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ARCHAEOLOGICAL TOPOGRAPHY

SETTLING STRATEGIES OF HUMAN COMMUNITIES IN PANNONIAN HOLOCENE RIVERSCAPE. A MICRO ZONE CASE STUDY FROM BANAT (ROMANIA)

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Abstract: To balance the advantages and disadvantages of living near a river, communities faced strategic choices when establishing their settlements: settling along an active river channel, a fossil (abandoned) channel, or avoiding watercourses. In this research, we aimed to identify these ancient options, establishing an absolute chronology for the fossil river channels. Therefore, in addition to producing a distribution map of historical human settlements, our study aims to reconstruct part of the local paleo-hydrographic network by integrating multiple methodological approaches. Former human settlements were identified through a systematic field survey covering the entire study area. The paleochannel network was reconstructed using high-resolution LiDAR data, which enabled a detailed analysis of the micromorphology of both inhabited and uninhabited areas. Furthermore, sediment samples were collected by drilling into former riverbeds and analyzed using Optically Stimulated Luminescence (OSL) dating to establish an absolute chronology for each paleochannel.

By correlating the results obtained from these approaches, we achieved a partial reconstruction of the spatial and temporal relationship between past human communities and nearby water resources[1].

Keywords: *Riverscape archaeology, Geoarchaeology, Geochronology, settling strategies, Romanian Banat.*

INTRODUCTION

From the earliest days of humanity, water has been a source of life, both material and spiritual. However, it also posed a constant threat, capable of bringing destruction or death to the property or members of a community. Historical knowledge provides unique opportunities to appreciate the solutions and mechanisms that societies have developed over time in their

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[1] This article is based on research previously presented in the first author's PhD thesis: Floca, C., *Banatul de câmpie, un ținut istoric al apelor. Habitatul uman la confluența râurilor Timiș și Pogăniș*. Cluj-Napoca: Editura Mega. (FLOCA 2024). The thesis was published in Romanian and is available online. The present paper represents an adapted version prepared for publication in English in order to ensure wider dissemination of the research results to the international scientific community. Portions of the text and figures have been reproduced from the doctoral thesis and translated into English. The author retains the copyright to the original material, and its reproduction in this article does not infringe upon any third-party rights.

interaction with water, in all its forms, from rainfall to groundwater[2]. Tradition provides us with contrasting examples of how the absence or excess of water has triggered the decline of ancient civilizations, just as it has facilitated the development of social complexity. Throughout history, humanity has tended to settle near rivers, which offer fertile lands and the potential for greater mobility (particularly the major rivers). The fundamental role that rivers have played in the economic development of societies is also evident in the fact that, nine out of ten urban agglomerations in the world are located in deltas or flood-prone areas[3].

In traditional societies, the life of communities was often constrained by areas adjacent to surface water. For example, agriculture was particularly sensitive to climatic fluctuations and changes in watercourses, resulting in increased societal vulnerability to these variables. If these hydrological changes (a response to climate changes) have been external causes historically leading to phenomena such as the abandonment of settlements, internal factors also operated on a much larger scale[4].

As advancements were made in food production, water management technologies, communication, infrastructure, and economic systems, premodern and capitalist societies began to see the risks of settling near floodplains outweigh the benefits. Previously, communities would often relocate in response to these challenges. However, there has been a shift toward a more proactive approach—modifying the hydrographic system itself through the construction of flood control structures to mitigate these risks.

In any case, settling in a floodplain also entailed significant risks. Beyond socio-economic factors, traditionally seen by classical historiography as key determinants of settlement dynamics or related phenomena, an increasing number of studies concerning the Pannonian Plain attribute an equally important role to hydroclimatic factors in the emergence or shaping of historical processes and events. In this regard, we sought to explore whether Holocene human societies within the Eastern Pannonian Plain had any settling strategies in relation to the historical hydrological network.

The Great Pannonian Plain is one of the most complex fluvial systems in Europe, shaped by tectonic and climatic factors. The latter induced significant vegetation changes, which in turn impacted the hydrography of the region[5]. Throughout history, rivers in this region have significantly altered their courses in response to uneven subsidence processes; these changes fundamentally reshaped the development of the landscape both in areas where the rivers reached and in those they abandoned. While the major rivers followed predictable meandering patterns throughout prehistory, the same cannot be said for the smaller tributary rivers[6], such as the Timiș and Pogăniș. These rivers frequently changed the pattern (morphology) of their channels in alluvial cones, often independently of climatic changes.

Throughout the Holocene, various habitats developed within the ecosystem of the Banat Plain. There were areas permanently covered with water (marshes, ponds), zones with ephemeral stagnation (temporary wetlands), and areas that were rarely or never touched by water, whether adjacent to it or not. The surrounding landscape was highly diverse, not only in hydrological terms but also in the development of vegetation and fauna, which adapted differently to the these environments.

The positioning of communities near expanses of standing water brought a series of benefits provided by the ecosystem developed there, attractive both for hydrophilic and aquatic fauna, significant food resources for past human communities. The biodiversity (species richness) and primary productivity of a marshy or permanently moist habitat in a temperate area are among the most productive ecosystems in existence. According to Dinnin and Van de Noort, primary productivity includes those plant matter (bacteria, algae, plankton) that support the life of the animal kingdom[7]. From a human perspective, the net primary productivity of an ecosystem is critical in determining the quantity of potential natural resources. Regarding risks, climatic fluctuations affected these standing water areas through a slower process than in the case of flowing waters, with the water level varying depending on river levels, groundwater, and precipitation amounts, yet sometimes posing a threat to the settlements surrounding them.

The integration of Banat into the possessions of the House of Habsburg after 1716 marked the beginning of a new era. The structure of the new Western leadership, technically superior and organized on mercantile principles, would be imposed through authoritarian political force. This transition led to major transformations of the entire local habitat, with actions taken by the new administration to "tame" what was considered a vast and hostile territory. Efforts were focused on expanding the land available for agriculture, improving the efficiency of space utilization, and reducing the frequency of natural damages caused by water. In essence, the primary goal was to increase the profitability of the territory[8].

The old natural landscape of the Banat region, characterized by numerous wetlands and marshy areas with valuable resources for archaic communities, was viewed by the new conquerors as a vast, unprofitable land, or even unsuitable for habitation.

This perception led to a dramatic reversal of forces. The force of nature, tangibly expressed in the low plains through the power of surface waters, was fundamentally curtailed by the power of the new society, which reshaped the territory. Watercourses were embanked and partially canalized by eliminating meandering loops (Fig.1). Lands that were previously exploited in patches were drained and expanded, being parceled, consolidated, and aligned. The archaic village, with its disorderly topography, was consolidated and aligned, becoming a dense and orderly agglomeration. Road networks were significantly reduced in density, becoming more linear.

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[2] SULAS/PIKIRAYI 2018.

[3] RIDOLFI/ALBRECHT/DI BALDASSARRE 2020.

[4] LIU *et alii* 2014.

[5] KISS T. *et alii* 2015.

[6] KISS T. *et alii* 2015.

[7] DINNIN/VAN DE NOORT 1999.

[8] GYEMANT 2018; ROTH 1988.

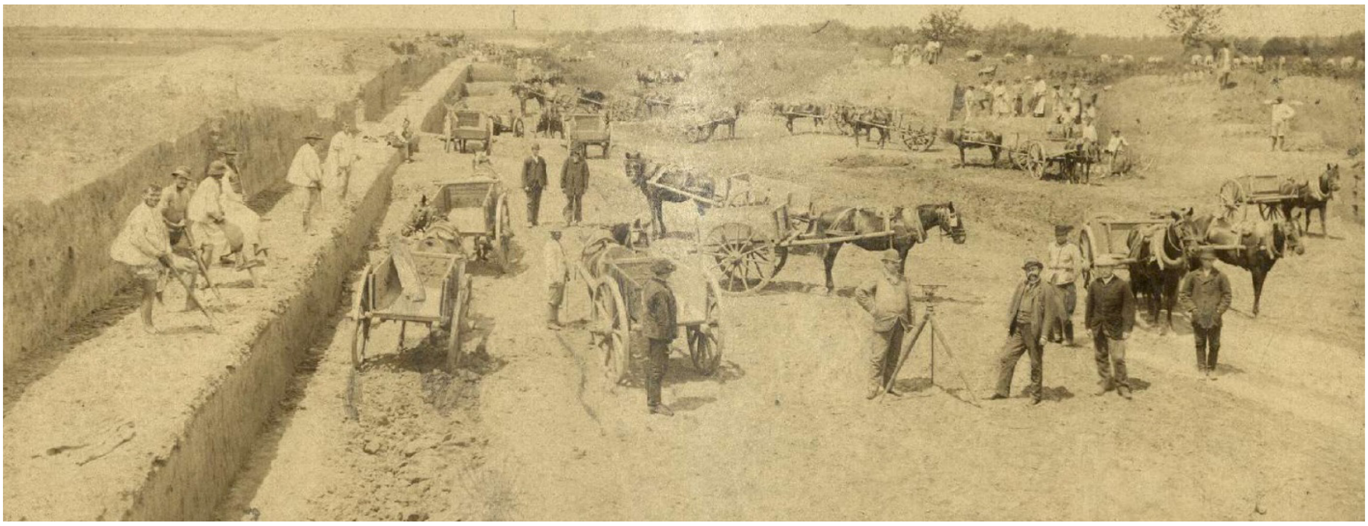

Fig. 1. Hydrotechnical works of a segment of the Timiș River at Sărcia (Serbian Banat). Photograph from 1896 (source: https://maps.hungaricana.hu/en/BFLTervtar/28994/view)

The transformation process in our region began at the first half of the 18th century, but in our study area almost a century later, and its effects became particularly evident towards the end of the 19th century, when the major hydro-improvement projects of the imperial administration were completed.

This palimpsest of natural and cultural landscapes demands a regressive geographical and historical analysis to decrypt and then remove the current anthropically altered layers of the landscape from the last two centuries, in order to reach the earlier natural and cultural layers where archaic communities thrived. Against this backdrop of historical and environmental context, several pertinent questions emerged as research questions: Can we determine the activity period of erstwhile rivers now fossilized? Did past communities preferentially settle only or mainly along active rivers? The main goal was to reconstruct spatial and temporal correlations between hydrography and past human settlements.

Within this natural landscape we developed the following research objectives in order to highlight the settling strategies within a micro-zone from southwestern Romania:

Conduct a systematic field survey to map former human settlements across the entire study area.

Utilize high-resolution LiDAR data to reconstruct the paleochannel network and understand the micromorphology of both occupied and uninhabited areas.

Collect sediment samples from old riverbeds for Optically Stimulated Luminescence (OSL) dating to establish an absolute chronology for each paleochannel.

Analyse the correlation between the mapped settlements, paleochannel network reconstruction, and OSL dating results to partially reconstruct the spatial and temporal relationship between past human populations and nearby water supplies.

