The sedimentary environment in the Ljubljansko barje basin during the pile-dwelling period

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Izvleček

Geološki procesi na Ljubljanskem barju po zadnjem glacialnem višku so le splošno poznani. Izjemoma sicer poznamo detajlne razmere, vendar so te prostorsko in časovno fragmentarne. Artefakti iz arheoloških najdišč so bili v preteklosti deležni natančnega proučevanja, sami sedimenti s kulturno vsebino, njihova talnina in krovnina pa bistveno manj. Pot do boljšega razumevanja okoljskih razmer v času kolišč verjetno vodi prav preko natančnega poznavanja sedimentov in pokopanih tal ter razumevanja evidentiranih stratigrafskih hiatusov.

Ključne besede: Ljubljansko barje, geološki procesi, kvartarno in holocensko okolje, jezerska kreda, gyttja, organski sedimenti, kolišča

Abstract

Geological processes on the Ljubljansko barje basin after the Last Glacial Maximum are known merely on a general level. At few points more detailed circumstances are known, but this information is fragmented spatially and temporally. While artefacts from the archaeological sites were studied in detail, the sediments were mostly only imperfectly described. Better understanding of the evolution of the environment requires accurate study of these sediments and buried soils, and detection of evident stratigraphical hiatuses.

Keywords: Ljubljansko barje, geological processes, Quaternary and Holocene environments, *Seekreide*, gyttja, organic sediments, pile-dwellings

INTRODUCTION

This contribution summarizes and comments on the geological perspective of select research results, which by using a variety of methods illuminate the geological processes in the region of the *Ljubljansko barje*. It also extends some new perspectives concerning the geological phenomena during the period of the Last Glacial Maximum, the Late Glacial and, especially most important from the archaeological perspective, during the Holocene. By no means do I presume that this review provides any definitive answer to an otherwise broad theme. On the contrary, it demonstrates the current exceptionally fragmentary and superficial grasp of the environment's circumstances. As the reader will also be able to judge, this contribution on several occasions is based mainly on comparisons made within the framework of critically scientific deductions. Many readers may query the lack of quantitative data. I believe, however, that prior to attempting a quantification of geological processes, their mutual interaction is worthy of detailed review. Otherwise we may face being drawn into a cycle of scientific falsities. I shall also draw notice to such instances in the continuation.

Let us first consider the terminology that will be used in this review. Fran Erjavec and Fran Levstik introduced the toponym *Ljubljansko barje* into the literature as a geographic concept as late as 1880 (Melik 1927, 1946). Professional geological terminology today uses the term *Ljubljansko barje* in two different contexts. On the one hand it refers to the Quaternary sedimentary basin (*sensu lato*). It also refers to the Holocene marshland landscape (*sensu stricto*) – in the sense that Levstik and Erjavec instituted – which developed where the lake had been. Archaeologists also need to understand the term in both contexts. Of course the marshland landscape, the former environment that engendered Erjavec's and Levstik's original labeling, is long gone. However, the sedimentary basin remains. The abridged term is simply Barje (capitalized), effectuated already by Levstik and Erjavec (Melik 1927, 33–34).

FORMATION OF THE LJUBLJANSKO BARJE *SENSU LATO*

How was the Ljubljansko barje *s.l.* formed? There is no doubt that its formation is tectonic, a strong influence on the relative subsidence of this region, or rather on the relative elevation of the Barje area. It is also a fact that the Pre-Quaternary foundation of the Barje is topographically very uneven, which is substantiated by the presence of the many isolated hills. As concerns the formation of the Ljubljansko barje *s.l.*, this is as far as the opinions of geologists reach in unity. Earlier researchers believe that the foundation is composed of tectonic clusters delimited by the vertical faults in the dinaric (NW-SE) and transdinaric (NE-SW) directions (Pleničar 1967; Buser 1968; Grad, Ferjančič 1974; Premru 1982). Mencej (1990) also advocated a similar fault pattern. The initial interpretations are thus based on the cluster structure of the foundation, which then presumably subsided differentially.

Vrabec (2001) offered a very different explanation for the formation of the Ljubljansko barje *s.l.* He anticipated that the Barje formed as a pull-apart sedimentary basin between the dinaric directed faults. Verbič (2006a) placed the origins of the Barje within the context of Quaternary active reverse faults between Ljubljana and Kranj. He adopted the opinion of earlier researchers that the Vič fault runs along the northern edge of the Barje, however that it has a reverse and atypical character (Verbič 2006a). The Vič fault is the most southern in a string of reverse faults between Kranj and Ljubljana. A fault directed E-W runs along the southern edge of the Barje (Verbič, Horvat 2009b), just as Mencej (1990) anticipated, however according to their explanation it is also reverse. The filled-in eroded valleys can explain the dynamic topography of the Pre-Quaternary foundation together with the isolated hills, thus making the tectonic cluster formation unnecessary for its explanation. Regarding recent and Quaternary activity of individual faults in the Barje, we have no appropriate data other than select data for the Vič fault (Verbič 2006a).

New data relating to when the Barje *s.l.* formed have long been lacking. That the formation of the Barje *s.l.* was a process, as opposed to having occured in a single moment, is particularly noteworthy. Perhaps a comparison between the Vič terrace (*fig. 1*) (Rakovec 1932, 1954; Šercelj 1967), the borehole near Dolgi most (Šercelj, Grimšičar 1960) and the BV-2 borehole (Šercelj 1966) would be the most revealing for a chronological classification of the beginnings of this process. Both boreholes exhibited *Mindel* sediments, which used to be attributed to the Lower Pleistocene, above the Pre-Quaternary foundations (cf. Šercelj 1967); today however, some authors more generally connect them with the Marine isotope stage 12 and/or 14 (the period before ca. 400–550 ka BP), which means we can presumably attribute them already to the Middle Pleistocene (Gibbard, Cohen 2008). Also attributed to the Mindel glaciation are sediments from the area of the former Vič brickfield. Earlier sediments (than *Mindel*) above the Mesozoic and Paleozoic foundations are as yet unknown from the Barje. Any new determinations should take into account that the Barje began to form as a sedimentary basin during the Middle Pleistocene. Little data regarding these earliest sediments are available at present, however several new results and interpretations may be anticipated in the future.

LAKE! UNTIL WHEN?

It seems to be the case that some *evidence* in science and geology is less *evidenced*, while some other evidence is more so. In particular, I am referring to the hypotheses and interpretations of individual analyses. Citing Karel Popper (1998) – which seems appropriate at this stage – the truth is that an individual hypothesis is all the more reliable proportionate to the number of attempts to falsify it and proportionate to how aggressive, in depth and exactness, these attempts were.

Why such an introduction? Simply: because it presents such an integrative response to the discussion of the former existence of the lake in the region of the Ljubljansko barje. It is hardly important who first interpreted the *lake chalk* (the highly accepted geological term in Slovene: "jezerska kreda"; German "Seekreide"; it is used for silty marl from a lake environment, here we will use term *lake silt*) in the Barje as one characteristic of a lake environment.

