Climatic Changes in the Carpathian Basin during the Middle Ages. The State of Research

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The aim of the paper is to present a summary of the current scholarship on the climate of the Carpathian Basin in the Middle Ages. It draws on the results of three substantially differing branches of science: natural sciences, archaeology and history are all taken into consideration. Based on the most important results of the recent decades different climatic periods can be identified in the scholarship. The paper attempts to summarize the different view of these major climatic periods. Based on present scholarship the milder climate of the Roman Period was followed by a cooler period from the 4th century, attested by both historical and natural-historical sources, and apparently climate had also become drier. The cool period of the Great Migrations concluded in the Carpathian Basin between the end of the 7th and the turn of the 8th-9th centuries. The winters in the first half of the 9th century were probably milder. In the warmer medieval period (called Medieval Climatic Anomaly in recent scholarship) winters had clearly become milder and summers warmer, while the climate was probably still dry. The first cooling signs of the "Little Ice Age" had already become apparent in the 13th century, but the cold and rainy character of the climate could only become dominant in the Carpathian Basin in the early 14th century, which then, albeit with great anomalies, endured until the second half of the 19th century.

Climatic Changes in the Carpathian Basin during the Middle Ages: The State of Research

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Climate historical research in Western Europe has a long tradition. The first weather compilations are gathered in the 18th century, although research based on critical assessment of sources does not have such a long past; detailed studies of regional climate history and the social historical aspects of weather first appeared in the 1960s.[1] Data gathered from historical sources now permit medium- and

long-term climate reconstructions for the past millennium (and even longer in some places).[2] Nothing similar is possible for the medieval climate of the Carpathian Basin. Written sources only appear in substantial quantity in the late medieval period, and even then do not provide enough data for continuous climatic reconstruction. Whereas European reconstructions usually use chronicles and annals, research on the Kingdom of Hungary, with a few exceptions, can only draw on narrative sources with from a climatological point of view inaccurate and more importantly scarce data. Written sources on the Middle Ages are mainly important for investigating extreme weather events,[3] although they are also used to research changes in lakes, water courses and their surroundings. The weather-related events covered by written sources are mostly of hydrometeorological nature: floods, waterlogged land and droughts appear in charters and annals, and may be used to reconstruct the water levels in rivers or standing waters, and to indirectly deduce precipitation levels in the catchment area.[4] Research into historic floods has greater potential

[*] By the will of the authors, in this article the names of the authors are not in alphabetical order.

[1] We would like to express our special thanks Ionel Popa, Zoltán Kern and András Grynaeus for sharing their results with us. We are grateful for the Rachel Carson Center at the *Ludwig-Maximilians*-Universität in Munich and for the Eötvös Loránd University of Sciences for their financial support (TÁMOP-4.2.1.B-09/1/KMR). Our work was supported by the Hungarian National Scientific Fund (OTKA 67583 and 69138) and has been carried out in 2011. We could include only minor bibliographical additions to note the major results since then.

For example: Ch. Pfister, *Klimageschichte der Schweiz 1525-1860. Das Klima der Schweiz und seine Bedeutung in der Geschichte von Bevölkerung und Landwirtschaft*, P. Haupt, Bern 1984 and Id., *Wetternachhersage. 500 Jahre Klimavariationen und Naturkatastrophen*, Haupt, Wien-Stuttgart-Bern 1999.

[2] R. Glaser, *Klimageschichte Mitteleuropas. 1000 Jahre Wetter, Klima, Katastrophen*, Primus, Darmstadt 2001. M.V. Shabalova, A.F.V. van Engelen, "Evaluation of a Reconstruction of Winter and Summer Temperatures in the Low Countries, AD 764-1998", in *Climatic Change*, 58, 1-2, 2003, pp. 219-242.

[3] For the most recent overview of the role of written evidence in historical climatology, see A. Kiss, "Historical Climatology in Hungary: Role of Documentary Evidence in the Study of Past Climates and Hydrometeorological Extremes", in *Időjárás*, 113, 4, 2009, pp. 315-339.

[4] Ibid., pp. 323-326.

for the Early Modern Times,[5] but it is possible to determine to some extent the nature and frequency of floods of major rivers, especially the Danube and the Tisza, in the Middle Ages. In addition to rivers, studies of some standing water yield valuable results for determining weather conditions in certain periods. The shallowness of lakes in the Carpathian Basin (especially of Lake Fertő) means that even small water level changes caused drying out or inundation of extensive areas. A study of written sources, mainly charters, relating to conditions of lakes and their surroundings allows us to determine certain dry or wet periods.[6] Such research, however, runs into the constant methodological problem of the significance of the human factor. Nonetheless, study of areas with a dense network of water courses, has considerable, as-yet untapped potential in the study of medieval and early modern environmental (and climatic) conditions. Despite the relatively wide scope of the written sources from the 15th century it is not possible to show short or long-term climatic tendencies in the Middle Ages; such becomes possible only in the 16th century with the increasing number of written sources and the especially with

[5] For the late medieval period: A. Kiss, J. Laszlovszky, "14th-16th-Century Danube Floods and Long-Term Water-Level Changes in Archaeological and Sedimentary Evidence in the Western and Central Carpathian Basin: an Overview with Documentary Comparison", in *Journal of Environmental Geography*, 6, 3-4, 2013, pp. 1-11. For the early modern times: A. Vadas, "Floods in the Hungarian Kingdom as Reflected in Private Letters (1541-1650) – Sources and Possibilities", in *Anuarul Scolii Doctorale. Istorie. Civilizație. Cultură V*, T. Nicoara (ed.), Accent, Cluj-Napoca 2011, pp. 77-101. For case studies: A. Vadas "The 'Waters Leave their Beds Frequently" – A Western-Hungarian Town and the Flooding of the Rába/Raab River in the Seventeenth Century (1600-1659)", in *Water History*, 5, 3, 2013, pp. 267-286. A. Kiss, "'*Suburbia autem maxima in parte videntur esse deleta*' – Danube Icefloods and the Pitfalls of Urban Planning: Pest and its Suburbs in 1768-1799", in *From Villages to Cyberspace*, Cs. Kovács (ed.), Szeged University Press, Szeged 2007, pp. 271-282.

[6] A. Kiss, "Changing Environmental Conditions and the Water Level of Lake Fertő (Neusiedlersee) before the Drainage Works (13th-18th centuries)", in *Annual of Medieval Studies at CEU 1997-1998*, pp. 241-248. A. Kiss Andrea, *Historical Study of the Changing Landscape of Fertő during the Later Middle Ages (13th c.-15th c.)*, MA Thesis, CEU, Budapest 1998. A. Kiss, F. Piti Ferenc, "A fertői fok", in *Soproni szemle*, 59, 2, 2005, pp. 164-184.

the appearance of new types of sources (e.g. private correspondence, diaries, town books, account books).[7]

Scientific research can also be very fruitful, especially for periods for which written sources do not exist or are of poor quality. Most of these are of importance in determining long-term climatic trends, although some also show up some extreme weather events. Dendroclimatological research, despite its promise, at present plays a very modest role in the research of the medieval climate of the Carpathian Basin. The only climate reconstruction from the territory of the medieval Hungarian Kingdom covering longer period (summer temperature reconstruction based on the Swiss Pines of the Călimani Mountains, Eastern Transylvania, Romania) gives an account of climatic conditions on an area on the forest fringes of the Carpathians.[8] There is an oak chronology (going back to the 1370s) forming a record of the growth of trees from the centre of the Carpathian Basin, but its raw data were not produced specifically for climatological research but rather for dating and thus not feasible for climate reconstruction[9] The other scientific techniques which have been applied in the Carpathian Basin are mainly suitable for determining trends over periods of decades, in some cases only centuries. The most promising is an investigation of cave ice cores in the Bihor Mountains (Western Transylvania, Romania). This has made an important contribution to the determination of average

[7] On Hungary: L. Rácz, *Climate History of Hungary: Present, Past and Future*, Center for Regional Studies, Pécs 1999. For the most recent Central-European reconstruction: P. Dobrovolný, A. Moberg, R. Brázdil, Ch. Pfister, R. Glaser, R. Wilson, A. van Engelen, D. Limanówka, A. Kiss, M. Halíčková, J. Macková, D. Riemann, J. Lüterbacher, R. Böhm, "Monthly and Seasonal Temperature Reconstructions for Central Europe Derived from Documentary Evidence and Instrumental Records since AD 1500", in *Climatic Change*, 101, 1-2, 2010, pp. 69-107.

[8] I. Popa, Z. Kern, "Long-Term Summer Temperature Reconstruction Inferred from Tree-ring Records from the Eastern Carpathians", in *Climate Dynamics*, 32, 7-8, 2009, pp. 1107-1117.

