A Computational Analysis of a Feasible Network of Routes in the Watershed of the Don River

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Abstract

The article presents a brief description of available datasets and resulting methodology applied when analysing feasible routes leading through the territory of the modern Southern Federal District of Russia. The examined time span falls between the late 7th and the early 3rd centuries BC, defined by the chronology of the archaeological datasets. The roads are calculated based on an anisotropic least cost path analysis, connecting find-spots which, albeit situated deep in the inland, revealed Greek imports. Rather than a separate study, the present outcome should be seen as a methodological supplement to a comprehensive work of S. Huy who collected the archaeological datasets and who also further interprets the results within their broader historical contexts (see contribution of S. Huy in this volume).

Introduction

The following study introduces results of a computational analysis of a feasible system of routes in the watershed of the middle and lower courses of the River Don (ancient *Tanais*[1]), flowing through the districts of Voronezh, Volgograd and Rostov. The outcomes supplement the study of S. Huy who suggested an existence of alternative overland routes to a traditional communication network using the river system.[2]

The studied area is located in the European part of the Russian Federation, in the modern Southern Federal District. The territory is of a challenging extent, covering more than 360,000 sq. km, and featuring a changing character of the landscape represented by a grass steppe in the south and a forest steppe in the north[3] (the border is outlined on the map fig. 1). Due to a lack of data concerning fluvial geomorphology of the River Don and its tributaries during the researched chronological frame, the analysis considers all the possible routes without excluding the riverbeds.

Geographic Characteristics (see Map fig. 1)

The analysed area is dominated by the River Don[4] and its numerous tributaries. The territory is delimited by watersheds of two other rives, by Dnieper in the west and by Volga in the east. The borders in the north and in the south follow the middle and lower parts of the course of the River Don, roughly delimited by the cities of Voronezh and

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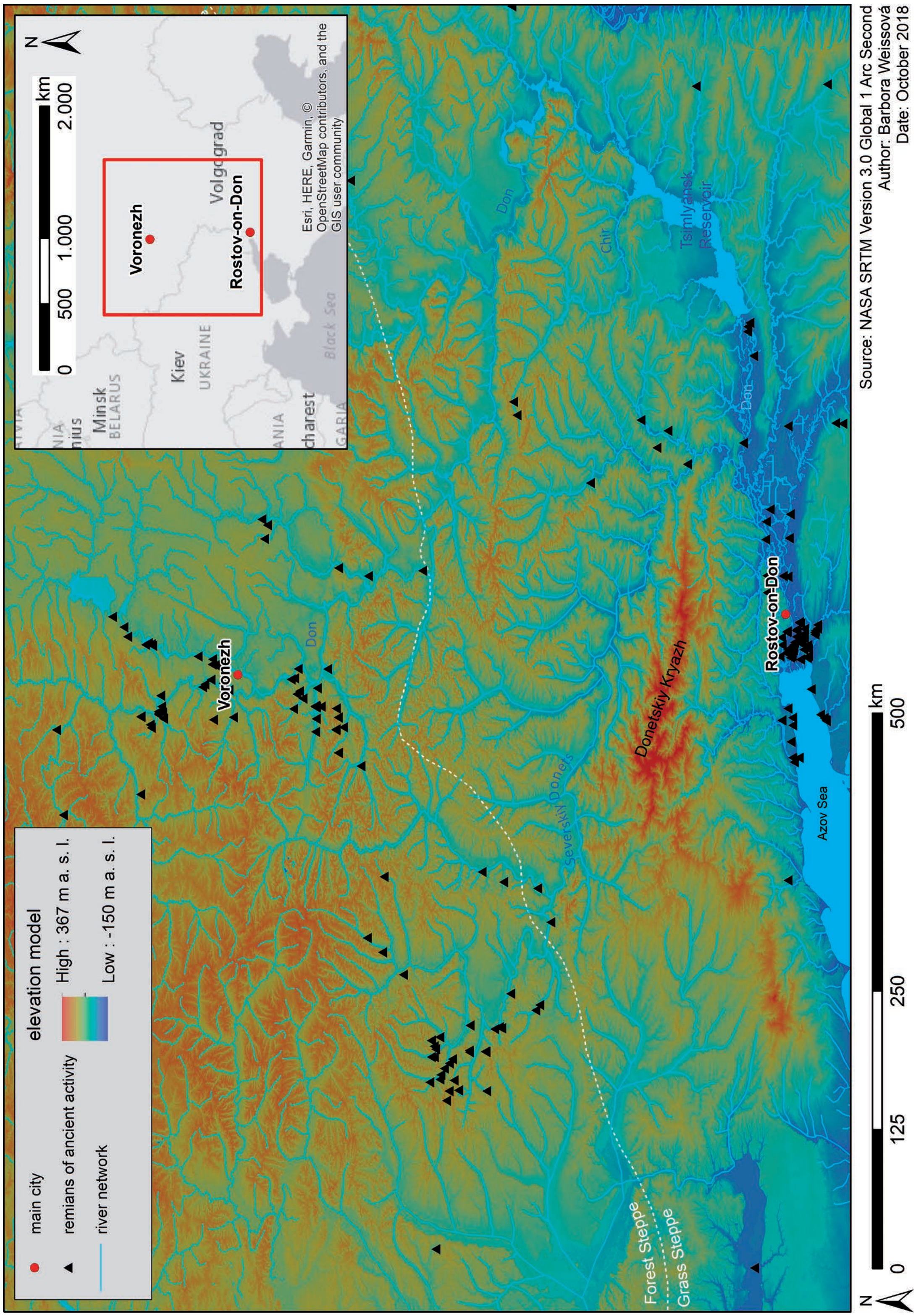