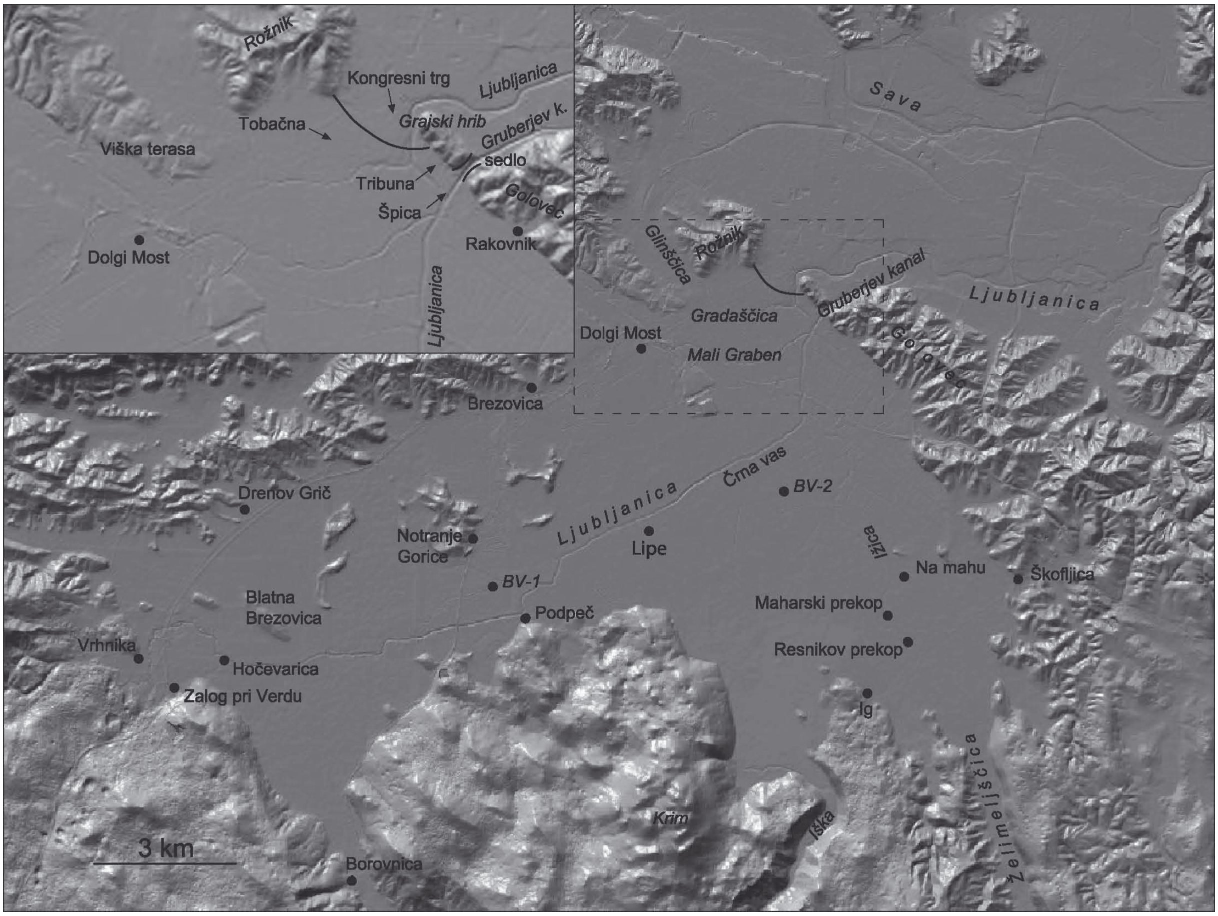

Fig. 1: Ljubljansko barje, locations cited in the text. The line between the Castle Hill and Rožnik delineates the southern edge of the Sava alluvial fan during the Last Glacial Maximum, when it cut off the alluvial outflow (Paleo-Ljubljanica) from the Barje. (Data: ©Surveying and Mapping Authority of the Republic of Slovenia).
Sl. 1: Ljubljansko barje z lokacijami, omenjenimi v tekstu. Linija med Grajskim hribom in Rožnikom prikazuje južni rob prodnatega savskega aluvialnega vršaja v času zadnjega glacialnega viška, ko je zaprl aluvialni iztok (Paleoljubljanico) z Barja. (Podatki: © GURS).

Perhaps it was Karl Deschmann or even someone before him, some engineers perhaps who in the mid-19th century set out to design a railway track across the Barje. Certainly these first researchers relied upon the interpretations of the sediment texture, the structure of the *lake chalk*, as well as on the general geological and geomorphological contexts of the Ljubljansko barje. The principles of actualism led them to such a conclusion; and their hypothesis was confirmed subsequently, especially in that the fossil content in the sediments corroborated the lake environment's existence (cf. Pavlovec 1967, 1973; Kroflič 2007). There is firm grounding for the hypothesis of a former lake environment in the Barje, and its credibility has yet to be contested by a falsification attempt or any other form of interpreting field observations and laboratory analyses. Indeed, the entire issue revolves solely around Šifrer's (1984) interpretation and I do not know of any other discussions that basically challenge the very existence of an Upper Pleistocene and Holocene lake sedimentary environment in the Barje.

The theories and conjectures in Šifrer's (1984) work are without geological substantiation and corroboration. For instance, he writes (p. 36): *From the perspective of the development of the Barje during the Last glacial period it seems especially significant that the fluvioperiglacial sedimentation here was ample and throughout competed with the sedimentation of the Sava glacier. This also supports why the former made its way only locally toward the Barje, and even then probably only as far as the then taut world of the Barje would allow. The premise follows that during the postglacial periods on the Barje there were no conditions for the stagnation of* *profuse amounts of water, let alone for the formation of a lake as was hypothesized by earlier researchers of this region (Kramer 1905; Seidel 1912; Rakovec 1939, 1955; Melik 1946).*

Luckily, the above assertions can be checked and as such have proven erroneous. How far the Sava sediments advance upon the Barje and its interior has little bearing on the formation of the lake; rather, that it closes the mouth of the river, the former Paleo-Ljubljanica, on the surface exiting the Barje (*fig. 1*). The youngest Sava river (glaciofluvial) infill in Ljubljana, the Last glacial period infill, is in the form of an alluvial fan that crossed through the center of Ljubljana, reaching to Mirje and then along the foot of the Castle hill and probably somehow all the way to the Šentjakob bridge. It literally "ran into" the Castle hill from the north, no doubt, thus closing off the Paleo-Ljubljanica towards the east. These locations are traceable; they have been verified and evidenced during construction and archaeological activities. The above cited excerpt is symptomatic also of Šifrer's assertion "*… only as far as the then taut world of the Barje would allow*". How does he know about the tautness of the Barje landscape, which today is buried beneath the *lake silt*?

His next argument negating the former lake environment cites that … "no delta sedimentation – which would be anticipated if the streams and rivers flowed out into the former lake – is evidenced anywhere " (p. 41). And yet he fails to cite where he even traced any evidence of lake sedimentation, either in the boreholes or cross-sections, so as to be able to justify that such sedimentation is not evidenced. Currently there are conflicting observations: the execution and recording of research boreholes at the Špica site (*fig. 1*) (Novšak et al. 2009), as well as subsequently during geologic research studies complementing the archaeological excavations, allowed us to trace in detail the detritic input of non-carbonate terigenous sand sediments into the lake environment, which is otherwise where the *lake silt* sank. At a distance of more than 100 metres we were able to determine the proximal and distal parts of the small delta of the currently unknown stream, perhaps the one from the erosive indent above Rakovnik. The *lake silt* was discovered also in the area of the Ljubljana Tribune, directly at the foot of the Castle hill. Other than this, *lake silt* was also discovered in 2009 during construction and archaeological research works along Tržaška cesta (the road towards Trieste) near the former Tobačna factory. Sand plates were also found among the silty *lake silt*. This latter determination is indicative of there having been a unified lake sedimentary environment throughout the entire Barje. The majority of the lake sediment in the Vič area (Gradaščica, Mali greben) was later eroded. Sedimentation in these proximal areas of the lake at the end of the Pleistocene was probably a rapid process, as a result of the detritic input of sediment material from the side of the Sava fan. Rapid sedimentation in this proximal lake environment presumably indicates also the small volume of pollen concentration in the lake sediment at the Špica site (pers. comm. by Andrič 2010 and by Culiberg 2010).

Indeed several of Šifrer's (1984) citations warrant critique. For instance, (p. 49): "…The findings that the lake clay (snail-clay soil) is limited mainly to the proximity of the limestone and dolomite hinterland are also in accordance with this." Several times the author supports some theory with debatable or even nonexistent arguments. Lake sediment was discovered at the Špica site, the Tribuna site and at the former Tobačna factory site, all of which are very far removed from the "limestone and dolomite hinterland".

The premise placing the existence of the lake environment on the Barje into question, or even denying it (Šifrer, 1984), is unfounded. This premise originally served select authors as an additional argument substantiating the interpretation that pile-dwelling settlements were not situated on or near the lake, but rather on the alluvial plain (cf. Budja, 1994). It emerged mainly due to the lack of critically reviewed scientific judgement. It is clear to geologists that Šifrer's (1984) premise for the above-stated interpretation is unnecessary.

The essential question in this regard concerns when the lake existed, and how its dimensions altered through time, and into what kind of environment the lake land change. This is a question for which we have only fragmentary answers. Otherwise, the more or less established and general theory asserts, on the one hand, that alluvial (fans, deltas, etc.) sediment created a lateral accretion of the lake sedimentary basin, while at the same time creating vertical accretion of lake sediment over the entire area of the lake. A massive area and amount of material in this field lies available for more detailed investigation, and quite likely several surprises await us all in the ensuing research development.

In the past, the predominant opinion claimed the *lake silt* to be exclusively Holocene sediment. Presumably, certain general and principled opinions, such as that climate conditions promoted sedimentation of the *lake silt* only from the Holocene onwards (cf.

Šercelj 1962, 1965, 1966), contributed to this stance more than did the results from analyses. Similar convictions are also more recent (Pohar, Culiberg 2002; Brenčič 2007). However, recent research is also depicting a different picture of the stratigraphic extent of the lake sediment. Currently four sites evidence only Pleistocene lake sediments, while the Holocene lake sediment was either eroded or never even deposited. These location sites include Notranje Gorice (Šercelj 1976), Zalog near Verd (Culiberg 2006; Verbič 2006b), Hočevarica (Culiberg 2006) and Špica (in the continuation). A relatively long Holocene stratigraphic hiatus was also determined above the *lake silt* at Resnikov prekop (Šercelj 1963; Andrič 2006). Šercelj (1981–1982) fleetingly mentions the results of trial trenching and pollen analyses along the laying out of the Ljubljana southern bypass road. He cites only Pleistocene sediments between Dolgi Most and the Ljubljanica river, and he explicitly does not cite the presence of any lake sediment. He infers, on the basis of the absence of Holocene sediments, that there were no pile-dwellings in this area. A long stratigraphic hiatus between the Pleistocene and Holocene sediments (younger than the pile-dwellings) is mentioned in the area of the Rudnik industrial zone. He describes a similar situation near the highway clover along the Dolenjska road. Nonetheless, it remains negligible that the Na mahu site (Andrič et al. 2008) is still the sole site where the transition between the lake and marsh sedimentary environment is linked and even chronologically well documented. Several other locations lack a radiometric chronological control.

