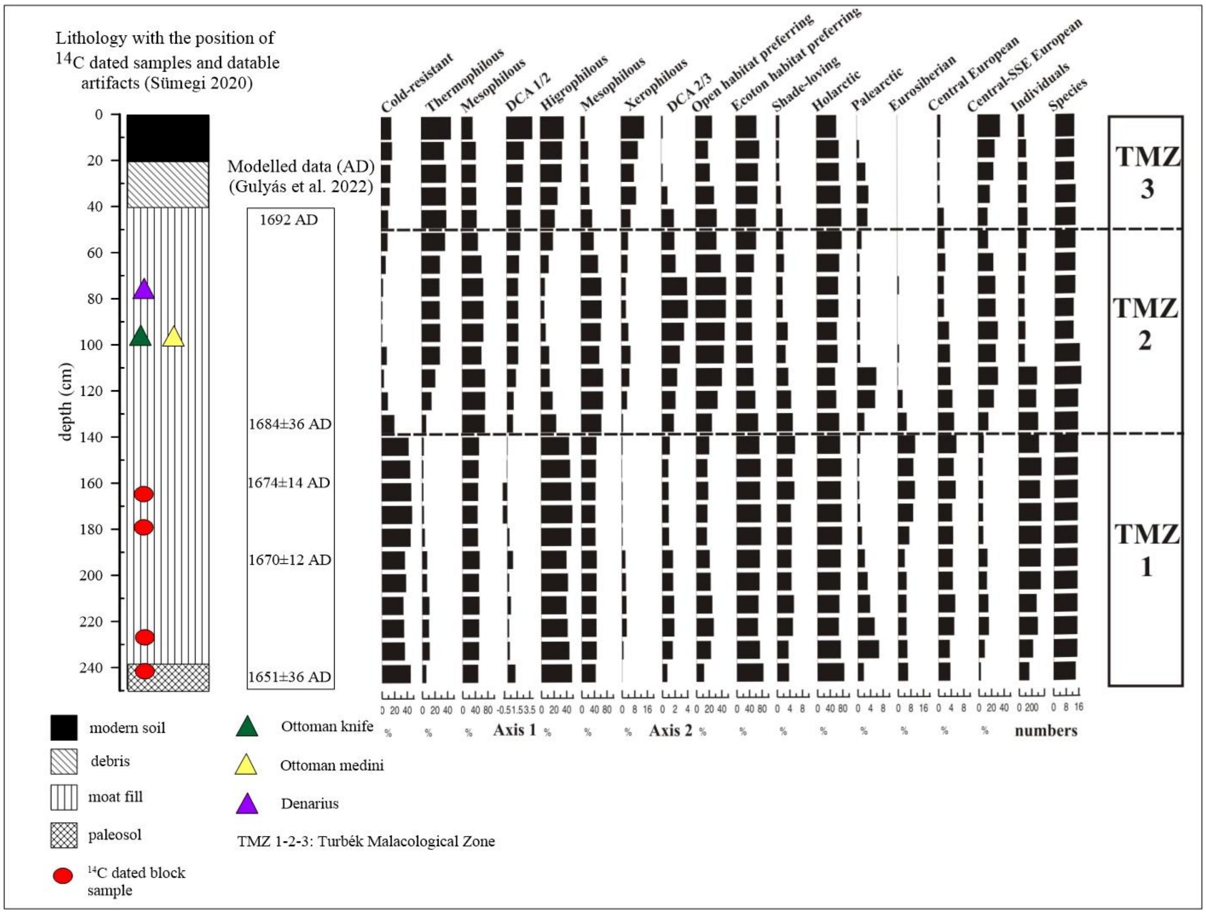

Fig. 1.: Changes in the dominance of snails from the filling of the moat along the profile, with calibrated radiocarbon data (Gulyás et al. 2022) and coins used in chronological analysis.

