In this paper the primary focus is on GIS modelling of import and distribution routes within a well-defined micro-region containing sites attributed to the late Neolithic and early Copper age. Vinča culture, a distinct feature of The Balkans and the southern edge of the Pannonian plain between the end of 6th and the mid 5th millennium cal. BC, is native to The Central Balkans region, but extends northwards into eastern parts of the Pannonian plain, and is analyzed here. Even though such analyses are not a novelty in modern archaeology, this study represents the first such attempt of this nature in the area of the Vinča culture for the period of the late Neolithic and early Copper Age. In this analysis, besides archaeological records, a model of reconstructed past landscapes, based upon data obtained through geological surveys performed in the area, has been used. Using GIS modelling, I show the possible routes of local exchange of a very specific and much sought after commodity in the Neolithic of The Central Balkans – volcanic obsidian glass – in respect to the reconstructed landscape of late Neolithic in the region, defined by the Alibunar depression in the west and northwest, the Vršac mountains in the east, and the rivers Karaš and Brzava in the south and northeast respectively (Fig. 1). Several thousand obsidian finds,¹

¹ Chapman 1981, 80.
originating from three meagrely excavated sites (At, Potporanj, Granice) dictate the importance of the reconstruction of trade and exchange routes in the area. Combining the archaeological data with the geomorphology of the region it becomes evident that the Vršac region was a prominent corridor for travel leading from The Danube to important Vinča culture sites such as Uivar, southwest of the present day Timișoara, in Romania, or Turdaș, east of Deva, in Transylvania. The results of the analyses provide new evidence of the importance of the Vršac region through the late Neolithic of the eastern edges of the Pannonian plains, already accentuated by the copious finds now housed in the Vršac museum. Even though the modern day Vršac municipality borders with the republic of Romania, no attention was given to modern territorial boundaries, but rather the boundaries were set by the extents of the 1:25 000 scale topographic maps of the Military Geographic Institute of Serbia used to produce a 3D model of the terrain in question.

The region of Vršac in the south east part of Serbian Banat (Fig. 2) is, today, a part of the Vojvodina province encompassing the north of Serbia. As a geographical region, Banat is a much larger area now divided between three countries of the region; Hungary (Csongrád county), Romania (Timiş, Caraș-Severin, Arad and Mehediţă counties) and Serbia (North, Central and South Banat regions) However, before 1918, it was a single region of the Habsburg Kingdom of Hungary. The early establishment of museums in the larger cities of the region (Vršac city museum established in 1882, Timişoara Muzeul Banatului in 1872 and Zrenjanin museum in 1906) made possible archaeological surveys and excavations by the end of XIXth century. In the Vršac area, the first archaeological surveys and excavations were carried out by Felix Müllecker, the custodian of the museum between 1882 and 1942. Müllecker’s six decade long archaeological career, the basis of an extensive archaeological collection housed in the City Museum of Vršac today, is very important for the archaeology of the region, but even more important are his field surveys that have led to the discovery of numerous archaeological sites dated from prehistory to the medieval period. Another important archaeological legacy of Felix Müllecker’s work is the abundant documentation related to the evidence of past cultures occupying the region. After the Second World War, further surveys were performed, especially during the first phase of the Danube-Tisza-Danube channel construction started in 1957. Today, close to 300 archaeological sites are known in the Vršac municipality, with about 80 being dated to the Neolithic period.
THE LANDSCAPE OF VINCĂ CULTURE IN SOUTHEAST BANAT

One of the key aspects of this paper is the realisation that the modern landscape of the Vršac region is not necessarily identical to the landscape of a period roughly dated between 5300 and 4500 cal. BC. In this view the analyses of past landscape will be based on a comparison of modern geographic and geological data, available paleoenvironmental analyses performed in the region and comparable macrobotanical studies performed on nearby archaeological sites of the period.

In the geomorphological sense, the area in question is dominated by the Vršac mountain range, sometimes subdivided into hilly and mountainous parts.3 The central mass of the mountains consists of four peaks and three saddles. The highest peak (called Gudurica peak) reaches 641 metres above sea level. The mountains comprise old rocks, crystalline schists (mostly gneiss) and younger, predominantly Pliocene, sediments which dominate the northern and southern piedmounds. The Vršac mountain range is a well known source of water, with springs on the steep northern side situated mostly between the Gudurica peak and Donji Verište, whilst on the gentler southern side are found larger water sources, such as the Mesić, Guzajna and Sočica streams beneath the watershed. The river and stream valleys on both sides of the mountain range are narrow and steep-sided in the upper part of the stream, gradually widening and meeting with tributaries in the hilly regions of the range, and in the flats.4