STUDY AREA

Our research is based in Banat, a historical region in the southeastern corner of the expansive Pannonian Basin - a notably low-lying geographical feature within the basin (Fig.2). The region is bounded by the Carpathian Mountains to the East and streamed by the Danube to the South, Tisza to the West and Mureș on North (Fig.2), being part of the Western Plain of Romania. Our specific research focus, measuring about 6000 hectares, lies on the convergence of two water streams within the region, specifically the Timiș and the Pogăniș Rivers and is 10 km SE far away to Timișoara city.

During the historical periods before the transformative changes of the 18th and 19th centuries, the region could be accurately described as a rich riverscape and, to some extent, a waterscape filled with marshlands in its lowest reaches. The area was waterlogged by numerous watercourses that frequently inundated the drylands, primarily during historical times. It is important to note that until the beginning of the Holocene (end of the Mesolithic), it is estimated that the rivers of the Pannonian Plain discharged three to eight times more water than they do today[9].

The meandering courses of rivers represented a widespread phenomenon, highly visible within our research area. Over time, both active and inactive (but filled with water) channels have sculpted an intricate network of streams. This labyrinthine waterway system posed formidable barriers to access during historical times and continues to present a complex puzzle to decipher in the present day. Here, the "islands" of dry land, slightly elevated above the water level, have garnered attention from human communities since the inception of early sedentary settlements. The presence of fertile soils and valuable minerals sources from the neighbouring mountains, in conjunction with the presence of freshwater, has exerted a tangible attraction. Over the past two decades of extensive field surveys, hundreds of new archaeological sites, predominantly settlements, have been brought to light, collectively contribute to a progressively more vivid understanding of the historical habitation within the region[10]. The archaeological discoveries highlight a

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[9] KISS T. *et alii* 2015.

[10] For this sites see: Măruia et alii 2011; Măruia et alii 2012; Floca 2013.

Fig. 2. The Pannonian Basin and Historical Banat (grey line), with the study area marked (red).

significant degree of chronological and cultural diversity. This spectrum begins with the early Neolithic communities of the Balkans and extends to encompass the migratory populations from the Far East during the Middle Ages, among many other examples (note that the area is a link between Balkans and Central Europe).

Regarding the historical hydrography of the area, the surveyed land is bordered to the north and west by vast surfaces with frequent wetting or flooding tendencies. The northwest corner of our studied area reaches this low tier, a fact well profiled on the digital terrain model based on LiDAR scans (Fig. 5).

Within this natural context, our research area is naturally delineated by the alluvial cone of the Pogăniș stream and the Timiș River. The confluence of these two watercourses and their hydrological dynamics have shaped a complex, albeit unsophisticated, hydrographic system. Utilizing

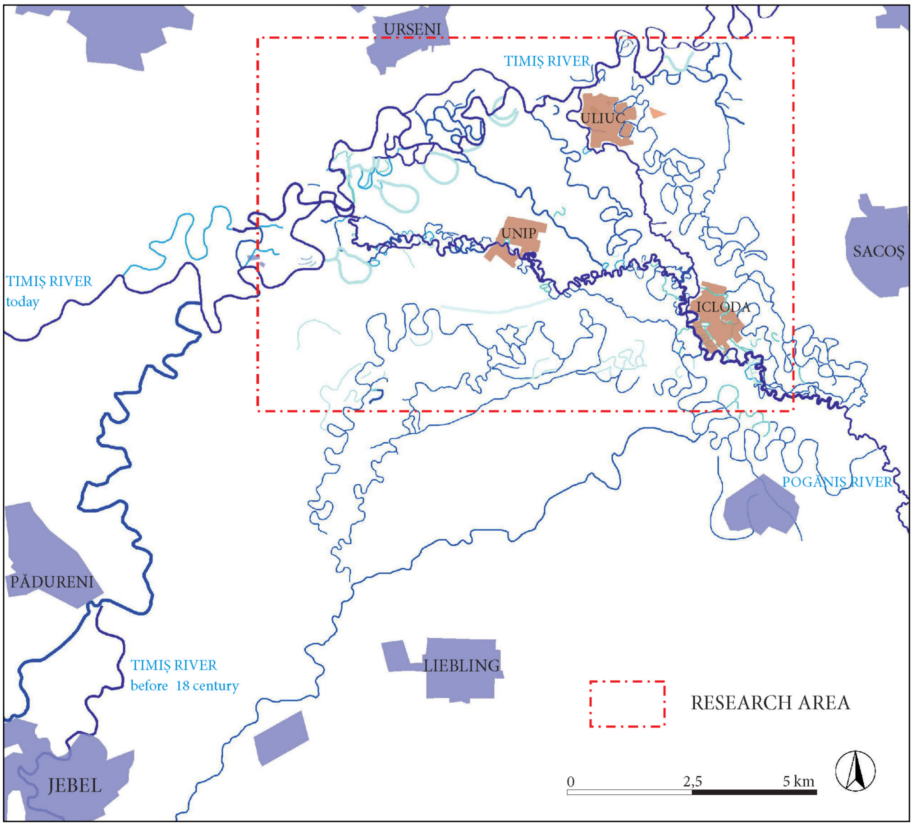

Fig. 3. Historical Pogăniș at the confluence with the Timiș River. The alluvial cone and the studied area (red frame).

satellite remote sensing and high-resolution LiDAR data, we have delineated the alluvial cone of the Pogăniș stream, which spans approximately 11,000 hectares and resembles the shape of a wide fan (Fig. 3). As the capturing river (Timiș) retreated northward and abandoned its old channels, the Pogăniș also shifted its course to a more restricted area, covering roughly 6,000 hectares. In this zone, the stream has formed a dense network of meandering channels, comprising six distinct generations, each clear in its path, which we have found suitable for attempts to reconstruct the evolution and dynamics of the area.

DATA AND METHODS

Our methodological approach pursued dual objectives. First, we aimed to map the historical settlements of the region through systematic field surveys. Simultaneously, we aimed to uncover the dynamics of historical hydrography. This was achieved using satellite remote sensing and LiDAR-based DTMs for spatial reconstruction of paleochannels, while another research trajectory focused on geoarchaeology, specifically geochronology, to ascertain the timeframe of the historical network of streams.

a. Systematic archaeological field survey

The various wandering generations of the Pogăniș stream broadly defined the physical boundaries of the terrain subjected to systematic survey. The natural boundaries defined by current or historical hydrographic landmarks encompass an investigation area spanning 6,000 hectares, including the core areas of three localities (Unip, Uliuc, Icloda), 335 hectares of forest (Pădurea Unip), and the floodplains of two river segments in the area (Timiș and Pogăniș), along with their associated water bodies (>50 ha). From the onset, we recognized that a realistic analysis of human and natural habitats could not be conceived without systematic data acquisition from the field.

We initially intended spatial analysis to be a cornerstone of the study, hence the desire to create an accurate map of the settlements, viewed in relation to the hydrographic network map. For this reason, overlapping settlements from different eras under the same boundary were seen as a deficit. Thus, before starting field verification, it was established that each cluster of artifacts that could be chronologically associated (epoch, phase, culture) should be delineated as a distinct archaeological site, regardless of the presence in the same area of artifacts from a different epoch.

The vast majority of artifacts collected from the surface survey, on which the dating of archaeological sites was based, consisted of ceramic fragments. Regarding ceramics, the dating of materials was relatively, based solely on typological classification. Periodization and correlation to absolute chronology were conducted following the guidance of several general (regional) monographs or applied (zonal) studies[11].

For the Middle Ages, we used, to some extent, the periodization of Pál Engel and Hungarian historiography[12], but with some substantive and formative changes (terminology), which we considered appropriate for the situation of the artifacts from the survey.

b. Absolute dating of Pogăniș alluvial fan using Optically Stimulated Luminescence (OSL)

For the application of geochronological methods, we attempted the absolute dating of various generations that shaped the alluvial cone of the Pogăniș stream using Optically Stimulated Luminescence (OSL) dating. Sample processing took place at the Luminescence Dating Laboratory of the Department of Physical Geography and Geoinformatics at the University of Szeged, Hungary.

An image of the hydrography prior to major modern water regulation interventions can still be clearly discerned in the current geomorphology of the territory. The Digital Terrain Model resulting from LiDAR scans conducted in 2007 for the Romanian Water Administration is highly relevant, representing, along with remote sensing images, the support for spatial reconstruction of paleochannels.

We conducted core drilling at specific key points and extracted samples shielded from sunlight (Fig. 4), from which quartz or feldspars were extracted. Each river generation was subject to 1 or 2 sampling zones, focusing on extracting samples from 1 or 2 samples from the point bar, where the stream deposited sediments during a phase of maximum activity, and one from the fossilized riverbed channel, where the course deposited sediments during a final phase (Fig. 5). In total, 27 boreholes were drilled using a manual corer (Fig. 4), from which over 30 samples were taken for the meticulous processing workflow of OSL dating. Out of these, 27 samples were dated, of which 23 samples are presented in the current study (Tab.1). A total of 3 samples were dated for an older generation of the river, named Pogăniș 7, and were estimated to be between 36-38,000 BP. The southern location of this generation, outside the archaeological research area, led us to exclude the data from this study. A fourth sample had problematic dating.

Each sample was assigned an indicator, marking the river generation (e.g., PI=Pogăniș 1), numbered from I to VI. Indicators were given to paleochannels based on a criterion of relative dating (as a working hypothesis), based on initial fluvial geomorphology observations from LiDAR; the numbering assumes that the number increases directly proportional to the age of the watercourse, such that P.I is the current Pogăniș and P.VI is the oldest course. The absolute datings will slightly overturn this initial relative order, without, however, affecting the discourse regarding historical times, which is of interest to us. This allowed us to establish the timeframes during which each channel was active by analysing two phases of sediment deposition. Sediment samples, collected using a cylindrical tube (Fig. 4), were protected from light exposure during both collection and laboratory processing, ensuring accuracy in the dating

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[11] LAZAROVICI/LAZAROVICI 2006; 2007; GOGÂLTAN 1999; GUMĂ 1993; MĂRUIA *et alii* 2019.

[12] PÁL 2006.

Fig. 4. OSL working flow. A: Sampling on the Pogăniș II generation, penetration of the first layers by coring; B: sample retrieval using a detachable head; C: The physical processing of the sample for separating the elements in the dark room; D: RISO TL/OSL DA-20 type luminescence reader with sample discs.

process. The samples underwent several physical and chemical procedures in a darkroom to isolate pure quartz from the rest of the sample (Fig. 4-C).

OSL dating was performed on the quartz fraction of samples, mostly from medium and coarse sand, which can represent either point bar or channel sediments. In the most cases, the usual coarse grain preparation techniques was used through the dating procedure[13]. Through sieving the coarser, but still usable amount of material for dating, was separated. The carbonate and organic material content was removed by 10% HCl and 10% H2O2 acids. The quartz was separated to the other minerals by heavy liquid (2.63-2.67 g/cm3) and a 50 minutes 40% HF treatments.

Samples equivalent dose (De) was determined by using a RISO TL/OSL DA-20 luminescence reader, which equipped with a calibrated 90Sr/90Y source, blue (470 nm) and IR (870 nm) LEDs[14]. Detection was made through a U-340 filter (quartz). Quartz measurements were made using the regular SAR (Single Aliquot Regeneration) protocol[15]. Based on preheat and dose recovery tests, the preheat temperature was set 220°C with the 160 °C Cut heat.