1. ábra: A türbe árkának betöltéséből előkerült csiga taxonok dominancia viszonyainak változásai szelvény mentén, kronológiai elemzéseknél felhasznált kalibrált radiokarbon adatokkal (Gulyás et al. 2022) és pénzérmékkel

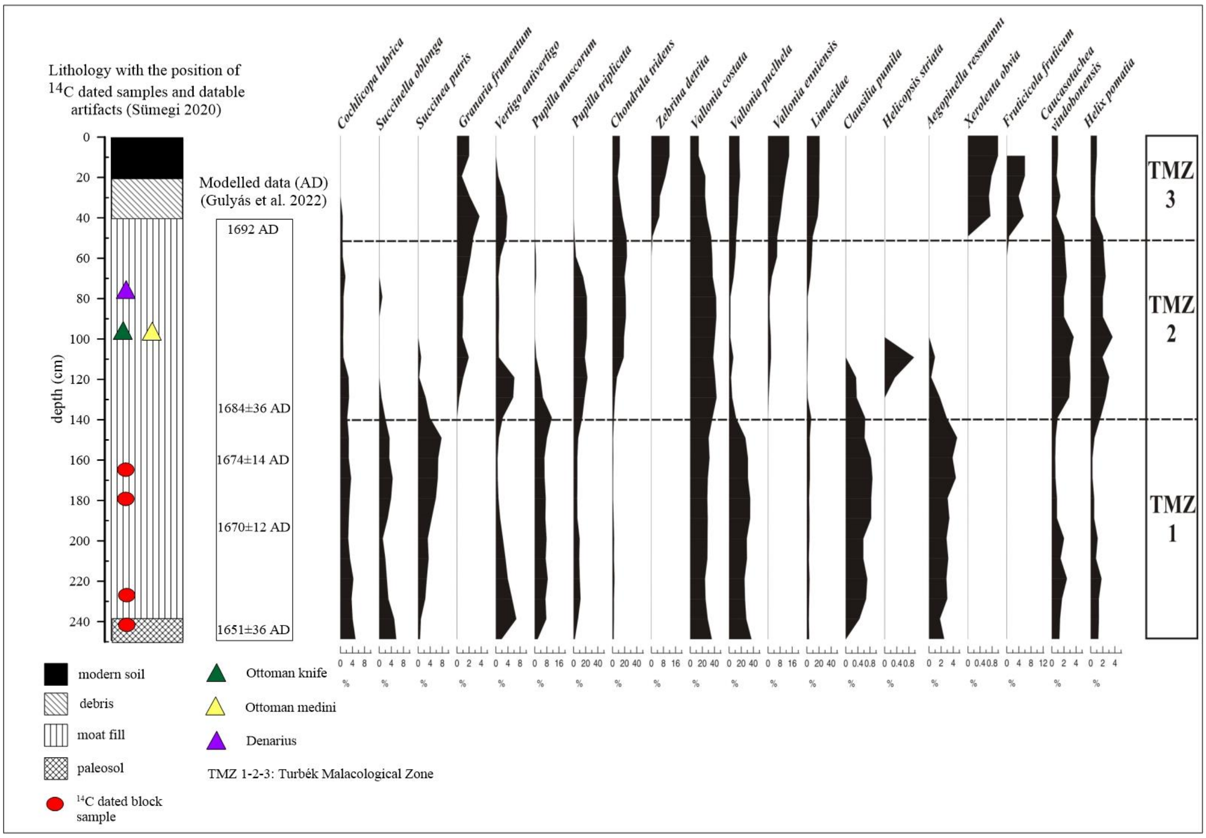

Fig. 2.: Changes in the dominance of palaeoecological groups set up on the basis of snails excavated from the filling of the moat along the profile, with calibrated radiocarbon data (Gulyás et al. 2022) and coins used in chronological analysis

2. ábra: A türbe árkának betöltéséből előkerült csigák alapján felállított paleoökológiai csoportok dominancia viszonyainak változásai szelvény mentén, kronológiai elemzéseknél felhasznált kalibrált radiokarbon adatokkal (Gulyás et al. 2022) és pénzérmékkel

Discussion

Based on the changes of certain species and the dominance changes of palaeoecological groups, as well as the detrended correspondence analysis (DCA), three malacological zones could be separated in the profile of the moat (**Figs. 1., 2.**).