[9] A. Grynaeus, "Dendroclimatologiam facere, necesse est! Dendrokronológia és/vagy dendroklimatológia?", in *Környezettörténet 2. Környezeti események a honfoglalástól napjainkig történeti és természettudományi források tükrében*, M. Kázmér (ed.), Hantken Kiadó, Budapest 2011, pp. 185-193.

winter temperature fluctuations in the region over the last millennia.[10] Several similar ice core studies are in progress, holding out the prospect of comparative analyses in the near future.

Palaeobotanical studies permits the determination of rapid environmental and climatic changes, and the relatively large number of such projects allows some general conclusions to be drawn.[11] Sporadic malacofauna studies and other palaeobiological findings in some cases refine the picture of long-term climatic processes. Borehole temperature and stalagmite oxygen isotope distribution studies also reach back to the medieval period, although they are beset by inherent uncertainties in methodology and dating.[12] The combination of the different scientific means makes the studies more reliable and in some cases may provide basis for quantitative climate reconstructions. In this respect a complex environmental (pollen, macrofossil and sediment analyses) reconstruction based on the study of layers of Lake Nádas at Nagybárkány (village in the central part of Nógrád county, in the Cserhát mountain range) has to be stressed as it provides data both for the average temperature of the coldest and the warmest month for the last two millennia.[13]

These are the two main sources, but in the recent decades with the appearance of environmental archaeology this field of study also

[10] Z. Kern, *Éghajlati és környezeti változások rekonstrukciója faévgyűrűk és barlangi jég vizsgálata alapján* (Climate and Environmental Changes Reconstructed From Tree Rings and Cave Ice), PhD dissertation, ELTE TTK, Budapest 2010, p. 53-80. Z. Kern, I. Fórizs, M. Kázmér, B. Nagy, A. Gál, Zs. Szántó, L. Palcsu, M. Molnár, "Late Holocene Environmental Changes Recorded at Ghețarul de la Focul Viu, Bihor Mts, Romania", in *Theoretical and Applied Karstology*, 17, 1, 2004, pp. 51-60.

[11] P. Sümegi, G. Jakab, P. Majkut, T. Törcsik, Cs. Zatykó, "Middle Age Palaeoecological and Palaeoclimatological Reconstruction in the Carpathian Basin", in *Időjárás*, 113, 4, 2009, pp. 265-298. Cs. Zatykó, I. Juhász, P. Sümegi (eds), *Environmental Archaeology in Transdanubia* (Varia Archaeologica Hungarica 20), Archaeolingua, Budapest 2007.

[12] Sümegi et al., *Middle Age Palaeoecological* cit., pp. 256-258. L. Bodri, P. Dövényi, F. Horváth, "Két évezred éghajlatváltozásai Magyarországon fúrólyukhőmérsékletek alapján", in *Környezettörténet. Az utóbbi 500 év környezeti eseményei történeti és természettudományos források tükrében*, M. Kázmér (ed.), Hantken Kiadó, Budapest 2009, pp. 421-436.

[13] Sümegi et al., *Middle Age Palaeoecological* cit., pp. 265-298.

has an input to the understanding of medieval environmental (and climatic) changes. It is particularly important in determining fluctuations in the levels of standing waters and rivers, dating floods and other hydrometeorological events, and – through research into settlement patterns – the understanding of environmental changes in small areas.[14] At present, however, there are few excavations where the study of the physical environment and the explanation of links between settlement location, settlement structure and environmental change have received much attention. Nonetheless, the part played by environmental archaeology in environmental and climate history research can be expected to increase in future.

Different sources permit different geographical and time scales for the discussion of climate history in the Carpathian Basin: firstly at the level of weather events, for which written sources are most prominent, then medium-range trends (temperature and possibly precipitation fluctuations over decades or longer periods), and finally long-term trends (fluctuations over a century or several centuries). According to the scientific literature in Western Europe and the partly in the Mediterranean during the Late Antiquity and Middle Ages, four major climatic-environmental changes set the environmental constraints on the historical ecosystems of traditional societies in much of Europe: after the Roman Climate Optimum the cooling of the Migration Period from the turn of the 4th-5th centuries AD up to the mid-9th century; the Medieval Climate Anomaly (MCA)

[14] Amongst others see: E. Gál, I. Juhász, P. Sümegi (eds), *Environmental Archaeology in North-Eastern Hungary* (Varia Archaeologica Hungarica 19), Archaeolingua, Budapest 2005. Cs. Zatykó, I. Juhász, P. Sümegi (eds), *Environmental Archaeology in Transdanubia* (Varia Archaeologica Hungarica 19), Archaeolingua, Budapest 2007. P. Sümegi, S. Gulyás (eds), *The Geohistory of Bátorliget Marshland: An Example for the Reconstruction of Late Quaternary Environmental Changes and Human Impact from the Northeastern Part of the Carpathian Basin*, Archaeolingua, Budapest 2004, M. Bálint, *Az Árpád-kori településhálózat rekonstrukciója a Dorozsma-Majsai Homokhát területén* (Reconstruction of the Árpád Period Settlement Network in the Dorozsma-Majsa Region), PhD dissertation, ELTE BTK, Budapest 2006. A. Pálóczi Horváth, "L'archéologie de l'environnement Écologique et les recherches des villages désertés médiévaix en Hongrie", in *Ruralia I*, J. Fridrich (ed.), Institute of Archaeology, Prague 1996, pp. 262-268.

(previously referred to as Medieval Warm Epoch [MWE]) from the 9th to the mid-13th centuries, in another approach up to the early 14th century; and finally, one of the strongest periods of cooling of historical times, the Little Ice Age (LIA), from the 14th century (earlier thought to have been dominant from 1560s) to the end of the 19th. To complete the list, we should also mention the recent period of warming which started in the final decades of the 19th century and has demonstrably been affected by global industrial activity.[15]

This study aims to discuss the environmental conditions from the Late Roman Period all throughout the Middle Ages in the Carpathian Basin. It must always be borne in mind, however, that the model proposed above is developed based on results from Western European areas. Since the climatic characteristics of each era can vary considerably from place to place, the climatic conditions of the East European Plain and Central Europe cannot be exactly matched to the periods observed in Western Europe. Therefore the study is to examine the validity of the climatic periodization developed for Western Europe in the Carpathian Basin based on the available historical, scientific and archaeological results of the last roughly two decades.

The Roman Climate Optimum

The first clearly-perceptible climatic period in the Carpathian Basin was the "Roman Climate Optimum" of Late Antiquity. Not only scientific but archaeological and historical data also suggests a well-marked warm and dry period. Dendroclimatological studies by András Grynaeus suggest that the climate in Pannonia was mild, in places sub-Mediterranean during these centuries. The tree-ring structure of Roman-era timber remains (Ménfőcsanak, NW-Hungary) are very dense, the average thickness of each oak ring being hardly more than 1 mm. Nowadays, the average oak tree ring thick-

[15] "For two recent overviews of the problem: R. Brázdil, Ch. Pfister, H. Wanner, H. von Storch, J. Luterbacher, "Historical Climatology in Europe: The State of the Art", in *Climatic Change*, 70, 3, 2005, pp. 363-430. W. Behringer, *Kulturgeschichte des Klimas Von der Eiszeit bis zur globalen Erwärmung*, C.H. Beck, München 2007, pp. 119-195.

ness in Transdanubia (W-Hungary) is 2-3 mms, and can be up to several times this in some places.[16] The dense tree rings show that the climate was unfavourable for oak trees, either cold or hot (the latter seeming more probable), but certainly dry. The tree-ring thicknesses of Roman-era oaks are similar to those of oaks now growing in Northern-Italy nowadays, warranting the conclusion that the climate was also similar. Ice-core studies by Zoltán Kern give an insight into the winter temperatures of the Roman Times. His climate reconstruction shows relatively mild winters in the eastern fringes of the Great Hungarian Plains up to the mid-3rd century, and then a steep drop in winter temperatures in the Late Antiquity.

The issue of Roman-era viniculture is a long-standing area of historical debate.[17] The argument centres around the question of whether the Romans introduced Mediterranean strains in the province. If the vines strains of the Apennine Peninsula were growing in the Carpathian Basin, then the climate in Pannonia must have been warmer and, in summer, drier than in the centuries of the Early Middle Ages.

Another pointer to sub-Mediterranean climate comes from finds of such plants as figs and peaches in Pannonia, which definitely fruited there but are not typical of the area in the modern era.[18]

[16] A. Grynaeus, "Új forráscsoport? A dendrokronológia eredményei: tanulmányok a történeti ökológia világából" (new set of data? The results of dendrochronology in Hungary), in *Táj és történelem: tanulmányok a történeti ökológia világából*, Á.R. Várkonyi (ed.), Osiris, Budapest 2000, p. 310.