Fig. 1: An Overview Map of the Analysed Territory

Rostov-on-Don respectively. The analysed length of the river stretches over 1100 km and it is divided into a middle and lower course by the Tsimlyansky Reservoir. The middle course is characterised by a valley of about 6 km wide, numerous floodplains, small lakes and relict channels. The width of the river varies between 100 and 400 m. The right bank is of a steeper character, with chalk, limestones, and sandstones predominating. The landscape on the right bank is characterised by undulating plains cut into by jagged gorges, and on the left bank by the smoother, pond dotted topography of the Oka-Don Lowland. The first 300 km of the lower course are taken by the Tsimlyansky Reservoir, followed by 313 km of the river flow before it reaches the Taganrog Bay. The valley along the lower section of the Don is between 20 and 30 km wide, including a large floodplain and a braided river channel. The width of the river varies between 400 and 600 meters.

Although 70 per cent of the lower Don basin are now ploughed and used for agriculture, under natural conditions the analysed area would be covered by forest-steppe and steppe vegetation.[5] The regime of the Don is largely influenced by the Tsimlyansky Reservoir and numerous dams along its lower course, equalising its runoff during the year and increasing the evaporation. The loss of the water is largely intensified by the irrigation of the agriculture areas.[6]

The highest hill in the territory, Mogila Mechetnaya, reaches mere 367 m a.s.l. and it is situated within the Donetskiy Kryazh Highlands.

Sources of Data

The archaeological data used in the study come from numerous publications, mostly reports focused on one site solely, and brought together by S. Huy.[7] Character of the data allowed for only a broad definition of archaeological sites represented in the assemblage, including settlements, fortified settlements, burial mounds, burial fields and sites of an unknown character. The nodal points were chosen from the dataset as representatives encompassing distinctive amounts and/or quality of Greek imports detected, assuming regular contacts with Greeks.