The sub-mountainous region extends from the foothills of the central mountain mass towards Mali Rit (Small Marsh) in the North, and Romania in the east, whilst towards the south it extends in the direction of the Korkana saddle. Approximately rectangular in shape, Mali Rit (Fig. 2) is 11 km long and 2.2 km wide, extending southwest to northeast between Vršac and Veliko Središte. The southeast side of Mali Rit is mostly formed of mountainous material of an older age, with sporadic loessoid accumulations, with the opposite side a loess terrace. The bottom section of Mali Rit comprises older and younger marsh/lake sediments. The initial formation of the region lasted until approximately 8000 BC and was followed by the beginning of the deposition of marsh/lake sediments and the formation of a marsh or a lake which lasted until approximately 5500 BC.5 The second large geomorphological characteristic of the Vršac region is the loess flats, which constitute a larger morphological unit – the South Banat loess flats encircling the Deliblato sands to the southwest of Vršac on three sides (Fig. 2). The loess zone consists of clay loessoid soils in the north and loess proper in the south, towards Deliblato. Geological coring of this region has shown the existence of three loess horizons, separated by two horizons of fossil soil. The loess accumulation appeared during the Würm I–III periods, with fossil soil forming during the Würm I–II and Würm II–III interstadials.6 To the northwest and northeast of the loess flats is an area of loess terrace that almost completely encompass Veliki Rit (Big Marsh or Alibunar depression), the most prominent geomorphological feature in the region, aside from the Vršac mountains. The loess terrace is, on average, around 83

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5 Bugarski et al. 1995, 30.
6 Zeremski 1972.
metres above sea level and between 5–8 metres higher than the depression itself. Two smaller depressions around the villages of Vlajkovac and Vatin are a part of this loess terrace.

The ellipsoid shaped Alibunar depression is the largest geomorphological feature in the Vršac region, elongated approximately northeast to southwest. It is 30 km long and about 11 kilometres at its widest point. Most of its base lies between 75 and 76 metres above sea level, with only occasional parts at around 78 metres. The shape of the depression was influenced by the 8.2kya climatic events during which, for about 200 or 300 years, a drop in temperature and a rise in the average humidity combined with an increase in rainfall and surface waters led to the formation of a marsh or a lake at the lowest point in the landscape, i.e. the depression. Until the mid XVIII century, Veliki Rit (Alibunar depression) survived as a lake/marsh environment filled by numerous waterways from various sides. Vast reclamation works undertaken in the XIX and especially the XX century have managed to change its effluence, with surface water now flowing out instead of accumulating in the area. One should also consider that the Vršac region was prone to seasonal flooding until 150 years ago with floods, even today, occurring occasionally despite almost two centuries of extensive reclamation works. The maximum levels of water flow occurred during late spring and early summer, overlapping with the maximum rainfall that must have, during the Atlantic period at least, been higher than today (about 550 mm).

The earliest studies of the paleoenvironment in the region, conducted on the environment of Körös culture in neighbouring Hungary, (early Neolithic period of the region) have clearly indicated the importance of surface water, both standing and flowing, in the selection of settlement locations in the early and middle Neolithic. Nandris states that “we have the important group of settlements in the area of Ludaš lake and at Kelebija [...], around what appear to have been permanent shallow lakes since Palaeolithic times, with favourable conditions for early agricultural settlement”. In the Vršac region, Neolithic sites of the period show the same pattern of settlement around large or permanent bodies of water (Fig. 3), such as Mali Rit and Veliki Rit, or between them (the best example being the multilayered site of At, where Palaeolithic finds occur underneath the early Neolithic Starčevo–Körös–Criş horizon). A more recent study, in central Hungary has shown that in the period between 6200 and 4800 cal. BC (Vinča culture is usually dated between 5500/5300–4800/4600 cal. BC) settlements were located in regions where broad-leaved trees dominated, with substantial evidence of hazel, ash,
alder, willow, lime and beech pollen, whilst a noticeable decline in grasses and other open-ground herbaceous types speaks of limited clearings in the settlements’ surroundings. A similar, albeit archaeobotanical analysis, performed much closer to the Vršac region on samples excavated at the late Vinča culture site of Opovo (located some 50 km southwest of the Vršac region and dated between 4700–4500 cal. BC), confirmed that the environment of the late Neolithic in Serbian Banat was similar to that of the Hungarian plains and Carpathian basin; the predominant plant-life being mixed oak/hazel woodland with limited clearances around settlements, a fact additionally supported by finds of charred oak, elm, willow and Cornelian cherry trees in macrobotanical samples. These findings were additionally supported by a large number of roe and reed deer remains in the movable finds assemblage of the site.13