[17] O. Dálnoki, Pannónia provincia római kori bor- és szőlőkultúrája (The Viticulture of Pannonia in the Roman Times), PhD dissertation, ELTE BTK, Budapest 2004. See most recently: Z. Havas, "Új adalékok a római kori szőlőműveléshez Aquincum környékén", in *Budapest régiségei*, 44, 2011, pp. 183-197.

[18] O. Dálnoki, "Collected or Cultivated? Exotic and Indigenous Fruit Remains from Celtic to Roman Times in Pest County Hungary", in *Plants and Culture: Seeds of the Cultural Heritage of Europe*, J.-P. Morel, A.M. Mercuri (eds), Centro Europeo per i Beni Culturali Ravello, Edipuglia, Bari 2009, pp. 145-151. Á. Patay, Sz.K. Póczy, "Gyümölcsmaradványok aquincumi múmiasírból", in *Magyar Mezőgazdasági Múzeum Közleményei*, 1964, pp. 135-146. F. Gyulai, *Archaeobotanika. A kultúrnövények története a Kárpát-medencében a régészeti-növénytani vizsgálatok alapján*, Jószöveg Műhely Kiadó, Budapest 2001, pp. 143-144. Most recently, see: F. Gyulai, *Archaeobotany in Hungary: Seed, Fruit, Food and Beverage Remains in the Carpathian Basin from the Neolithic to the Late Middle Ages*, Archaeolingua, Budapest 2010.

This may also explain the apparent "conservatism" of Roman villas, i.e. why the villas built in Pannonia had the same structure as those in Italy and Hispania, lands which are now much warmer. These "peristyle villas" gave way to enclosed buildings towards the end of the Roman Era, possibly prompted by the gradual change to colder weather. The villas in the early period had no means of general heating; later villas had hypocaust systems.[19]

The water level fluctuation of Lake Balaton during the Roman period and afterwards is a long lasting debate in Hungarian historical, scientific and archaeological literature.[20] The reconstruction of László Bendefy, who carried out the most accepted reconstruction amongst scientists puts the water level about the 104.5 m above sea level which is close to today's average water level. In the reconstruction he and his colleague V. Nagy emphasizes the predominant role of human activity on the water level changes already in the Roman Times. He supposes the existence of a sluice built near Siófok during the rule of Galerius (305-311) as an explanation for the stable Roman-period water level in the lake, but how the sluice operated, and whether it even existed, are hotly debated issues. Furthermore the existence of the sluice does not reinforce the low water level of the lake in the Late Roman Period.[21]

The other rather widespread Balaton-reconstruction is carried out by Sági and Füzes. They, unlike Bendefy attribute the fluctuation of the water level to the changes of the natural climatic conditions. Their reconstruction – because of its more careful source-criticism – is more accepted amongst historians and archaeologists.[22] They also suppose a

[19] Grynaeus, *Új forráscsoport* cit., p. 314.

[20] For an overview of the problem, see: A. Kiss: *Floods and Long-Term Water-Level Changes in Late Medieval Hungary*, PhD dissertation, CEU, Budapest-Szeged 2011, pp. 65-70.

[21] L. Bendefy, I. László, V. Nagy, *A Balaton évszázados partvonalváltozásai*, Műszaki Kiadó, Budapest 1969. K. Sági, M. Füzes, "Újabb adatok a Balaton 1863 előtti vízállás-tendenciáinak kérdéséhez", in *Somogyi Múzeumok Közleményei*, 1, 1973, pp. 247-261.

[22] Most recently scientists also seem to use this reconstruction rather than the one by Bendefy, László, Nagy, *A Balaton évszázados* cit. See e.g., Z. Kern, "Balaton-felvidéki tölgyek évgyűrűszélességének kapcsolata a Balaton vízszintingadozásával", in *Környezettörténet. Az utóbbi 500 év környezeti eseményei történeti*

relatively low water level in the Roman Period based on the settlement network of the period. In the later period the two reconstructions significantly differ which gave space to the long lasting scientific debate.

Significantly, Lake Fertő, the other major lake in Transdanubia, has also been found to have been very low during the time of the Roman Empire.[23] Remains of some Roman graves and buildings are now submerged under the water of Lake Fertő, whose level today is, significantly, not the product of regulation. Further evidence for the climate having been dryer then than now is that most of the Roman *limes* forts now lie under the surface of the Danube (such as Contra Aquincum in Buda) or have long since been washed away.[24] The stone bridge on the Iron Gates of the Danube built by Emperor Trajan between 101 and 106 AD, and used for 170 years, also bears witness to a mild climate. A structure of this kind, resting on – and constricting – the river channel, especially on a stretch where the flow is so strong, could only have remained intact for so long if the Danube never, or very rarely, froze over.

The written records for this period are too scarce to draw any conclusion based on that. Sporadic data on the Roman times are known mostly from narratives presented military campaigns in Pannonia.

The cooling of the Migration Period

A period of cold and in places dry climate in the western part of Europe started in the late 4th century and lasted until the early or mid-9th century, i.e. during the Migration Period. For data on temperature at the time, we have to rely purely on scientific results. Zoltán Kern's previously noted research in Focul Viu Cave clearly indicates falling temperatures during the Migration Period. The survey lead by

és természettudományos források tükrében, M. Kázmér (ed.), Hantken Kiadó, Budapest 2009, pp. 303-312.

[23] Grynaeus, *Új forráscsoport* cit., p. 312.

[24] P. Zsidi, "Duna szerepe Aquincum topográfiájában", in *Budapest régiségei*, 41, 2007, pp. 57-83. L. Nagy, *A dunai árvizek és árterületek Budapest környékén az őskortól a magyar honfoglalás idejéig* [Manuscript], Budapesti Történeti Múzeum (Budapest Historical Museum), Régészeti Adattár H. ltsz. No. 206-79.

Pál Sümegi's in Nagybárkány also finds substantial cooling, in terms of the average temperature of the coldest month, although less stabilised than the cooling found by Zoltán Kern for the Bihor area.

An environmental archaeological reconstruction on a site next to the Danube in the Mezőföld (Middle-Hungary) reinforces the view that climate in the Carpathian Basin was relatively dry at this time. The Roman and medieval archaeological strata are separated by set of shifting sand up to two metres thick. The sand movement first appear after the abandonment of Roman land use in the 4th century, and severe wind erosion and sand deposits can be traced, with some breaks, until the 14th century. The shifting sands could have been caused by intensive land use, but much more probable is that the drying of the environment thinned out the vegetation. Similarly significant sand movement can be shown in the Danube-Tisza Interfluves area during the Avarian Period (6th-8th centuries AD) however the author in this case attribute the sand movement to overgrazing rather than climatic change.[25]

Unlike in the case of the Roman Period although with a lot of incertitude borne in mind one can draw interesting conclusions regarding the environmental and climatic conditions of the Migration period based on historical evidence. György Györffy and Bálint Zólyomi have proposed that the relatively dry climate was predominant in the Carpathian Basin until the mid-8th century, and probably was decisive in the demise of the Avar Empire in the Carpathian Basin.[26]

[25] Z. Horváth, Á. Dávid, L. O. Kovács, "A földtani és talajtani vizsgálatok alkalmazása régészeti ásatásokon a környezetváltozások nyomon követése céljából. Esettanulmány (M6 TO 18 számú ásatás: Paks, Cseresznyés)", in *Környezet-történet 2. Környezeti események a honfoglalástól napjainkig történeti és természet-tudományi források tükrében*, M. Kázmér (ed.), Hantken Kiadó, Budapest 2011, pp. 233-253. See also T. Kiss, D. Nyári, Gy. Sipos, "Homokmozgások vizsgálata a történelmi időkben Csengele területén", in *Táj, környezet és társadalom*, A. Kiss, G. Mezősi, Z. Sümegi (eds), SZTE Éghajlattani és Tájföldrajzi Tanszék - SZTE Természeti Földrajzi és Geoinformatikai Tanszék, Szeged 2006, pp. 373-383. Further researches were carried out by the same research group during the last decade: http://www.geo.u-szeged.hu/web/toerteneti-idok-homokmozgasainak-vizsgalata-nyirseg-duna-tisza-koez-belso-somogy (last accessed: 20/11/2012).