OSL intensities were fitted with a single saturating exponential function. Based on Murray/Wintle[16], standard rejection criteria were used to select the correct aliquots. The feldspar contamination was monitored by the IR/OSL depletion ratio as proposed by Duller[17]. Sample De values was calculated using central age model (CAM) or minimum age model (MAM)[18], based on the CAM overdispersion values, in the R luminescence package[19]. The abanico plots[20] were generated also in RStudio.

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[13] SIPOS/KISS/TÓTH 2016; TÓTH *et alii* 2017.

[14] BØTTER-JENSEN/THOMSEN/JAIN 2010.

[15] MURRAY/WINTLE 2000, 2003; WINTLE/MURRAY 2006.

[16] MURRAY/WINTLE 2000.

[17] DULLER 2003.

[18] GALBRAIGHT *et alii* 1999.

[19] KREUTZER *et alii* 2012.

[20] DIETZE *et alii* 2016.

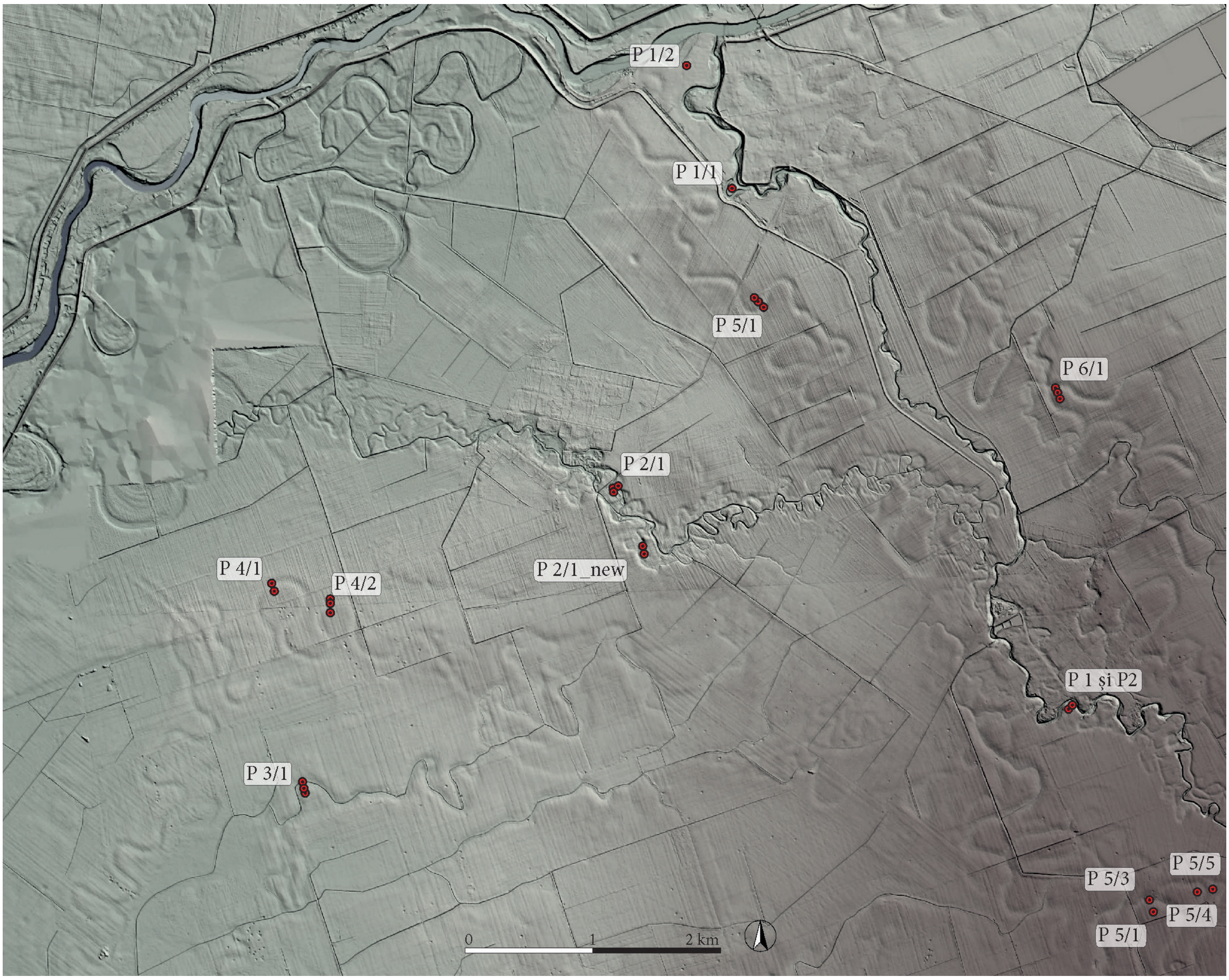

Fig. 5. Map of the distribution of OSL samples. Digital Terrain Model (LiDAR, ABA Banat/POS Mediu).

Environmental dose rate (D*) was determined with high-resolution, extended range gamma spectrometry (Canberra XtRa Coaxial Ge detector). The dry dose rates were assessed on Adamiec and Aitken conversion factors[21]. Attenuation factors for α and β dose rates were used after Brennan/Lyons/Phillips (1991) and Brennan (2003)[22]. Wet dose rates were calculated from in situ water contents[23]. The cosmic ray exposure of the samples was determined from the equation of Prescott and Hutton[24].

The spatial and chronological evolution of the Timiș River, especially complex in the northern area of the study region, is challenging to reconstruct in absolute terms, and this study does not attempt to do so. However, at least part of this river's trajectory can be relatively dated and associated with the ages determined for the Pogăniș, aiding spatial analysis efforts. For example, the confluence point with the Pogăniș II generation indirectly dates this section of the Timiș River, indicating it was an active capturing river during the activity period of the P.II channel.

RESULTS

a. Systematic archaeological field survey

The studied area has witnessed intensive habitation throughout various historical periods (Fig. 6A), boasting a multitude of settlements (over 200 settlements on 6,000 hectares), ranging from the Neolithic period to the Middle Ages (based on ceramic typology), predominantly consisting of small to medium-sized rural, open settlements. Following archaeological surface surveys in the hydrographic system at the confluence of Pogăniș-Timiș, 284 archaeological sites were defined, of which 231 are primary and 53 secondary, covering a broad period of 8,000 years (Fig.11). An additional 15 sites were defined along the riverbeds, consisting of wooden structures preserved by water, representing hydrotechnical installations or bridges[25]. The topography of the sites and the appearance of the artifacts suggest that most of the findings are generally human settlements and to a much lesser extent, sites with other types of activities, such as milling ensembles, metallurgical workshop zones, and a possible tumulus grave).

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[21] ADAMIEC/AITKEN 1998.

[22] BRENNAN *et alii* 1991; BRENNAN 2003.

[23] AITKEN 1985.

[24] PRESCOTT/HUTTON 1994.

[25] FLOCA *et alii* 2021.

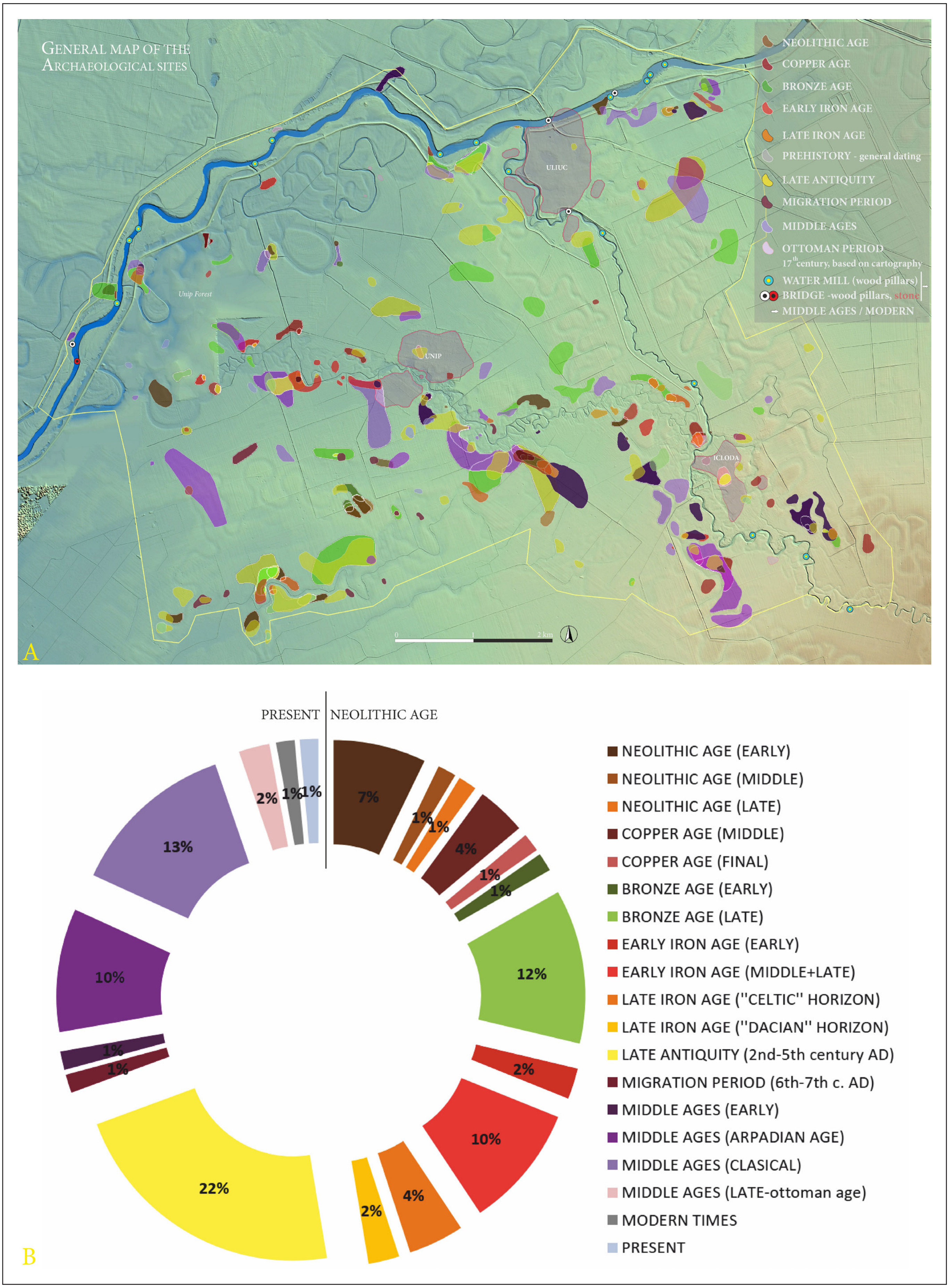

Fig. 6. Archaeological Sites Discovery: A. Digital Terrain Model (LiDAR) showcasing the boundaries of the verified area (highlighted by a yellow line) and sites perimeters (colored polygons); B. The overall chart of archaeological sites, divided by epochs and presented as percentages.

