The Climate of the Khagan. Observations on palaeo-environmental Factors of the History of the Avars (6th-9th century AD)*

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Abstract

Based on palaeoenvironmental, historical and archaeological data, the paper proposes possible climatic impacts on the history of the Avar Khaganate, which comprised the Carpathian Basin between the late 6th and the early 9th century AD. While the establishment of the Avars in East Central Europe took place within a period characterised by cold and dry climatic conditions (recently identified as “Late Antique Little Ice Age”), more stable climatic parameters may have favoured the stabilisation of Avar rule after a crisis in the aftermath of 626 AD. Data indicates growth of settlement and agricultural activity up to the mid-8th century. These developments did not necessarily strengthen central power, but may have contributed to a greater autonomy of various groups on the basis of increased resources. The Khaganate quickly disintegrated faced by the Carolingian advance of the 790s; the last decades of documented Avar presence were again accompanied by environmental vicissitudes.

In an article published in 2016, Büntgen et alii on the basis of palaeoenvironmental data from Central Europe and Central Asia identified a prolonged cool period across Eurasia between 536 and 660 AD, initiated by a series of volcanic eruptions, which they described as “Late Antique Little Ice Age” (= LALIA) (fig. 1, top). Among the various political and socio-economic upheavals during these decades between the Mediterranean and China, the authors listed the advance of the Avars to the Danube and the following migration movements, especially of Slavs, towards the Byzantine Balkans. Recently, also McCormick and colleagues as well as Cook have mentioned adverse climatic conditions in the Central Asian steppes as one factor contributing to the collapse of the Rouran Khaganate in ca. 552 AD and the following movement of groups, which we encounter as Avars in Byzantine and other sources, to the Carpathian Basin; Cook in tree ring data from Dulan-Wulan in North-Central China identified a “multi-decadal megadrought” in the mid-6th century. And most recently, Sümegi et alii have addressed the question of climate change in the Avar period on the basis of a regional study on Lake Baláta in

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1 Büntgen et alii, Cooling and societal change. Cf. Gunn (ed.), Year without Summer; Stathakopoulos, Famine nr. 92 (on the “dust-veil event” of 536); McCormick et alii, Climate Change; Haldon et alii, Climate. For the historical events cf. Pohl, Awaren 29-37.

2 McCormick et alii, Climate Change; Cook, Megadroughts.
southwest Hungary. On the basis of these new findings, the present volume devoted to one of the leading experts in the archaeology of the Avars provides the opportunity to further reflect on possible climatic factors to the history of this people and their Khaganate, which comprised the Carpathian Basin and adjacent areas between the 6th and the 9th century AD.

For this purpose, we use the temperature reconstructions provided by Büntgen et alii in their study, who integrated tree ring data from the European Alps and the Russian Altai in order to model climatic fluctuations across the main theatre of Avar history from the Danube to Central Asia (fig. 1, top). In addition, Büntgen and colleagues in 2011 created a reconstruction of spring precipitation in Central Europe for the last two Millennia, which supplies a further palaeo-environmental parameter of Avar presence in Pannonia on a wider scale (fig. 1, middle and bottom). Based on similar data, Cook et alii present spatial reconstructions of summer wetness and dryness across Europe and the Mediterranean for the last 2000 years in their “Old World Drought Atlas” (OWDA); for the period under consideration, the OWDA fortunately also covers the Carpathian Basin. In contrast to these annually resolved over-regional reconstructions, other proxy data from the Carpathian Basin such as lake sediments and pollen provide more locally confined information on changes in the landscape on a long term scale, caused both by changing climate conditions and/or human agency (fig. 2). These “archives of nature” can be compared with historical and archaeological data as “archives of society”; also here, over-regional, regional and local as well as centennial, decadal and annual scales can be observed.

Especially extreme events such as droughts, colds or floods affected human societies; they damaged vegetation (pastures, but also arable crops of agricultural communities within nomadic empires) and could lead to a reduction of water resources (especially in the semiarid areas of Central Asia). This in turn affected livestock, which also could be exposed to an increased risk of epizootics due to specific weather conditions. The same was true for humans (e.g. the outbreak of the “Justinianic plague” during LALIA), who equally suffered from malnutrition. Hunger would first affect younger and older as well as

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3 Šümegi et alii, Extreme Dry Climate.
4 From the numerous studies of Falko Daim we would like to mention especially: Daim (ed.), Awarenforschungen; Daim et alii (eds.), Hunnen und Avenen; Daim, Structures of Identification; Daim (ed.), Die Awaren am Rand; Daim, Avars and Avar Archaeology.
5 Büntgen et alii, Climate Variability. Another relevant recent (oak) tree ring series ranging back to 761 AD stems from the Czech Republic: Dobrovolný et alii, A tree-ring perspective.
6 Büntgen et alii, Climate Variability. Another relevant recent (oak) tree ring series ranging back to 761 AD stems from the Czech Republic: Dobrovolný et alii, A tree-ring perspective.
7 Cook et alii, Old World megadroughts. The Balkans and the Eastern Mediterranean unfortunately are not covered during the 6th to 9th centuries.
8 See the various types of data (and also the problems with their dating and use) mentioned below. Cf. Bojňanský / Fargašová, Atlas of Seeds and Fruits; Werger / van Staaldhuizen (eds.), Eurasian Steppes 209-252.
9 For historical sources from the neighbouring Byzantine Balkans as well as Merovingian/Carolingian Central Europe, we possess now a number of exhaustive catalogues which are used and cited for the present study: Telelis, Μετεωρολογικά φαινόμενα; Stathakopoulos, Famine; Newfield, The contours of disease and hunger; McCormick et alii, Geodatabase (in the studies of Telelis and Newfield also full citations of sources can be found).
10 For a longer overview on these types of data, their scales and the problems of their temporal and spatial resolutions cf. Preiser-Kapeller, Collapse (with further literature). Cf. also Juhász, Reconstitution palynologique; Zatykó / Juhász / Šümegi, Environmental archaeology; Izdebski et alii, Palynological Data.
11 Stathakopoulos, Famine, esp. nr. 159 for an outbreak of the plague among the Avars reported for the year 598 during a campaign in Byzantine Thrace (while this event was recorded in Byzantine sources, we learn nothing about outbreaks of the plague in the Avar core regions in the Carpathian Basin). For the plague as a possible factor
as poorer members of a community, but also delegitimise the claim to leadership of elites and increase social conflict. Especially in the case of nomads, such crises could motivate mobility in search for other sources of resources, thus leading to conflict with neighbouring groups, both nomadic and sedentary. Besides these general impacts, after the establishment of Avar rule in the Carpathian Basin (fig. 2) one has to take into consideration specific natural hazards in these areas, which included both extreme colds and droughts, as documented in fluctuating water levels of Lake Balaton and Lake Fertő/Neusiedlsee, for instance. On the other hand, before the hydro-engineering measures of the 19th and 20th century wide flood plains characterised the areas along Danube, Tisza and their tributaries (summing up to 12-15 % of the entire Carpathian Basin, ca. 30,000 km²). Extreme flood events resulted from increased precipitation and the snowmelt, especially in the upper (alpine) catchment of the Danube, or extreme cold, leading to devastating ice (jam) floods. Resulting limitations to permanent settlement are well documented for the high and late Middle Ages; recent studies indicate similar environmental factors for settlement site selection at the edges of floods areas in the Avar period. Floods would equally impede military movements, also of nomadic troops, as a recent study of Büntgen and Di Cosmo on the Mongol invasion of 1242 illustrates. Landscape degradation in the Carpathian Basin, in turn, has been attributed to nomadic pastoralism of Huns, Avar, Magyars and Cumans between the 5th and 13th century, a still ongoing debate. Without doubt, Avar pastoralism created a huge demand of pasture lands for economic and military purposes (for an army of maybe 20,000 horsemen). Yet their realm always and increasingly included permanent settlements and depended on agriculture, as also archaeobotanical evidence illustrates.