[26] Gy. Györffy, B. Zólyomi, "A Kárpát-medence és Etelköz képe egy évezred

The military class or “true Avars”, and the partially semi-nomad and partially settled Gepidas and Bulgarian Turks who settled on the Carpathian plains together with the Avars, would have felt the effects most severely, loss of livestock condemning them to starvation. This hypothesis would explain why, in 791, the Franks met serious resistance in only one of their three great campaigns on what are now Austria and Slovenia. The Inner Asian steppe zone is thought to have dried out in the mid-8th century, and that is almost certainly when – well before the Frankish wars – the Avars’ cattle started to decline, causing a flight to the surrounding forested hills, although the imperial administration still functioned and the landowning section of society remained in place. This is borne out by a piece of indirect information. A letter by “Cleric R.” to Bishop Dado of Verdun (c. 880-923), written in the years after 900, tells of the origins of a people hitherto unheard of, the *Hungri.* After some attempts at explanation using the Bible and classical literature, he proposes that the name of the people derives from the German word *Hunger*. The following story about hunger occurs to him: “I will tell what I have heard from the elders when the name of that accursed people was first spoken in our vicinity, whether it be a true story or a fable. At some time a terrible famine spread throughout Pannonia, Istria and Illyria, and the neighbouring peoples”.[27] The land to which these ancient names apply exactly corresponds to the territory of the collapsed Avar Empire, and so the story may be linked to the internal affairs of the Avars in the 8th-9th centuries. The writer of the letter

előtt”, in *Honfoglalás és régészet*, Gy. Györffy, L. Kovács (eds), Balassi Kiadó, Budapest 1994, pp. 13-37.

[27] “Referam, quid audierim a maioribus, cum primum execrandae huius gentis nomen apud nos auditum est, sive illud historia sive sit fabula. Fames inmanissima quondam omnem Pannoniam, Histriam quoque et Illiriam ac vicinas gentes invasit.” The original text of the letter is edited by A. Németh, “A Dado verduni püspökhöz írt levél”, in *Források a korai magyar történelem ismeretéhez* (Magyar Őstörténeti Könyvtár 16), A. Róna-Tas (ed.), Balassi Kiadó, Budapest 2001, pp. 113-161. The cotatoin, here: p. 116. On the problem of the name: *Hungri*, see: A. Németh, “A Dado-levélben szereplő eredettörténet jelentősége a Hungri népnévvel kapcsolatban”, in *Tanulmányok Ritoók Zsigmond hetvenedik születésnapja tiszteletére*, I. Hermann (ed.), Egyetemi Széchenyi Kör, Budapest 1999, pp. 105-126.

claims that the people who survived the famine acquired the name *Hungri*. The Slavic population no doubt had stouter defences against the drought, because their pigs could forage in the beech and oak forests in the foothills, where the clearings could also be ploughed to grow rye, and they were also skilled in beekeeping and fishing. This was probably why the early Slavic placenames in the Carpathian Basin are confined to forest and wetlands that could support such a way of life.[28] There were almost certainly environmental as well as political factors in the break-up of the Avar Empire.

The Medieval Climate Anomaly (MCA)

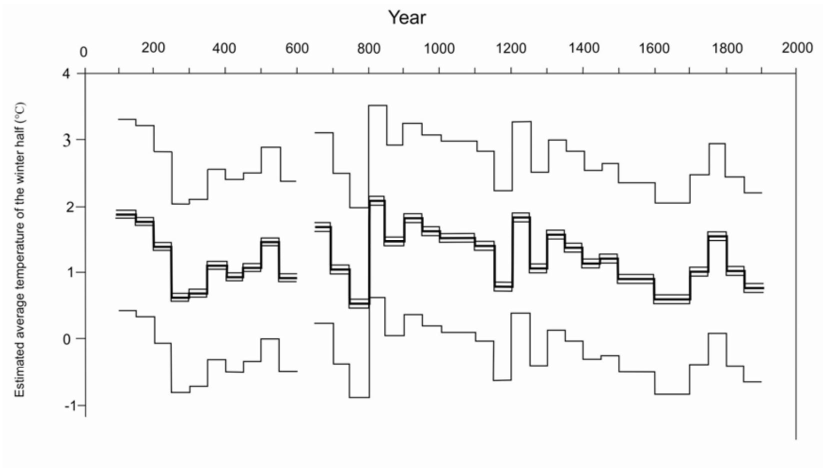
According to research on the climate of Western Europe a period of extensive warming started in the 9th century which lasted up to the turn of the 13th and 14th centuries. First it was identified in the 1960s by the founding father of British climate historical research, Hubert H. Lamb (1913-1997). He called it the Medieval Warm Epoch but recent literature rather uses the term Medieval Climate Anomaly as the climate during this period varied significantly from place to another and there were rather short but well expressed cold years, decades during this period as well.[29] The MCA is one of the most-researched epochs of historical climatology, but historical sources containing climatic and environmental information on Hungary are inadequate to reconstruct this period and the climate of medieval Hungary in general. Before considering the potential of historical sources in researching weather conditions in the Árpádian Period and late medieval Hungary, it is to discuss the wider results of scientific methods and archaeological studies.

Borehole temperature studies provide the lowest-resolution climatic data series, giving trends over periods of centuries. A recently-published study indicates a warm period in the 5th century AD in

[28] Gy. Kristó, "A Kárpát-medence népei a honfoglalás előtt", in *Nem magyar népek a középkori Magyarországon* (Kisebbségkutatási könyvek), Id. (ed.), Budapest 2003, pp. 23-37 esp. pp. 28-32.

[29] H.H. Lamb, "The Early Medieval Warm Epoch and Its Sequel", in *Paleogeography, Paleoclimatology, Paleoecology*, 1, 1965, pp. 13-37.

Figure 1. Reconstructed winter six-month average temperature based on stable isotope data from ice bores in Focul Viu Cave in the Bihor Mountains, 50-year resolution. The errors from the analytic (dark grey line) and calibration (light grey line) uncertainties are shown cumulatively



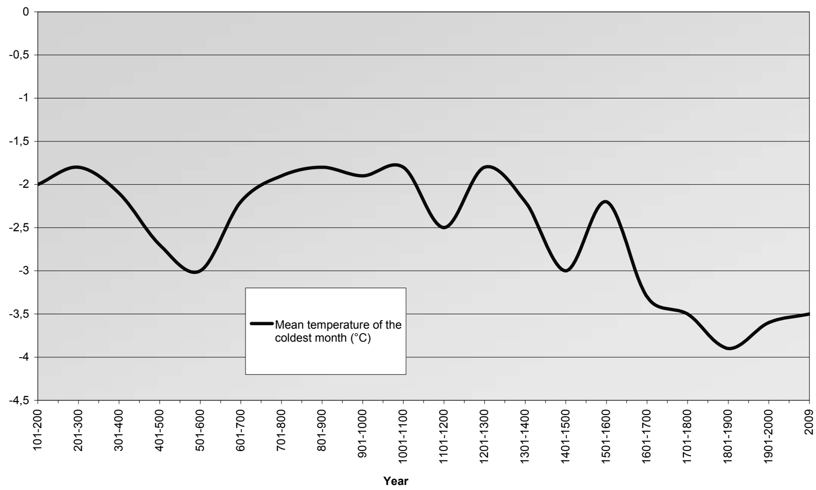
Source: Kern, *Éghajlati és környezeti* cit.

the Carpathian Basin followed by slow decrease up to the last decade of the 16th century, in direct contradiction to the accepted macro-regional climatic trends in contemporary Europe.[30]

It is possible that the proposed dominance of cold winters following the mid-3rd century was broken at the turn of the 8th and 9th centuries by warming, and the milder winter weather became permanent. The already referred ice core study in the Bihor Mountains has found that the winters in the first half of the 9th century were the mildest in the last two millennia, with an increase of 1.5°C over the temperature in the previous period (see: *Figure* 1). The intensity of the warming later decreased, but mild winter climate remained dominant in the eastern edge of the Great Hungarian Plains, and probably in the entire Carpathian Basin, up to the mid-12th century. Although a short cold period in the late 12th century broke the

[30] Bodri, Dövényi, Horváth, *Két évezred éghajlatváltozásai* cit., p. 429.