What about the spatial extent of the lake environment? Simple inference tells us that the entire Barje region was under water during the time of the greatest lake formation at a height of approximately 297 m; this height presumably reached as far as to the Sava river infill between Rožnik and the Castle hill. The role played by the saddle between the Castle hill and Golovec is somewhat more ambiguous. The above sea-level height of this saddle prior to the construction of the Gruberjev canal is not known exactly; however, it would seem that it was higher than the transition from the NW edge of the Castle hill, as there are no sedimentation records from Poljane that can be linked to the spilling over of water from the Barje side. If the above stated theory holds in general, then some truly fascinating hydrological conditions reigned in the area between Rožnik and the Castle hill, at least during the formation of the Sava alluvial fan. The water, which ran into the lake from the karst sources and surface streams along the edge of the Barje, had to also flow off from it as well; this took place precisely across the Sava alluvial fan. As to how the water *traffic* was organized we can only guess. Quite likely there was an antagonism between two hydrological systems, in the sense that the Sava alluvial fan, during its activation, presumably made no allowance for the alluvial efflux of the modern day Ljubljanica to cut through from the lake any more rapidly. Perhaps the hydrological regime was of an exceptionally seasonal nature. Furthermore, two thick strata of fine-grained sediments are traceable between the sand gravel near the construction of the garage house beneath Kongresni trg. These two strata are indicative of sedimentation due to suspension, that is, from the stagnant water in the alluvial fan.

The contracting of the lake was connected with the erosive capacity of the lake outflow to incise, as well as the lowering of the local base levels. Nonetheless, caution is called for in evaluating this contraction, as it is undoubtedly also connected with the dynamics of the subsidence of the lakebed. Several issues remain unresolved in this concern. What influence did the sudden static load from this area, coming from an approximately 10m-high water tower, have upon the subsidence? Obviously, it accelerated the subsidence of the lakebed; the problem lies in how to quantify this acceleration. The subsidence of the Barje basin is a complex issue with numerous variables and their reciprocal interactions. As the dynamics of the subsidence of the Barje basin had their influence upon the environmental conditions, I will grant a little extra consideration to this matter in the continuation.

THE LJUBLJANICA! SINCE WHEN?

The Ljubljanica, which serves as the main drainage vein from the Ljubljansko barje, further substantiates the conclusion that the Ljubljansko barje is an exceptional sedimentary environment in terms of its extreme characteristics. The geomorphological literature rarely refers to such extreme rivers as the Ljubljanica. The Ljubljanica also lacks adequate description and a sufficient number of relevant measurements from a geomorphological perspective. Nonetheless, some characteristics are known: it formed in the region of the former lake, it is fed mainly by the karst aquifers, and it has almost no underground sediment load. The erosive power of the Ljubljanica is exceptionally small, especially as

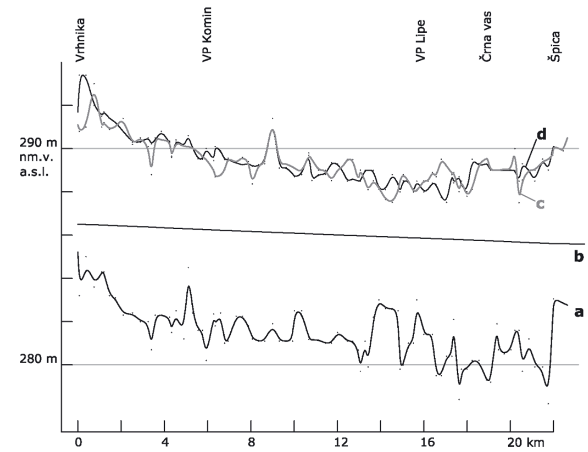

Fig. 2: Geodetic topographic measurements along the Ljubljanica river between Vrhnika and Špica (data from: Stojič 1994). The smoothed curve of the riverbed (**a**); the level of the Ljubljanica river at average flow (VP Moste) 55 m^3/s (**b**); smoothed curves of the height of the levee on the left (**c**) and right (**d**) banks of the Ljubljanica river.
Sl. 2: Geodetske topografske meritve vzdolž Ljubljanice med Vrhniko in Špico (podatki po: Stojič 1994). Zglajena krivulja dna struge (**a**); gladina Ljubljanice pri povprečnem pretoku (VP Moste) 55 m^3/s (**b**); zglajeni krivulji višine obrežnega nasipa na levem (**c**) in na desnem (**d**) bregu Ljubljanice.

concerns side erosion. For almost its entire length through the Barje, it cuts through the cohesive *lake silt*. The surface level of the Ljubljanica (*fig. 2*) along its course between Vrhnika and Ljubljana (a distance of 22 km) indeed falls by 2 m during strong currents (above 100 m^3/s) and only 40 cm at a flow of 20 m^3/s (Stojič 1994). During lower water levels, the gate levels throughout Ljubljana regulate the surface level of this entire segment of the Ljubljanica.

The alluvial outlet from the Ljubljansko barje is an essential element, which throughout history determined the hydrological conditions there. Of course several other environmental variables also affected these conditions, however the water regime was primarily determined by the capacity of water to outflow from the sedimentary basin, that is, from the height of local base levels. The Ljubljanica covered this surface during the infill of the Sava river alluvial fan, and then after the Sava moved northwards it began to cut its bed through the Sava alluvial fan. The oldest segment of the modern Ljubljanica is thus the segment beneath the Castle hill, running from the Šentjakob bridge, down and eastwards to its efflux into the Sava.

Throughout the Barje region the Ljubljanica is younger. Currently there exists very little geological data that allows at least indirect inferences regarding the origins of the Ljubljanica at individual segments. Consequently, I can only restate archaeological argumentations that until the Middle Bronze Age, the Ljubljanica undoubtedly formed its own basin in at least select areas of the Barje (Gaspari 2009b, 40).

A general geological framework, without chronological dimensions, can be established for the origins of the Ljubljanica. As already mentioned above, almost the entire length of the Ljubljanica in the Barje cuts through the cohesive *lake silt*. Due to the predominantly karst water systems and the cohesive riverbanks, its bedload is very limited in quantity. The bedload is what enables the formation of alternating ridges, which can then initiate meandering in itself (cf. Leopold et al. 1964; Schumm 1981, 1985). The third distinctive feature of the Ljubljanica is its extremely low gradient. Such conditions (cohesive riverbanks, almost no bedload, extremely low gradient) significantly limit the meandering of the river.

The orientation and lineal segment of the Ljubljanica before it reaches Podpeč, almost at the edge of the Barje, is noteworthy. Despite apparent inconsequence, its direction is perhaps determined by entirely natural conditions. A borehole was drilled already in 1953 in the courtyard of the former Hoja works along the left bank of the Ljubljanica and just north of Podpeč; according to my data this borehole revealed the thickest horizon of *lake silt* (17.5 m) yet known (Grimšičar, Ocepek 1967). It follows that in this area, due to the faster subsidence, the lake was preserved for a longer time and the Ljubljanica coming from the western part of the marsh drained into the then lake, simply because it flowed down the largest gradient. Turk and Horvat (2009) also mention a similar outflow of the Ljubljanica into the lake somewhat upstream. This wide strip with a thick layer of *lake silt* continues on towards Črna vas. Perhaps it bespeaks the lakes enduring for a longer period between Podpeč and Črna vas than elsewhere in the Barje. Such circumstances would support repeat investigations of the location of the Roman *pontonium* near Lipe (Gaspari 1998). That it was found directly on the *lake silt* is perhapsindicative of formerly very shallow and wide canals for filling the lower parts of the Barje with water from the Ljubljanica, while at the same time for outflowing floodwaters back to the Ljubljanica depending on the hydrological conditions.

THE LJUBLJANSKO BARJE DURING THE PILE-DWELLING SETTLEMENTS

The period of pile-dwellings on the Barje is merely one in the continuum of the formation of the area; to fully understand, it demands familiarity with the environment during the periods before and after the pile-dwellings. Nonetheless, the focal point of scientific archeological interest in the area has always been the actual period of the pile-dwellings. It is quite likely that the marsh environment at the time was not monotone, and the differences between the various parts of it were probably greater than today. The question arises as to whether the same sedimentary context can be expected at all pile-dwelling sites. Contrasting sedimentary environments can have similar individual charateristics. Quite simply, the polemics have currently come to a plateau at the *pro et contra* level, in general simply trying to account for the pile-dwelling settlements either along the lake's edge or in the alluvial plain; and the Maharski prekop pile-dwelling is just an example of such a situation (cf. Budja, Mlekuž 2008a; Velušček 2009a). Andrič (2009) already noted the inappropriateness of these polemics. There are several other intermediary environs, which are otherwise not cited in the basic sedimentology textbooks. These intermediary environs are usually more difficult to recognize, requiring more data, observations and analyses to do so.