contributing to Avar and Slavic expansion on the Byzantine Balkans and its potential effect on pastoral societies cf. also Soltysiak, The plague pandemic. For a more nuanced discussion of the potential effect of plague epidemics on nomadic communities and the debates on this issue cf. also Varliik, Plague and Empire 113-118, and Franz / Riha / Schubert, Plagues in Nomadic Contexts. Remains of the black rat (rattus rattus) have been found in Hungary within and beyond the Roman borders, dating to the 3rd-4th century; unfortunately, there is no archaeological evidence for the following period until the 13th century, cf. Kovács, Dispersal History.

12 For a detailed analytical framework for the impact of environmental hazards on pre-modern societies cf. Krämer, Hungerkrise. Cf. also Newfield, The contours of disease and hunger, esp. for epizootics, and Telélis, Environmental History.

13 Vadas / Rácz. Climatic Changes; Eitzinger et alii, Auswirkungen einer Klimaänderung; Soja et alii, Climate impacts; Sümegi et alii, Lake Balaton; Kiss, Floods 65-73; Lóczy (ed.), Landscapes 19-24.

14 Kiss, Floods, esp. 21-38 (with detailed discussion of the hydrology of the area); Brilly (ed.), Hydrological Processes, esp. 25-77 and 121-123; Lóczy (ed.), Landscapes 24-27; Vadas / Rácz. Climatic Changes; Sümegi et alii, Long environment change; Sümegi, Link.

15 Bugarski, The Geomorphological Matrix; Odler, Avarské sídliska; Pinke et alii, Settlement Patterns; Sümegi, Link.

16 Büntgen / Di Cosmo, Climatic and environmental aspects.

17 Werger / van Staalduinen (eds.), Eurasian Steppes 209-252 (highlighting the most significant modifications of landscapes during the last 200 years); Sümegi et alii, Long environment change, esp. 19-20; Sümegi, Link. See also Daim, Avars and Avar Archaeology 485.

18 Pohl, Awaren 37-38, 189-191; Curta, Avar Blitzkrieg, esp. 73-75; Priskin, Horses. Cf. also Bowlus, Lechfeld 22-27, on the “carrying capacity” of the Carpathian Basin for steppe nomadic pastoralism and warfare.

19 Pohl, Awaren 191-193; Curta, Southeastern Europe 65-66; Vida, Raumkonzepte; Gyulai, Archaeobotany in Hungary; Gyulai, The History of Broomcorn Millet; Rapan Papeša / Kenéz / Pető, The Archaeobotanical Assessment; Noche-Dowdy, Multi-Isotope Analysis. Cf. Daim, Structures of Identification 83-84. Cf. also Hämäläinen, Comanche Empire, esp. 351-353, and Hämäläinen, Kinetic Empire, on the dependence of pastoral federations on “viable agricultural societies” across and within their borders. Hämäläinen describes a “kinetic
The Early Avar period (568 to 630 AD)\textsuperscript{20}

During LALIA, a first period of extremely cold summers affected Central Europe from 535 to 558; spring precipitation was low from the late 530s to the early 570s, with minima in 544 and 567 (fig. 1, middle). Also written sources register various weather extremes in Central and Western Europe during these decades\textsuperscript{21}. Byzantine texts report an extreme winter for 558/559, which allowed “Barbarian” groups to cross the frozen Danube\textsuperscript{22}. We also have more specific proxy data for the Carpathian Basin and neighbouring regions such as the Upper Dniester valley, where a transition to a period of increased floods took place before the last quarter of the 6th century\textsuperscript{23}. Pollen, macrofossil and sediment analyses at Lake Nádas in northern Hungary indicate a severe drop of temperatures in the 6th century and rapid change from very low water levels in the 5th century to high levels in the 6th and 7th centuries, accompanied by increased annual precipitation (fig. 3)\textsuperscript{24}. For other regions, however, a change towards drier conditions can be observed in the 6th century, as for the Tăul Muced bog in the Eastern Carpathian Mountains; for Lake Balaton, in turn, recently rising water levels have been reconstructed for the 5th to 7th century\textsuperscript{25}. Thus, we have to reckon with different regional shapes of the general trend of LALIA; the overall impact on agricultural communities, however, seems to have been negative. Trajectories of grain pollen for three sites from Hungary, where sample size was sufficient of our period of interest (Lake Balaton, Nagy-Mohos and Pólóske), all show a downwards trend in the 6th century (fig. 4, with citations of data sources); but the dating for these layers is highly problematic in all three sites, which very much limits (or maybe even invalidates) their explanatory value for the Avar period.\textsuperscript{26} Yet at least similar trajectories can be observed in a recent synthetic (and significantly more reliably datable) reconstruction of agricultural outputs for two neighbouring areas, the region south of Cracow (Poland) and Bohemia, undertaken by Izdebski et alii\textsuperscript{27}.

The first period of extreme cold was followed by an interval of shorter temperature fluctuations from 560 until the early 590s (fig. 1, middle); in these decades between 568 and 582 (conquest of Sirmium)
the establishment of Avar power in the Carpathian Basin took place. Besides climatic vicissitudes, violence, unrest and migrations (such as the emigration of part of the Lombards to Italy or the resettlement of Gepids) accompanying this process damaged existing agricultural communities; recent studies, however, indicate also a significant continuity of settlement and of networks of exchange within and beyond the Carpathian Basin, into which the newcomers now (forcefully) integrated.