The digital terrain model has been released by NASA[8] and it is the SRTM[9] Version 3.0 Global 1 arc second (henceforth the SRTMGL1). The SRTMGL1 is a void-filled product with a precision of about 30 meters,[10] allowing for calculating more than a satisfactory environment for the performed analyses. Vectorised inland waters and rivers[11] are products of the GIS-Lab,[12] only moderately adjusted in order to add some of the missing data. The outlines of the coastline[13] and the digitised open waters[14] follow the Barrington Atlas of the Greek and Roman World.[15]

Methodology

Given the extensive territory of about 360,000 sq. km and a relative insufficiency of the available datasets, I decided for applying a simple anisotropic least cost path analysis (henceforth the LCPA)[16] performed in GRASS GIS.[17] In other words, the cost-of-passage, a decisive factor for final outcomes, solely bases upon the slope of the land.[18] The slope is calculated using the SRTMGL1 and the necessary relative cost raster bases upon the equation *'tan (Slope) / tan (1)'*[19] applied to the smoothed slope.

The following and rather cumbersome step within the LCPA represent the road equations between the provided points of interest. Firstly, since the sites were digitised in Google Earth Pro and as such available only in a .kml (.kmz) format, it was necessary to convert and further transform them to shapefiles in order to enable their analysis.[20] An outcome of this work represents a spatial database created in ESRI ArcGIS.[21] The targeted points including Elizavetovka, Ol'chvatovskoe Pos., Cheperskiy, Konstantinovska, Krasnoyakova 2, Lyubotino, Russkaya Trostyanka, Mostishche and Chastye Kurgany, were one by one exported from the database as single point shapefiles and uploaded to GRASS GIS. In the following, it was necessary to calculate an accumulated cost raster and finally a drain between each pair of the nodal points.

In case of the real nodal points, interconnection of nearest neighbours brings sufficient results, covering all the possible routes. However, as the examined points are not real nodal points, but points of interest chosen based on the presence of the Greek imports, it was necessary to calculate all the possible routes. In other words, it was essential to connect each single point with all the other points, notwithstanding the distance or presence of points seemingly lying between the analysed ones. This approach proved to be legitimate since it revealed several feasible connections on top of the ones based on interconnecting the nearest neighbours exclusively.

One more issue represented the proximity of the Azov Sea when calculating routes leading from Elizavetovka to Lyubotino (from south to NW). Since the seas naturally feature the lowest level, the first route was calculated using the Sea of Azov on the first place, turning inland to take a relatively direct route to Lyubotino. Creation of a high cost raster for the Azov Sea appeared to be a prerequisite for a successful calculation of a route leading through the inland (both of the routes are depicted on the map fig. 2).

Results and Further Interpretations (see map fig. 2)

The routes calculated based on the LCPA revealed rather questionable results. The first obvious discrepancy is the length of the routes, since most of them are much longer than the beelines, in other words the shortest connections. To underline this observation with total figures, the lengths of the calculated roads are listed in the table fig. 3, accomplished with the lengths of the beelines and percentual expressions of the dif-