Pile-dwellings by the lake?

The interpretation that places the pile-dwellings along the lakeside supposedly originates from the mid 19th century, during a period when history was idealized, also in the form of romantic images (Grajf 1997). Indeed, idealized portrayals of pile-dwellings amidst the lake do exist from this time. However, there were more modern and entirely realistic analogies known from then as well. The interpretation is also based on the inference to, or actually even the response to the question: 'what kind of environment (with regard to the Barje at the time) would have most suited the inhabitants at the time?' Rightfully though, we may here wonder whether the "expediency" of choosing a location from our perspective is truly the only guideline on the basis of which we may conjecture as to the former pile-dwelling environment. As Grajf cited (1997, p. 12): *By emphasizing certain aspects that influenced upon the development of the pile-dwelling settlements we easily fall into a deterministic and simplistic form of explanation.*

Archaeological excavations were carried out at the site of Špica at the end of 2009 and the beginning of 2010. On the basis of the uncovered groundplan and the cross-section with the connection between the *lake silt* and the cultural layer in the northern part of the site (*fig. 3*), I did extend my own hypothesis about how former inhabitants might have settled directly along the edge of the lake. The following field observations served to justify my hypothesis:

– absence of soil horizons or at least the onset of pedogenesis directly upon the *lake silt*;

– absence of erosive forms upon the surface of the lake sediment (slanted erosional cuts, basins, gutters, …), which would otherwise be expected had the terrain, prior to the generation of the cultural layer, been incorporated into the (alluvial) erosion;

– absence of alluvial sediments directly above the *lake silt*, which would at the same time also substantiate possible erosion and/or a sedimentation hiatus;

– lamination of the *lake silt*, traced throughout the entire cross-section, demonstrating a slight inclination towards the Barje; however the same inclination also demarcated the border between the *lake silt* and the cultural layer.

The cross-section characteristics described above could be interpreted as the transition from the lake sedimentary environment into the anthropogenically conditioned marsh environment at the shore – lake border. Why anthropogenically conditioned? Because between the vertical piles and directly above the lake sediment were lenses (cm and dm dimensions) of alluvial flooding siliciclastic sediments as well as organic detritus, mollusk shells and fragments of pottery. This flooding material, caught between the vertical piles, could also be the consequence of the lake water's undulation, or even the consequence of occasional and modest alluvial flooding from the hinterland. Interpretations of observations to date have always proceeded with full acceptance. Wrongly so! The entire situation has changed exceptionally already between individual excavations.

Prior to the end of the excavations, cross-sections showing a poorly defined erosive surface from between the lake sediment and cultural layer were opened in the southern part of the excavation field; concurrently, I received some information by word of mouth (Meta Culiberg and Maja Andrič) that the

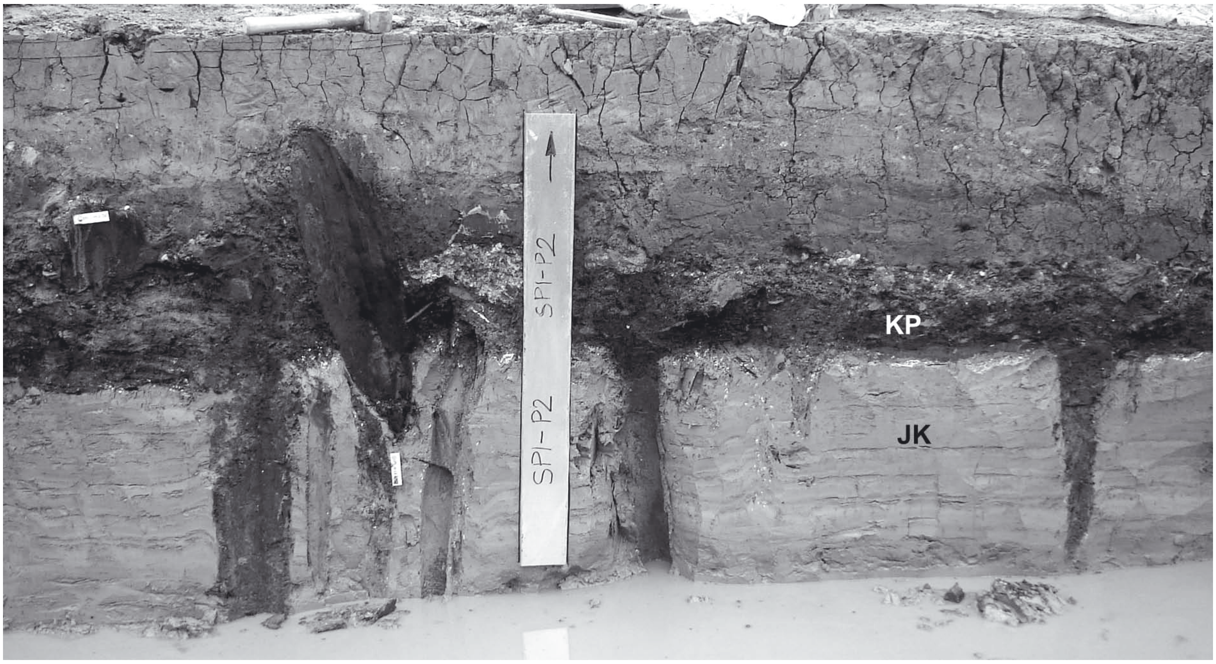

Fig. 3: Špica, 2010 archeaological excavations. Part of the southeastern cross-section of trench 1001. The stratigraphic hiatus between the lake sediments (*lake silt*) (JK) and the cultural layer (KP), estimated on the basis of luminescence dating (OSL), extends over approximately 14,000 years. The height of the sampling profile (SPI-P2) measures 1 m. (Photograph by Tomaž Verbič, archaeological excavations directed by the Ljubljana Museum and Art Gallery, 2010.)
Sl. 3: Špica, arheološka izkopavanja 2010. Del jugovzhodnega preseka sonde 1001. Stratigrafski hiatus med jezersko kredo (JK) in kulturno plastjo (KP), ocenjen na podlagi luminiscenčne datacije (OSL), obsega približno 14.000 let. Višina profila za vzorčenje (SPI-P2) je 1 m. (Fotografija Tomaž Verbič, vodenje arheoloških izkopavanj Muzej in galerije mesta Ljubljane, 2010.)

pollen content suggests assigningthe lake sediment dates to the Pleistocene and not the Holocene. Luminescent analyses of the *lake silt* sample subsequently provided more exact results: the *lake silt* is approximately 18,000 years old, so it was generated during the period of the Last Glacial Maximum (Johanna Lomax, electronic mail 27.1.2011).

Combining these new observations, or analyses, with all the above mentioned descriptions would seem conducive to helping explain the stratigraphic hiatus in the context of sedimentary, erosive and pedological processes. Was this during the time that people settled in the Špica area, or in the direct vicinity of the lake? Probably not. It will be quite a stretch to explain the evidenced, approximately 14,000-year stratigraphic hiatus between the lake sediment and the cultural layer without a trace of pedogenesis, and with a poorly defined erosive surface. If we disregard the lake's sedimentary environment, with what shall we replace it? These are questions without answers as of yet. Nonetheless, we agree that vertical piles in the lake sedimentation are not in themselves proof of a settlement along the edge of the lake (Budja, Mlekuž 2008a).

Pile-dwellings in the alluvial plains?

The thesis that the pile-dwellings were situated in the alluvial plains along the watercourses probably originated from the interpretations of aerial photos of Maharski prekop and its surroundings (Bregant 1975, 49); these were subsequently supplemented (excellent quality!) with LIDAR photos together with interpretations of radiometric dates for the fill in the channel of the former watercourses (Mlekuž et al. 2006; Budja, Mlekuž 2010). At the same time, the authors of this hypothesis for the most part also relied upon the interpretation of geologic and sedimentologic data. Obviously, by interpreting the geologic processes they wished to take a step forward in understanding the former environment. The thesis may be appealing, however the data and results from archaeological excavations up to date predominantly fail to support it, in fact sometimes they even contradict it. It would seem that this thesis is currently drawing near a dead end, leaving open in its wake some general and locally conditional scientific questions. I shall limit myself to two.

Generally speaking, the most disturbing aspect in this interpretation is the absence of alluvial siliciclastic sediments, which would presumably be connected with the former floodplain and – corresponding to this hypothesis – also with the cultural layers. The cultural layer at Maharski prekop is linked to the organic sediments, gyttja[1], while elsewhere it is deposited directly on the surface of the lake sediment (Bregant 1975). This type of initial conditions implicitly demands that the floodplain be covered exclusively with gyttja during the settlement period. This hypothesis in turn preconditions the environment interpretation: preserving the organic sediments, even gyttja, is connected with a more or less constant *body of water*, or however we choose to call it. It follows that sedimentologically, we cannot classify it as a floodplain.

Let it be known that the advocates of this hypothesis (Mlekuž et al. 2006, 257) expressly cite the putative alluvial (river) bedload, which was supposedly even the cause for change in the river's regime. Nonetheless, other than organic sediments, no such bedload was discovered during any of the archaeological excavations and trial trenching.