First malacological zone (250–140 cm):

In the bedrock of the profile besides the Holarctic fauna elements, hygrophilous, cold-tolerant Eurosiberian fauna elements (*Succinea* = amber snails) dominated (**Figs. 1, 2.**). Based on their presence, the inner surface of the moat was wet for a longer period of the year (growing season) and the high number of these species might be related to the colder climate and colder meso- and microclimate of the 17th century.

Unfortunately, we do not have a comparative malacological material for terrestrial species in the Carpathian Basin for the 17th century. The mollusk fauna of sedimentary basins indicates Boreo-Alpine and Eurosiberian species appearance and dominance that supports a colder climatic phase in this level (i.e. the 17th century) (Sümegi 2004; Sümegi et al. 2011, 2022). In parallel, the remains of the thermophilous species (*Granaria frumentum*) were also detected at this level. As a result, it can be assumed that the climate of the Little Ice Age in the Carpathian Basin changed according to the micro-topography and vegetation cover, so it was not uniform. As a result, the regionally colder and wetter climatic phase that was modelled (Pinke et al. 2016, 2017) in the fluvial basins of the Great Hungarian Plain, may have been more distinct on the south-facing slopes of the Transdanubian Mountains. So, the locally more favourable exposure angle, with significant energy input, compensated for the global–regional temperature tendency. We cannot exclude that thermophilous species were active only during the warmest periods of the growing season (Nyilas & Sümegi 1987), while during the coldest phases of the growing season, cold-tolerant fauna was much more dominant. The high number of shade-tolerant species (Sólymos et al. 2004; Potoczak & Pokryszko 2020) suggests that the moat was covered by vegetation (shrubs, weeds) in the major part of the year.

Second malacological zone (140–50 cm):

Based on the malacofauna, the filling up of the moat gradually changed from 140 cm upwards, where the number of hygrophilous and cold-tolerant Eurosiberian fauna elements decreased and disappeared from the profile (**Figs. 1., 2.**). Simultaneously, mesophilous and thermophilous Central and South-eastern European (Welter-Schultes 2012) species, favouring open vegetation spread and became dominant (*Chondrula tridens*, *Vallonia costata*, *Caucasotachea vindobonensis*, *Helix pomatia*). In parallel with moisture-loving elements, the number of shade-loving species decreased as well in this horizon. This suggests that the moat filled up, and became a dry habitat with open vegetation, which was no longer favourable for moisture-loving (and shade-loving) species. Probably, in this stage of evolution, the moat had already lost its drainage and protection function (Beneš et al. 2002).

Third malacological zone (50 cm towards the surface):

The fauna of the moat changed basically. The number of mesophilous species decreased drastically (**Figs. 1., 2.**). Thermophilous Central and South-Eastern European taxa and open vegetation dominated in this section of the profile (*Granaria frumentum*; *Zebrina detrita*; *Vallonia enniensis*, *Xerolenta obvia*). At the same time, *Fruticicola fruticum* species appeared as well that indicate a milder climate and wet climatic conditions. So, it can be assumed that the near-surface part of the moat, the upper 40–50 cm, filled up during the 18th century, or was filled up at the beginning of the 18^{th} century (Gyenizse & Bognár 2014).

So, the changes in the ratio of certain taxa and palaeoecological groups had been influenced by the alterations of mesoclimate and microclimate and active human activity.