Figure 2. Average temperature in the coldest month in the last 2000 years in the Nagybárkány area, from pollen, macrofossil and sediment analyses of layers of Lake Nádas



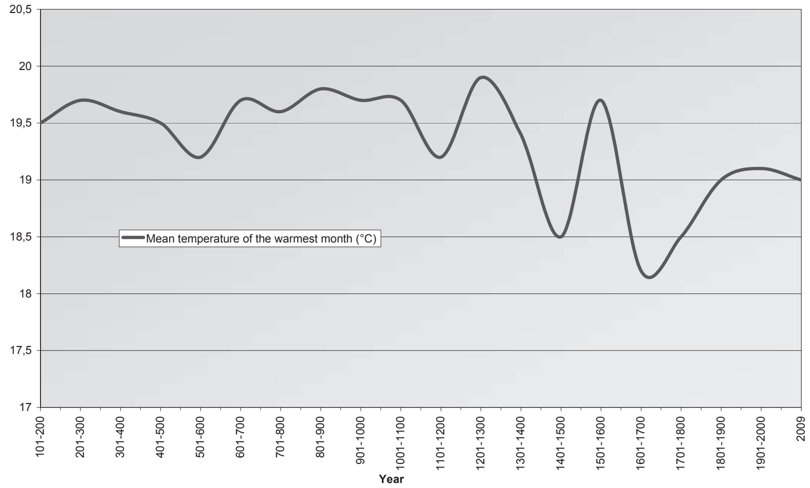
Source: Sümegi et al., *Middle Age Palaeoecological* cit.

dominance of mild winters, the first half of the 13th century produced one of the mildest average winter temperatures of the last millennium. The positive winter temperature anomaly in the first half of the 14th century ended with sustained winter cooling.[31] Similar results were obtained from the Nagybárkány-reconstruction, which shows definitely mild winter climate in the Northern Mountain Range from the late 7th century up to the 13th century (see: *Figures* 2 and 3).[32] Although there was a brief cold period around 1100, this area also shows significantly higher winter temperatures than the marked cooling of the Little Ice Age.

The main source for the average temperature of summer is the Muntii Călimani reconstruction (*Figure* 4). This study has found a long cold period in the Transylvanian mountains between 1250 and 1650, although cooling was steady only after the 1390s. From oxy-

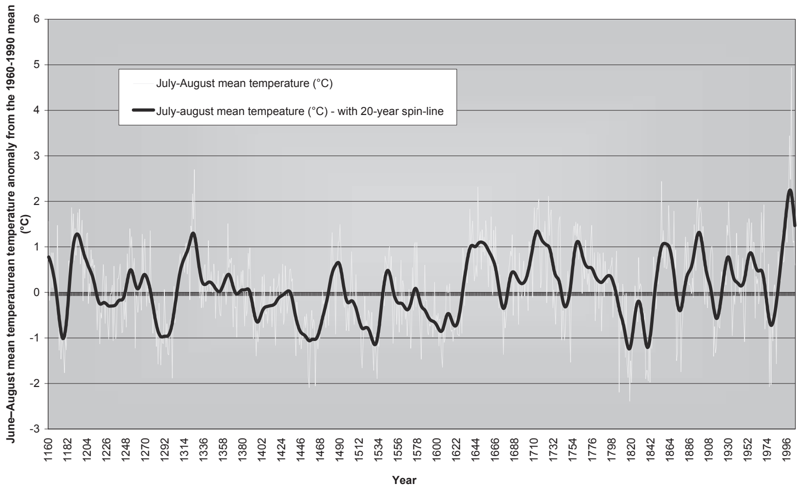
[31] Kern, *Éghajlati és környezeti* cit., p. 84.
[32] Sümegi et al., *Middle Age Palaeoecological* cit., pp. 285-291.

Figure 3. Average temperature in the warmest month in the last 2000 years in the Nagybárkány area, from pollen, macrofossil and sediment analyses of layers of Lake Nádas



Source: Sümegi et al., *Middle Age Palaeoecological* cit.

Figure 4. Average summer temperature anomaly from the 1961-1990 mean in the Muntii Càlimani (Romania) in the last thousand years, inferred from Swiss Pines. Data smoothed by 20-year third-order splines (cutoff frequency 50%)



Source: Popa, Kern, *Long-term Summer* cit.

gen isotope ice core studies and dendroclimatological reconstructions, the MCA may be approximately dated to between 800 and 1250. The last marked dominance of mild winters in the Carpathian Basin was in the 1220-1440 period, although there is a strong suggestion of even colder winters in the first half of the 9th century.[33]

The study of the Nádas Lake at Nagybárkány has indicated a dry climate during the Árpádian Period (11th–13th century) in the mountain range zone (NE-Hungary), which peaked when the lake dried out in the 13th century.[34] The authors link the drying out of the lake in the 13th century to sources the Mongol invasion, which mention dry summers and extremely cold winters in 1241-1242. In the period all throughout Europe droughts can be supposed as well, however the available written sources form an insufficient basis for any proposal of a long dry period.[35] The relatively dry climate of Upper Hungary (this historical geographical region is almost equal to today's Slovakia) in the 13th century is also borne out by the excavation of a well in Szécsény, also in the Cserhát mountain area, where a structure which was demonstrably still in use in the 13th century was built over with a parish church in the 14th century.[36] After the well was filled in, the timber structure rotted down to the average groundwater level at the time it was built; this was about two metres lower than the average in the 20th century. Another indication of dry climate when the well was made is that the timber is not damp-loving peduncular oak but sessile oak, which has greater drought tolerance.[37] Somewhat diver-

[33] Kern, *Éghajlati és környezeti* cit., p. 84.

[34] Sümegi et al., *Middle Age Palaeoecological* cit., p. 285.

[35] Ibid., pp. 284-85. A. Kiss, "Weather Events During the First Tatar Invasion in Hungary (1241-42)", in *Acta Geographica Universitatis Szegediensis*, 37, 2000, pp. 149-156. A. Kiss, "'Ecce, in hyemis nivis et glaciei habundantia supervenit'. Időjárás, környezeti krízis és a tatárjárás", in *Tatárjárás*, B. Nagy (ed.), Osiris, Budapest 2003, pp. 439-452 (see below in details).

[36] A. Grynaeus, "A szécsényi 92/5. számú XIII. századi kút faszerkezetének dendrokronológiai vizsgálata (rezümé)", in *XXI. Országos Tudományos Diákköri Konferencia Humán Tudományok Szekciója: [1993. április 7-9., Szombathely] : a dolgozatok összefoglalói*, I. Mózer (ed.), Berzsenyi Dániel Tanárképző Főiskola, Szombathely 1993, pp. 150.

[37] A. Grynaeus, *Dendrokronológiai kutatások Magyarországon*, (Dendrochrono-

gent results have been obtained from a study performed not far from Nagybárkány and the Cserhát area, in the Bükk Mountains, where the climate could not have been much different. The first stalagmite isotope distribution study in Hungary has found the MCA to be shorter than most frequently mentioned in the literature, and puts it at between 1000 and 1150. The study finds warm, wet climate during this period, followed by four centuries of wide fluctuations.[38]

The already referred soil stratigraphy based research carried out in the Mezőföld area has found that the climate was permanently dry from the 4th to the 14th centuries. The level of Lake Balaton, as during the Roman Era and the Early Middle Ages, was low to average in the 11th–13th centuries, the reconstruction of Sági and Füzes puts it at 105 metres above sea level (present level 104.5 m), which partly agrees with the level found in the Bendefy reconstruction (see: *Figure* 5).[39] By contrast, a new study based on an investigation of settlement structure in Nagyberek (swampy area, which surrounds the southwestern part of Balaton) puts the level of Lake Balaton in the 11th century at 103 metres above sea level.[40] A reconstruction of the settlement pattern on the southern shore of Lake Balaton finds that the level of water in the lake began to rise in the 12th century, and villages were gradually relocated to higher, dry land to the south. During the 13th century, the rising water of Lake Balaton almost certainly inundated some formerly marshy areas of Nagyberek.

There are sporadic historical sources on the medieval weather of the Carpathian Basin that date from as early as the 11th century. These sources usually concern single events of extreme weather, or rare atmos-

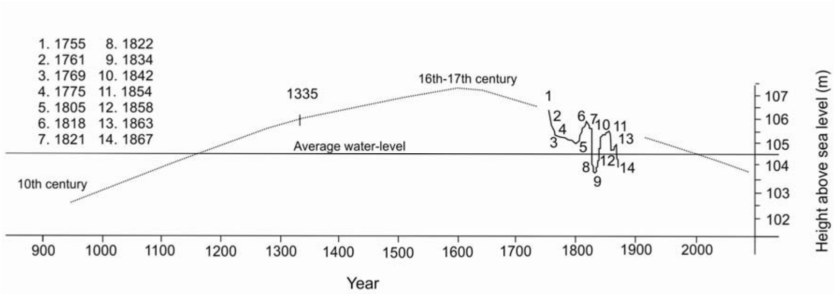
logical research in Hungary), Dissertation for the Hungarian Academny of Sciences, MTA, Budapest 1997.

[38] Z. *Siklósy, A. Demény, I. Szenthe, Sz. Leél-Őssy, S. Pilet, Y. Lin, S. Chuan-Chou,* "Reconstruction of Climate Variation for the Last Millennium in the Bükk Mts. (NO Hungary) from a Stalagmite Record", in *Időjárás*, 113, 4, 2009, pp. 245-263, here: p. 258.