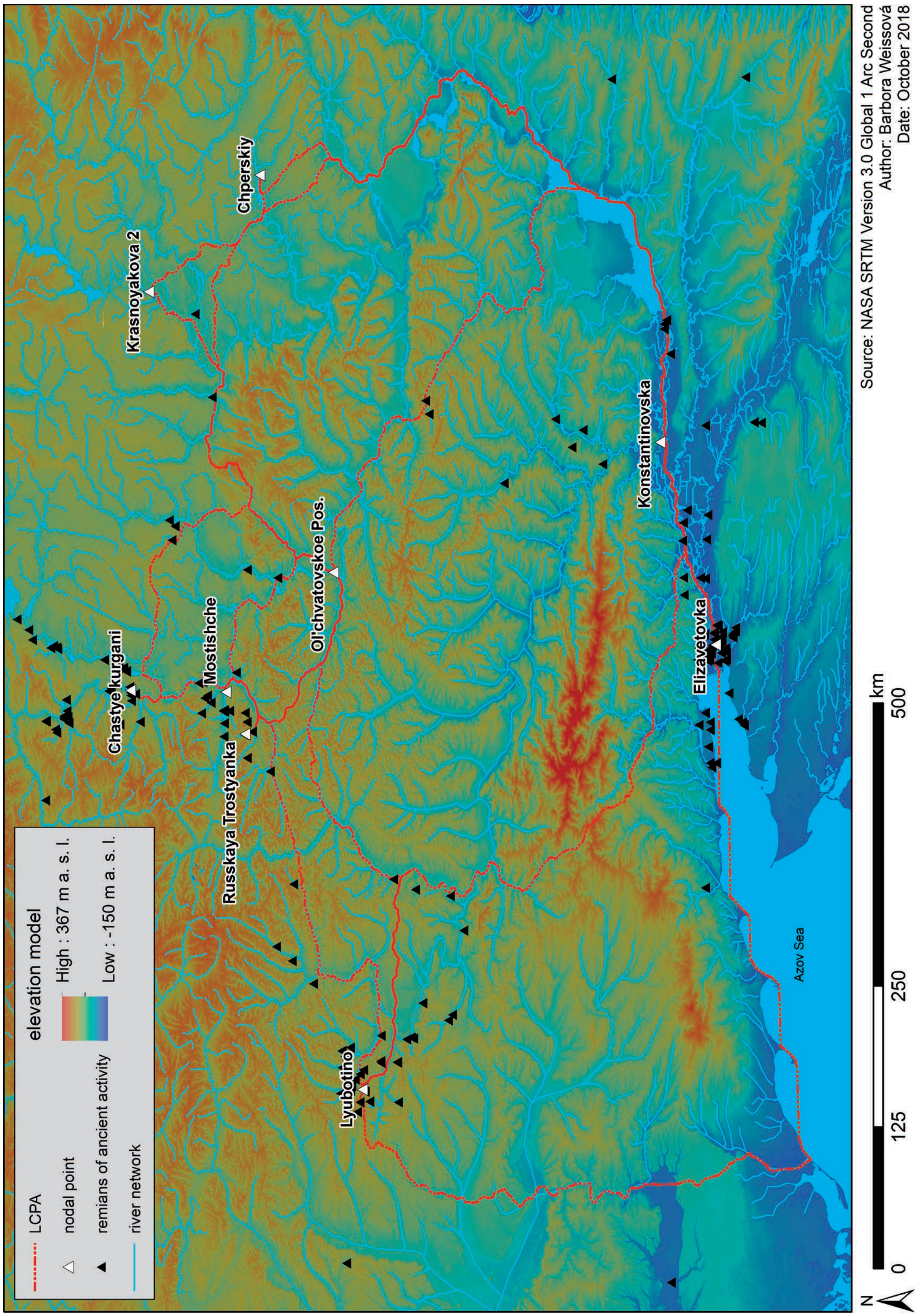

Fig. 2: Results of the Least Cost Path Analysis Interconnecting all the Points of Interest

Routes Between the Points of Interest		Distance (km)		Length of beeline (%)
From	To	LCPA	beeline	(LCPA represents 100%)
Elizavetovka	Krasnoyakova 2	960	544	57
Elizavetovka	Chperskiy	837	487	58
Elizavetovka	Lyubotino	909	408	45
Elizavetovka	Lyubotino	655	408	62
Elizavetovka	Ol'chvatovskoe Pos.	847	350	41
Ol'chvatovskoe Pos.	Chperskiy	399	233	58
Ol'chvatovskoe Pos.	Krasnoyakova 2	335	226	67
Ol'chvatovskoe Pos.	Mostishche	180	116	65
Ol'chvatovskoe Pos.	Chastye kurgani	365	191	52
Ol'chvatovskoe Pos.	Chastye kurgani	317	191	60
Ol'chvatovskoe Pos.	Russkaya Trostyanka	176	120	68
Ol'chvatovskoe Pos.	Lyubotino	445	295	66
Ol'chvatovskoe Pos.	Konstantinovska	683	299	44
Konstantinovska	Lyubotino	719	461	64
Russkaya Trostyanka	Lyubotino	380	226	59

Fig. 3: Computed Routes and their Lengths Compared with the Length of the Beeline

ferences between both of them (results of the LCPA represent 100 per cent to the length of the beelines). On average, the distances as the crow flies are one third shorter than the routes calculated by the LCPA. Considering that in absolute numbers the maximum difference reaches in one case not less than 497 km, it is highly probable the calculations based on the LCPA do not always respond to the most feasible routes in reality.