A second prolonged cold period occurred between 595 and 615, while drier conditions continued between 604 and 614 and between 617 and 625 (fig. 1, middle). These years were characterised by frequent warfare between the Avars and the Byzantine Empire. From written sources, we especially learn about impacts of extreme weather on the Byzantines and their troops; for 599, they register a cold winter which also led to the death of draft animals. For 602, we read about a famine in Constantinople early that year and colds and rains affecting the army in the Balkans in autumn, both contributing to the fall of Emperor Maurice. A drought year is referred to for Constantinople in 610, when Emperor Phokas was replaced by Heraclius. For the very dry year of 618, sources report another famine in Constantinople (also caused by the loss of Egypt to the Sasanians). For the early Avar realm, success in these wars was essential; as Falko Daim has explained: “if it were not for Byzantium, the Avar Empire would never have been founded, because large annual payments from Constantinople and rich loot from raids on the Balkans stabilised the khagan’s power.” Accordingly, the successful Byzantine campaigns of the 590s brought about a first crisis of the Khaganate, which was saved by the violent end of Maurice and the following internal turmoil in Byzantium. A second crisis emerged after the failure of the Avar siege of Constantinople in 626, in the midst of another cold period with a minimum in 626/627 (fig. 1, middle). The following years saw a civil war in the Khaganate, the rise of the realm of Samo in Bohemia and the creation of “Great Bulgaria” under Kuvrat in the Ukrainian steppes. These perturbations at ca. 630 also led to the end of the important settlement of Keszthely-Fenékpuszta, a

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28 Pohl, Awaren 52-76; Kislinger, Regionalgeschichte 25-40, 72-101.
29 Pohl, Awaren 225-236; Curta, Southeastern Europe 61-69; Vida, Conflict and coexistence; Vida, Local and Foreign Romans; Pohl, Awaren 128-162; Curta, Avar Blitzkrieg; Kardaras, Αβαροι 118; Breuer, Byzanz an der Donau: Csikey / Magyar-Harsheghyi, Wine. Cf. also Hämäläinen, Comanche Empire, esp. 349-350, and Hämäläinen, Kinetic Empire, for “expansionist and exploitative” strategies of nomadic empires with regard to the material wealth and also labour force of neighbouring societies. For similar observation on the Avars see also Vida, Raumkonzepte.
30 Telelis, Μετεωρολογικά φαινόμενα nr. 203, 275-276. On the Avar-Byzantine wars cf. Pohl, Awaren 128-162, 237-256; Curta, Avar Blitzkrieg; Kardaras, Αβαροι 70-136; Hambanić, Vpády Avarov. Cf. Bowlus, Lechfeld 27-36, on possible limits of humid weather for nomadic warfare, especially for the use of composite bows.
31 Telelis, Μετεωρολογικά φαινόμενα nr. 205, 277-279 and nr. 206, 279-280; Stathakopoulos, Famine nr. 165; Pfeilschifer, Kaiser 252-293. Cf. also the reconstruction of Cook et alii, Old World megadroughts.
32 Telelis, Μετεωρολογικά φαινόμενα nr. 212, 288-289.
33 Telelis, Μετεωρολογικά φαινόμενα nr. 215, 291-292; Stathakopoulos, Famine nr. 173. Cf. Cook et alii, Old World megadroughts, who reconstruct a severe drought across large parts of East Central and Eastern Europe for 618.
34 Daim, Byzantine Belt Ornaments 62. Cf. Whitby, Emperor Maurice (for the Byzantine-Avar wars in the 590s); Pohl, Awaren 178-185, 205-215; Curta, Avar Blitzkrieg; Curta, Southeastern Europe 64-65; Breuer, Byzanz an der Donau: Csikey / Magyar-Harsheghyi, Wine. Cf. also Hámáláinen, Comanche Empire, esp. 349-350, and Hámáláinen, Kinetic Empire, for “expansionist and exploitative” strategies of nomadic empires with regard to the material wealth and also labour force of neighbouring societies. For similar observation on the Avars see also Vida, Raumkonzepte.
35 Pohl, Awaren 156-162; Curta, Southeastern Europe 68-69, 75-76; Kardaras, Αβαροι 86-102.
36 Daim, Avars and Avar Archaeology 481-482; Pohl, Awaren 256-282; Curta, Southeastern Europe 76-78; Kardaras, Αβαροι 118-126, 137-155. On the siege of 626 cf. also Hambanić, Posledná.
former Roman fortress at Lake Balaton, where a “sub-Mediterranean” agriculture based on the cultivation of wine, wheat and walnut had continued until the 7th century, as recent palaeo-environmental studies by Sümegi et alii have demonstrated (fig. 2).37

The Middle Avar period (630-680 AD)

The crisis in the aftermath of 626 was followed by a phase of “re-organisation of the Avar Empire” between the 630s and 670s, as Daim has outlined; from the mid-7th century onwards one observes also again an increased inflow of Byzantine coins and objects, now presumably through trade and as diplomatic gifts rather than from plunder and as tribute. Towards the end of this period, the “process during which the Avar Empire had gradually re-gained its strength had (…) been more or less completed”38. This process included also the extension of settlement in various areas, such as the Vojvodina, along the Danube to the west and in the core region of Avar power between Danube and Tisza (fig. 2).39 Confiming these archaeological observations, data from Lake Baláta (fig. 2) indicates increasing stock-breading activity as well as cereal cultivation from the mid-7th century onwards.40 Much less reliable (see above), also the trajectories of grain pollen from three sites in Hungary show an upwards trend of agricultural output in the 7th century (fig. 4). Also Curta assumes population growth during this period, contributing and benefiting from socio-economic changes, which also have been proposed by Herold on the basis of her re-interpretation of Avar ceramics. For her the emergence of “slow-wheel-turned pottery” in the Middle Avar period “reflects a change in the organisation of pottery production, which was most likely connected to other (economic) changes in the Avar Khaganate that are less readily detectable by archaeological methods”41.

Consolidation and growth would also have been supported by climatic trends; the reconstructions of Büntgen et alii still show often fluctuating temperature and precipitation conditions for these decades, but not long periods of more extreme colds and droughts as in the preceding period (fig. 1, middle). Some extremely dry years (647, 662 and 671) and a cold one (648) clustered around the middle of the 7th century; for 647/648 we also learn about heavy storms in Constantinople42. From the Carpathian Basin, the data of Lake Nádas indicates an increase of temperatures from the mid-7th century onwards (fig. 3).43

37 Daim, Avars and Avar Archaeology 473-476; Pohl, Awaren 282; Sümegi et alii, Reconstruction, esp. 557-564; Sümegi et alii, Fenékpuszta, esp. 11-12; Varga et alii, Multivariate Statistics. For the import of wine from the Byzantine Mediterranean cf. Csiky / Magyar-Harsheghyi, Wine.
38 Daim, Avars and Avar Archaeology 481-490, 517; Daim, Byzantine Belt Ornaments 66-67; Pohl, Awaren 282-287; Curta, Southeastern Europe 90-92.
39 Stadler, Ethnische Gruppen 126-127 (who assumes that the expansion to the west also included the “re-integration” of Slavic groups temporarily part of the realm of Samo between 630 and 660); Balogh, Problems; Bugarski, The Geomorphological Matrix; Odler, Avarské sídliská; Noche-Dowdy, Multi-Isotope Analysis 25-26; Knipl / Sümegi, Life at the interface, esp. 445; Curta, Southeastern Europe 92.
40 Sümegi et alii, Extreme Dry Climate, esp. 481-484.
41 Curta, Southeastern Europe 92-93; Herold, Insights 225-227.
42 Telelis, Μετεωρολογικά φαινόμενα pp. 224, 299-302. Cf. Cook et alii, Old World megadroughts.
43 Sümegi et alii, Middle Age; Vadas / Rácz, Climatic Changes 212 (fig. 2).
The Late Avar period and the end of Avar rule (680-822 AD)

Agricultural and demographic growth did not necessarily strengthen the central power, but may have contributed to a greater autonomy of various groups and regions within the Khaganate on the basis of increased resources. Already the turn from the middle to the late Avar period was marked in 680/681 by a conflict between the Khagan and a group of descendants of deportees from the Balkans under the leadership of Kouber; obviously, they possessed a distinct organisation as community, left the Avar realm and crossed the Danube until reaching Byzantine territory.