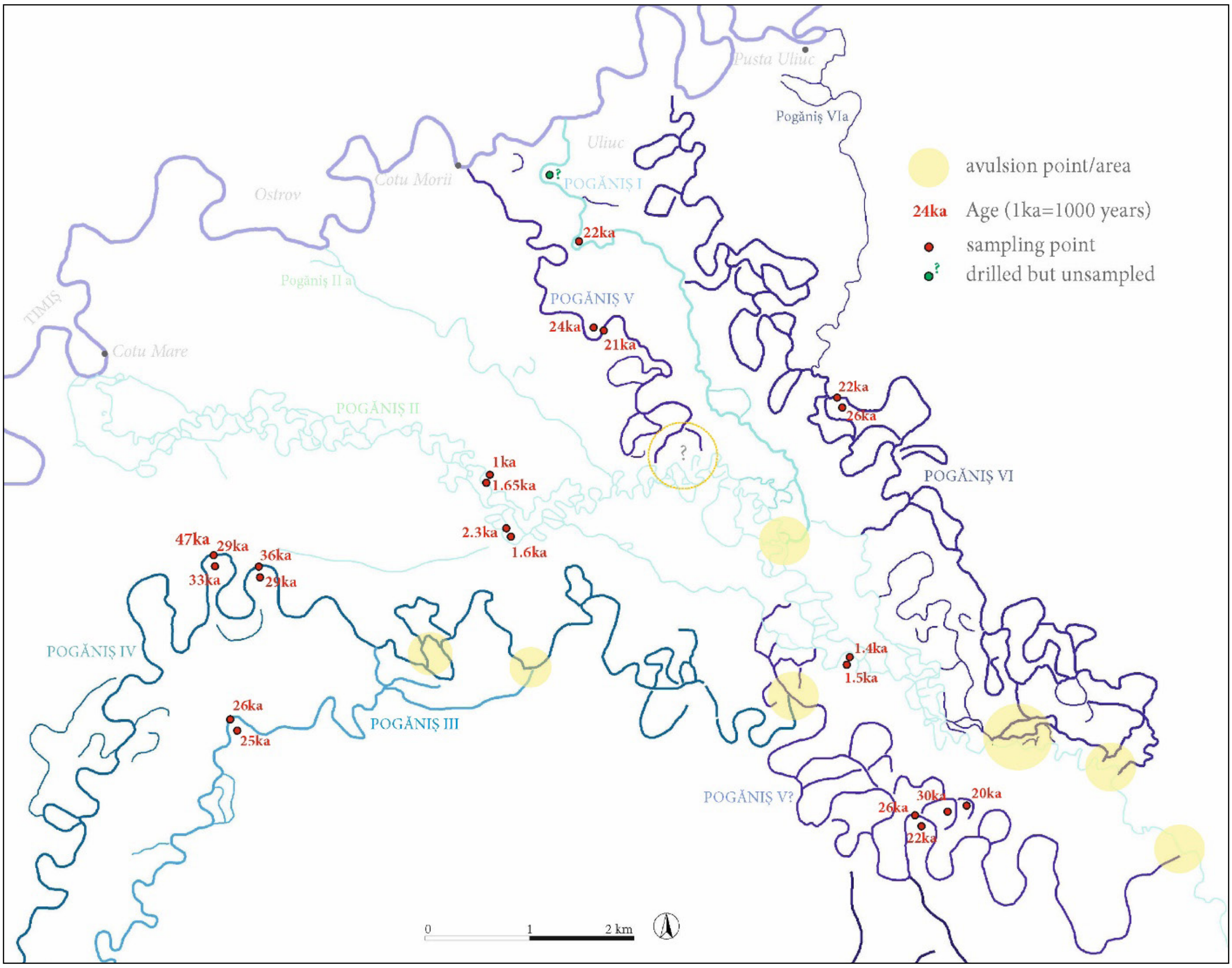

Fig. 7. The alluvial cone of Pogăniș stream with its various generations and their absolute ages.

The density of the sites varies greatly from one era to another. For each major historical stage, there is a peak in habitation, as well as drastic declines in the traces discovered, sometimes reaching zero, even for several centuries (Fig. 6B). The discussion regarding the synchronism of the settlements within a particular chronological stage exceeds the competence of surface surveys, but certainly a significant part of them functioned simultaneously.

b. Absolute dating of Pogăniș alluvial fan using Optically Stimulated Luminescence (OSL) - The Riverscape before Modern Times

The reconstruction of the ancient hydrographic network provides a clear depiction of the riverscape before significant modern hydrotechnical interventions. This network, existing from the Neolithic to the 18th century, comprised naturally shaped active and inactive watercourses, along with minor wetland areas. Geomorphologically, six main generations of channels were carved by the Pogăniș stream in this area, each with its secondary arms.

The absolute dating of the collected samples offers compelling insights (Fig. 7). Excluding the current course of the Pogăniș stream, which remains uncertain in absolute dating terms but likely spans several centuries based on historical and cartographic evidence, Pogăniș II is the only active watercourse during the Holocene. This phase is dated between 1000- and 2300-years BP (Tab. 1). The other four generations display geological ages from the late Pleistocene, ranging from 20,000 to 47,000 years BP, a period corresponding to the last glacial era (Würm).

These Pleistocene channels, inactive during historical times, have persisted as permanently wet, functioning similarly to wetlands, a result of the larger rivers and higher water table of the Pannonian Plain before modern times[26]. Known today as "The Old Pogăniș," the Pogăniș II was active from the Late Iron Age (La Tène) through the Middle Ages (~10th century AD), and likely during prehistoric times, though direct dating samples from these periods are lacking.

Examining the dated alluvial cone map (Fig. 7), it's evident that nearly all channel generations exhibit strong meandering, except for the current course (P.I), which shows reduced activity and has undergone hydrotechnical

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[26] KISS T. *et alii* 2015.

Table 1. Absolute chronology of various generations of channels within the Pogăniș alluvial cone, established using the Optically Stimulated Luminescence method. For Site ID: PB=point bar and CH=channel

Coordinates (GPS, WGS)	Field ID	River generation	Depth (m)	Water content (%)	Grain size (µm)	U (ppm)	U error (ppm)	Th (ppm)	Th error (ppm)	K (%)	K error (%)	Age modell[1]	D*[2](Gy/ka)	De[3] (Gy)	Age (ka)
45°40'17.40"N	P1/1-PB2	**Pogăniș I / P V (?)**	2.6	15±10	90-300	3.06	0.05	11.18	0.24	1.55	0.04	CAM	2.70±0.13	60.11±2.33	**22.3±1.41**
21°21'9.75"E	P1/1-PB2		2.4	14±10	90-300	3.24	0.06	11.95	0.26	1.54	0.04	MAM	2.8±0.14	60.09±3.88	**21.46±1.74**
45°38'9.42"N 21°23'11.41"E	P1+P2 PB2/130	**Pogăniș II**	130	5±5	90-300	1.12	0.02	4.37	0.11	1.48	0.04	CAM	2.06±0.09	3.10±0.22	**1.50±0.13**
45°38'10.62"N 21°23'12.04"E	P1+P2 PB1/90		90	12±10	90-300	2.25	0.04	9.37	0.21	1.39	0.04	CAM	2.40±0.14	3.27±0.42	**1.37±0.19**
45°39'4.19" 21°20'28.36"	P2/1-PB1		250	13	300-360	2,04	0,03	7,45	0,14	1,64	0,06	MAM	2.24±0.15	2.38±0.22	**1.06±0.12**
45°39'4.88" 21°20'30.07"	P2/1-CH		100	7	300-630	0,81	0,01	2,80	0,06	1,15	0,04	CAM	1.43±0.09	2.36±0.24	**1.65±0.20**
45°38'48.06" 21°20'39.44"	P2/1_new -PB1		2.2	16±10	90-300	1.30	0.03	5.28	0.14	1.58	0.05	CAM	2.00±0.13	4.55±0.34	**2.28±0.22**
45°38'49.81" 21°20'38.97"	P2/1_new -CH		1.4	19±10	11_20	2.29	0.05	8.31	0.20	1.68	0.05	Mean±SE	2.88±0.19	4.54±0.10	**1.58±0.11**
45°37'49.50" 21°18'37.98"	P3/1-PB1	**Pogăniș III**	180	17	90-300	2,27	0,04	9,18	0,20	1,57	0,04	MAM	2.40±0.13	59.46±4.66	**24.75±2.33**
45°37'51.00" 21°18'37.50"	P3/1-CH		215	10	90-300	2,00	0,03	7,69	0,17	1,47	0,06	CAM	2.33±0.15	59.88±2.37	**25.73±1.94**
45°38'35.75" 21°18'47.43"	P4/2-CH	**Pogăniș IV**	300	9	300-630	0,90	0,01	3,38	0,07	1,21	0,05	CAM	1.5±0.09	53.94±2.57	**36.06±2.75**
45°38'35.75" 21°18'47.43"	P4/2-PB1		130	5	90-300	2,04	0,02	7,84	0,14	1,32	0,05	MAM	2.35±0.09	69.13±3.96	**29.42±2.05**
45°38'38.67" 21°18'27.46"	P4/1 PB1/190		190	8	90-300	1.45	0.02	5.50	0.12	1.47	0.06	CAM	2.1±0.09	71.39±2.56	**33.67±1.91**
45°38'40.59" 21°18'26.50"	P4/1 CH/230		230	9	90-300	1.36	0.02	4.72	0.12	1.30	0.05	CAM	1.87±0.09	54.50±2.71	**29.09±1.98**
45°38'40.59" 21°18'26.50"	P4/1 CH/350		350	15	11_20	2.30	0.03	9.94	0.17	1.59	0.06	Average	3.38±0.31	2Do[4] (Gy) 160.09±3.26	**Minimal Age[5](ka)** 47.27±4.45
45°39'51.86" 21°21'18.91"	P5/1 PB2/150	**Pogăniș V**	180	7	90-300	2.32	0.03	8.90	0.17	1.48	0.06	CAM	2.58±0.1	61.58±1.94	**23.95±1.19**
45°39'49.71" 21°21'21.97"	P5/1 CH/240		240	13	300-630	2.30	0.03	8.80	0.15	1.47	0.06	CAM	2.24±0.15	46.94±2.57	**20.99±1.79**
45°37'18.66" 21°23'41.04"	P5/3 PB		130	8	90-300	1,75	0,03	6,44	0,16	1,60	0,07	MAM	2.37±0.1	52.61±3.24	**22.16±1.66**
45°37'21.60" 21°23'39.66"	P5/3-CH		167,5	19	90-300	2,13	0,03	8,93	0,16	1,61	0,06	CAM	2.35±0.13	61.43±3.08	**26.14±1.92**
45°37'23.57" 21°23'56.70"	P5/4-PB		120	13	90-300	2,37	0,03	9,08	0,16	1,43	0,05	MAM	2.41±0.14	74.18±4.47	**30.83±2.55**
45°37'24.30"N 21°24'2.34"E	P5/5-PB		220	11	90-300	2.76	0.04	9.94	0.19	1.67	0.07	CAM	2.77±0.45	56.63±2.69	**20.41±1.47**
45°39'29.25" 21°23'6.26"	P6/1-CH	**Pogăniș VI**	300	14	300-630	1,15	0,02	4,36	0,08	1,39	0,05	CAM	1.67±0.14	37.54±1.3	**22.51±2.05**
45°39'28.34" 21°23'6.93"	P6/1-PB1		130	11	90-300	2,37	0,04	8,97	0,18	1,65	0,07	CAM	2.63±0.15	68.62±2.31	**26.06±1.73**

1-Procedure used to calculate age. MAM (Minimal Age Modell), CAM (Central Age Modell); 2-Total dose rate; 3-Equivalent dose;
4-Saturation dose, the maximum dose that can be absorbed by the sample; 5-Age based on saturation dose. The sample is probably older than this value.

modifications. The P.II course is notably complex in its meandering, indicating prolonged activity along this channel. The other four channels (P.III-VI) show broader meandering with extensive loops.