The second issue that the hypothesis of pile-dwelling settlements in the alluvial plain left unresolved regards the stratigraphic sequence of events along the Ižica, where the authors gathered samples and dated the fill from the alluvial channel (Budja, Mlekuž 2008b, 2010). They found only a dark, fibrillar, organic sediment beneath the ground layer in all five boreholes and through their entire depth, and only under this lay the *lake silt*. None of the five boreholes revealed any type of siliciclastic sediment. A similar situation is known also from the excavated field near Maharski prekop, only that a thin cultural layer is interpreted between the lake sediment and the gyttja in these cross-sections (Bregant 1975). The author interpreted these types of conditions to be an alluvial channel filled with organic sediment and concurrent with the settlement (Bregant 1975). The stratigraphic sequence is more varied outside these channels. A gyttja deposit (prior to the construction of the pile-dwellings) lies above the *lake silt* and is covered by a cultural layer (for which gyttja provides the base ingredient), while above it lies predominantly a light grayish-yellow oily clay. In a sedimentary context this clay can probably only be interpreted as alluvial sediment, which corresponds with Bregant's opinion (1975). Furthermore, this would of course be a younger cultural layer, although the real focus would be on the stratigraphic relationship to the channels rather than to the erosive forms and to the fill in the channels. It is probably needless to add that the alluvial sediments were deposited in a continuous plane, as far as the circumstances allowed for the continuous overflow of waters with suspension sediments. What could have obstructed the generation of alluvial sediment above the existing channels, as the latter lay upon topographically lower levels than the so-called alluvial plain? The authors (Budja, Mlekuž 2008b, 2010) do not explore this matter.

The explanation that the channel was chronologically concurrent with the settlement is not self-evident; furthermore, it does not correspond with stratigraphic principles and the sedimentological circumstances. A more likely and perhaps the only plausible explanation[2] for the stratigraphic conditions described would be that the channels are younger than the cultural layers, and are of the light grayish-yellow oily clay as well. The alluvial channels at this location probably cut through the already flooded light grayish-yellow oily clay and

[1] I use the term 'gyttja' here corresponding to Bregant's usage (1974, 1975), even though in the continuation I express doubt concerning this usage.

[2] The concurrency of the water channels and the cultural layers could also be explicated under specific conditions. For instance, all the channels would have to be stable through all the chronological periods, and not just during the formation of the cultural layer and possibly before it. Rather, also later, during the formation of the gyttja above the cultural layer, as well as during the formation of the light grayish-yellow oily clay, that is, the alluvial sediment. In the instance that a channel was not active during the formation of this clay, then the latter would have to cover it; and this fails to hold true. Another consideration would be that the water with the clay suspension material overflowed the alluvial plain directly from these channels. This would prove a relatively inadvertent thesis, as then we would expect an alluvial sediment in the context of the earlier layers as well (in the cultural layer and the gyttja from before the settlement), which would have formed during the period of activity of the water channels. However, the circumstances at hand demonstrate no reason for the absence of alluvial sediments in the context of earlier layers. The conditions at Maharski prekop are to the contrary: the alluvial sediment is linked practically to a single layer in the top part of the cultural layer. No matter how we go about clarifying the recorded stratigraphic conditions according to a model of concurrent channels and cultural layer (Bregant 1975, 13; Mlekuž et al. 2006; Budja, Mlekuž 2010), the line of argument flounders. As such, this explication seems unfounded. It seems that the primary argument for this model of interpretation of a concentration of vertical piles in the shape of a breakwater, is not the only possible explanation (Velušček 2009a, 305).

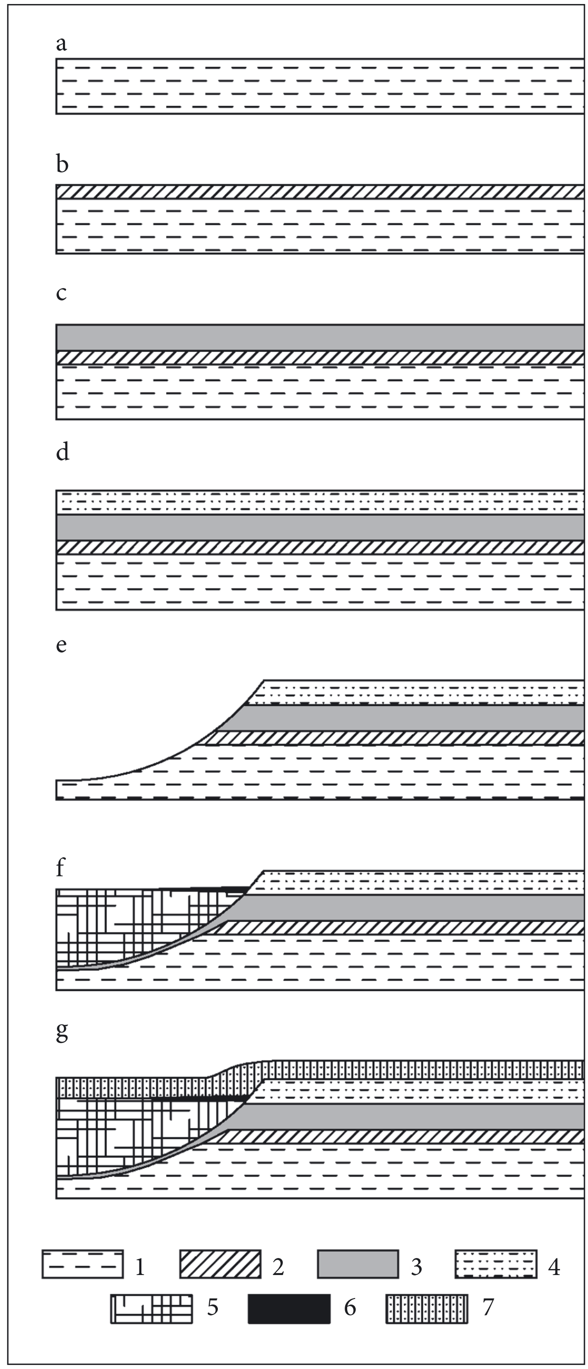

Fig. 4: Conceptual stratigraphic sedimentological model for the formation of the sedimentary environment near Maharski prekop, as can be formulated on the basis of archaeological documentation (Bregant 1974, 1975). Sedimentation of the lake sediments (**a**); formation of gyttja prior to the pile-dwellings (**b**); formation of the cultural layer (**c**); flooding of the light grayish-yellow oily clay (**d**); alluvial erosion, active stream basin (**e**); filling-in of erosion channel with sediments (**f**), select areas with first a thin layer of resedimentation of the cultural layer and then followed by gyttja, entirely on the top, select areas also with a thin layer of yellow clay, layers that Bregant (1975) refers to with the terms humus and subhumus (**g**).
1 – lake sediments; **2** – gyttja prior to the pile-dwellings; **3** – cultural layer; **4** – grayish-yellow oily clay; **5** – younger gyttja; **6** – yellow clay; **7** – humus and subhumus.
Sl. 4: Konceptualni stratigrafsko-sedimentološki model razvoja sedimentacijskega okolja ob Maharskem prekopu, kakor ga lahko konstruiramo na podlagi arheološke dokumentacije (Bregant 1974, 1975). Sedimentacija jezerske krede (**a**); nastanek gyttje pred kolišči (**b**); nastanek kulturne plasti (**c**); naplavljanje svetle sivorumene mastne gline (**d**); aluvialna erozija, aktivno potočno korito (**e**); zapolnjevanje erozijskega korita s sedimenti (**f**), ponekod najprej tanka plast resedimenta kulturnega horizonta, sledi mlajša gyttja, povsem na vrhu pa ponekod še tanka plast rumene gline in plasti, ki jih Bregantova (1975) označuje z izrazoma humus in subhumus (**g**).
1 – jezerska kreda; **2** – gyttja pred kolišči; **3** – kulturna plast; **4** – svetla sivorumena mastna glina; **5** – mlajša gyttja; **6** – rumena glina; **7** – humus in subhumus.

then dug deeper through the cultural layer and the gyttja prior to the building of the pile-dwelling, even also into the *lake silt* (*fig. 4*). The drawing including the stratigraphic relationships implies this to be a more likely interpretation (Bregant 1975, insert 3; Bregant 1974, insert 1)[3]. A more firm answer to this problem would give OSL dating of this flood sediment.

The authors of the hypothesis that the pile-dwelling settlement was situated on the alluvial plain will presumably lean on the radiometric datings of the gyttja and the fibrous organic sediment in these channels (Budja, Mlekuž 2008b, 2010). Nonetheless, there is only one dating from each borehole core. Resedimentation of earlier organic material is an alternative reasoning of the circumstances. Similar resedimentation could even be construed from Bregant's cross-sections (1975, insert 3 and 4) in the thin cultural layers from the channels directly above the *lake silt* (see also *fig. 4f*).

Apropos Maharski prekop, the fan-like trajectories of piles, as well as the positioning and orientation of the corresponding houses along the postulated current (Bregant 1975, insert 2, 3; Mlekuž et al.