In all probability, the reason of this great disparity lies in the terrain model. Although the Donetskiy Kryazh Highlands situated in the southern part of the grass steppe reach mere 367 m a.s.l. in the maximum altitude, they still represent a considerable barrier for the LCPA, trying to avoid them at all costs and choosing the routes along the River Don.

This leads me to the second issue; the River Don was during the analysed timespan considerably mightier than today, and possibly running out of its confines and submerging surrounding areas once in a while. Large rivers represented a crucial problem and they were always avoided regardless the dating and/or character of the road system.[22] It follows that the routes were either using the river itself or avoided it as well as its vicinity, since there is no safe road along such a mighty flow.

Regardless of the abovementioned issues, a brief spatial analysis of the distribution of the sites revealed an appealing observation. Some 33 (45) of the sites (excluding the points of interest) showed a linear clustering along the predicted routes when using buffers of 2 km (3 km). Spatial allocation of their vast majority is in the northern part of the territory. This fact largely supports the results achieved with the LCPA. Given all the aspects of the results, it seems that the inaccuracy of the LCPA is bordered to the southern part of the area.

In order to model a possible network within the erroneous southern part, one could take an advantage of the sustainability of the road systems, possibly featuring analogous routes for regional as well as supra-regional roads from the prehistory until today.[23] An examination of the modern road network, however, did not bring satisfactory results. The main road connecting Rostov-on-Don and Voronezh makes a bow to the east in order to avoid the state borders, a barrier which had not played any role during the analysed time span. Therefore, it is rather improbable the prehistoric and ancient routes followed the same course, as the direct north – south line is equally demanding but shorter.

Another possibility how to reconstruct the feasible route represent the remains of ancient activities, in this case the five (eventually seven when considering also the two in the NE) points dispersed between Konstantinovska and Ol'chvatskoe Pos. As all of the points represent burial mounds, some of them may have also served as road markers. Unfortunately, they do not feature any observable linear clustering, which would point to their function as the road markers.

Deficiency of the Analysed Dataset

During the analysis, several issues of the dataset appeared to be decisive, although not apparent at the first sight. The first one is the geographic precision of the record, which proved to be rather insufficient. For instance, within the seven burial mounds discussed above, the southernmost point represents not one but ca. 30 burial mounds from various periods. In such a case, any analysis of possible linear clustering is hindered.

The second issue is the enormously large scale, largely confusing when interpreting the data. For example, the two clusters appearing on the map in the northwest and north are scarcely distributed points in reality. In particular, the point cloud in the northwest features 30 sites dispersed within the territory covering more than 2400 sq. km.[24]

To achieve a more precise and reliable reconstruction of the routes, it is essential to streamline and enrich the current archaeological dataset. Shorter and more precisely defined segments, especially in the territory of the Donetskiy Kryazh Highlands, have a great potential to reveal more feasible results.

Conclusion

Based on the careful evaluation of the results of the LCPA, I suggest seeing the entire territory and the numerous riverbeds as a matter of subsequent but relatively rapid, and possibly also seasonal change. This fact most likely largely influenced the routes of the communications. Since the elevations within the grass steppe do not overreach 367 m a.s.l. and for the most part vary between 50 and 150 m a.s.l., it is plausible the routes led directly towards the north, crossing the highlands and avoiding the longer and unstable route along the Don. As the territory is cut with a number of smaller rivers, it is expectable the road system was flexible to a given extent, adjusting to current conditions. This assumption would not be acceptable when speaking about an established road system, as, for instance, in case of the Roman paved roads, but since the analysis concerns nomadic movements, it is possible to speak about a relatively rapidly adjustable system of routes, depending on current weather conditions/season.