GIS RECONSTRUCTION OF PALEOENVIRONMENT

GIS aided reconstructions of paleoenvironments are certainly not a novelty in modern archaeology,14 representing the first step in the computer aided analysis of past societies. In the case at hand, the first step was the generation of a three dimensional terrain model (i.e. a DEM), based on a series of fifteen 1:25000 scale topographic maps published by the Military Geographic Institute in Belgrade. Isohypses spaced at 2.5 metres, combined with available SPOT heights enabled the creation of a DEM covering an area of 49 x 38 km, which was used as a base layer for the analysis. A hydrological layer was constructed, combining several sources, such as historic maps from the Austro-Hungarian period (late 18th and 19th century), satellite images and modern topographic maps, were used in the process of digitising vector shapes for free flowing surface water. Additionally, upon construction of the DEM, hydrological analysis was performed using a GIS algorithm, a technique well known and used in archaeology for several decades.15 One of the results of the hydrological analysis was the support of the notion of Veliki Rit being the focal point of ground water runoff (Fig. 4). After analysing the height values of Vinča culture site positions, it was possible to deduce that the minimum level of surface water in the Veliki Rit region was above 77 metres, whilst the highest possible water table level would have been around 79.75 metres. It must be noted that the maximum water table level does not represent a formal model or a simulation of flooding, but more a possible influence of flood water levels on the landscape at the end of the 6th and in the first half of the 5th millennium BC. A separate data layer, consisting of 19 point locations of Vinča culture sites, was also created with several more sites being excluded on the basis of insufficient or uncertain data (Fig. 5).

15 e.g. Gillings 1997.
Before proceeding with the main analysis i.e. the GIS aided modelling of obsidian trade and exchange pathways in the late Neolithic period of the Vršac region, it is necessary to make a short detour and explain in brief the origin and occurrence of this material in the south Pannonian plain and the Balkans. Obsidian appears even in the earliest of excavations of Starčevo or Vinča culture sites, as noted by Miloje Vasić during his excavations on the eponymous site of Vinča culture at the beginning of the 20th century. It must be stated that obsidian finds are not limited to certain areas of Vinča culture, but appear throughout its territory, obviously as a desired and valued commodity. Thanks to a century of archaeological research on the site of Belo Brdo in Vinča, we have evidence that obsidian occurs through the complete Neolithic sequence of the Central Balkans, with the possible exception of the very end of Vinča culture.

The Belo Brdo site has so far yielded around 1700 pieces of obsidian artefacts or raw material deposited throughout its 8 metres of Neolithic layers. In the Vršac region, obsidian has been evidenced on several sites, some in significant quantities. The most numerous finds originate from At and Potporanj Kremenjak, with other sites including Kozluk Kremenjak, Selište (Crveni Bunar) and Staro Selo (Potporanjske granice). Two of the sites mentioned, At and Kozluk Kremenjak, can safely be attributed to the early Neolithic Starčevo culture (with Selište/Crveni Bunar being possibly the third, although the evidence is based solely on surface polished and chipped stone finds). These are followed by obsidian finds of exquisite quality from the period of Vinča culture recovered from Potporanj Kremenjak, accompanied by finds from the sites Staro Selo and Kozluk Kremenjak (Fig. 6).

The first chemical (trace element) analyses of Vinča or Starčevo culture obsidian, performed in the 1960’s, indicated Trebišov Mountains in present day Slovakia as the point of origin for all samples. This source, known as Carpathian 1 (the Carpathian 2 obsidian source lies on the opposite side of the same mountain range, now in Hungary) accounted for almost all samples of Central Balkans obsidian examined. Recently, a much larger sample (60 pieces from all depths of the Belo Brdo site in Vinča) was studied using an EDXRF spectrometer confirmed initial analyses results. A similar undertaking performed on Criš culture obsidian, further established that amongst early Neolithic samples around 80% of obsidian finds originate from the Carpathian 1 source, with the percentage rising to well over 90% by late Neolithic.
The question of exchange routes and methods between such distant origin and discovery areas rises immediately when confronted with the amount of examples collected in the Vršac area. Earlier explorers considered this to be evidence of developed and continuous contacts with contemporary cultures gravitating to the Tisza river basin (Kőröš, Szakalhat and Tisza cultures). Confirmation was often sought in abundant finds typical of these cultures at Vinča or Starčevo culture sites, found well away from their core areas. Although some studies have shown that the quantity of obsidian declines with the increase in the distance from the source, it is still possible to definitely say that it’s not a case of down the line trade. On the other hand, there is also no definite evidence for specialised traders operating in the area, asymmetrically supplying certain centres, at the expense of others. Since most of the obsidian in the Vršac area was collected arbitrarily (either as surface finds or as part of limited span excavations) or without clear collection strategies, we must also be aware of possible distortions in the data. Analysis of obsidian trade in the Caucasian region, clearly indicates that linear distance is not the only basis for obsidian exchange, something that must also be applied here. The fact that the superior (and also the more distant of the two, in respect to sites of Vinča culture) Carpathian 1 source was preferred during the Neolithic, further supports this proposition of distance disregard, clearly indicating that the quality of the material was also an important issue for the consumers of the period.