[3] At some parts of the profiles from Bregant (1975, insert 3 and 4; 1974, insert 1) she draws grayish-yellow oily clay as it covers gyttja at the edge of alluvial channel, it seems that channel fill is older than the grayish-yellow oily clay at that point. My opinion is that this stratigraphic situation could be due to rain washing, perhaps also due to minor inaccuracy during drawing stratigraphic relationships. In any case, the majority of the profiles (together 80 m) shows that the gyttja is not covered with grayish-yellow oily clay.

2006, figs. 5, 7, 8), could be descrying a former alluvial dynamic. This led me to cover these trajectories with a LIDAR recording (Mlekuž et al. 2006, fig. 4; Budja, Mlekuž 2010, fig. 4). The result was remarkable to behold: the fan-like trajectories of piles coincide well with the postulated water current dating to phase 1, that is, contingent to its flowing north to south and then out into an alluvial fan in the lower lying channel of phase 3. I do not claim that my interpretation is exact; contrarily, I believe that this observation merely demonstrates that reliance solely upon remote sensoring can lead to false conjectures, which further provide the basis for drawing no more than false interpretations and conclusions.

THE SUBSIDENCE OF THE BARJE BASIN AND THE INFLUENCE OF THE SEDIMENTARY ENVIRONMENT

The *Ljubljansko barje Park* today encompasses an inherited, anthropogenically degraded landscape that is connected only by history with the sedimentary environment of the Barje. Rarely is the influence of mankind on the environment as severe as upon the Barje. In a geological context, the influence of anthropogenic activities on the Barje is the greatest as regards the dynamic of the subsidence of the basin. The evaluation of the subsidence during individual periods, that is, recognizing the dynamic of subsidence, could contribute to a better understanding of past environmental changes on the Barje. Furthermore, subsidence might have a determinative impact upon the urbanistic development and settlement pattern on the Barje in the future.

Ground subsidence is today presumably the most complex natural geologic process on the Barje, while at the same time it is also partly anthropogenically driven. Even without anthropogenic influence, ground subsidence on the Barje is composed of at least two independent processes: natural compactions of nonlithified sediments and tectonic subsidence. The drying up of the Barje further influences new processes: the subsidence and compaction of the soil due to the subsiding level of groundwater, ground subsidence due to the cutting, burning and decomposition of peat, as well as the decaying of organic sediments and the soil. Of course, there is also the question of the kind of influence that the recent unloading of the bog soil has due to the above mentioned consequences of drying up. Other than this, the Barje in the past few decades has witnessed engineering endeavors that have an exceptional, albeit local influence on the subsidence of the basin (for example, Vodarna Brest).

Several attempts have been carried out to quantify the subsidence, differing mainly in their methodology. The most successful of the attempts are the geodetic surveys of recent subsidence, especially those in the smaller anthropogenically degraded areas, where the subsidence is monitored for technical reasons (cf. Ježovnik, Jakljič 2003; Ježovnik 2009). The methodology for these measurements is straightforward, and errors are ranked; however, the difficulty is that the measured values of the surveys represent the cumulative sum of different causes for the subsidence (local anthropogenically conditioned subsidence, subsidence due to natural compactions of sediments, subsidence due to the decaying of organic soil, tectonic subsidence…). By no means can the results of these measurements be transferred: neither into (geologic) history or the future (urban planning), nor to any other location on the Barje. The subsidences due to construction by anthropogenic influences are usually disproportionally larger than natural subsidence. On the other hand, there are some attempts to quantify the subsidence on the Barje according to individual causes (Breznik 2000; Bračič Železnik et al. 2003). Contrary to the geodetic measurements, the methodology with these evaluations is relatively unclear, and the errors are unranked. These evaluations are for the most part unverified values, in a technical sense.

Brenčič (2007) aimed to remedy this situation with a relatively original methodology. He established on the basis of linear regressions determined between the depth and dates of the sediments in boreholes BV-1 and BV-2, that the Barje sank in these two locations relatively uniformly during the Holocene, with a speed of 1.235±0.011 mm/year and 1.357±0.005 mm/year. He deduced the numeric age of the sediments solely on the basis of correlations with pollen diagrams; this puts the results under question, as it is a very inexact and unreliable method. More striking is the conceptual error in this equation. The base premise in his model (Brenčič 2007) was always the sedimentation at the ground level. This of course fails to hold true in the case of the Ljubljansko barje, as ignoring the depth of the sedimentation basin implicitly negates the former lake environment where the majority of sedimentation formed. *Figure 5* presents two conceptual models at the same end stance, the formation of a 10 m thick sedimentation column that formed during 10,000 years. The first example

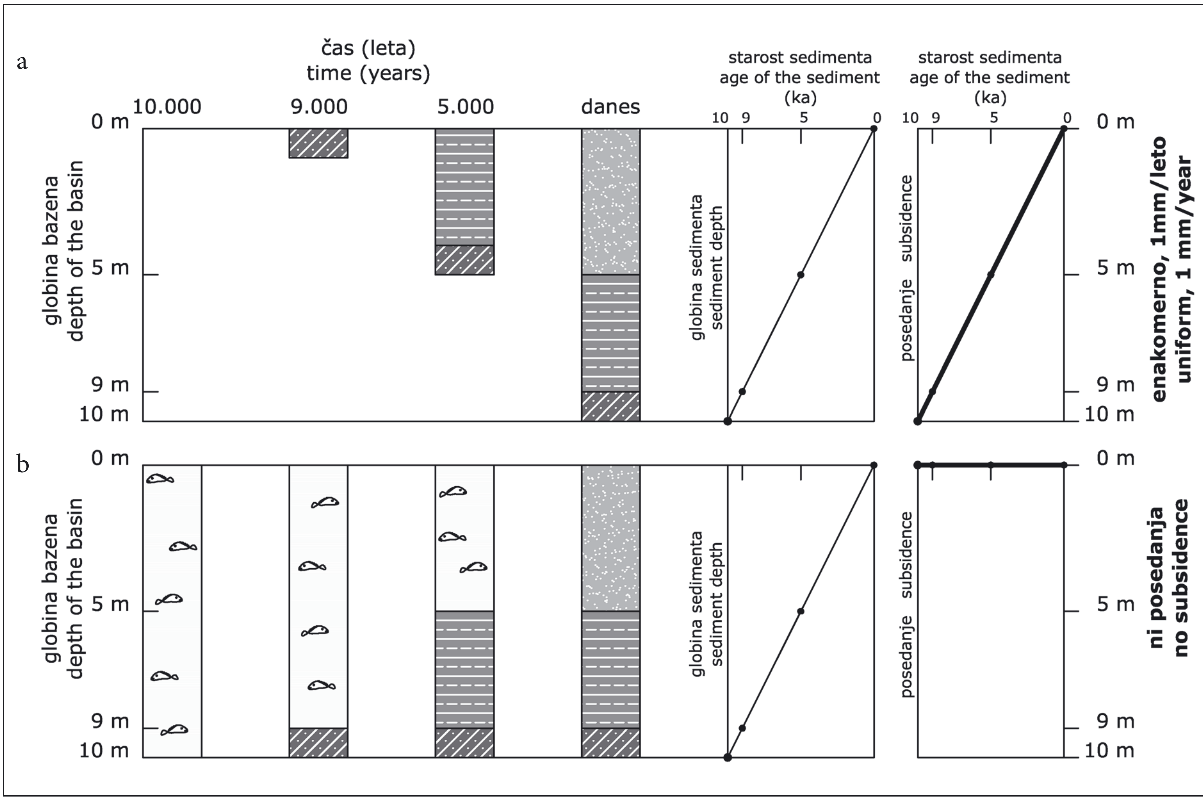

Fig. 5: The influence of the depth of the sedimentary basin with regard to the evaluated subsidence rate. Insofar as the sedimentation forms at the same level, then the current depth of the sedimentation may disclose the subsidence during the chosen time period (**a**). If however the sedimentation formed at different levels that changed through time, then the current depth of the sediment alone does not enable any estimate of subsidence. The depth of the sedimentary basin (the level of sedimentation) during individual periods must also be known. Example (**b**) demonstrates a situation where the conditions, which are otherwise the same as today's, lead to an entirely different evaluation of sinkage than in example (a). I would like to additionally caution here that the above examples observe the behavior of the sedimentary basin within its own frame. These are not relative comparisons with the environment of the sedimentary basin (for instance, the Barje basin with the edge of the Barje basin), nor with absolute geodetic values.
Sl. 5: Vpliv globine sedimentacijskega bazena na oceno hitrosti posedanja. Če poteka sedimentacija na enakem nivoju, potem nam današnja globina sedimenta lahko pokaže na posedanje v izbranem časovnem obdobju (**a**). Če pa je usedanje potekalo na različnih, s časom spreminjajočih se nivojih, nam današnja globina sedimenta sama ne omogoča ocene posedanja. Poznati moramo tudi globino sedimentacijskega bazena (nivo sedimentacije) v posameznih obdobjih. Primer (**b**) prikazuje situacijo, kjer sicer enake današnje stratigrafske razmere vodijo do popolnoma drugačne ocene posedanja kot pri primeru (a). Pri tem moram še dodatno opozoriti, da zgornja primera opazujeta obnašanje sedimenatcijskega bazena znotraj zaprtega okvira. Tu ne gre za relativne primerjave z okolico sedimentacijskega bazena (na primer Barje z obrobjem Barja), seveda tudi ne za absolutne geodetske vrednosti.