Also climatic condition became more turbulent again, with a dramatic cooling trend between 685 and 690, the coldest summer in the late period; strong ups and downs also characterised precipitation, with minima in 688 and especially 695, one of the driest years in this period, while 700 was extremely wet (fig. 1, middle). Warmer conditions returned from 695 to 709, followed by another short term cooling with a minimum in 714 (fig. 1, middle and bottom). Accordingly, we learn about harsh winters and great floods in Carolingian sources for 709-711, floods in Rome in the winter of 716/717 and an extreme winter during the Arab siege of Constantinople in 717/718. Such extreme colds were not seen again until the mid-740s (fig. 1, bottom).

Archaeological evidence and data from Lake Baláta (fig. 2) suggest a continuation of growth until the mid-8th century; this may have led to a “better organised and more ‘egalitarian’ society for the Late Avar Period, also reflected in the metal finds, which become much more widespread and more unified in the Late Avar Period”. This could have further promoted a “shift of power away from the centre”, as Daim has called it, with border regions gaining greater weight and the emergence of regional centres such as Carantania at the western periphery of the Khaganate, which from the 740s onwards allied with Bavaria. Also Peter Stadler has observed regional differentiation on the basis of material findings and identifies 14 regional clusters, which were characterised by more dense internal exchange. Between the middle and end of the 8th century, however, growth of settlement and agricultural output seems to have been replaced by stagnation or even recession in some regions of the Khaganate; archaeologists state an “end of colonisation” between Danube and Tisza and of the expansion of settlement in modern-day Slovakia around that time, for instance. The (problematic) pollen data from the three sites already mentioned (fig. 4), but especially also the analysis of the much better dated sediments in Lake Baláta in

44 Cf. Hämäläinen, Comanche Empire, esp. 348-350, and Hämäläinen, Kinetic Empire, for similar observations on the interplay between economic expansion, centrifugal forces and cohesion of a nomadic polity.  
45 Pohl, Awaren 278-281; Curta, Southeastern Europe 106-107; Kardaras, Άβαροι 177-179. 
46 Also confirmed in the reconstruction of Cook et alii, Old World megadroughts. 
47 McCormick et alii, Geodatabase nr. 687 and 688; Telélis, Μετεωρολογικά φαινόμενα nr. 249, 321-323; Stathakopoulos, Famine nr. 208; Newfield, The contours of disease and hunger 418 (nr. 1-11); Glaser, Klimageschichte 56-57. 
48 Sümegi et alii, Extreme Dry Climate, esp. 481-484. 
49 Herold, Insights 225-227; cf. Curta, Southeastern Europe 92-93. 
50 Daim, Avars and Avar Archaeology 503-504, 511; Pohl, Awaren 292-308; Curta, Southeastern Europe 92-95. 
51 Stadler, Quantitative Studien, esp. map 201; Stadler, Ethnische Gruppen, esp. 118-120, 126-127. 
52 Balogh, Problems; Odler, Avarské sídliská.
Southwestern Hungary indicate downwards trends of agricultural output in the second half of the 8th century.\(^{53}\)

Again, less beneficial climatic conditions may have contributed to this reversal of trends; locally, the data from Lake Nádas shows a change towards drier conditions from the 7th to the 8th century (fig. 3).\(^{54}\)

In the data of Büntgen et alii, drier spring conditions show up between 747 and 750 with 749 as extremely dry year (fig. 1, bottom). Not visible in their summer temperature reconstruction is the extreme winter of 763/764, which was probably caused by another major volcanic eruption and is registered both in Latin and in Byzantine sources from Western Europe to the Balkans; but it shows up as a negative extreme in the tree ring series from the Czech Republic for the year 764.\(^{55}\) A short term cold occurred from 771 to 775 (when we learn about heavy storms in Thrace in 774), and two further cold spells until 785/786 (when sources register a harsh winter in Saxony in 785 followed by floods impeding the campaign of Charlemagne) (fig. 1, bottom).\(^{56}\) Stronger fluctuations also continued in precipitation until the end of the 8th century, with dry spells around 764, 773, 782, 790 and especially 797 (fig. 1, bottom). The reconstruction is confirmed by news about droughts in Constantinople in 764 and 766/767, in Saxony in 772, in the Moselle region in 783 and in Burgundy in 797.\(^{57}\) A wet year on the contrast is documented both in the precipitation reconstruction and in the written sources for 793, when constant rain impeded the digging of a canal between Rhine and Danube as initiated by Charlemagne.\(^{58}\)

This canal may also have played a role in the strategic planning of Charlemagne against the Avar Khaganate, which he first attacked in 791. Initial successes were however undone by an equine epizootic, which damaged the war horses of the Carolingian army. This disease may as well have affected the Avars; as Newfield points out: “(…) it is possible that the Avars sustained considerable losses in Pannonia and that this may have partially accounted for their military decline and defeat in 796”. The same may have been true for two epizootics registered in Carolingian sources in 801 and especially in 809/810, when it is said that “Noricum (…) suffered these things in particular, together with the neighbouring regions to it”. This epidemic was accompanied by a widespread drought across Central and Western Europe, as also reflected in the reconstruction of the OWDA (fig. 5) and in the tree

\(^{53}\) Náfrádi et alii, Reconstruction 1567, 1571-1573; Sümegi et alii, Extreme Dry Climate, esp. 489-490.

\(^{54}\) Kiss, Floods 61-62 (with fig. 11).

\(^{55}\) McCormick et alii, Geodatabase nr. 743; Telelis, Μετεωρολογικά φαινόμενα nr. 271, 342-350; Newfield, The contours of disease and hunger 308-310, 418-419 (nr. 18-33); McCormick / Dutton / Mayewski, Volcanoes and the Climate Forcing, esp. 878-881; Dobrovolný et alii, A tree-ring perspective (supplementary material); Glaser, Klimageschichte 56-57.

\(^{56}\) Telelis, Μετεωρολογικά φαινόμενα nr. 278, 357.

\(^{57}\) McCormick et alii, Geodatabase nr. 757; Newfield, The contours of disease and hunger 422 (nr. 45).

\(^{58}\) Telelis, Μετεωρολογικά φαινόμενα nr. 272, 351-352 and nr. 275, 355-356; McCormick et alii, Geodatabase nr. 744, 745, 755, 768; Newfield, The contours of disease and hunger 420-421 (nr. 35, 42), 428 (nr. 66). Cf. Cook et alii, Old World megadroughts.

\(^{59}\) McCormick et alii, Geodatabase nr. 765; Newfield, The contours of disease and hunger 78, 427 (nr. 62); Ettel et alii (eds.), Großbaustelle. The spatial reconstruction of Cook et alii, Old World megadroughts, suggests that these extremely moist conditions were confined to the region around the canal, while droughts affected other parts of the Carolingian Empire.
ring series from the Czech Republic for 810. At this time, the Khaganate after civil wars following the campaign of 791 and a Frankish advance towards the central “Ring” in 796 had already disintegrated into various principalities, many of which were now nominally under Carolingian suzerainty. The last reference to an Avar political entity is dated to 822 AD.