The origin of raw obsidian points us to the most likely route of transfer from the source to the Vršac area; the Tisza basin. The distance of only several dozen kilometres between the source in the Trebišov region and the river (Fig. 7) can be a reliable clue for the transport of goods, either by land or by water. It could even be assumed, with a certain degree of plausibility, that the river itself was partially or completely used for obsidian transport, either up or downstream. Chapman has suggested that obsidian entered the Vinča exchange network at the confluence of the Mureş and Tisza rivers. Such a view would allow us to assume the possible two pronged import of obsidian into Vinča culture sites in the Vršac area. Studies have suggested that the average movement speeds on water and over land, in the timeframe studied here, were approximately the same, i.e. for water transport 4 km/h, and about 5 km/h for land transport. Thus, in the context of speed, there would not exist a clear and decisive advantage in choosing one means of transport over the other. On the other hand, this realisation could indicate that as the travelling speed was similar, the predominant factor in

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23 Chapman 1981, 80, Fig. 108.
25 Chapman 1981, 81, Fig 109 for Vršac area.
28 Tichy 2000.
deciding the means of transport could be dependent on other factors, such as the maximum possible amount of goods transportable. Additionally, bearing in mind the pronouncedly meandering character of watercourses in the Pannonian plains, a fact most applicable to the Tisza river, (with a paleo-course of almost 1500 kilometres through modern Hungary alone shortened to 965 km by meander cutting in the modern period), a trip of about 600 kilometres from Carpathian 1 to the Vršac region (not possible directly using only the river) could have been much quicker if one opted for a land route instead. The problem, however, lies in the significant number of tributaries or marshes that presented obstacles for land travel in the Neolithic. Trade and exchange connections in the region must have existed from very early on, as the obsidian finds in the material culture of early Neolithic Starčevo–Körös–Criș complex would indicate, but in the late Neolithic the presence of sites belonging to the Tisza–Herpály–Csőszhalom culture complex (a likely culture to exploit the Slovakian obsidian during this period), in the region of Novi Bečej (Matejski brod site) that settled directly on the remains of early Vinča culture sites, indicates a live interaction between these cultures or possibly even the replacement of one tradition with the traits of another. The contacts in the region are additionally evidenced by finds of vessels attributed to the Tisza culture that show direct influences of early Vinča pottery types, such as the iconic prosopomorphic lids, found manufactured to Tisza pottery traditions on several Tisza settlements in Serbian Banat. Furthermore, extensive contacts can also be evidenced by Tisza–Herpály–Csőszhalom culture finds discovered as far south as the site of Belo Brdo in Vinča, that can only be explained through either trade contacts or marital exchange.

**MODELLING EXCHANGE PATHWAYS IN THE VRŠAC REGION USING GIS**

For the purpose of this article, an assumption of water transport down the Tisza into the region between Zrenjanin and Pančevo where it meets Danube is adopted as one of two possible hypotheses. It is assumed that the disembarkation of obsidian took place near Opovo, where two Vinča culture sites exist; Trnovača

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31 Marinković 2006.
32 Vasić 1936 a, Pl. XXVIII–XXII; Vasić 1936 b, Pl. XXXI, 74d, Pl. LVI, 115–118.
near Baranda to the north of Opovo, belonging to an earlier period of Vinča culture, and Ugar Bajbuk to the east of Opovo dated to the late Vinča culture period. Once disembarked, the goods continued overland towards Alibunar, entering the Vršac area from the west edge of Veliki Rit (Fig. 8). An alternative disembarkation point would be in the vicinity of Perlez, north of Opovo, although this is off the direct Tisza watercourse (it lies on the Begej river which meets the Tisza at Titel, west of Perlez) and slightly further away from the Vršac area. Here a large multilayered prehistoric site with a Neolithic settlement exists at Batka (Fig. 8). On the basis of being further away from Vršac by land, this region was excluded from the analysis, although the trajectory to the Alibunar region would not differ significantly from this point either. Unfortunately, the area between Opovo (or Perlez) and Alibunar has never been archaeologically surveyed (at the time of the writing of this paper, an archaeological survey of central Banat is underway, but no results have been published yet), so information about the locations of Vinča culture sites is unavailable, even though there obviously had to be some present.