(*fig. 5a*) demonstrates Brenčič's (2007) model, the sediment forming always at a relative level of 0 m, let us say at ground level. Subsidence in this example is truly 1 mm/year, the same as the speed of sedimentation itself. This speed would seem actual to many, despite that this model bases itself entirely on the false premises negating the lake sedimentary environment.

The other example (*fig. 5b*) develops from the filling of the sedimentary basin (e.g. the lake), 10 m deep, at a uniform speed of 1 mm/year. The sedimentary basin does not even subside in this model; rather it fills (*fig. 5b*). The entry data for this second model are in a general size class similar to the conditions on the Barje following the Last Glacial Maximum: 10,000 years of sedimentation, 10 m of sediment (*lake silt*), the beginning depth of the lake at 10 m. By incorporating a relatively real parameter into the model (beginning depth of the lake at 10 m), the result yields a subsidence rate that is entirely erroneous. In this example it is the consequence of deficiencies in a still exceptionally simple model; after all, it fails to pay regard to the interactions between individual variables. No, I in no way contend that there were no subsidences on the Barje basin during this time.

This example well demonstrates how the model and all its variables, as well as the reciprocal dependencies within it, must be understood prior to attempting any form of quantification. A recently presented model (Verbič, Andrič 2010) indicates anything but a linear dynamic in the subsidence on the Barje from the Last Glacial Maximum through to today. The sudden static load on the basin of an approximately 10m-high water column when the lake formed certainly generated a nonlinearity in the subsidence on the Barje basin. In particular, a quantitative evaluation of the influence of this load on the subsidence of the former lakebed will be necessary in the future. Recent subsidence of the basin, corresponding to the individual reasons mentioned above, is even more complex. The authors' estimates of subsidence have so fare usually not taken into consideration past and especially future subsidence due to decaying organic soil. This component of subsidence is in some places perhaps greatest today. The decaying of organic sediments and soil, wherever they exist, will continue at the current water-level of groundwater on the Barje (Hacin 2004).

It follows that the curves of the heights of both banks of the Ljubljanica (*fig. 2*) are interpretatively telling. These curves, including the curve of the Ljubljanica bed, were constructed on the basis of topographic cross-sections (a total of 96 cross-sections between Vrhnika and Špica; Stojič 1994). The heights of both levees along the Ljubljanica (*fig. 2:* curves *c* and *d*) indicate an accelerated subsidence between Podpeč and Črna vas, of course as compared with the environment up- and downstream. The curves in this segment are visibly bent; it would seem that the sedimentation process is not fast enough to fill the bend in the relief with alluvial sediments. The data are almost 20 years old; as such, new measurements are in demand.

SEDIMENTS AND THE SEDIMENTARY ENVIRONMENT

Following a review of the published discussions concerning the pile-dwellings on the Barje, I would first like to point out that the data indicate that the pile-dwellings were built during different sedimentary environments. Bregant (1984, 23) already cited this. A brief appraisal of only four pile-dwellings – Špica, Maharski prekop (Bregant 1975), Notranje Gorice (Harej 1976) and Parte (Harej 1981–1982) – shows several differences among them, all resulting from the differing sedimentary and erosive contexts.

Currently there are enough justifications guiding researchers to be careful in the future, with regard to both leading interpretations, at least as concerns the use of one general model for all pile-dwellings (e.g. Budja, Mlekuž 2009, 366). The absence of alluvial sediments in the context of cultural layers at Maharski prekop and the simultaneous preservation of organic sediments do not support the model for pile-dwellings in the alluvial plain. At the same time, the uncertainty about the correctness of this hypothesis is also demonstrated by the stratigraphic conditions evidenced at this site. Contrarily, the sedimentary conditions at the Notranje Gorice pile-dwelling, as can be reconstructed from the report (Harej 1976), could be indicative of a much less marshy terrain. They might even have afforded dry building ground. The most complex lithostratigraphic sequence is evidenced at the Parte location (Harej 1981–1982). Here the flooding of various materials (sand, shells of mollusks, pottery, vegetation remains) in the cultural layer is characteristic, as well as in the layers above. This type of situation is somewhat reminiscent the sedimentary characteristics in the cultural layer at Špica; while at the same time, there are several differences (thickness of the cultural layer, amounts of siliciclastic and carbonate components, circumstances in the upper part of the cultural layer …) between the two locations.

The circumstances at Maharski prekop suggest, regardless of how insensitive it may seem to the former inhabitants, more of a marshy environment with a very quick growth rate of organic sediments. Stritar's (1975) analysis of the cultural layer would seem highly significant, as it confirmed the presence of calcium carbonate. The report does not cite any clear internal stratification (e.g. laminations), which leads to my reasoning that the calcium carbonate was relatively uniformly dispersed throughout the cultural layer. This would mean that in addition to organic sediments, an (autogenous) carbonate was also deposited concurrently, thus indicating the edge of the lake environment. The support is indisputable in this frame of reference for the inference of there being a *pure lake* (Velušček 2009a) prior to the Maharski pretok pile-dwelling. The richly carbonated cultural layer at Parte (Stritar, Lobnik 1985) can afford a similar interpretation, only that this location is categorized by several sedimentary structures connected with siliciclastic sediments (Harej 1981–1982). Perhaps these forms correspond to the location near the influx of mineral components into the lake environment, perhaps with the flooding along the lakeshore. Otherwise, in order to directly confirm the hypothesis of pile-dwellings along the edge of the lake, we could for instance take into consideration the numeric dating of the lake sediment under the *concurrent* cultural layer at the site, without any stratigraphic hiatus in-between or lake sediment covering the cultural layer.

Velušček (2009b) also cites the marshy environment along the edge of the lake within the context of the Stare gmajne site. Turk and Horvat (2009) mention the possibility of a preserved, continuous sedimentary record at the transition from the lake to marshy environment near Blatna Brezovica; however, at the same time, they warn that a stratigraphic gap is not impossible, as the *lake silt* is not dated.

Surprisingly, an approximately 14,000 year stratigraphic hiatus was determined between the lake sediment and the cultural layer at Špica. This leaves us facing a similar dilemma as that at Resnikov prekop (Andrič 2006). Currently a variety of hypotheses are being posed, attempting to clarify on the one hand the long stratigraphic hiatus, and on the other hand the very poorly exhibited discordance (as regards pedology, erosion and sediments). The flooding of material between the piles in the context of the cultural layer still remains one of the primary observations determining the then sedimentary environment. It would seem that this type of flooding might correspond with running water as well as with the ebb and flow along the edge of standing water. Standing water, of course, would not have any direct link with the former lake from the period of the Last Glacial Maximum, which is when the bedload of the cultural layer at Špica was deposited. No other intermediary events are known to date; perhaps this location was connected with the bank of the Ljubljanica during the pile-dwelling period. The Ljubljanica, during the Holocene, probably functioned similarly to the outflow from periodic lakes. Furthermore, the seasons precipitated heavy fluctuation in the level of surface water on the Barje. Various natural processes, perhaps even landslides from the Castle hill or similar, might have given rise to disturbances in the outflow of water from the Barje. Such unpredictable conditions could for a short time, perhaps a few decades or more, decisively alter the conditions on the Barje. Sedimentary records for such events are rare and usually very difficult to interpret and unreliably readable. Nonetheless, these are currently only hypothetical ruminations.

The final segment of this contribution should put forth the future course I believe would lead to answers regarding environmental interpretations from the period pile-dwelling settlements on the Ljubljansko barje. Firstly, I believe it is highly necessary to implement a precise description and analysis of all the sediments in the context of archaeological sites on the Barje, not just of the cultural layers, but also of their bedloads and overburdens. This refers in particular to the organic sediments and gyttja (Hansen 1959), as well as the *lake silt* (*Seekreide*, Merkt et al. 1971). New research endeavours should incorporate among others also sedimentary, mineralogical, chronological and geochemical analyses (cf. Andrič et al. 2008; Turk, Horvat 2009). Most importantly, these analyses should demonstrate the differences between organic sediments and lake sediments at various locations on the Barje. Almost certainly there are differences, albeit they have yet to be evidenced. I believe these data will be of consequence to environmental interpretations. And now a brief assessment of how we understand both sediments today and what we would wish for in the future.