At this time, another longer cold period (from 821 to 840) had started (fig. 1, bottom); Byzantine sources report strong colds, heavy storms and famines in the early 820s. Diseases affected Carolingian troops in “Upper Pannonia” at the river Drave in 820, while equally strong rain, floods and bad harvests afflicted the Carolingian lands in 820-822. Again, volcanic eruptions possibly contributed to these weather extremes across Europe. Thus the Avar era ended at it had begun – with a clustering of extreme weather events.

**Conclusion**

Even before the recent studies mentioned at the beginning of this paper, climatic factors have been proposed as motivator of the migration of the Avars and the emergence of their Khaganate. The same is true for its demise; Györffy and Zólyomi for instance in 1994 hypothesised “that a 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”, since it reduced the resource basis for nomadic pastoralism. As also our short study on the basis of most recent data has shown, “there were almost certainly environmental as well as political factors in the break-up of the Avar Empire”.

But when comparing palaeo-environmental, historical and archaeological data, “one must exercise caution in interpreting the correlations of environmental and social crises”. Simple, mono-causal scenarios cannot do justice to the complex interplay between socio-economic, political and environmental dynamics, especially in their regional variations. In contrast to the hypothesis of Györffy and Zólyomi, our reconstruction indicates that it may have been the growth of settlement and resources, favoured by more stable climatic conditions after the end of the Late Antique Little Ice Age, which

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60 Newfield, The contours of disease and hunger 76-78 (with fn. 242), 169-170, 196-203 (for epizootics in 801 and 809/810), 423-424 (nr. 50-51), 432-435 (nr. 86-91, with translations of sources); Newfield, A great Carolingian panzootic, esp. 200-204; Cook et alii, Old World megadroughts; Dobrovolný et alii, A tree-ring perspective (supplementary material).
61 Cf. Pohl, Awaren 312-328; Curta, Southeastern Europe 130-131.
62 Pohl, Awaren 323.
63 Telelis, Μετεωρολογικά φαινόμενα nr. 302, 379-381, nr. 303, 381-382, nr. 307, 384-385 and nr. 308, 385.
64 Newfield, The contours of disease and hunger 437-440 (nr. 100-110); Glaser, Klimageschichte 56-57. Cf. the OWDA-reconstruction of Cook et alii, Old World megadroughts.
65 McCormick / Dutton / Mayewski, Volcanoes and the Climate Forcing 881-884.
66 For an overview of such approaches see Ráczi, Magyarország környezettörténete; Vadas / Rácz. Climatic Changes.
67 Györffy / Zólyomi, A Kárpát-medence és Etelköz; Vadas / Rácz. Climatic Changes 208-209; Rapan Papeša / Kenéz / Pető, The Archaeobotanical Assessment 265-266.
68 Vadas / Rácz. Climatic Changes 210.
69 Sümegi et alii, Middle Age, esp. 295 for the citation; Vadas / Rácz, Climatic Changes 212.
70 Cf. also Preiser-Kapeller, Collapse.
71 See also Sümegi et alii, Reconstruction, esp. 563 (fn. 85), and Sümegi et alii, Extreme Dry Climate, on this scenario and its problems.
contributed to a differentiation and decentralisation of power within the Khaganate even before the Carolingian offensive. The reversal of this trend at the mid-8th century as outlined above, however, cannot be observed in the neighbouring regions of Bohemia and Southern Poland, where pollen data indicates on the contrast the beginning of agricultural growth in this period\textsuperscript{72}. And while the disintegration of the Avar Empire at the turn from the 8th to the 9th century was once more accompanied by a series of natural disasters, similar conditions affected the Carolingian realm without restricting its ability to expand its power into the Carpathian Basin. Climatic parameters thus were relevant, but on their own not sufficient to explain that the “Avar Empire did not come to grips with the transition to a medieval state”\textsuperscript{73}. Further data and research is necessary to better estimate their actual contribution.

Bibliography

Balogh, Problems: C. Balogh, Problems of colonization in the territory between Danube and Tisza Rivers in the Avar Age [Doctoral dissertation, Budapest 2013].

Bojňanský / Fargašová, Atlas of Seeds and Fruits: V. Bojňanský / A. Fargašová, Atlas of Seeds and Fruits of Central and East-European Flora. The Carpathian Mountains Region (Heidelberg, New York, Dordrecht, London 2007).

Bowlus, Lechfeld: C. R. Bowlus, The Battle of Lechfeld and its Aftermath, August 955. The End of the Age of Migrations in the Latin West (Aldershot 2006).

Breuer, Byzanz an der Donau: E. Breuer, Byzanz an der Donau. Eine Einführung in Chronologie und Fundmaterial zur Archäologie im Frühmittelalter im mittleren Donauraum (Tettnang 2005).

Brilly (ed.), Hydrological Processes: M. Brilly (ed.), Hydrological Processes of the Danube River Basin. Perspectives from the Danubian Countries (Heidelberg, New York, Dordrecht, London 2010).

Bugarski, The Geomorphological Matrix: I. Bugarski, The Geomorphological Matrix as a Starting Point for Determining the Position of Avar-Time Settlements in Pannonia: the Example of the Bačka Region. Archäologisches Korrespondenzblatt 38, 2008, 437-455.

Büntgen et alii, Climate Variability: U. Büntgen et alii, 2500 Years of European Climate Variability and Human Susceptibility. Science 331, 2011, 578-583.

Büntgen et alii, Cooling and societal change: U. Büntgen et alii, Cooling and societal change during the Late Antique Little Ice Age from 536 to around 660 AD. Nature Geoscience 9, 2016, 231-236.

Büntgen / Di Cosmo, Climatic and environmental aspects: U. Büntgen / N. Di Cosmo, Climatic and environmental aspects of the Mongol withdrawal from Hungary in 1242 CE. Nature Scientific Reports May 2016 (DOI: 10.1038/srep25606).

Cook, Megadroughts: E. R. Cook, Megadroughts, ENSO, and the Invasion of Late-Roman Europe by the Huns and Avars. In: W. V. Harris (ed.), The Ancient Mediterranean Environment between Science and History. Columbia Studies in the Classical Tradition 39 (Leiden, Boston 2013) 89-102.

\textsuperscript{72} Izdebski et alii, Palynological Data, esp. 17-24 and 27.
\textsuperscript{73} Daim, Avars and Avar Archaeology 523.
Cook et alii, Old World megadroughts: E. R. Cook et alii, Old World megadroughts and pluvials during the Common Era. Science Advance, November 2015 (DOI: 10.1126/sciadv.1500561).

Csiky / Magyar-Harsheghyi, Wine: G. Csiky / P. Magyar-Harsheghyi, Wine for the Avar elite? Amphorae from Avar period burials in the Carpathian Basin. In: G. R. Tsetskhladze / A. Avram / J. Hargrave (eds.), The Danubian Lands between the Black, Aegean and Adriatic Seas (7th Century BC-10th Century AD) (Oxford 2015) 175-182.