Regarding the second hypothesis that obsidian was transported to Vršac region up the Mureș river to the area north of it, offloaded somewhere around present day Timișoara and transported south on foot overland, we can say for certain that a number of Vinča culture sites exist there, making it quite plausible. In this paper we model a possible route from the north of Vršac, entering the region somewhere between the villages of Moravitsa and Vatin, in the vicinity of the recently surveyed Vinograd site (Fig. 9).

GIS aided reconstructions of obsidian exchange pathways are not a novelty in modern archaeology, with a growing number of examples from various parts of the world. The majority of authors base their modelling on the movement through space as a function of one (or more) of its characteristics. The most commonly used is the terrain gradient, expressed in measurable values like percentage or degrees. Based on the gradient, it is possible to model a cost surface which is a function of effort needed to cross a certain distance between two points in space. In both theory and practice, an

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33 Jovanovic 1965.
36 conf. Whitley, Hicks 2003; Chataigner, Barge 2007; Contreras 2011, to name but a few.
37 Whitley 2003, 80.
increase in terrain gradient results in an increase in travelling costs, although there are some caveats that need to be considered, such as the fact that sometimes modelling can overemphasize the cost of traversing short but steep sections of a straight line in favour of a longer, more indirect route over flatter terrain. In order to avoid (or to at least decrease) the occurrence of such errors, it is possible to use alternative values obtained as a function of the terrain gradient value, like the value of the walking speed in kilometres per hour for example. These values can be calculated using an exponential function better known as Tobler’s hiker function. This function, resulting from years of experimentation by an American-Swiss geographer named Waldo Tobler, is defined as:

\[
Km/h = 6 \ast \left\{ \exp \left(-3.5 \ast \text{abs}\left(\frac{dh}{dx} + 0.05\right)\right) \right\}
\]

In this function \(dh/dx\) is actually the gradient of the terrain at a measuring point, expressed in degrees. In his work, Tobler also added the notion of multiplying speed values by an offset factor in order to define the walking as being on path, off path or on horse (factors being 1, 0.6 and 1.25 respectively). As the notion of moving goods on foot (no evidence of horses or carts exist on late Neolithic sites in the Pannonian plain or the central Balkans) in this paper is that they were moved over long term and well established paths known to all, an offset factor value of 1 has been omitted in the formula, as it does not influence the final calculation. The maximum speed value obtained through this formula is about 6 km/h on a 3° downwards sloping terrain, whilst the maximum speed on flat terrain is about 5 km/h.

Based on the DEM used for this paper, the maximum calculated speed was 5.03 km/h, obviously a result of insufficiently detailed maps used for the construction of the DEM. In order to distinguish the difference in terrain, the speed values were reclassified as five classes (each class consisting of values between two integers e.g. 0–1 or 1–2 km/h) and assigned generic costs of 150, 50, 25, 10 and 0, preferring surfaces that allow the fastest walking speeds (the 4–5.03 km/h surfaces).

Aside from terrain gradient, an equally important factor when choosing the path is the position of bodies of water, either permanent or seasonal. As established earlier in this paper, the two main (permanent) bodies of water were Mali and Veliki Rit, the latter heavily influencing possible pathways in the Vršac region. Aside from these, numerous smaller waterways like ponds, marshes, streams or rivers (some seasonal but most permanent) were also present in the area and hindered transport (like the Vlajkovac depression). If overland transport is assumed as the primary means of transport of obsidian from the Tisza region into the Vršac area, either via the northern or southern corridor, then these waterways need be treated as smaller or larger obstacles that must have deflected transportation away towards drier lands. In order to accomplish this, two separate layers with the disposition of all bodies of water were

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\(\text{abs} – \text{denotes absolute value of the expression in the brackets, dh – the elevation difference, dx – the distance}\)