At the same time, we should note that snail species, due to their size and living space, reflect their microenvironment, and the dominance change of hygrophilous, mesophilous and xerophilous species may indicate not only mesoclimatic change but the filling up of the moat and the periodic and cyclic drying up of the continuously wet moat (**Figs. 1., 2.**). Thus, in addition to climate change, the filling up of the moat may have had a strong impact on the mollusk fauna, which is extremely sensitive to the microenvironment. It is unambiguous that at the beginning of the filling up of the moat cold-resistant and hygrophilous species dominated the moat, while at the end of the filling up of the moat, the number of these species reduced and Central European and South-south-eastern European (Pontian) thermophilous, xerophilous elements, including shade-loving taxa, became dominant.

The environmental change during the last stage of the filling up of the moat was indicated not only by the change in the composition of the fauna but also by the drastic decrease in the number of individuals. As a result, the upper 100 cm of the profile was especially dry, while the upper 50 cm of the profile was characterized by a single filling up (or it was filled up by people) and an unfavourable environment for the mollusk fauna and diversity. In these levels the number of individuals decreased and xerophilous species reflecting anthropogenic environment spread (**Figs. 1., 2.**). Based on this (Douafer & Soltani 2014), the debris material of the memorial complex could be used to fill the moat up, and the site was utilized as pasture and arable land and for horticulture (Georgiev & Georgiev 2002).

Summary

Based on the malacological material of more than 5700 individuals of 20 species, we were able to distinguish three different malacological zones in the moat of the memorial tomb at Szigetvár (**Figs. 1., 2.**). In the bedrock of the 250 cm deep moat, a wet phase could be identified, and from 140 cm towards the surface the sediment of the moat dried up gradually – based on the composition of the mollusk fauna. As a result, two different levels of infilling were separated, and two diverse environments were reconstructed at the level of the 17^{th} century of moat.

The first horizon may have evolved during the active period of the moat; based on the written sources (Hancz 2014; Kitanics 2014; Gyenizse & Bognár 2014; Fodor 2020) and radiocarbon data, the archaeological findings and Osman and Habsburg (Gulyás et al. 2018, 2022) coins it is probable that before 1664 (between 250 and 140 cm).

During the first stage of the development, the moat may have been deeper and had a double function: a drainage and protection function. In the wet and humid microenvironment, shrubs and weeds could cover the surface of the moat. In the second part of the 17^{th} century (maybe after the winter campaign in 1664), the filling up of the moat became faster (second malacological horizon), and gradually a dry, open vegetation covered shallow sedimentary basin developed with herbaceous plants. By this time, the moat had lost its drainage function and probably its protective role as well.

In the third malacological horizon, the depression was filled up with soil and the ruins of the memorial tomb. The demolition of the memorial place may have taken place after the successful siege of Szigetvár, after 1689/1692, at the end of the 17th century and the beginning of the 18th century, when the new land use and estate system was established (Gyenizse & Bognár 2014). Based on the significant amount of cold tolerant, Eurosiberian fauna elements a cold climate with significant precipitation characterized the 17th century, until 1664 (or maybe until 1670), which correlates well with other European and North-Asian climate reconstructions (Helama et al. 2004; Dieppois et al. 2013; Jakab et al. 2021; Kempf 2022). However, it is also unambiguous that the local microclimate had changed already during the period of the filling up of the moat, and mesophilous, later thermophilous species dominated the section. So, a milder climate phase could be developed in the vicinity of the memorial tomb in the second part of the 17th century (**Figs. 1., 2.**). This was especially evident after 1689/1692 when Central and South-eastern European drought-tolerant, thermophilous species dominated the malacological material of the profile of the moat. It is probable that human activity and the filling up of the moat also had an impact on the composition of the malacofauna, but the local microclimate and vegetation cover may have been the determining factors. Based on these, a cool and wet climate developed in the first two-thirds of the 17th century, while at the end of the 17th century, a milder and drier climate emerged.