The presented analysis is the first attempt to shed light on the system of routes in the territory along the River Don and rather than representing final results, it should prompt a more intense discussion and research in the area. In particular, I do hope to inspire other studies in order to improve the mapping and spatial analyses of the distribution of the sites and their possible interconnections in the watershed of the River Don.

Notes

[1] For an overview of ancient authors mentioning Tanais, see Herrmann 1932, 2162–2166.

[2] For instance, see Grivenetsky et al. 2015, 245.

[3] Chibilyov 2008, 253.

[4] For more details about the River Don and its tributaries, see Vvedenskiy 1952, 88–90; Mart'nova – Aleksenko 2009, 31–32; French 1964, 577–578.

[5] Sidorchuk et al. 2011, 6.

[6] Nikanorov et al. 1994, 251; Blinnikov 2011, 16; Koronkevich 2008, 132. 134.

[7] Huy 2019.

[8] NASA stands for the National Aeronautics and Space Administration. For further information, see URL: <https://www.nasa.gov/> (25. 10. 2018).

[9] SRTM stands for the Shuttle Radar Topography Mission. For a detailed information, see URL: <https://www2.jpl.nasa.gov/srtm/> (25. 10. 2018).

[10] NASA SRTM 3.0 Global 1 arc second void-filled product combines elevation data from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Global Digital Elevation Model 2 (GDEM2),

USGS Global Multi-resolution Terrain Elevation Data (GMTED) 2010, and USGS National Elevation Dataset (NED).

[11] Shapefiles in the forms of polygons and lines respectively.

[12] For a detailed information, see URL: <http://gis-lab.info/about.html> (20. 10. 2018).

[13] Ancient World Mapping Centre, “Coastline”, URL: <http://awmc.unc.edu/wordpress/map-files/> (10. 10. 2018).

[14] Ancient World Mapping Centre, “Open Water”, URL: <http://awmc.unc.edu/wordpress/map-files/> (10. 10. 2018).

[15] Talbert 2000. The digitisation is curated by the Ancient World Mapping Centre. For detailed reports about activities of the centre, see URL: <http://awmc.unc.edu/wordpress/awmc-annual-reports/> (25. 10. 2018).

[16] For more on the anisotropic least cost path analysis, see Wheatley – Gillings 2002, 151–154.

[17] GRASS Development Team, 2018. Geographic Resources Analysis Support System (GRASS) Software, Version 7.4.0. Open Source Geospatial Foundation. URL: <https://grass.osgeo.org> (25. 10. 2018).

[18] Bell – Lock 2000, 88.

[19] Bell – Lock 2000, 89.

[20] The outcomes of the database represented by several maps are published within the Doctoral thesis of S. Huy, forthcoming.

[21] The licence was provided by the Institute of Archaeological Studies at the Ruhr University Bochum.

[22] Compare French 1981. The reconstructed route of the Pilgrim’s road between *Nicaea and Iuliopolis* crosses the mountainous plateau and avoids much easier but longer and often flooded route along the Sakarya River.

[23] Compare with ‘Royal road’, where the Roman road is explicitly described by Hdt. 5,52 as coinciding with the route of the ‘Royal road’. Based on the linear clustering of prehistoric settlements, it even dates back to the 2nd mill BC (How – Wells 1957, 21–22). The territory around the Iznik Lake, NW Turkey, revealed even a more remarkable pattern, as the estimated deviation between the prehistoric routes and modern roads do not overreach 1 km (Weissová – Pavúk 2016, 11–21).

[24] In other words, the density of the sites (not even settlements!) in this area is one per 80 sq. km.

Image Credits

Fig. 1: Barbora Weissová. – Fig. 2: Barbora Weissová. – Fig. 3: Barbora Weissová.

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