38 Tobler 1993.
39 \(\text{abs} – \text{denotes absolute value of the expression in the brackets, dh – the elevation difference, dx – the distance}\)
modelled, the first one containing ponds, marshes or lakes and the second with rivers or streams. The ponds, marshes and lakes layer was reclassified using extremely high generic values (100 for ponds and marshes and 250 for lakes), completely eliminating them as possible surfaces of transport. Contrary to this, the river/stream layer was reclassified by creating buffers with ascribed values around vector representations of river ways, making river beds less desirable than dry land but not totally excluded from crossing, avoiding the need to create paths that circumvent rivers or streams completely. In general, all rivers or streams in the Vrač area were, and still are, possible to cross, with more or less effort (the Moravička and Karaš, the two largest rivers of the region have maximum depths of about 4 metres, but throughout the year these values lie in the 2–2.6 metre range).\(^{40}\) In order to simulate different degrees of difficulty in crossing streams or rivers, ascribed values were envisaged so that smaller values identify more traversable watercourses and larger values denote less traversable. This adjustment allowed the program routine to favour crossing of waterway in places where dry land was the second best choice because of a higher terrain gradient (i.e. smaller travel speed). The effort of crossing waterways must be treated as no bigger than that needed to traverse slanted or uneven ground, especially when performed out of season with a low water table. It must be noted that these generic values used to weight the traversability of waterways do not represent metric units of cost (e.g. caloric consumption per kilometre) but rather they are a generic unit of cost identical to those used for the reclassification of speed values.

Using the assumptions made above, calculations were made using two different starting points: the first path originates at starting point 1, in the region of present day Alibunar (Fig. 9 left) to three Vinča culture sites with confirmed obsidian finds; Potporanj–Kremenjak, Staro Selo and Kozluk. On the other hand, the second path begins on the northern edge of the area at starting point 2, near the modern village of Vatin (Fig. 9 right). Looking at the calculated paths that originate from point 1, we can see a clear tendency for overlapping in the initial segments that follow the proposed southern bank of Veliki Rit up to the vicinity of modern day Banatski Karlovac. It is not a surprise that this occurs, as the terrain here is limited by a narrow corridor of dry land between the waters of Veliki Rit and the ridge line, which slowly descends from Alibunar towards Banatski Karlovac (in a south to southeast direction), where it finally merges with the surrounding terrain. The prominent ridge line in this region most likely represents the maximum water level of Veliki Rit (possibly attained during the last Ice Age). As the landscape opens up towards the southeast, in the region of Banatski Karlovac, more routes become possible. One striking feature of the calculated path towards the site of Potporanj–Kremenjak is the direct crossing of Vršački Put (Vrač road).

\(^{40}\) Values obtained from Serbian Hydrometeorological Service of Serbia at http://www.hidmet.gov.rs
site (Fig. 10, red path) somewhat north of it. Toponym *Put-road* is the name of the site, and the name of the village located nearby – Izbište (*izba* being a wooden house, *izbište* – place with wooden houses) is an obvious reflection of the history of the area from a time before extensive reclamation works when there was less traversable and habitable land, which made these locations important enough to acquire names. The Vršački Put site is located on the bank of a dried up stream and could possibly be a satellite or seasonal settlement of the much larger nearby site of Potporanj Kremenjak, an important archaeological location for the Neolithic of the region as it contains a complete chronological sequence of Vinča culture. Unfortunately there are no other sites of late Neolithic period detected in the area of the modelled road to Potporanj so we cannot make any more comparison to see how well a modelled road fits into the documented situation in the field.

The modelled pathway (Fig. 09, yellow) leading towards the site of Kozluk has a slightly different route. Starting at the same point near Alibunar in the west as the previous one, it follows the same southwest bank of Veliki Rit, but does not change its trajectory after Banatski Karlovac, instead following the bank all the way to present day Vlajkovac. The location of the Vlajkovac depression, a probable marsh or a shallow lake in the late Neolithic period to the south of Veliki Rit, creates a narrow dry land corridor which our modelled road follows before taking a turn to the east in the region of the modern day village of Pavliš. Similar to the modelled pathway leading to Potporanj, this one crosses directly over Ritine (Fig. 10), a Vinča culture site with only surveyed data, and about 900 metres from the Pavliš Beluca/Maršala Tita location, where another site with a large significant body of evidence for both Vinča and Starčevo cultures exists under the houses of the present day village. Moving further east and entering the present day city of Vršac, the modelled path passes within one kilometre of three Vinča culture sites (Kanal Mesić, Abraševiceva Ulica and Dečanska/Banatska Ulica). The closest to the modelled route is the Abraševiceva Ulica site, but we have only limited knowledge of the material, as the site is located in the centre of the modern city and was discovered by chance (only a very small area was excavated) when excavating for foundations of a modern residence complex in the 1970’s. This fact in itself complicates the estimate of the exact or approximate boundaries of the settlement, making it possible that the site is actually much closer to the modelled path than indicated by these chance finds. After the Abraševiceva Ulica locality, the modelled path enters a narrow corridor formed by Mali Rit in the northwest and the Vršac Mountains; northern piedmont, ending at the site of Kozluk. The deviation of the modelled road in respect to the position of some sites along the way does not influence the fact that the general direction of the path is a good one, as suggested by its passing near or over two sites in Pavliš and the urban Vršac area. This could suggest the necessity of a more detailed analysis of the terrain to fine tune the modelling.