At the same time, the filling up of the moat in the 17th century shows that the cool and wet phase that was previously reconstructed both regionally (Pinke et al. 2016, 2017) and globally (Lamb 1972; Grove 1988), had different effects in areas with diverse geomorphological conditions. Thus, based on our data, favourable agricultural production conditions developed on the south-facing slopes during the Little Ice Age (Lamb 1972; Grove 1988).

Our data indicates that we need to treat differently the climate change and its effects on agriculture in the Carpathian Basin, and should not set out from the North-Atlantic negative effects (Lamb 1972; Groove 1988). Signs of this have already appeared in the latest economic history studies for specific crop yields (Rácz 2020). The mosaic environmental conditions of the Carpathian Basin, reconstructed based on previous malacological studies (Sümegi 1995, 2005), compensated for the unfavourable climatic conditions of the Little Ice Age.

Contribution of authors

Sümegi Pál Writing – Original draft.

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References

ALEXANDROWICZ, W.P. (2004): Molluscan assemblages of Late Glacial and Holocene calcareous tufas in Southern Poland. *Folia Quaternaria* **75** 1–309.

BENEŠ, J., KAŠTOVSKÝ, J., KOČÁROVÁ, R., KOČÁR, P., KUBEČKOVÁ, K., POKORNÝ, P. & STAREC, P. (2002): Archaeobotany of the Old Prague Town defence system, Czech Republic: archaeology, macroremains, pollen, and diatoms. *Vegetation History and Archaeobotany* **11/1** 107–120. https://doi.org/10.1007/s003340200012

BOYCOTT, A.E. (1934): The habitats of land Mollusca in Britain. *The Journal of Ecology* **22** 1–38.

DIEPPOIS, B., DURAND, A., FOURNIER, M. & MASSEI, N. (2013): Links between multidecadal and interdecadal climatic oscillations in the North Atlantic and regional climate variability of northern France and England since the 17th century. *Journal of Geophysical Research: Atmospheres* **118/10** 4359–4372. https://doi.org/10.1002/jgrd.50392

DONG, Y., WU, N., JIANG, W., LI, F. & LU, H. (2020): Cascading response of flora and terrestrial mollusks to last deglacial warming. *Global Ecology and Conservation* **24** e01360, 1–9. https://doi.org/10.1016/j.gecco.2020.e01360

DOUAFER, L. & SOLTANI, N. (2014): Inventory of land snails in some sites in the Northeast Algeria: Correlation with soil characteristics. *Advances in Environmental Biology* **8/1** 236–243.

EVANS, J.G. (1972): *Land snails in archaeology*. Seminar Press, London. pp. 448.

FODOR, P. (2020): Turbék, Szulejman Szultán szigetvári Türbevárosa a 16–17. századi oszmán-török forrásokban. MTA Bölcsészettudományi Kutatóközpont, Budapest, pp. 176.

GEORGIEV, D. & GEORGIEV, B. (2002): Terrestrial gastropods as intermediate hosts of protostrongylid nematodes in pastures for sheep and goats in the region of Stara Zagora, Bulgaria. *Acta Zoologica Bulgarica* **54/3** 47–54.

GROVE, J.M. (1988): *The little ice age*. Routledge, London. pp. 498.

GULYÁS, S., BALOGH, CS., MARCSIK, A. & SÜMEGI, P. (2018): Simple calibration versus Bayesian modelling of archeostatigraphically controlled ^{14}C ages in an Early Avar Age cemetery from SE Hungary: results, advantages, pitfalls. *Radiocarbon* **60** 1335–1346. https://doi.org/10.1017/RDC.2018.116

GULYÁS, S., TORMA, A., PAP, N., FODOR, P., KITANICS, M., GYENIZSE, P., MOLNÁR, M. & SÜMEGI, P. (2022): Tackling erosion-accumulation events in a moat sequence from a unique Ottoman memorial place (Szigetvár, SW Hungary) using ^{14}C and geoarcheological data. *Archaeological and Anthropological Sciences* **14/1** 1–12. https://doi.org/10.1007/s12520-021-01479-x

GYENIZSE, P. & BOGNÁR, Z. (2014): Szigetvár és környéke 16–17. századi tájrekonstrukciója kartográfiai és geoinformatikai módszerekkel. In: PAP, N. ed., *Szülejmán szultán emlékezete Szigetváron/Kanuni Sultan Süleyman'ın Sigetvar'daki Hatırası. Mediterrán és Balkán Fórum* **8 (különszám)** Pécsi Tudományegyetem, Kelet-Mediterrán és Balkán Tanulmányok Központja, Pécs, 73–90.