The early dating of these clearly traced channels (to a large extent) indicates a very stable natural habitat throughout the Holocene, where these paleochannels were neither silted up nor eroded. After this chronological interval, the stream's flow was taken over by the P.II course, which then followed a long and stable path. Although the samples collected do not provide dates older than antiquity for P.II, this is likely due to the sampling locations and depths, which did not reach this chronological tier of the river. Besides the logical deduction from this dating (during the Holocene, one of the generations must have taken over the water flow, being active), a significant historical argument is the density of settlements from all historical epochs, which is highest along the banks of this course, Pogăniș II, directly linking it to the stream's activity from prehistory through the 19th century, when it is known to have been deactivated.

The ages determined for the stream generations III, IV, V, and VI clearly show that their active periods occurred long before human communities settled in the area, as evidenced by artifacts. The chronological order of these four generations, according to the new absolute dating, shows that the oldest course is P.IV, followed by the other three, which are very close in age or even largely overlapping chronologically; this suggests a contemporaneity of certain branches, which would have operated simultaneously, sharing the stream's flow. After the most recent ages, placed around 20,000 years ago, no major sedimentary deposits are recorded in any of the four channels, indicating that the main flow of the stream shifted from these channels, which became inactive branches. When the first civilizations settled in the area, these watercourses were essentially dead arms, but they still retained water in their channels, fostering the development of a rich aquatic ecosystem along them.

Regarding the Timiș River, relative dating based on geomorphological or historical cartographic analysis, combined with the absolute dates of the Pogăniș branches flowing into it, definitively illustrates the presence of an active river in this area throughout the Holocene, even though the exact course of the river cannot be reconstructed with the data we possess.

Also noteworthy are the wetland areas present in the studied region, particularly in the marginal zones (SW, NW, NE - Fig. 6A and Pl. 1-4). Geomorphology, historical cartography, and oral history attest to the presence of several stretches of permanent or ephemeral water, covering areas ranging from several tens to several hundred hectares, true wetlands that allowed the development of diverse and flourishing ecosystems. These historical wetlands would merit a study, alongside that of the rivers.

DISCUSSIONS

Considering both the settlements and the surface water network, it becomes clear that settlement locations are directly linked to the terrain's morphology, primarily shaped by the hydrography. Settlement placement, whether near active or inactive riverbeds, is generally influenced by the presence of a watercourse. During prehistory, proximity to a watercourse is a common thread, but starting with antiquity, some of the settlements are situated at a greater distance from riverbeds (over 100 meters). For each specific period, we conducted several statistics regarding the distance of archaeological sites from the watercourse (active or inactive), the type of terrain where the settlement is located, its proximity to a particular watercourse, and the total categorization of settlements by the type of watercourse (active or inactive) (Fig. 8).

Neolithic Age - we observe that all Neolithic sites were situated on river terraces, near watercourses (96% bordering the watercourses, and 4% located no more than 100 meters away). The distribution concerning the type of water flow is well-balanced, with half of the discoveries being situated near active watercourses and the other half near inactive ones (Fig. 8; Pl. 1). This proximity to water is not surprising, as it is a characteristic especially of the early communities (Starčevo-Criș) across the low Banat plain[27]. This phenomenon may also be associated to the occupation of fishing, which was an important food source of these ancient communities, in this watererscapes, along with hunting[28].

Copper Age - the discoveries of the Copper Age best speculate the inactive water branches among all the epochs analysed, with 81% of cases (Fig. 8; Pl. 1). In this context, it is worth mentioning the reconstructed hydrological situation for the Timiș plain in the period 5000-4000 BCE when the flow was up to three times greater than present[29], a situation not to be overlooked in a low plain with sensitive elevation differences. It is not excluded that the speculation of inactive streams during the middle part of the epoch (4500-4200 BCE) is related to this hydroclimatic aspect, with settlements preferring proximity to courses with a much lower water flow than active courses (lower flood risks), but greater than during arid phases (advantageous for the development of flora and fauna). However, it should be noted that the analysed sample is quite small (16 points).

Bronze Age - a balanced proportion exists between the discoveries of the Bronze Age placed on the channels P IV, V, and VI, which, along with generation PIII, account for 53% of the preferred courses, being water branches inactive at that date. Among the 47% of settlements located on an active course, 14% are also bordered by an inactive channel (Fig. 8; Pl. 2).

Early Iron Age - for this epoch, we observe a very interesting distribution, being among the most uniform alignments of settlements among all the studied epochs (Pl. 2). Of the 31 spatially analysed objectives, half are found on the bank of the Pogăniș II stream, forming a general SE-NW alignment. Certainly, we must consider that the settlements are not all contemporary. Moreover, all points extend over fluvial morphological units, terraces (81%) or bars (19%), representing the highest percentage of settlements arranged on such alluvial terraces. It is also the clearest preference for proximity to an active watercourse among all the historical epochs analysed, with a percentage of 73%, compared to 27% of sites located on inactive channels (Pl.1).

Late Iron Age - distinguished between two different chrono-cultural horizons (the early-Celtic and the late-Dacian), it is noted that the objectives of the "Celtic" horizon are equally divided between the vicinity of an active course and an inactive one, while all "Dacian" discoveries are located on the banks of active courses (Fig. 8; Pl. 3). We admit that the analysed sample is small, consisting of 19 points.

Late Antiquity - although settled, the communities of this time were very mobile, numerous settlements being inhabited for short durations[30], a fact that explains the very high density, attributed to this "swarming" of communities. More than half of the settlements of this era (58%) were located during their period of habitation on the banks of inactive channels, being the most significant settlements in terms of extent (average of 5.1ha), compared to the objectives placed on active courses (42%), with an average area around the value of 3 ha (Fig. 8; Pl. 3). We note a concentration of settlements around areas of permanent wetlands.

Migration Period - the horizon of the early Slavs (mid-6th century to mid-7th century), documented in our study area through invasive research at Unip – Dealu Cetățuica, is represented by only three objectives, the analysed sample being too small for any statistical analysis.

Middle Ages - Looking at the overall situation of the distribution of medieval discoveries across the entire area, we observe that three quarters (76%) of the objectives were located on the bank of an active watercourse (of which 17% also neighboured an inactive watercourse), while a quarter of the sites were positioned next to inactive channels during their time (Fig. 8; Pl. 4). Several large settlements are noted that overlap an inactive course, a phenomenon observed only for the major settlements of the medieval era.

Modern Times - the situation undergoes a drastic transformation, primarily influenced by human intervention.

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[27] CIOBOTARU/ ROGOZEA, CIOCANI 2020, 53.

[28] VITEZOVIĆ 2018, 39; EL SUSI 1996, 179-180.

[29] KISS *et alii* 2012.

[30] GRUMEZA 2020.

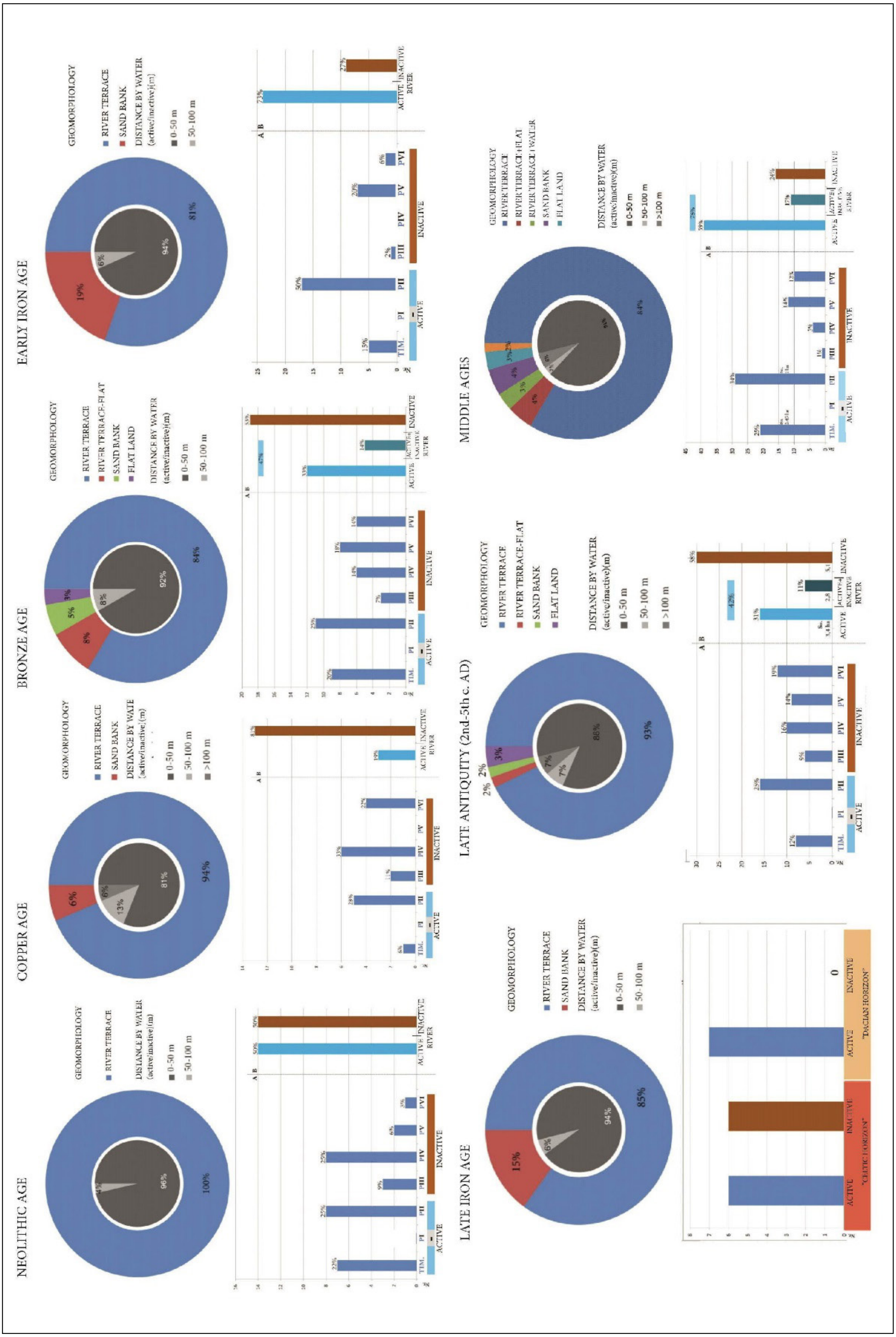

Fig. 8. Circle: Diagram of the morphological unit (color) and distance from water (gray) of archaeological sites; Columns: number and percentage of sites associated with different channels (left: TIM.=Timiș; PI-VI = Pogăniș, 6 generations), and with adjacent water flow types at sites (right: active/inactive). Sm.= average area occupied by sites.