[39] Sági, Füzes, *Újabb adatok a Balaton* cit., pp. 247–261.

[40] O. Mészáros, G. Serlegi, "The Impact of Environmental Change on Medieval Settlement Structure in Transdanubia", in *Acta Archaeologica Academiae Scientiarum Hungaricae*, 62, 1, 2011, pp. 199-219.

Figure 5. Lake Balaton water level fluctuations over the past millennium



Source: Sági, Füzes, *Újabb adatok a Balaton* cit.; graph after: Kiss, *Floods and Long Term Water Level* cit.

pheric phenomena, and survive mostly in chronicles and annals. As studies have pointed out, there are no more than a few dozen climate historical sources for the first two centuries of the Árpádian Period. There are very few weather events in the 11th and 12th centuries for which there is more than one source. One of these is the weather at the time of the Battle of Ménfő (northwestern part of Transdanubia, near Győr). There are accounts of the battle in two independent sources, the Altaich Annals and the *Histories* of the Burgundian Benedictine monk Rodulfus Glaber.[41] The entry for 1044 of the Altaich Annals attributes the victory of Henry III, Holy Roman emperor and Peter Orseolo, former king of Hungary over Aba Sámuel the reigning king in Hungary at that time to the appearance of a sudden sandstorm. A partly similar entry is found in the account by Rodulfus Glaber, who explained the defeat of the much larger Hungarian armies by a sudden darkness which fell on them.[42] These two texts, written in places far

[41] A. Vadas, *Weather Anomalies and Climatic Change in Late Medieval Hungary: Weather events in the 1310s in the Hungarian Kingdom*, VDM Publishing, Saarbrücken 2010, p. 21.

[42] "Ette ecce turbo vehemens, ex parte nostratium ortus, pulverem nimium adversariorum ingessit obtutibus", G.H. Pertz (ed.), *Annales Altahenses maiores: ex recensione W. de Giesebrecht et Edmundi L. B. ab Oefele / recognovit Edmundus L. B.*

removed from each other, are almost certainly mutually independent, quite exceptionally for 11th and 12th century climate history sources on the Carpathian Basin. Research during recent decades has produced some data on this period which can be fitted into the framework of European climatic reconstruction. One of these is related to the winter of 1074, when King Solomon led his army to the Battle of Kemej across the frozen River Tisza. Since we know the exact date of the battle (26 February), the river crossing may be placed in the days beforehand. Contemporary sources record that the winter of that year was also very cold in the areas of Lower Saxony, Westphalia, Franconia and Hesse which explains the ice-coverage of the river in late February.[43] According to Byzantine sources, the winter of 1125-1126 was very cold in the south of Hungary.[44] The winter was similarly hard in Bohemia and Moravia that year.[45] There are very few known weather events in the 13th century, particularly because the sources for this period have not been subjected to a thorough review of the kind carried out for the early centuries of the Árpádian Period by Andrea Kiss. There is one brief period during this century, however, for which we do have substantial information. Studies have dealt with the weather events and their consequences during the Mongol invasion.[46] There is a relative wealth of sources for this period in general, particularly narrative sources. Rogerius, Thomas of Spalato and charters have all provided useful con-

ab Oefele, Monumenta Germaniae Historica, Hannoverae 1891, p. 41. "[I]nitoque certamine, tanta caligo ac tenebrę occupauerunt Vngrorum partem ut uix iuxta se positum quis illorum posset agnoscere", J. France (ed.), *Rodulfi Glabri historiarum libri quinque*, Oxford University Press, Oxford 1989, p. 248.

[43] A. Kiss, "Időjárási adatok a XI-XII. századi Magyarországról. Időjárási adatok a 11-12. századi Magyarországról", in *Magyaroknak eleiről…*, F. Piti, Gy. Szabados (eds), Szegedi Középkorász Műhely, Szeged 2000, pp. 249-263, here: p. 257. For Western-European parallels: P. Alexandre, *Le climat en Europe au Moyen Age. Contribution à l'histoire des variations climatiques de 1000 à 1425, d'après les sources narratives de l'Europe occidentale*, EHESS, Paris 1987, p. 340.

[44] Kiss, *Időjárási adatok a XI-XII. századi* cit., p. 259.

[45] R. Brázdil, O. Kotyza, *History of Weather and Climate in the Czech Lands I: Period 1000-1500* (Züricher Geographische Schriften 62), ETH, Zürich 1995, p. 226.

[46] Kiss, *Weather Events During* cit., pp. 149-156. Id., *Ecce, in hyemis* cit., pp. 439-452.

tributions regarding the weather in the Carpathian Basin during the Mongol invasion.[47] The most important and most severe consequences of the weather and related events of the period must have been the winter freezing of the Danube, which was not unheard of in 13th century Hungary, but is nonetheless a clear indication of colder-than-average winter weather. In the case of the freezing over of the Danube in 1241-1242, it is possible to date the beginning of the ice cover with some accuracy, although there is some contradiction between foreign and domestic sources. From two royal charters, the date of crossing may be put somewhere between mid-January and 2 February. The freezing of the Danube certainly exacerbated the destructive effects of the Mongol invasion, especially in Transdanubia, which might have been partly spared if the ice cover had been thinner and unsuitable for crossing, or if the winter had been mild, without durable frost.

Weather and climate of the Little Ice Age

The turn of the 13th and 14th centuries is one of the most important climatic epoch boundaries in European history, the time when the MCA came to an end and the Little Ice Age (LIA) began. Originally coined by François Matthes, the term is used in two senses by climate researchers, firstly for the age of glacier expansion between the 14th and 19th centuries, and secondly as a metaphor for the climate of the period. Researchers are sharply divided as to the start of the cold period. Christian Pfister has claimed the Little Ice Age started in the early 14th century, while Raymond S Bradley (after Hubert H. Lamb) has dated it to 1560s.[48]

[47] For the texts, see D. Karbic, M. Sokol, J.R. Sweeney, O. Perić (eds), *Historia Salonitanorum atque Spalatinorum pontificum / Thomae Spalatensis*, CEU Press, Budapest/New York 2006. R. Martyn, L. Veszprémy, J.M. Bak (eds), *Anonymi Bele Regis Notarii Gesta Hungarorum / Magistri Rogerii Epistola in miserabile carmen super destructione regni Hungarie per Tartaros facta*, CEU Press, Budapest/New York 2010.

[48] R.S. Bradley, P.D. Jones, "When was the 'Little Ice Age'?", in *The Little Ice Age Climate*, T. Mikami (ed.), Department of Geography, Tokyo Metropolitan University, Tokyo 1992, pp. 1-4. Pfister, *Klimageschichte der Schweiz* cit. Id., "Five Centuries of Little Ice Age Climate in Western Europe", in *The Little Ice Age Climate* cit., pp. 208-213.

Although the climate of the Carpathian Basin in the 14th century is shrouded in almost as many uncertainties as the climate during the Árpádian Period, scientific and historical research has made some valuable findings on the weather and climate of that time. The Nagybárkány study supposes significant cooling from the mid-13-th century. It shows that the 13th was the warmest century of the time around it, followed by slow cooling over several centuries in terms of the average temperatures in both the warmest and coldest months, which fits well with Western European climate reconstructions. In the late 14th century, apart from one short warmer period, a sustained period of cooling set in and lasted up to the second half of the 19th century, when the temperature started to rise steeply.[49] In parallel with the fall in temperature, precipitation started to increase, and from the 14th century onwards, the annual precipitation exceeded the average of the preceding millennium. A complex environmental historical survey in another sample area – Lake Baláta in South Transdanubia – dates the start of the changes earlier: the area was already cold and wet in the late 13th century.[50] A comprehensive environmental history study has also found the spread of cold-tolerant species in Northern-Hungary, in the area of the Bátorliget marsh in the late 13th century. One of the species found to have advanced at this time is *Gyraulus riparius*, a characteristic indicator of weather suddenly turning cold.[51] Research using a similar method in the Jászság area (between the Danube and the Tisza) has also confirmed the hypothesis of a colder late Árpádian Period.[52]

The average summer temperatures from the above mentioned cli-

[49] Sümegi et al., *Middle Age Palaeoecological* cit., p. 286.

[50] Zatykó, Juhász, Sümegi, *Environmental Archaeology in Transdanubia* cit., pp. 251-253. Cs. Zatykó, "The Medieval Environment of the Lake Baláta in the Light of Geology and Documentary Sources", in *Human Nature. Studies in Historical Ecology & Environmental History*, P. Szabó, R. Hédl (eds), Institute of Botany of the ASCR, Brno 2008, pp. 124-129, here: p. 126.

[51] Sümegi, Gulyás, *The Geohistory of Bátorliget* cit., pp. 193 and 277.