Curta, Southeastern Europe: F. Curta, Southeastern Europe in the Middle Ages 500–1250. Cambridge Medieval Textbooks (Cambridge 2006).

Curta (ed.), The Other Europe: F. Curta (ed.), The Other Europe in the Middle Ages. Avars, Bulgars, Khazars, and Cumans. East Central and Eastern Europe in the Middle Ages, 450-1450, 2 (Leiden, Boston 2008).

Curta, Avar Blitzkrieg: F. Curta, Avar Blitzkrieg, Slavic and Bulgar Raiders, and Roman Special Ops: Mobile Warriors in the 6th-Century Balkans Central Eurasia in the Middle Ages. In: I. Zimonyi / O. Karatay (eds.), Studies in Honour of Peter B. Golden (Wiesbaden 2016) 69-90.

Daim (ed.), Awarenforschungen: F. Daim (ed.), Awarenforschungen. Archaeologica Austriaca Monographien 1. Studien zur Archäologie der Awaren 4 (Vienna 1992).

Daim et alii (eds.), Hunnen und Awaren: F. Daim et alii (eds.), Hunnen und Awaren: Reitervölker aus dem Osten. Begleitbuch und Katalog. (Eisenstadt 1996).

Daim, Structures of Identification: F. Daim, Archaeology, Ethnicity and the Structures of Identification: The Example of the Avars, Carantanians and Moravians in the Eighth Century. In: W. Pohl / H. Reimitz, Strategies of Distinction. The Construction of Ethnic Communities, 300-800 (Leiden, Boston, Cologne 1998) 71-93.

Daim (ed.), Die Awaren am Rand: F. Daim (ed.), Die Awaren am Rand der byzantinischen Welt. Studien zu Diplomatie, Handel und Technologietransfer im Frühmittelalter, Monographien zur Frühgeschichte und Mittelalterarchäologie 7 (Innsbruck 2000).

Daim, Avars and Avar Archaeology: F. Daim, Avars and Avar Archaeology: An Introduction. In: H.-W. Goetz / J. Jarnut / W. Pohl (eds.), Regina and Gentes. The Relationship between Late Antique and Early Medieval Peoples and Kingdoms in the Transformation of the Roman World (Leiden, Boston 2003) 463-570.

Daim, Byzantine Belt Ornaments: F. Daim, Byzantine Belt Ornaments of the 7th and 8th Centuries in Avar Contexts. In: Ch. Entwistle / N. Adams (eds.), Intelligible Beauty: recent research on Byzantine jewellery. British Museum Research Publication 178 (London 2010) 61-71.

Dobrovolný et alii, A tree-ring perspective: P. Dobrovolný et alii, A tree-ring perspective on temporal changes in the frequency and intensity of hydroclimatic extremes in the territory of the Czech Republic since 761 AD. Climate of the Past 11, 2015, 1453-1466.

Eitzinger et alii, Auswirkungen einer Klimaänderung: J. Eitzinger et alii, Auswirkungen einer Klimaänderung auf den Wasserhaushalt des Neusiedler Sees. BOKU-Met Report 1 (Vienna 2009).

Ettel et alii (eds.), Großbaustelle: P. Ettel et alii (eds.), Großbaustelle 793. Das Kanalprojekt Karls des Großen zwischen Rhein und Donau. Mosaiksteine 11 (Mainz 2014).

Franz / Riha / Schubert, Plagues in Nomadic Contexts: K. Franz / O. Riha / Ch. Schubert (eds.), Plagues in Nomadic Contexts: Historical Impact, Medical Responses, Cultural Adaptations in Ancient to Mediaeval Eurasia (Leiden, forthcoming).
Gałka et alii, A 9000 year record: M. Gałka et alii, A 9000 year record of cyclic vegetation changes identified in a montane peatland deposit located in the Eastern Carpathians (Central-Eastern Europe): Autogenic succession or regional climatic influences? Palaeogeography, Palaeoclimatology, Palaeoecology 449, 2016, 52-61.

Gębica et alii, Medieval accumulation: P. Gębica et alii, Medieval accumulation in the Upper Dniester river valley: The role of human impact and climate change in the Carpathian Foreland. Quaternary International 293, 2013, 207-218.

Glaser, Klimageschichte: R. Glaser, Klimageschichte Mitteleuropas. 1200 Jahre Wetter, Klima, Katastrophen (Darmstadt ²2008).

Gunn (ed.), Year without Summer: J. D. Gunn (ed.), The Year without Summer. Tracing A.D. 535 and its Aftermath (2000).

Györyffy / Zólyomi, A Kárpat-medence és Etelköz: Gy. Györyffy / B. Zólyomi, A Kárpat-medence és Etelköz képe egy évezred előtt, in: Gy. Györyffy / L. Kovács (eds.), Honfoglalás és régészet (Budapest 1994) 13-37.

Gyulai, Archaeobotany in Hungary: F. Gyulai, Archaeobotany in Hungary. Seed, Fruit, Food and Beverages Remains in the Carpathian Basin: an Archaeobotanical Investigation of Plant Cultivation and Ecology from the Neolithic until the Late Middle Ages (Budapest 2010).

Gyulai, The History of Broomcorn Millet: F. Gyulai, The History of Broomcorn Millet (Panicum Miliaceum L.) in the Carpathian-Basin in the Mirror of Archaeobotanical Remains II. From the Roman Age until the Late Medieval Age. Columella - Journal of Agricultural and Environmental Sciences 1, 2014, 39-47.

Haldon et alii, Climate: J. F. Haldon et alii, The Climate and Environment of Byzantine Anatolia: Integrating Science, History, and Archaeology. Journal of Interdisciplinary History 45,2, 2014, 113-161.

Hämäläinen, Comanche Empire: P. Hämäläinen, The Comanche Empire (New Haven, London 2008).

Hämäläinen, Kinetic Empire: P. Hämäläinen, What's in a concept? The kinetic empire of the Comanches. History and Theory 52 (1), 2013, 81-90.

Herold, Insights: H. Herold, Insights into the chronology and economy of the Avar Khaganate and the post-Avar Period: pottery production and use in the Carpathian Basin from the late 6th to the 10th century AD. Acta Archaeologica Carpathica 49, 2014, 207-229.

Hurbanič, Posledná: M. Hurbanič, Posledná vojna antiky. Avars ký útok na Konstantinopol roku 626 v historických súvislostiach. Byzantinoslavica, Monographiae I. (Prešov 2009).

Hurbanič, Vpády Avarov: M. Hurbanič, Vpády Avarov na balkánske územia Východorímskej ríše v rokoch 582-626. Historický časopis 63/3, 2015, 387-404.

Izdebski et alii, Palynological Data: A. Izdebski et alii, On the Use of Palynological Data in Economic History: New Methods and an Application to Agricultural Output in Central Europe, 0–2000 AD. Munich Personal RePEc Archive Paper No. 54582, March 2014 (online: http://mpra.ub.uni-muenchen.de/54582/)

Juhász, Reconstitution palynologique: I. Juhász, Reconstitution palynologique de la végétation depuis le Tardiglaciaire dans la région de Zala, sud-est de la Hongrie [PhD Dissertation. University of Aix-Marseille III and University of Pécs, 2002].
Kardaras, Άβαροι: G. Th. Kardaras, Το Βυζάντιο και οι Άβαροι (ΣΤ´-Θ´ αι.). Πολιτικές, διπλωματικές και πολιτισμικές σχέσεις (Athens 2010).