HANCZ, E. (2014): Nagy Szülejmán Szultán Szigetvár környéki sátorhelye, halála és síremléke az oszmán írott forrásokban/Osmanlı Kaynaklarına Göre Kanuni Sultan Süleyman'ın Sigetvar'daki Otağ Yeri, Ölümü ve Türbesi. In: PAP, N. ed., *Szülejmán szultán emlékezete Szigetváron/Kanuni Sultan Süleyman'ın Sigetvar'daki Hatırası. Mediterrán és Balkán Fórum* **8 (különszám)** Pécsi Tudományegyetem, Kelet-Mediterrán és Balkán Tanulmányok Központja, Pécs, 55–71.

HELAMA, S., LINDHOLM, M., TIMONEN, M. & ERONEN, M. (2004): Detection of climate signal in dendrochronological data analysis: a comparison of tree-ring standardization methods. *Theoretical and Applied Climatology* **79/3** 239–254. https://doi.org/10.1007/s00704-004-0077-0

HORSÁK, M., JUŘIČKOVA, L. & PICKA, J. (2013): *Mollusc of the Czech and Slovak Republics*. Kabarek, Zlin. pp. 264.

JAKAB, G., PÁL, I., SILYE, L., SÜMEGI, P., TÓTH, A., SÜMEGI, B., FRINK, J.P., MAGYARI, E.K., KERN, Z. & BENKŐ, E. (2021): Social Context of Late Medieval and Early Modern Deforestation Periods in the Apuseni Mountains (Romania) based on an Integrated Evaluation of Historical and Paleobotanical Records, *Environmental Archaeology*, **28(5)** 345-366. https://doi.org/10.1080/14614103.2021.1942744

KEMPF, M. (2022): Documentary Evidence of 17th Century Landcover and Climate Change in Northern China and Mongolia Compared to Modern Spectral Greening Trends. *Land* **11/1** 100. https://doi.org/10.3390/land11010100

KERNEY, M.P., CAMERON, R.A.D. & JUNGBLUTH, J.H. (1983): Die Landschnecken Nord- and Mitteleuropas. Parey, Berlin. pp. 384.

KITANICS, M. (2014): Szigetvár–Turbék: A szultán temetkezési helye a 17–18. századi magyar, német és latin források tükrében/Sigetvar–Turbék: 17.–18. Yüzyıllara Ait Macarca, Almanca ve Latince Kaynaklar Temelinde Kanuni Sultan Süleyman'ın Mezarının Oluşturulduğu Bölge. In: PAP, N. ed., *Szülejmán szultán emlékezete Szigetváron/Kanuni Sultan Süleyman'ın Sigetvar'daki Hatırası. Mediterrán és Balkán Fórum* **8 (különszám)** Pécsi Tudományegyetem, Kelet-Mediterrán és Balkán Tanulmányok Központja, Pécs, 91–109.

KROLOPP, E. (1973): Quaternary malacology in Hungary. *Földrajzi Közlemények* **21** 161–171.

KROLOPP, E. (1983): Biostratigraphic division of Hungarian Pleistocene Formations according to their Mollusc fauna. *Acta Geologica Hungarica* **26** 69–82.