[52] P. Sümegi, "The Environmental History of the Jászság", in *Environmental Archaeology in North-Eastern Hungary* (Varia Archaeologica Hungarica 19), E. Gál, I. Juhász, P. Sümegi (eds), Archaeolingua, Budapest 2005, pp. 112-114.

mate reconstruction based on the Swiss pines of the Călimani Mountains show a brief cold period around 1300. After a short-term warming, cold summer temperatures dominated continuously between 1370 and 1630.[53] There are two extreme summer cold anomalies that merit particular attention: the negative extreme of 1455 and the series of cold summers between 1602 and 1606. The years 1490 to 1545 also diverge from the Central European trend, the reconstruction showing the summer weather to have been temporarily warmer.[54]

According to the Bihor oxygen isotope ice core study, the winter temperatures over some three and a half centuries from the mid-13th century steadily decreased, by about 1.2°C. The low point of the cooling was in the 17th century, which was the coldest century by winter temperature of the whole past millennium.[55] Summarising the results of the Swiss pine-based dendroclimatological studies and the oxygen isotope ice core analyses, the dominant period of the LIA in Hungary lasted from about 1370 to the mid-17th century, whereas the MCA probably came to an end some time in the mid-13th century.[56]

There is also archaeological evidence that the precipitation balance in the Carpathian Basin had a greater surplus in the Late Middle Ages than in recent times. In the early Árpádian Period, settlements on the south and west shores of Lake Balaton mainly grew up beside the main water courses of the region. Many of these were on the edge of Nagyberek, but in the 13th century, the Balaton water level started to rise, ultimately by several metres, and almost certainly inundated the whole of the Nagyberek area.[57] The level probably peaked in the 16th and 17th centuries, during which it constitut-

[53] Popa, Kern, *Long-term Summer* cit.

[54] Kern, *Éghajlati és környezeti* cit., pp. 97-98. For Central European trends, see Dobrovolný et al., *Monthly and Seasonal Temperature Reconstructions* cit., p. 93.

[55] Kern, *Éghajlati és környezeti* cit., p. 84.

[56] Ibid., p. 101.

[57] Mészáros, Serlegi, *The Impact of Environmental Change* cit. Cs. Hosszú, "A Nagyberek változó arca a települési struktúra tükrében", in *Környezettörténet 2010. Konferencia. Környezeti események a honfoglalástól napjainkig történeti és természettudományos források tükrében*, M. Kázmér (ed.), Hantken Kiadó, Budapest 2010, pp. 36-37.

ed one of the main guiding factors in the formation of settlements there. So was the case in the South-eastern part of the Carpathian Basin, in the Tisza-Maros-Danube interfluves area where according to cartographic data the so-called Lake Becskerek might have had its biggest extent in the same period.[58] The archaeological topographies well indicate that many medieval settlements on the Great Hungarian Plain were not rebuilt, and new dwellings were often built in the vicinity of old villages, on more protected, higher land. There were similar tendencies along some rivers, such as near Szer (Ópusztaszer, southern area of the Great Hungarian Plain) in the Tisza valley, where the settlement clearly expanded towards higher-lying land, and in the area of what was the county of Békés (SE-Hungary), where lower-lying land along many minor mortlakes became depopulated after the Árpádian Period.[59]

In the 14th century, the floor of the Récéskút Basilica (Zalavár, near Lake Balaton) had to be raised because of the rising level of the lake and the groundwater.[60] Historical topographical research had found that boundary determinations and revisions in the Great Hungarian Plains in the 13th-15th centuries often faced the problem of boundary markers being inaccessible because of the water.[61] Another indicator of wetter climate from the 13th century is the spread of water mills on streams whose water was insufficient to drive mills in the

[58] A. Vadas, "Late Medieval Environmental Changes of the Southern Great Hungarian Plain. A Case Study", in *Annual of the Medieval Studies at CEU*, 17, 2011, pp. 41-60.

[59] K. Vályi, "Szer középkori településtörténete a régészeti leletek tükrében", in *Falvak, mezővárosok az Alföldön* (Az Arany János Múzeum Közleményei IV), L. Novák, L. Selmeczi (eds), Arany János Múzeum, Nagykörös 1986, pp. 119-124. For instances from Békés county, see B.D. Jankovich (ed.), *Békés megye régészeti topográfiája. Békés és Békéscsaba környéke* (Magyarország régészeti topográfiája 10), Akadémiai Kiadó, Budapest 1998, pp. 673-677. J. Makkay (ed.), *Békés megye régészeti topográfiája. A Szarvasi járás* (Magyarország régészeti topográfiája 8), Akadémiai Kadó, Budapest 1989, p. 367.

[60] A. Pálóczi Horváth, "A környezeti régészet szerepe Magyarországon a középkor kutatásában", in *Európa híres kertje. Történeti ökológiai tanulmányok Magyarországról*, L. Kósa, Á.R. Várkonyi, (eds), Orpheusz, Budapest 1993, pp. 44-66.

[61] Györffy, Zólyomi, *A Kárpát-medence és Etelköz* cit., p. 15.

20th century.[62] Archaeological findings for the late medieval period suggest a rise in the level of the Danube, for example in the Danube Bend area[63] which can also be confirmed by some historical data.[64]

The amount of historical data on weather events increases from the 14th century, in parallel with the advance of literacy. The meagreness of chronicle literature means that charters constitute most of the sources for climate history. The charters of the Angevin Era suggest periods in which extreme weather events gave rise to crises, periods of high flood frequencies, catastrophic flood events and famine in the Carpathian Basin. The Hungarian Angevin Era is of particular importance in European climate history. Many researchers have called this period the start of the transition into the LIA, and there is a unanimous view that the second decade of the 14th century formed one of the most extreme periods. Although the latest research does not bear out the sustained cold period with certainty, the high number of weather extremes, especially the series of hard, cold winters and summers make the 1310-1330 period one of the most notable climatic features of the 14th century.[65] Research on the Carpathian Basin also focused on extreme periods. Al-

[62] T. Vajda, "Hazai vízimalmaink 1301 és 1325 közötti okleveles adatai", in *Középkortörténeti tanulmányok. A III. medievisztikai PhD-konferencia (Szeged, 2003. május 8-9.) előadásai*, B. Weisz (ed.), Szegedi Középkorász Műhely, Szeged 2003, pp. 193-213.

[63] M. Héjj, "Településföldrajzi megfigyelések. Visegrád a 14-16. században", in *Visegrád 1335. Tudományos tanácskozás a visegrádi királytalálkozó 650. évfordulóján*, J. Köblös (ed.), Pest Megyei Levéltár, Budapest 1988, pp. 47-62. J. Laszlovszky, "Királyi palota, ferences kolostor és városi település (Gondolatok a késő középkori Visegrád településfejlődéséről)", in *Es tu scolaris – Ünnepi tanulmányok Kubinyi András 75. születésnapjára* (Monumenta Historica Budapestinensia XIII), F. Romhányi, Beatrix et al. (eds), Budapesti Történeti Múzeum, Budapest 2004, pp. 61-71. Mészáros, Serlegi, *The Impact of Environmental Change* cit. And most recently: Kiss, Laszlovszky, *14th-16th-Century Danube* cit.

[64] A. Vadas, "Long-Term Perspectives on River Floods. The Example of the Dominican Nunnery of the Margaret Island (Budapest) and the Danube", in *Interdisciplinaria Archaeologica*, 4, 1, 2013, pp. 73-82. Kiss, Laszlovszky, *14th-16th-Century Danube* cit.

[65] For instance, H. Lucas, "The Great European Famine of 1315, 1316 and 1317", in *Speculum*, 5, 4, 1930, pp. 343-377, I. Kershaw, "The Great Famine and Agrarian Crisis in England 1315-1322", in *Past & Present*, 59, 5, 1973, pp. 3-50.

though the number of sources on weather become gradually more numerous during the Angevin Era, they still do not permit as detailed account of each period as in some Western European areas. Nonetheless, a systematic investigation of Angevin-era charters has drawn attention some short crisis periods.[66] One of these is definitely the 1310s. Several studies have investigated the appearance in the Carpathian Basin of the period of famine and floods which is well documented in Western Europe. Earlier research into contemporary Hungarian sources did not find records of the environmental crisis in the Carpathian Basin, but recently-published results permit the conclusion that extreme weather did affect this area, if not to the same extent as in Western Europe, and – given the political turmoil of the time – must have given rise to serious crises in some areas.[67] Similarly well studied are the 1340s which seem to have been a better documented crisis period than the 1310s. Undoubtedly many weather extremes (mainly floods) occurred in these years and so was the case in other Central European countries and in parts of Western Europe.[68] Many charters mention floods

W.Ch. Jordan, *The Great Famine. Northern Europe in the Early Fourteenth Century*, Princeton University Press, Princeton 1996. Id., "The Great Famine: 1315-1322 Revisited", in *Ecologies and Economies in Medieval and Early Modern Europe: Studies in Environmental History for Richard C. Hoffmann*, S.G. Bruce (ed.), Brill, Leiden 2011, pp. 44-61.