Kislinger, Angriff: E. Kislinger, Ein Angriff zu viel. Zur Verteidigung der Thermopylen in justinianischer Zeit. Byzantinische Zeitschrift 91, 1998, 49-58.

Kislinger, Regionalgeschichte: E. Kislinger, Regionalgeschichte als Quellenproblem. Die Chronik von Monembasias und das sizilianische Demenna: Eine historisch-topographische Studie (Vienna 2001).

Kiss, Floods: A. Kiss, Floods and Long-Term Water-Level Changes in Medieval Hungary [Doctoral dissertation, Budapest 2011].

Knipl / Sümegi, Life at the interface: I. Knipl / P. Sümegi, Life at the interface of two distinct landscapes - relationship of humans and environment in the periphery of the Danube-Tisza Interfluve between Hajós and Császártöltés. Central European Journal of Geosciences 4(3), 2012, 439-447.

Kończ, 568: I. Kończ, 568 - a Historical Date and its Archaeological Consequences. Acta Archaeologica Academiae Scientiarum Hungaricae 66, 2015, 315-340.

Kovács, Dispersal History: Zs. E. Kovács, Dispersal history of an invasive rodent in Hungary - subfossil finds of rattus rattus. Acta Zoologica Academiae Scientiarum Hungaricae 58 (4), 2012, 379-394.

Krämer, Hungerkrise: D. Krämer, “Menschen grasten nun mit dem Vieh”. Die letzte große Hungerkrise der Schweiz 1816/17 (Basel 2015).

Lóczy (ed.), Landscapes: D. Lóczy (ed.), Landscapes and Landforms of Hungary. World Geomorphological Landscapes (Heidelberg, New York, Dordrecht, London 2015).

McCormick / Dutton / Mayewski, Volcanoes and the Climate Forcing: M. McCormick / P. E. Dutton / P. A. Mayewski, Volcanoes and the Climate Forcing of Carolingian Europe, a.d. 750–950. Speculum 82, 2007, 865-895.

M. McCormick et alii, Climate Change: M. McCormick et alii, Climate Change during and after the Roman Empire: Reconstructing the Past from Scientific and Historical Evidence. Journal of Interdisciplinary History 43, 2, 2012, 169-220.

McCormick et alii, Geodatabase: M. McCormick et alii, Geodatabase of Historical Evidence on Roman and Post-Roman Climate, DARMC Scholarly Data Series, Data Contribution Series # 2012-1 (Cambridge, Mass. 2012) online: https://dataverse.harvard.edu/dataset.xhtml?persistentId=hdlm1902.1/22615

Náfrádi et alii, Future Climate Impacts: K. Náfrádi et alii, Future Climate Impacts in Woodland and Forest Steppe Based on Holocene Paleoclimatic Trends, Paleobotanical Change in Central Part of the Carpathian Basin (Hungary). American Journal of Plant Sciences 4, 2013, 1187-1203.

Náfrádi et alii, Reconstruction: K. Náfrádi et alii, Reconstruction of the Vegetation and Environment during Different Climatic and Sociotechnical Conditions of the Last 3000 Years in Southwestern Hungary. American Journal of Plant Sciences 5, 2014, 1557-1577.

Newfield, The contours of disease and hunger: T. Newfield, The contours of disease and hunger in Carolingian and early Ottonian Europe (c.750–c.950 CE) [Doctoral dissertation, McGill University, Montreal 2010].

Newfield, A great Carolingian panzootic: T. Newfield, A great Carolingian panzootic: the probable extent, diagnosis and impact of an early ninth-century cattle pestilence. Argos 46, 2012, 200-210.
Noche-Dowdy, Multi-Isotope Analysis: L. D. Noche-Dowdy, Multi-Isotope Analysis to Reconstruct Dietary and Migration Patterns of an Avar Population from Sajópetri, Hungary, AD 568-895 (MA Thesis, University of South Florida 2015).

Odler, Avarské sídliská: M. Odler, Avarské sídliská v strednej Európe: problémová bilancia. Studia Mediævalia Pragensia 11, 2012, 17-96.

Pfeilschifter, Kaiser: R. Pfeilschifter, Der Kaiser und Konstantinopel. Kommunikation und Konfliktäußerg in einer spätantiken Metropole (Berlin, Boston 2013).

Pinke et alii, Settlement patterns: Z. Pinke et alii, Settlement patterns as indicators of water level rising? Case study on the wetlands of the Great Hungarian Plain. Quaternary International (2016) (in print).

Pohl, Awaren: W. Pohl, Die Awaren. Ein Steppenvolk in Mitteleuropa 567-822 n. Chr. (Munich 2015).

Preiser-Kapeller, Collapse: J. Preiser-Kapeller, A Collapse of the Eastern Mediterranean? New results and theories on the interplay between climate and societies in Byzantium and the Near East, ca. 1000–1200 AD. Jahrbuch der Österreichischen Byzantinistik 65, 2015, 195-242.

Priskin, Horses: K. Priskin, Archaeogenetic Analysis of the Avar and Early Hungarian Horses from the Carpathian Basin [Doctoral Dissertation, Szeged 2010].

Rácz, Magyarország környezettörténete: L. Rácz, Magyarország környezettörténete az újkorig (Budapest 2008).

Rapan Papeša / Kenéz / Pető, The Archaeobotanical Assessment: A. Rapan Papeša / A. Kenéz / Á. Pető, The Archaeobotanical Assessment of Grave Samples from the Avar Age Cemetery of Nuštar (Eastern Croatia). Prilozi Instituta za arheologiju u Zagrebu 32, 2015, 261-288.

Rudnicki, New Avar finds: M. Rudnicki, New Avar finds from the western part of Lesser Poland. Acta Archaeologica Carpathica 44, 2009, 233-249.

Soja et alii, Climate impacts: G. Soja et alii, Climate impacts on water balance of a shallow steppe lake in Eastern Austria (Lake Neusiedl). Journal of Hydrology 480, 2013, 115-124.

Sołtysiak, The plague pandemic: A. Sołtysiak, The plague pandemic and Slavic expansion in the 6th-8th centuries. Archaeologia Polona 44, 2006, 339-364.

Stadler, Quantitative Studien: P. Stadler, Quantitative Studien zur Archäologie der Awaren I (Vienna 2005).

Stadler, Avar Chronology: P. Stadler, Avar Chronology Revisited, and the Question of Ethnicity in the Avar Qaganate. In: Curta, The Other Europe 47-82.

Stadler, Ethnische Gruppen: P. Stadler, Ethnische Gruppen im Awarenreich. In: W. Pohl / M. Mehofer, Archaeology of Identity. Archäologie der Identität (Vienna 2010) 111-143.

Stathakopoulos, Famine: D. Stathakopoulos, Famine and Pestilence in the Late Roman and Early Byzantine Empire. A Systematic Survey of Subsistence Crises and Epidemics. Birmingham Byzantine and Ottoman Monographs 9 (Aldershot 2004).