Looking at the third path from starting point 1, the one leading to the site of Staro Selo (Fig 9, blue line), the modelled path differs only slightly from the path to Potporanj, being that the Staro Selo site is in its immediate vicinity. There are no striking features for this path, mostly because there are no known late Neolithic sites on its trajectory. It diverts from the path to Potporanj just east of Uljma (Fig. 9), at a confluence of three smaller streams. East of this feature, there is a slightly elevated plateau which has all the potential for a Vinča culture settlement, but as this area has never been archaeologically surveyed no information about the existence of a site is available.

Turning our focus to the north, to the region of starting point 2, we have a similar situation, two shorter paths and one significantly longer. The first to be analysed is the shortest one leading to Kozluk, on the eastern bank of Mali Rit (Fig. 9, green path). Immediately, the path deviates to the east, cutting across flat terrain...
away from the eastern edge of Veliki Rit towards the northeast bank of Mali Rit, before taking a sharp turn just west of Majdan (only chance finds, never excavated), the only site of Vinča culture close to the path, and ends at Kozluk. The immediate vicinity of the site of Majdan to the modelled path indicates the possibility of obsidian finds being discovered here on future excavations. The lack of known sites in this part of the region prevents a more detailed discussion.

The other two paths (towards Staro Selo and Potporanj) do not differ much in their course for almost their entire length (Fig. 10). At the very beginning, the modelled paths stick to the eastern bank of Veliki Rit and follow its edge to the northern outskirts of present day Vršac. On its course, the pathway crosses in the immediate vicinity of the Utrine site (only partially surveyed), before reaching the urban part of the modern city, where it passes within 1.5 to 2 km of several groups of sites (Fig. 10). Proceeding past the city itself, both of the pathways lead directly south, passing close (less than a kilometre) to the Sauacker site, crossing the Keveriš River to the west of the site and continuing towards Staro Selo and Potporanj. From Sauacker to the latter there are no known sites of the period, making in-depth analysis of the model impossible.

If we were to analyse the overlay of all six modelled pathways presented here against site locations, one striking feature becomes very apparent (Fig. 10). The modelled pathway leading from starting point 1 to Kozluk and two of three originating from starting point 2 create an intersection just west of the centre of modern Vršac. Looking at the situation in more detail, it becomes evident that a large majority of known Vinča culture sites are located within a 5 kilometre diameter formed around the intersection location (Fig. 11, blue circle). Out of a total of 27 known Vinča culture localities in the region, over a third – 37% (10) to be exact, are within, or just outside, this area of 5 kilometres. Extending the boundary to 7.5 kilometres (Fig. 11, green circle) accounts for just one more site located on the outer edge of the limit, Sauacker, to the south of the main cluster. This almost self evident clustering further accentuates the already high number of sites in a triangle formed by Veliki and Mali Rit to the northwest and northeast and the Keveriš River to the south. As studies have shown that the average walking speed of an adult person can range from 4.51 to 5.43 km/h on flat terrain, this would put the sites in the 5 km cluster within half an hour walking distance of the modelled pathways’ intersection (the centre of a circle with a radius of 2.5 kilometres), whilst Sauacker, the farthest site, would fall within a one hour boundary (just over 4 kilometres from the intersection point). Such a constellation would make trade and exchange easy to perform, be it of an intra or inter regional type. Further studies on settlement patterns in this area will show whether this argument of site clustering has any deeper meaning or if it is merely a coincidence of the position of water bodies and preferable environmental factors.

CONCLUDING REMARKS

The premiere GIS aided study of the movement of obsidian through the Vršac region presented here relies heavily on modelling based on the reconstruction of the past environment in the Vršac region. Although further studies are needed, especially for a better, more detailed reconstruction of Vinča settlement environments, some patterns are already distinguishable in the modelling. The existence of large bodies of surface water like Mali and Veliki Rit or the Vlajkovac depression obviously had a significant influence on the choice of settlement positioning, but also influenced the creation of paths in the landscape. Furthermore, the position of the Vršac mountain range and the Deliblato sands in the southwest further narrowed the possible corridors of travel, leaving only a limited amount of landscape easily traversable throughout the year. This corridor, predominantly oriented southwest to northeast, acted as a natural funnel shaping the pathways connecting well established settlements like the eponymous site of Belo Brdo in Vinča with Uivar and Turdaș in Romanian Banat and Transylvania. The distance of about a 130 kilometres between these markers of the Vinča world (approximate distance between Uivar and Belo Brdo) could have been surmounted in a matter of a week when travelling on foot, so cost efficiency was not in question at all. The longevity of obsidian trade in the Pannonian plain, as evidenced by obsidian finds ranging from the early Neolithic Starčevo–Criș–Körös sites to the very end of the Vinča culture, indicates the longevity of the pathways in the landscape. These arteries connecting more or less permanent settlements in the region were obviously well known and permanently established by the time of the end of the Neolithic. Furthermore, it is possible that