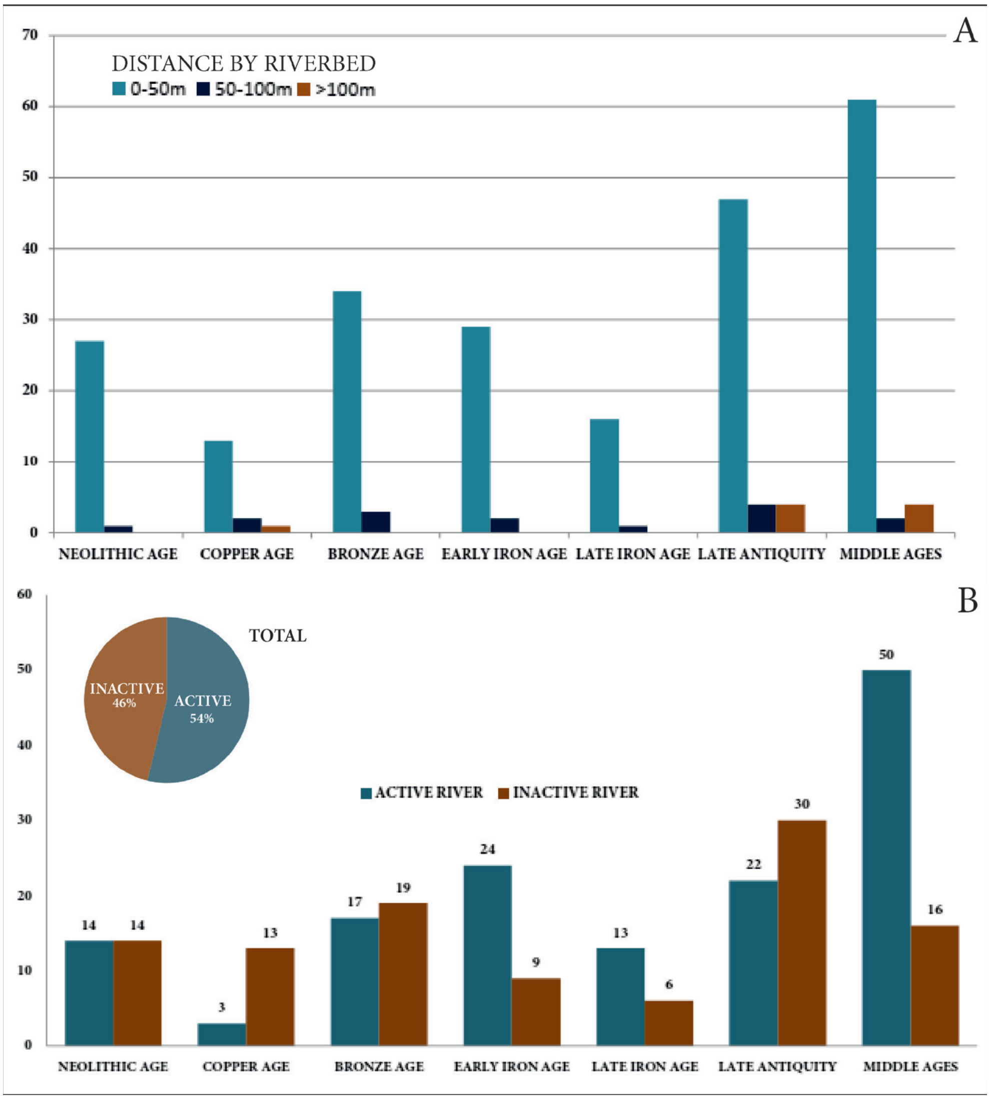

Fig. 9. A. The distance of archaeological sites from the nearest channel. The total number of sites (primary and secondary) and categorization into 3 distance categories (0-50m, 50-100m, >100m); B. The watercourse status (active/inactive) associated with archaeological sites, for each epoch individually (columns) or overall (circle); for the overall percentage, the PI channel, which is debatable regarding its dating of initiation, has been excluded.

Human activities redirected the historical course of the Pogăniș stream, rendering it inactive until the 20th century, and now it remains fossilized.

For the entire period of habitation of the plain in the studied area, a simple visual analysis over the Digital Terrain Model (LiDAR) can ascertain that the morphological units of the terrain on which the archaeological objectives are located are almost exclusively fluvial forms; these are generally represented by terraces (fluvial terraces) and secondarily by bars, and the latter are also of fluvial origin (Fig. 6).

Except for three epochs, for all chronological stages the discovered points are found entirely on these relief forms, or on combined forms, containing partially fluvial units. The three epochs that are exceptions correspond with the maxima of habitation at a general level, namely the end of the Bronze Age, the period of the 2nd-5th centuries AD, and the Middle Ages, all with a percentage of 97% occupation of fluvial units or associated with them and a percentage of 3% occupation of quasi-flat terrains, unrelated directly to the surface water network.

The proximity of archaeological objectives to a watercourse, in the form of an active or inactive channel, is the reason why almost all settlements were located on fluvial terrain forms. Without exception, settlements from all historical epochs preferred to settle near a channel or a zone of prolonged or permanent wetlands. It is no less true that the density of these channels in the studied area was, even then, very high. In fact, in all historical epochs, communities seeking to settle in this area found the historical hydrographic network of the Pogăniș, as dense as we see it today (Fig. 6B), the exception being the current course (upstream of Icloda), non-existent until a few centuries ago. In this sense, placing a settlement far from a channel was, in fact, quite a difficult endeavour. Consequently, in all epochs, most (90%) settlements or objectives of another nature, are located near a watercourse (active or inactive), meaning a maximum distance of 50 m from the edge of the objective to the nearest channel (Fig. 9A).

In each historical stage, one or more objectives are placed at a short distance from the channel (50-100m), most of them being found in the period of the 2nd-5th centuries AD (four) and the end of the Bronze Age (three). A medium to large distance from the channel (100 to 300m) is encountered in four situations in the Middle Ages and in the period of the 2nd-5th centuries AD, with the ancient period actually having the most objectives positioned at some distance from channels, in a number of eight, a fact that can also be attributed to the generalization of wells in this era, as an alternative water supply source (e.g., 5-12 fountains/settlement in the Pannonian Lowland in Late Antiquity)[31].

Regarding whether the watercourses were active or inactive during the time of settlement, some general and specific observations can be made. Across all periods, the distribution of settlements is well-balanced in relation to the type of riverbed, with 54% of the points located on active watercourses during their respective time frame, and 46% on inactive riverbeds (Fig. 9B). The relatively high percentage of settlements situated near inactive riverbeds may be

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[31] GRUMEZA/URSUȚIU/COPOS 2013.

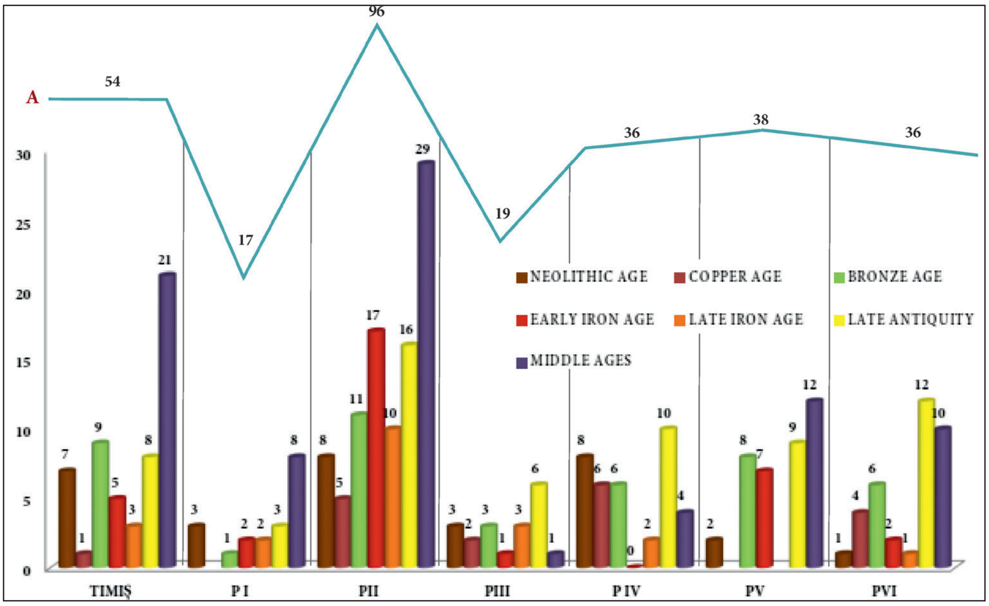

Fig. 10. The diagram of the number of archaeological sites (by epochs), grouped for each watercourse separately, and the diagram showing the evolution of the total number of objectives on a specific watercourse (A).

explained by the fact that these riverbeds still retained water, at least for a significant portion of the year, being an important hydrological and food resource for settlements. In this context, we recall the situation of the secondary channel of the Pogăniș VI generation (P VIa), which, although active over 20,000 years ago, still retained water in the 18th century, as indicated by the maps of that time (see Josephinische Landesaufnahme, 1769-'72).

For the Neolithic and Bronze Ages, a balance in this choice is notable at the general level. However, for other periods, communities exhibited a more pronounced preference for one of the options. For instance, the Early and Late Iron Ages, as well as the Medieval period, showed a higher interest in active watercourses, while the Copper Age and the Late Antiquity, saw a greater inclination toward inactive watercourses.

Analysing the riverine ecosystem from the perspective of the studied hydrographic units (Fig. 10), it's obvious that the most populated generation in different historical times is Pogăniș II, with a number of 96 objectives (32%), followed by the Timiș River with 54 points (18%). These active watercourses, encompassing the entire Holocene period, attracted a total of 150 settlements, compared to the 130 sites collectively associated with the four inactive riverbeds in the Holocene (PIII-VI).

A very balanced ratio is observed between these three old channels of the stream (P IV, V, and VI), all with a percentage of 12-13% of the objectives located on their banks (between 36 and 38 objectives each).

The current course (P I) represents a particular situation, with the statistical analysis being suggestive in this regard. We observe that this channel is the least speculated by settlements (17 objectives - 6%) followed by channel PIII (19 points). In the case of channel PIII, it concerns a very short segment of the channel analysed, but intensely speculated by settlements, an aspect visible on the density map of habitation (Fig. 11).