[66] A. Kiss, "Some Weather Events fom The Fourteenth Century (1338-1358)", in *Acta Climatologica Universitatis Szegediensis*, 30, 1996, pp. 61-69. Id., "Some Weather Events in the Fourteenth Century II. (Angevin period: 1301-1387)", in *Acta Climatologica Universitatis Szegediensis*, 32-33, 1999, pp. 51-64.

[67] Id., *Some weather events* cit. Id., *Some weather events II* cit. R. Szántó, "Az 1315-17. évi európai éhínség", in *Medievisztikai tanulmányok. A IV medievisztikai PhD konferencia előadásai*, Sz. Marton, É. Teiszler (eds), Szegedi Középkorász Műhely, Szeged 2005, pp. 135-142. R. Szántó, "Környezeti változások Európában a 14. század első évtizedeiben", in *Középkortörténeti tanulmányok*, *5. Az V. Medievisztikai PhD-konferencia előadásai*, É. Révész, M. Halmágyi (eds), Szegedi Középkorász Műhely, Szeged 2007, pp. 159-164. R. Szántó, "Természeti katasztrófa és éhínség 1315-1317-ben", in *Világtörténet,* 27, 1-2, 2005, pp. 50-64. A. Vadas, "Documentary Evidence on Weather Conditions and an Environmental Crisis in 1315-1317: Case Study from the Carpathian Basin", in *Journal of Environmental Geography*, 2, 3-4, 2009, pp. 67-76. Vadas, *Weather Anomalies* cit.

[68] Id., *Some Weather Events* cit., pp. 65-66.

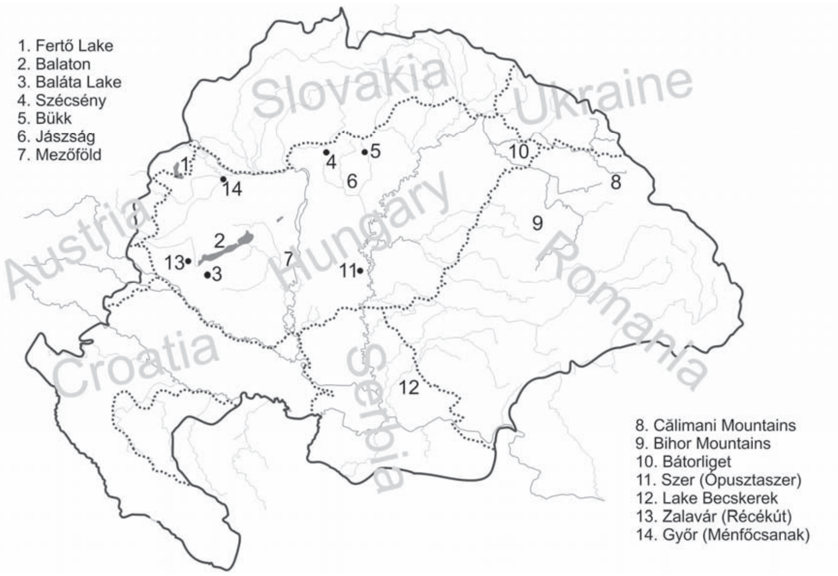
on several rivers in spring and summer 1342, followed in September by snow and more floods. Although there are fewer sources on the weather of subsequent years, Andrea Kiss has found data on floods in the country in 1343, and then in nearly every year in the second half of the decade.[69] Although weather in the Carpathian Basin often differs greatly from that in Western Europe, there are some periods for which there are very close parallels in the Kingdom of Hungary and Central European areas. The 1310s and 1340s are certainly among these. There are also several sources for particular years which indicate close weather relationships between the Carpathian Basin and certain areas of Central Europe. For example, it has been established almost without doubt that in many areas of Western and Central Europe, 1363-1364 was one of the coldest winters of the last thousand years, and there is one charter which records the same phenomenon in Hungary.[70] From the 14th century, there are many more charters, and from the 15th century there are contributions from other types of source usable in climate history research: narrative sources, sources of economic character (mainly customs registers), personal correspondences. However this period is almost entirely untouched by scholarly research. Lacking in new results – and especially the study of weather events in late medieval charter evidence – research still highly relies on the compilation of Antal Réthly and lacking in the critical assessment of Réthly's dataset for this period scholars still quote Réthly's frequently inaccurate compilation on the weather events.[71] Despite the better research possibilities only a few

[69] A. Kiss, "Floods and Weather in 1342 and 1343 in the Carpathian Basin", in *Journal of Environmental Geography*, 2, 3-4, 2009, pp. 37-47. Id., "időjárás, környezeti problémák és az 1340-es évek elejének tatár hadjáratai", in *Hadtörténeti közlemények*, 125, 2, 2012, pp. 483-509.

[70] Id., *Some weather events II* cit., pp. 57 and 60. On the European weather of this decade: Ch. Pfister, G. Schwarz-Zanetti, M. Wegmann, "Winter Severity in Europe: the Fourteenth Century", in *Climatic Change*, 34, 1, 1996, pp. 91-108, here p. 101. Ch. Pfister, G. Schwarz-Zanetti, F. Hochstrasser, M. Wegmann, "The Most Severe Winters of the Fourteenth Century in Central Europe Compared to Some Analogues in the Most Recent Past", in *Documentary Climatic Evidence for 1750-1850 and the 14th Century*, B. *Frenzel*, E. Wishman, M.M. Weiss (eds), Gustav Fischer Verlag, Stuttgart-Jena-Lübeck-Ulm 1998, pp. 45-62.

[71] A. Réthly, *Időjárási események és elemi csapások Magyarországon 1700-ig*,

Figure 6. Most important geographical names referred in the article



The medieval borderline of the Hungarian Kingdom is marked with continuous red line, the red broken line shows the present-day political borders.

late medieval sources has been studied from a climate historical point of view. Charters relating to flooding up to 1500 has been thoroughly studied by the dissertation of Andrea Kiss and some specific sources, as the town books of Bratislava (Pressburg) has also been dealt with from an economic-environmental historical point of view but in this respect the next decades are to provide fundamental results.[72]

Akadémiai Kiadó, Budapest 1962. On his collection, see Kiss, *Historical Climatology in Hungary* cit., pp. 317-320.

[72] Id., *Floods and Long-Term Water-Level* cit. J. Király, *A pozsonyi nagy-dunai vám- és révjog története*, Drotleff, Pozsony 1890.

Medieval climatic periods in the Carpathian Basin

The main purpose of this review of the state of climate historical research on the Hungarian Middle Ages has been to determine the main characteristics of climate during this period and to show how trends differ from what is dominant in Western European literature. A combination of scientific, archaeological and historical research results have outlined the characteristics of the climate historical periods during the Middle Ages:

1. The shift between the Roman Optimum and the cold period of the age of Migration in quite visible not only in the paleoenvironmental reconstructions but also in the archaeological strata. The Migration period might have been characteristically colder than the previous centuries with dryer conditions.

2. The start of the Medieval Climate Anomaly in the Carpathian Basin should be sought between the late 7th and early 9th centuries, but it would be premature to take up a definite position in this question on the strength of the data available. Environmental reconstructions based on scientific sources find a warmer period starting in the 7th century and ending at the turn of the 13th and 14th centuries. Pál Sümegi's environmental reconstructions from sporadic sites of the Carpathian Basin, the dendroclimatological reconstruction of Popa and Kern from the Eastern-Carpathians and Kern's ice-core research all strengthen the idea that the cooling already started in the 13th century. However the characteristically cold climate might have only been dominant only from the end of the 14h century. The precipitation conditions characteristic of the MCA may be classed in the "dry-on-average" category, but it is certain that precipitation in the Carpathian Basin increased (or conditions were wetter owing to the lower temperature) in the 13th century, and setting off the several-century rise in the Lake Balaton water level, which peaked in the 16th-17th centuries.

3. The start of the Little Ice Age may be dated to between the mid-13th and early 14th centuries. The scientific, archaeological and historical data all point to a continuity in cold, wet climate up to the second half of the 19th century. The predominant period of cooling and in-

creasing precipitation was undoubtedly the “long 17th century”. In this period, from the final decades of the 16th century up to the start of the 18th century, the Carpathian Basin had a colder climate, with higher precipitation, than at any other time in the last two thousand years.