by the end of the Neolithic, areas close to or directly on the established pathways were favoured when deciding the positions of new settlements, as suggested by the evident clustering of sites close to the intersection of the modelled pathways presented in this paper. It is the hope of the author that future research in the region will be focused on new archaeological surveys, especially in the western part around Banatski Karlovac and Alibunar, where an obvious lack of information about archaeological sites hinders our knowledge. The discovery of more late Neolithic sites in the area could help us refine the future modelling of pathways in the period of the region, but also enable a better understanding of settlement patterning and the reasons behind it.

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Резиме: МИРОСЛАВ МАРИЋ, Балканолошкi институт, Српска академија наука и уметности, Београд

МОДЕЛОВАЊЕ ПУТАЊА ТРОГВИНЕ ОПСИДИЈАНОМ ТОКОМ КАСНОГ НЕОЛИТА У РЕГИЈОНУ ВРШЦА И ЈУЖНОГ БАНАТА ПОМОЂУ ГИС-а

Кључне речи. – Неолит, винчанска култура, ГИС, моделовање путања, трговина и размена, опсидијан.

Примарни фокус овог рада јесте рачунарско моделовање путања унosa и дистрибуције опсидијана у једно јасно дефинисано микроподручје насељено знатном популацијом у време краја неолита на овом простору. Помоћу ГИС-а, моделовање се могуће путање размене једне врло специфичне и тражене потрошнице у неолиту Балкана, опсидијана, у подручју које дефинишу Алибунарска депресија (Велики рит) – на северу и северозападу, Вршкачке планине – на истоку и североистоку и реке Караш и Бразава – на југу и североистоку (Сл. 1). Из времена винчанске културе, са неколико истражених локалитета (Козлук, Ат, Потпорава, Старо Село – Границе) почиње неколико хиљада опсидијанских налаза (1), што овај данашњи музеум окохоликовидно желимо да реконструкциремо вероватну путање размене и трговину у овој области. Један од клучних аспекта овог рада јесте схватање да савремени изглед прегледа околне Вршка није нужно идентичан са оним из периода који се овим смешта у време између 5300. и 4600. године пре н. е. Узимајући ово у обзир, анализа прегледа праштирије заснована је на поређењу савремених географских и геолошких података, на доступним анализама палеолитичке средине из региона и на упоређивању са модерном петрографским структурама са овластених локалитета винчанске културе. Алибунарска депресија је највећа геоморфолошка зона региона Вршка, изузета приближно равним североисток–југозапад, а настала је отектонским активностима у периоду квартара. До 18. века, ова депресија, коју заједно чине Мали и Велики Рит, опстала је као мочварно-језерска област. Неолитски локалитети у региону Вршка показују образац насељавања око великих, трајнијих водених површина (Сл. 3), попут Малог и Великог Рита или простора између њих (најбољи пример је вишеслојни локалитет Ат где се, поред неолитских налаза, налазе и палеолитски налази). Насеља су локирана у подручјима где доминира дрвеће широког листа, уз обиле локације у виду полена леске, јаблана, јове, врбе, липе и букве, у којима је видљив нелостатак трава и другог биља што указује на постојање ограничених искречених површини. Моделовање се заснива на знатној корисности као читаоцу овог рада, уз посебни акцент на опсидијану, која представља важан материјал у изучавању свогегеографског и геолошког контекста овог региона, али и у бројним других аспектима, као што су у прегледу протеклих периодних претворби и у прегледу структуре и функције урбаног просторије. Моделовање путања унosa и дистрибуције опсидијана у региону Вршка покушава да се уочи тао у прегледу структуре и функције урбаног просторије. Моделовање путања унosa и дистрибуције опсидијана у региону Вршка покушава да се уочи тао у прегледу структуре и функције урбаног просторије. Моделовање путања унosa и дистрибуције опсидијана у региону Вршка покушава да се уочи тао у прегледу структуре и функције урбаног просторије. Моделовање путања унosa и дистрибуције опсидијана у региону Вршка покушава да се уочи тао у прегледу структуре и функције урбаног просторије. Моделовање путања унosa и дистрибуције опсидијана у региону Вршка покушава да се уочи тао у прегледу структуре и функције урбаног просторије.