In the case of P I, however, the relative dating based on several criteria, which dates the origin of the course in the late medieval period, is reinforced by the statistical diagram, with the necessary explanations. Of the 17 objectives spatially associated with the current course of the stream, only three objectives prior to the medieval period are linked only to this channel, the others being associated with other courses. Indeed, starting with the late medieval period (the Ottoman era) and the establishment of the current village centres here, we observe that the ratio of points increases for this channel, the six points now representing different nuclei of households of these two villages (defined as secondary objectives, spatially distinct and introduced into the statistics according to the methodology applied to all epochs).

Further discussions particular to each generation of channel can be developed in parallel with human habitation, such as the significant presence of medieval objectives on active courses, the consistent presence of these on channels PV and VI, and the almost general absence of medieval habitation on generations PIII and P IV or the lack of representation for several epochs for channel P V, inhabited mainly in "demographic peaks," by large settlements. These aspects may be related to a series of natural or historical phenomena, within more careful geographical and historical analyses in the future.

The high density of sites along the Pogăniș II generation is vividly depicted on our density map (Fig. 11), where darker shades represent higher point densities. This illustration reveals that human habitation extensively covered the entire expanse of this riverbed, with only minor exceptions, seemingly due to low-lying and easily inundated terrain.

CONCLUSIONS

From an environmental perspective, during the Holocene, the Banat Region (as lowlands of the Pannonian Basin) had a natural and natural-culturally specific landscape with a plain fragmented by a hydrographic network with a great density of active and inactive streams, along with smaller or larger areas of marshlands. As a characteristic in preindustrial times, the region has a Riverscape and, partially, Waterscape specific.

From a historical point of view, we can say that the human settlements are developing around and among watercourses and both types of streams (active, inactive)

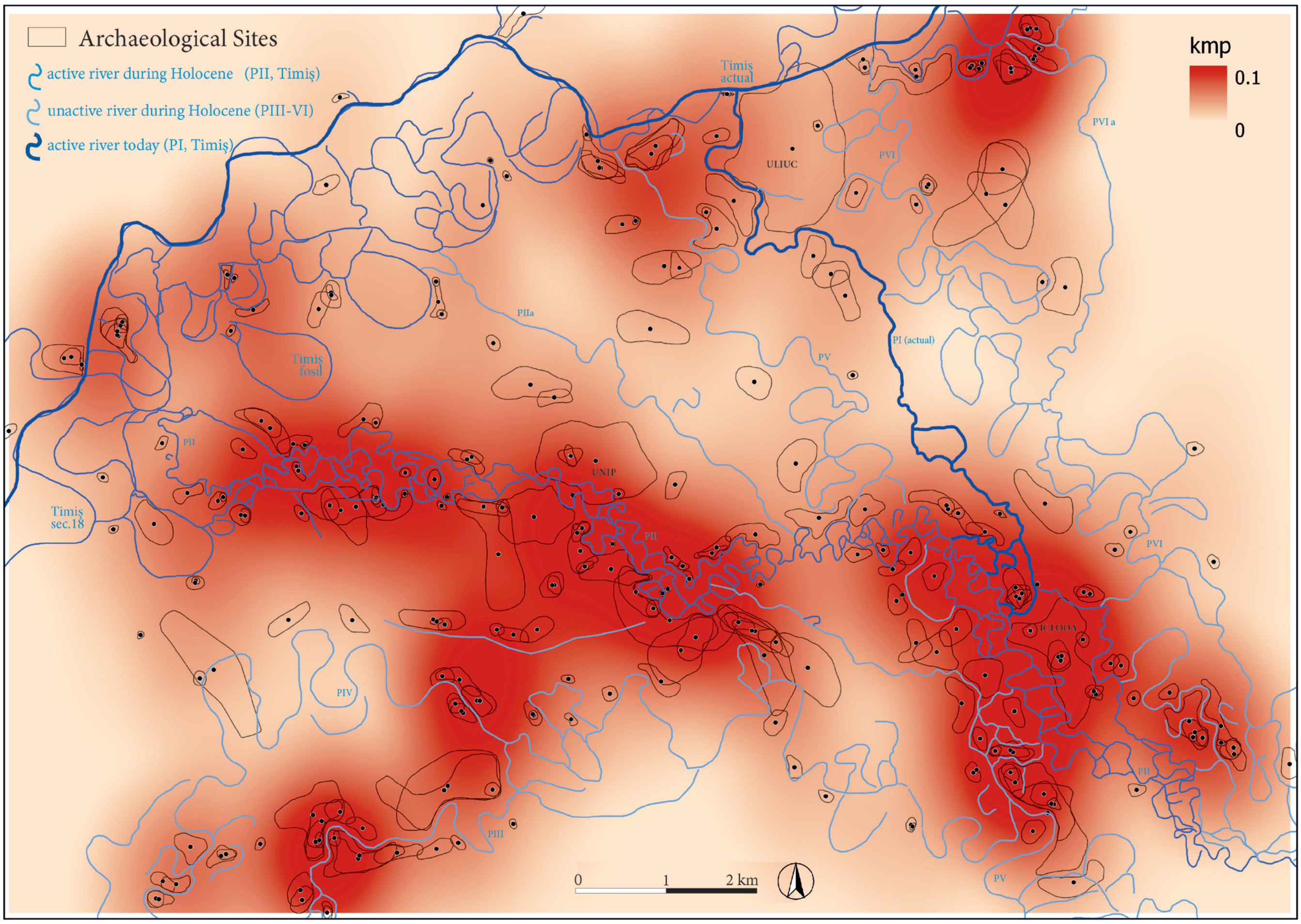

Fig. 11. Map of archaeological sites and their density (based on point density, where 1 point = 1 objective) and the hydrographic network. Kernel Density Estimation method.

were cherished and harnessed by human settlements during the Holocene. The apparent preference for settling near inactive watercourses, during specific ages, with much lower water flow compared to their active counterparts, may be linked to reduced flood risks but still very advantageous conditions for the development of aquatic flora and fauna.

Until modern times, the human-nature relationship was a balanced one, the changes suffered being of small amplitude over thousands of years. Major hydrography is dominant, it shapes the land naturally and human settlements are developing around and among watercourses which are in continuous dynamics and often flood large areas. Together (human and hydrography) composed an organic and unitary system, thriving for life.

Also, some methodological conclusions can be made. First, the spectrum of analysed hydrological units and historical settlements should be larger for trying to reconstruct some settling strategies and patterns. Considering this, we believe that the paleo-hydrography of a lowland can be reconstructed partially (spatial and chronological), but the entire approach depends on (and starts with) the complexity of the hydrographic network.