Sümegi, Link: P. Sümegi, A link between regions - The role of the Danube in the life of European communities. In: Gy. Kovács / G. Kulcsár (eds.), Ten Thousand Years along the Middle Danube. Life and Early Communities from Prehistory to History. Varia Archaeologica Hungarica XXVI (Budapest 2011) 9-41.
Sümegi et alii, Extreme Dry Climate: P. Sümegi et alii, Did an Extreme Dry Climate Lead Actually to the Collapse of the Avar Empire in the Carpathian Basin - A Fact or Fiction? In: Á. Bollók / G. Csíky / T. Vida (eds.), Between Byzantium and the Steppe. Archaeological and Historical Studies in Honour of Csanád Bálint on the Occasion of His 70th Birthday (Budapest 2016) 469-497.

Sümegi et alii, Fenékpuszta: P. Sümegi et alii, The Environmental History of Fenékpuszta with a special Attention to the Climate and Precipitation of the last 2000 Years. Journal of Environmental Geography 2/3-4, 2009, 5-14.

Sümegi et alii, Lake Balaton: P. Sümegi et alii, Holocene paleoclimatic and paleohydrological changes in Lake Balaton as inferred from a complex quantitative environmental historical study of a lacustrine sequence of the Szigliget embayment. Documenta Praehistorica 35, 2008, 33-43.

Sümegi et alii, Long environment change: P. Sümegi et alii, Long environment change in forest steppe habitat of the Great Hungarian Plain based on paleocological data. In: J. Rakoczai / Z. Ladányi (eds), Review of climate change research program at the University of Szeged (2010–2012) (Szeged 2012) 7-24.

Sümegi et alii, Middle Age: P. Sümegi et alii, Middle Age Palaeoecological and Palaeoclimatological Reconstruction in the Carpathian Basin. Időjárás 113/4, 2009, 265-298.

Sümegi et alii, Reconstruction: P. Sümegi et alii. Reconstruction of the environmental history of Keszthely-Fenékpuszta. In: O. Heinrich-Tamáska (ed.), Keszthely-Fenékpuszta im Kontext spätantiker Kontinuitätsforschung zwischen Noricum und Moesia (Budapest et al. 2011) 541–572.

Telelis, Environmental History: I. Telelis, Environmental History and Byzantine Studies. A Survey of Topics and Results. In: T. Kolias / K. Pitsakis (eds.), Aureus. Volume dedicated to Professor Evangelos K. Chrysos (Athens 2014) 737-760.

Telelis, Μετεωρολογικά φαινόμενα: Ι. G. Telelis, Μετεωρολογικά φαινόμενα και κλίμα στο Βυζάντιο, 2 Vol.s (Athens 2004).

Vadas / Rácz. Climatic Changes: A. Vadas / L. Rácz. Climatic Changes in the Carpathian Basin during the Middle Ages. The State of Research. Global Environment 12, 2013, 198-227.

Varga et alii, Multivariate Statistics: P. Varga et alii, Multivariate Statistics on Roman and Migration Period Populations of the Carpathian Basin. Anthropologie 41/1-2, 2003, 135-144.

Varlik, Plague and Empire: N. Varlik, Plague and Empire in the Early Modern Mediterranean World The Ottoman Experience, 1347-1600 (Cambridge 2015).

Vida, Conflict and coexistence: T. Vida: Conflict and coexistence: the local population of the Carpathian Basin under Avar rule (sixth to seventh century). In: Curta (ed.), The Other Europe 13-46.

Vida, Local and Foreign Romans: T. Vida, Local and Foreign Romans? The Problem of the Late Antique Population of the 6th-7th Centuries AD in Pannonia. In: D. Quast (ed.) Foreigners in Early medieval Europe. Thirteenth International Studies on Early Medieval Mobility, Monographien des Römisch-Germanischen Zentralmuseums 78 (Mainz 2009) 233-260.

Vida, Raumkonzepte: T. Vida, Raumkonzepte der Awaren und Byzantiner und deren Auswirkungen im unteren Donauboomen im 6.7. Jahrhundert. In: Sv. Hansen / M. Mayer (eds.) Parallele Raumkonzepte. Topoi Berlin Studies of the Ancient World 16 (Berlin, Boston 2013) 307-323.
Werger / van Staalduinen (eds.), Eurasian Steppes. M. J. A. Werger / M. A. van Staalduinen (eds.), Eurasian Steppes. Ecological Problems and Livelihoods in a Changing World. Plant and Vegetation 6 (Dordrecht, Heidelberg, New York, London 2012).

Whitby, Emperor Maurice: M. Whitby, The Emperor Maurice and his Historian. Theophylact Simocatta on Persian and Balkan Warfare (Oxford 1988).

Zatykó / Juhász / Sümegi, Environmental archaeology: C. S. Zatykó / I. Juhász / P. Sümegi, Environmental archaeology in Transdanubia. Varia archaeologica Hungarica 20 (Budapest 2007).

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Figures

Fig. 1 top: Summer temperature anomalies in the Russian Altai (green) and in Central Europe (orange), C° (in comparison with the period 1900-2003), 500-900 AD; doted lines: 10 years moving average; middle: summer temperature anomalies in Central Europe (orange), C° (in comparison with the period 1900-2003) and reconstructed spring precipitation in Central Europe (blue), 500-700 AD; bottom: summer temperature anomalies in Central Europe (orange), C° (in comparison with the period 1900-2003) and reconstructed spring precipitation in Central Europe (blue), 700-900 AD; (data: Büntgen et alii, Cooling and societal change; Büntgen et alii, Climate Variability; graph: Preiser-Kapeller, 2016).
Fig. 2 Map of selected sites from the Avar period (yellow circles) and sites of origin of palaeoenvironmental data (red triangles) mentioned in the paper (Preiser-Kapeller 2016)
Fig. 3 top: Reconstructed mean temperatures of the coldest and the warmest month in the 2nd-10th cent. AD on the basis of data from Lake Nádas in northern Hungary; bottom: reconstructed mean annual precipitation and water level of the pound in the 2nd-10th cent. AD on the basis of data from Lake Nádas in northern Hungary (data: Sümegi et al., Middle Age; graph: Preiser-Kapeller, 2016)
Fig. 4 Indices of the concentration of grain pollen in samples from the southwest of Lake Balaton (red), Nagy-Mohos (green) and Pölöske (purple), 400-900 AD. Please note that the dating for these layers is highly problematic, which very much limits (or maybe even invalidates) their explanatory value (data: Juhász, Reconstitution palynologique; Zatykó / Juhász / Sümegi, Environmental archaeology; EPD: European Pollen Database [http://www.europeanpollendatabase.net/]; graph: Preiser-Kapeller 2016)
Fig. 5 Reconstruction of summer wetness and dryness across central and western Europe for the year 810 AD; the colour scale from red to green shows the Palmer Drought Severity index, ranging from -4 or less (extreme drought) to +4 or above (extremely moist) (data: Cook et alii, Old World megadroughts; map: Preiser-Kapeller 2016)