KROLOPP, E. & SÜMEGI, P. (1995): Palaeoecological reconstruction of the Late Pleistocene, Based on Loess Malacofauna in Hungary. *GeoJournal* **26** 213–222. https://doi.org/10.1007/BF00813173

LAMB, H.H. (1972): *Climate: present, past and future*. Methuen, London. pp. 648.

LIMONDIN, N. & ROUSSEAU, D.D. (1991): Holocene climate as reflected by a malacological sequence at Verrières, France. *Boreas* **20/3** 207–229. https://doi.org/10.1111/j.1502-3885.1991.tb00152.x

LOŽEK, V. (1964): Quartärmollusken der Tschechoslowakei. *Rozpravy Ústredniho ústavu geologického* **31** 1–374.

NYILAS I. & SÜMEGI P. (1987): Adatok az imókői (É-Magyarország, Bükk-hg.) növénytársulások Mollusca faunájához. *Malakológiai Tájékoztató* **7** 43–47.

PAP, N., FODOR, P., KITANICS, M., GYENIZSE, P. & HANCZ, E. (2023): Introduction. Historical and archaeological data for integrated multiproxy environmental historical analyses on the moat profile of the türbe complex of Sultan Suleiman I at Szigetvár – Turbék vineyard hill site (Hungary). *Archeometriai Műhely* **XX/3** 195–200. https://doi.org/10.55023/issn.1786-271X.2023-016

PINKE, Z., FERENCZI, L., GÁBRIS, G. & NAGY, B. (2016): Settlement patterns as indicators of water level rising? Case study on the wetlands of the Great Hungarian Plain. *Quaternary International* **415** 204–215. https://doi.org/10.1016/j.quaint.2015.11.032

PINKE, Z., FERENCZI, L., ROMHÁNYI, B.F., GYULAI, F., LASZLOVSZKY, J., MRAVCSIK, Z., PÓSA, P. & GÁBRIS, G. (2017): Zonal assessment of environmental driven settlement abandonment in the Trans-Tisza region (Central Europe) during the early phase of the Little Ice

Age. *Quaternary Science Reviews* **157** 98–113. https://doi.org/10.1016/j.quascirev.2016.12.010

POTOCZAK, K. & POKRYSZKO, B.M. (2020): Terrestrial malacocoenoses of the monastery park in Henryków near Ząbkowice Śląskie (SW. Poland). *Folia Malacologica* **16/2** 75–87. https://doi.org/10.12657/folmal.016.012

RÁCZ, L. (2020): Carpathian basin–the winner of the little ice age climate changes: long-term time-series analysis of grain, grape and hay harvests between 1500 and 1850. *Ekonomska i ekohistorija: časopis za gospodarsku povijest i povijest okoliša* **16/1** 81–96.

ROUSSEAU, D.D. (1987): New approach to the Pleistocene Land Snails. In: PÉCSI, M. & FRENCH, H.M. eds., *Loess and Periglacial Phenomena.* Akadémiai Kiadó, Budapest, 151–163.

ROUSSEAU, D.D. (1990): Statistical analyses of loess molluscs for paleoecological reconstructions. *Quaternary International* **7** 81–89.

ROUSSEAU, D.D. (1991): Climatic transfer function from Quaternary molluscs in European loess deposits. *Quaternary Research* **36** 195–209.

ROUSSEAU, D.D. (2001): Loess biostratigraphy: new advances and approaches in mollusk studies. *Earth-Science Reviews* **54** 157–171. https://doi.org/10.1016/S0012-8252(01)00046-0

SÓLYMOS, P., GAUDENYI, T., DELI, T. & NAGY, A. (2004): Data on the land snail fauna of the Fruska Gora Mountain (Serbia) with some biogeographical remarks. *Malakológiai Tájékoztató* **22** 149–153.

SOÓS, L. (1943): *A Kárpát-medence Mollusca-faunája.* Akadémiai Kiadó, Budapest. pp. 478.

SPARKS, B.W. (1961): The ecological interpretation of Quaternary non-marine Mollusca. *Proceedings of the Linnean Society of London* **172** 71–80.