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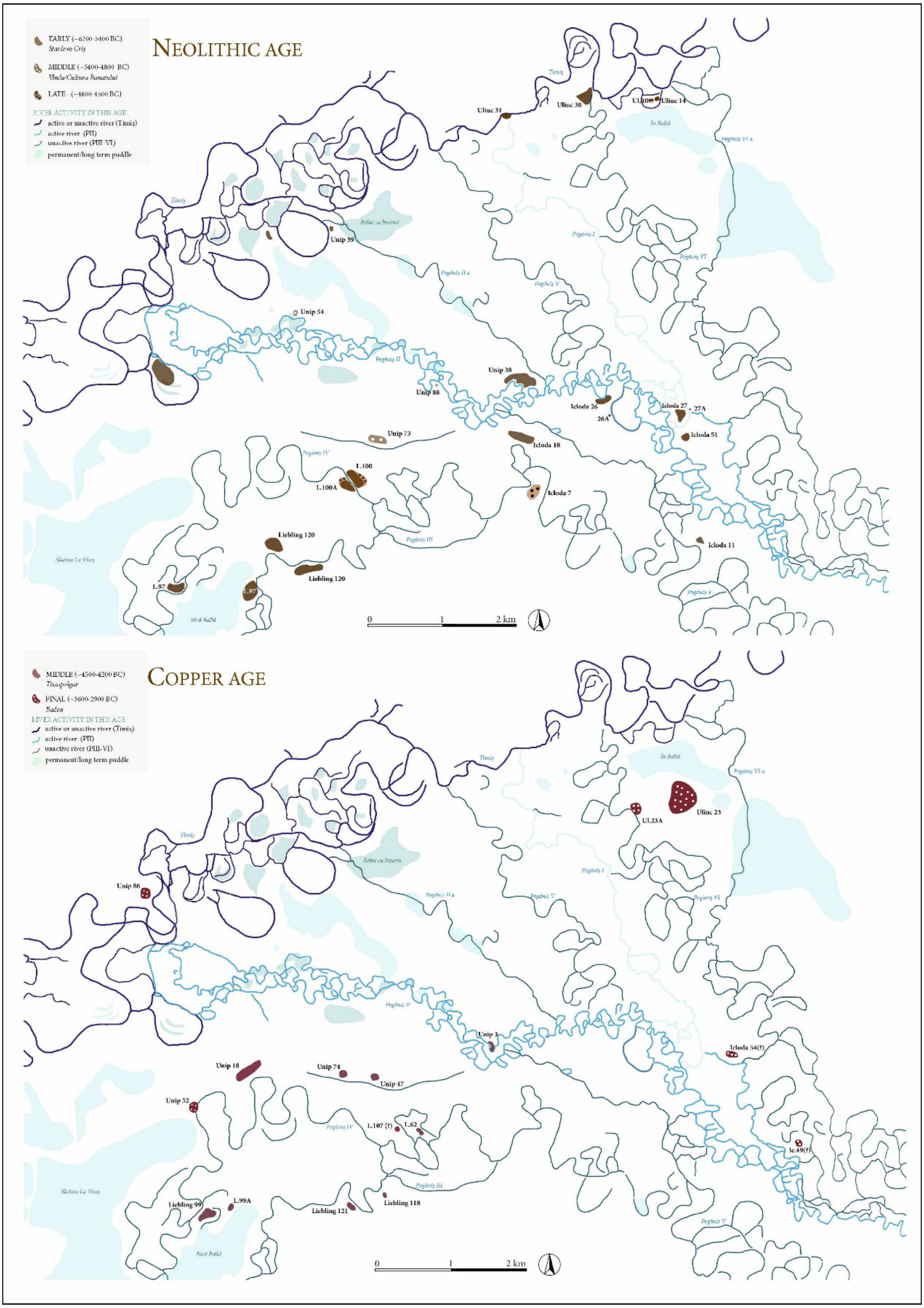
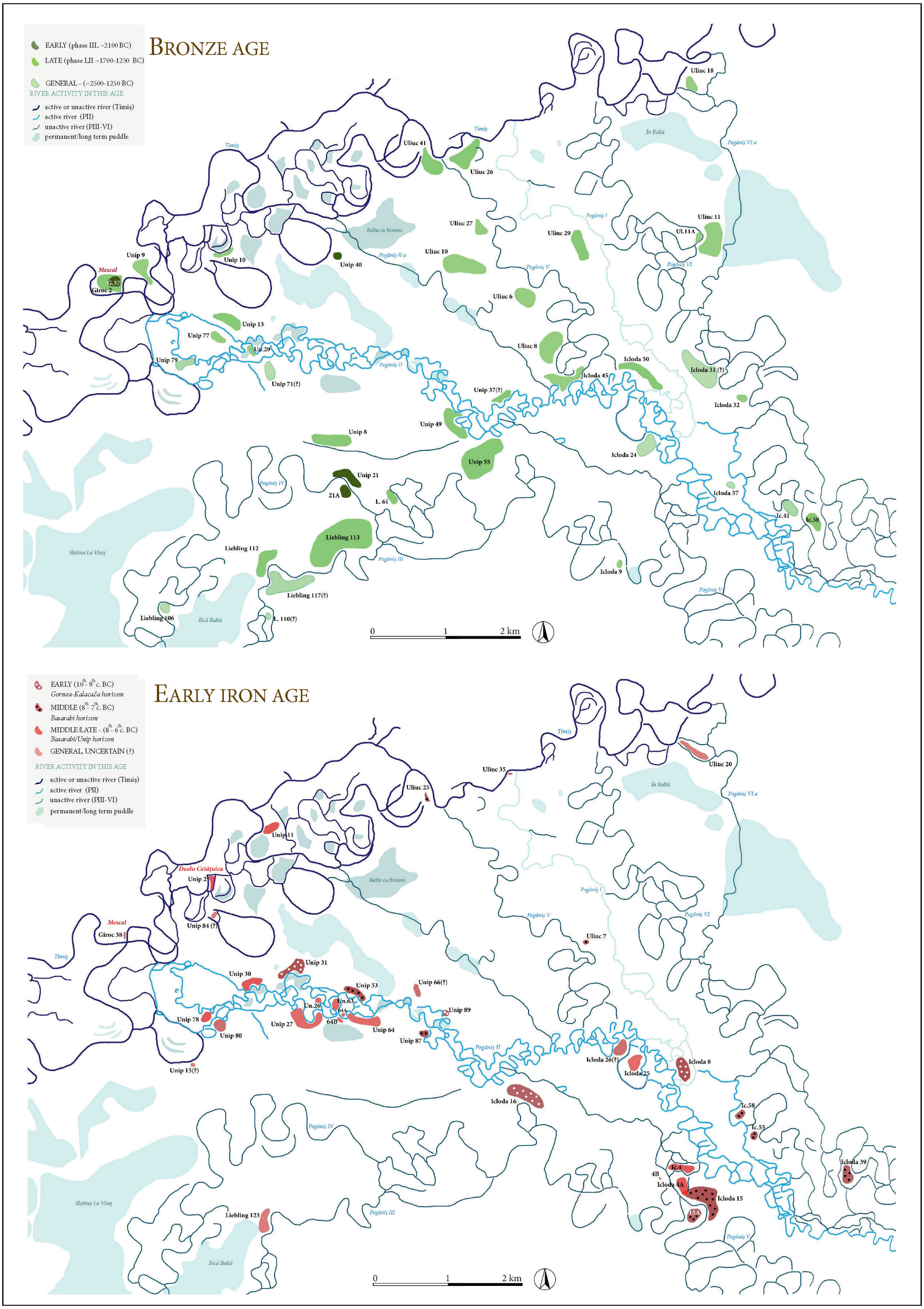
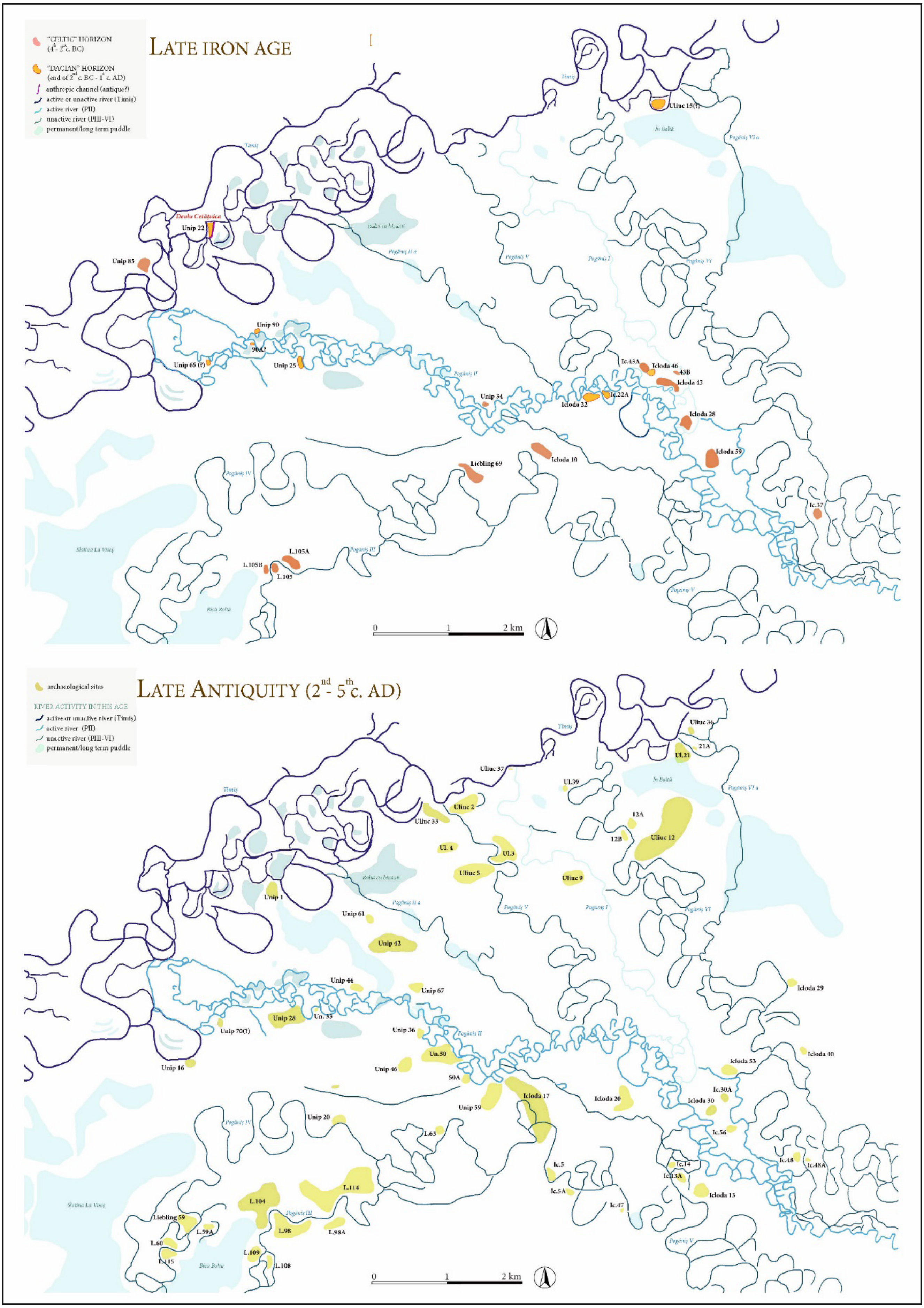
ANNEX 1



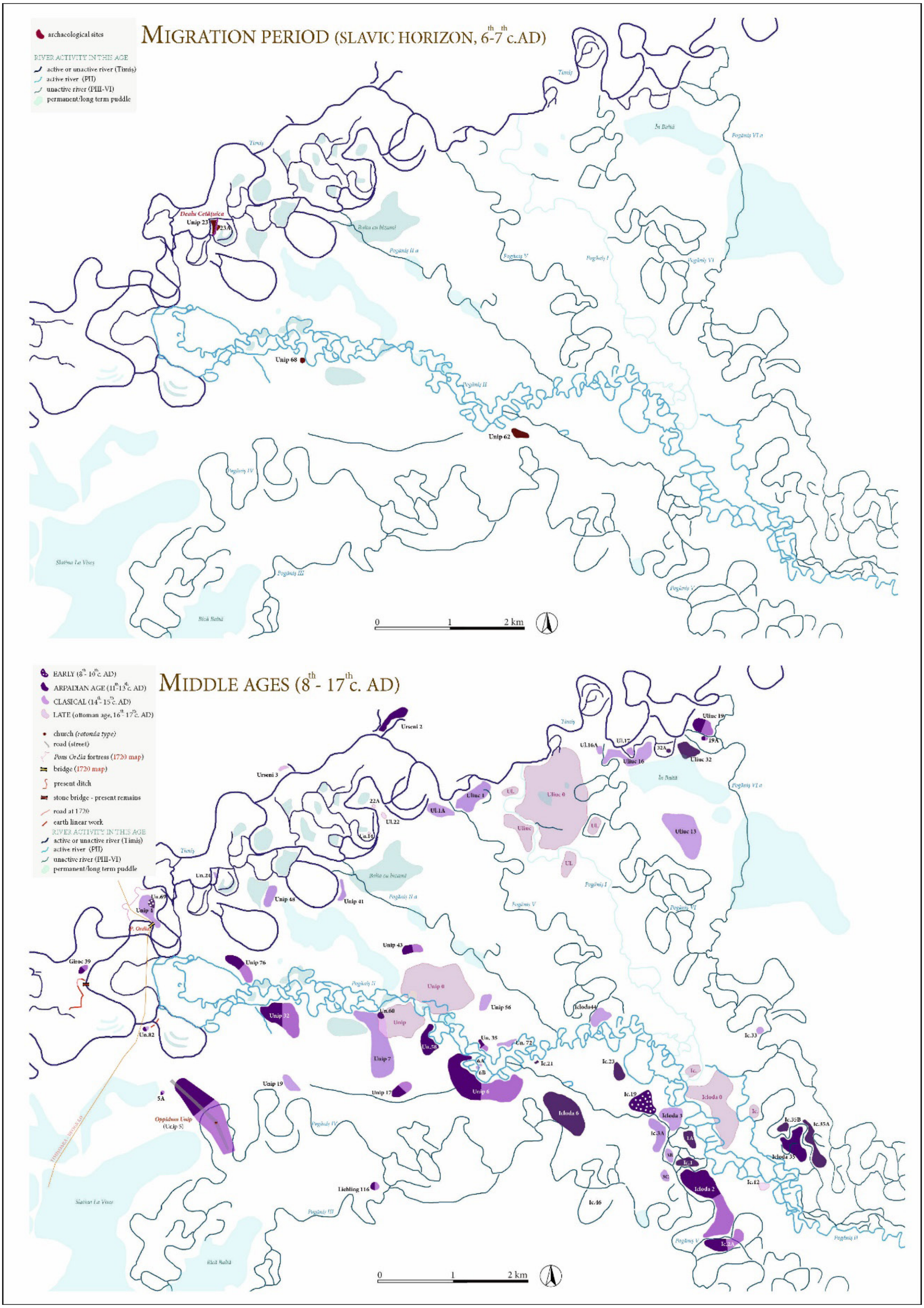
Pl. 1. Neolithic and Copper Age. Map of archaeological sites discovered during the surveys and paleo-hydrography of the area



Pl. 2. Bronze Age and Early Iron Age. Map of archaeological sites discovered during the surveys and paleo-hydrography of the area



Pl. 3. Late Iron Age and Late Antiquity. Map of archaeological sites discovered during the surveys and paleo-hydrography of the area



Pl. 4. Migration Period and Midle Ages. Map of archaeological sites discovered during the surveys and paleo-hydrography of the area