SÜMEGI, P. (1995): Az utolsó 30 000 év változásainak rekonstrukciója őslénytani adatok alapján a Kárpát-medence centrális részén. In: TAR, K. (ed.): *Berényi Dénes professzor születésének 95. évfordulója tiszteletére rendezett tudományos emlékülés előadásai.* MTA Debreceni Területi Bizottsága, Meteorológiai Munkabizottság és KLTE Meteorológiai Tanszék Kiadvány, 244–258.

SÜMEGI, P. (2004): The results of paleo-environmental reconstruction and comparative geoarcheological analysis for the examined area. In SÜMEGI, P. & GULYÁS, S. eds., *The geohistory of Bátorliget Marshland*. Archaeolingua Press, Budapest, 301–348.

SÜMEGI, P. (2005): *Loess and Upper Paleolithic environment in Hungary*. AureaKiadó, Nagykovácsi. pp. 312.

SÜMEGI, B.P. (2020): A szigetvári Szulejmán türbe palánk északi árkának feltárása és üledékföldtani elemzése. In: TÖRŐCSIK, T., GULYÁS, S., MOLNÁR, D. & NÁFRÁDI, K. eds., *Környezettörténet. Tanulmányok Sümegi Pál professzor 60 éves születésnapi köszöntésére.* Geolitera, Szeged, 449–456.

SÜMEGI, P. & KROLOPP, E. (2002): Quarter-malacological analyses for modeling of the Upper Weichselian palaeoenvironmental changes in the Carpathian Basin. *Quaternary International* **91** 53–63. https://doi.org/10.1016/S1040-6182(01)00102-1

SÜMEGI, P., MOLNÁR, M., JAKAB, G., PERSAITS, G., MAJKUT, P., PÁLL, D.G., GULYÁS, S., JULL, A.J.T. & TÖRŐCSIK, T. (2011): Radiocarbon-dated paleoenvironmental changes on a lake and peat sediment sequence from the central part of the Great Hungarian Plains (Central Europe) during the last 25.000 years. *Radiocarbon* **52** 85–97. https://doi.org/10.1017/S0033822200034378

SÜMEGI, P., MAGYARI, E., DÁNIEL, P., MOLNÁR, M. & TÖRŐCSIK, T. (2013): 28,000-year record of environmental change in SE Hungary: terrestrial response to Dansgaard-Oeshger cycles and Heinrich-events. *Quaternary International* **278** 34–50. https://doi.org/10.1016/j.quaint.2012.07.032

SÜMEGI, P., MOLNÁR, D., NÁFRÁDI, K., MAKÓ, L., CSEH, P., TÖRŐCSIK, T., MOLNÁR, M. & ZHOU, L. (2022): Vegetation and land snail-based reconstruction of the palaeocological changes in the forest steppe eco-region of the Carpathian Basin during last glacial warming. *Global Ecology and Conservation* **33** e01976. pp. 1–28. https://doi.org/10.1016/j.gecco.2021.e01976

TORMA, A., NÁFRÁDI, K., TÜRŐCSIK, T. & SÜMEGI, P. (2023): Integrated archaeobotanical evidences for the vegetation reconstruction around the tomb of Sultan Suleiman I at Szigetvár (Southwestern Hungary). *Archeometriai Műhely* **XX/3** 201–226. https://doi.org/10.55023/issn.1786-271X.2023-017

TUGYA, B. (2023): Archeozoological data of the moat system of Sultan Suleiman's türbe. *Archeometriai Műhely* **XX/3** 227–242. https://doi.org/10.55023/issn.1786-271X.2023-018

WELTER-SCHULTES, F. (2012): *European non-marine mollusc, a guide for species identification.* Planet Poster Edition, Göttingen. pp. 478.

ZAR, J.H. (1990): *Biostatistical Analysis*. Englewood Cliffs, Prentice-Hall. pp. 674.