The term gyttja is usually understood as sediment, which we may describe as an organic mud; the base is organic sediment, while autogenous, biogenous and/or detritic mineral components may also be present (Hansen 1959). That largely sums it up. It is a very flexible term that can be applied to describe different types of deposits corresponding to their structure as well as to their quantitative composition. Furthermore, various authors in the past have annexed various adjectives to the term, such as lime gyttja. Abroad, the term gyttja also has a similarly flexible spectrum (see examples in Schnurrenberger et al. 2003). This led to the suggestion, already four decades ago, to avoid usage of this term (Merkt et al. 1971). Budja and Mlekuž (2010) presumably were following such guidelines when they classified the sediment in the channels at Maharski prekop as "*dark organic fibrous deposit*". I do believe that this sediment is entirely different from the organic sediment at the Špica location. It would be truly interesting to compare, on the basis of a variety of analyses, the organic sediments from the location along the Ižica: gyttja from before settlement and gyttja from during as well as from above the cultural layer (Bregant, 1975), and also the "*dark organic fibrous deposit*" (Budja, Mlekuž 2010) in the channels. Furthermore, I have not found any data regarding the type of vegetation that composes these sediments.

Lake silt is a well established term in Slovenia, while less so abroad; this is supposedly due to the fact that the first contributions on this theme (cf. Merkt et al. 1971) were published only in German (Schnurrenberger et al. 2003). The term is used flexibly in Slovenian geological terminology, referring to biochemical as well as clastic carbonate deposits, which formed in the lake environment. The term *lake silt* is too general for more detailed clarifications, leaving too wide a margin for interpretation; so additional clarifications are necessary also here. The term fails, for instance, to disclose the amount of carbonates throughout the sediment, or whether it is a detritic or autogenous carbonate, all of which can play a determinative role in the interpretation of the sedimentary environment. Considering the model of the Paleo-Ljubljanica efflux from the Barje eastwards, one would anticipate a very intensive rate of sedimentation, even of detrital carbonates. This would be even more so in the proximal, NE part of the lake, all until the alluvial fan between Rožnik and the Castle hill was active; after all, at that time the Sava probably also carried a huge amount of suspension material in addition to gravel. Luminescence dating of the *lake silt* from Špica also supports this anticipation; it suggests that already during the Last Glacial Maximum lake deposit was intensively filling in this part of the lake. The Špica location, like the location near the former Tobačna factory, was in fact a distal part of the Upper Pleistocene Sava alluvial fan, which with its gravelly sedimentation towards the south reached almost to Mirje. OSL analyses demonstrate that the beginning of the last lake formation of the Barje can be attributed to the period of the Last Glacial Maximum.

Later, especially during the Holocene, the detrital material input presumably decreased enormously, while sediment from the Sava side was already finished; the rate of sedimentation supposedly decelerated, while autogenous carbonates presumably played a larger role. Autogenous carbonates were precipitated from the oversaturated lake waters; water flowed in mostly through karst aquifers. Of course, currently this is only a model constructed on the basis of available data; further analyses that would either substantiate or disprove, or at least shed some additional light, are necessary.

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Translation Rachel Novšak

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Sedimentacijsko okolje na Ljubljanskem barju v času kolišč

UVOD

Razprava na eni strani povzema in hkrati z geološke plati komentira nekatere rezultate raziskav, ki z različnimi metodami osvetljujejo geološke procese na območju Ljubljanskega barja, na drugi pa ponuja nekatere nove poglede na geološko dogajanje v obdobju zadnjega glacialnega viška, v poznem glacialu in predvsem, kar je za arheologe seveda bolj zanimivo, v holocenu. Seveda si nikakor ne domišljam, da ta pregled ponuja jasen odgovor na sicer široko naslovno temo. Nasprotno, nakazuje celo na trenutno izrazito fragmentarno in tudi površno poznavanje okoljskih razmer. Kot bo bralec lahko presodil tudi sam, tekst na številnih mestih sloni predvsem na primerjavah v okviru kritičnega naravoslovnega sklepanja. Marsikdo mu bo morda očital pomanjkanje kvantitativnih podatkov. Menim, da je pred poskusom kvantifikacije geoloških procesov potrebno podrobno poznati njihovo medsebojno prepletenost. Sicer se lahko kaj hitro znajdemo v krogu znanstvenih nesmislov. Tudi na take primere bom opozoril v nadaljevanju.

Naprej nekaj besed o izrazoslovju, ki ga bom uporabljal v tem pregledu. Toponim Ljubljansko barje kot geografski pojem sta v literaturo uvedla Fran Erjavec in Fran Levstik šele leta 1880 (Melik 1927, 1946). V strokovno geološko izrazoslovje je danes *Ljubljansko barje* vključeno v dveh različnih vsebinskih pomenih. Na eni strani se nanaša na kvartarni sedimentacijski bazen (*sensu lato*), na drugi pa na holocensko barjansko krajino (*sensu* *stricto*), ki je nastala na mestu nekdanjega jezera, torej v Levstikovem in Erjavčevem smislu. Tudi arheologi ga morajo razumeti v obeh pomenih. Barjanske krajine, torej nekdanjega okolja, ki je bilo razlog za Erjavčevo in Levstikovo originalno poimenovanje, seveda že dolgo ni več, sedimentacijski bazen pa je ostal. Skrajšano ime je kar Barje (z veliko začetnico), ta skrajšava se je uveljavila že z Levstikom in Erjavcem (Melik 1927, 33–34).

NASTANEK LJUBLJANSKEGA BARJA *SENSU LATO*

Kako je Ljubljansko barje *s. l.* sploh nastalo? Ni dvoma, da je nastanek tektonski in da je prišlo do relativnega posedanja tega območja oziroma do relativnega dvigovanja okolice Barja. Dejstvo je tudi, da je predkvartarna podlaga Barja topografsko močno razgibana, to dokazujejo številni osamelci. Tu pa se enotnost geologov glede nastanka Barja *s. l.* skoraj konča. Starejši raziskovalci so menili, da je podlaga sestavljena iz tektonskih grud, ki so omejene z vertikalnimi prelomi v dinarski (SZ–JV) in prečnodinarski (SV–JZ) smeri (Pleničar 1967; Buser 1968; Grad, Ferjančič 1974; Premru 1982). Podobno grudasto razkosanost s prelomi je zagovarjal tudi Mencej (1990). Prvotne interpretacije so torej slonele na grudasti zgradbi podlage, ko naj bi se ta diferencialno posedala.

Precej drugačno razlago nastanka Ljubljanskega barja *s. l.* je podal Vrabec (2001). Menil je, da je Barje nastalo kot razporen (*pull-apart*) sedimentacijski bazen med dinarsko usmerjenimi prelomi. Verbič (2006a) je postavil nastanek Barja v kontekst kvartarno aktivnih reverznih prelomov med Ljubljano in Kranjem. Od starejših raziskovalcev je prevzel mnenje, da poteka Viški prelom vzdolž severnega roba Barja, vendar ima reverzen in ne normalen značaj (Verbič 2006a). Viški prelom je najjužnejši v snopu reverznih prelomov med Kranjem in Ljubljano. Ob južnem robu Barja poteka prelom v smeri vzhod–zahod (Verbič, Horvat 2009a), kot je to menil Mencej (1990), vendar je po njuni razlagi tudi ta reverzen. Samo razgibano topografijo predkvartarne podlage skupaj z osamelci lahko razlagamo z zasutimi erozijskimi dolinami, tako da za njeno razlago grudasta tektonska zgradba ni potrebna. O recentni in kvartarni aktivnosti posameznih prelomov na Barju nimamo ustreznih podatkov, razen v manjši meri za Viški prelom (Verbič 2006a).

Na vprašanje, kdaj je Barje *s. l.* nastalo, na žalost že dolgo časa ni novih podatkov. Najbolj pomembno je, da se zavedamo, da nastanek Barja *s. l.* ni trenutek, ampak proces. Morda je za časovno opredelitev začetka tega procesa najbolj zgovorna primerjava med Viško teraso (*sl. 1*) (Rakovec 1932, 1954; Šercelj 1967), vrtino pri Dolgem mostu (Šercelj, Grimšičar 1960) in vrtino BV-2 (Šercelj 1966). V obeh vrtinah so nad predkvartarno podlago domnevno *mindelski* sedimenti, ki so jih nekoč uvrščali v spodnji pleistocen (cf. Šercelj 1967), danes pa jih nekateri sicer bolj ohlapno povezujejo z morsko izotopsko stopnjo 12 in/ali 14 (obdobje pred pribl. 400–550 ka BP), torej jim lahko verjetno pripišemo že srednjepleistocensko starost (Gibbard, Cohen 2008). V mindelski glacial pa so uvrščeni tudi sedimenti na prostoru bivše opekarne na Viču. Starejši sedimenti (od *mindelskih*) nad mezozojsko in paleozojsko podlago na Barju še niso ugotovljeni. Do morebitnih novih ugotovitev velja, da je Barje kot sedimentacijski bazen začelo nastajati v srednjem pleistocenu. Hkrati poudarjam, da je podatkov o teh najstarejših sedimentih malo, tako da lahko na tem področju v prihodnosti pričakujemo številne nove rezultate in interpretacije.

JEZERO! DO KDAJ?

Je že tako, da so nekateri *dokazi* v znanosti na splošno, prav tako tudi v geologiji, manj *dokazani,* drugi pa bolj. Govorim seveda o hipotezah in interpretacijah posameznih analiz. Če se sklicujem na Karla Popperja (1998), kar se na tem mestu zdi kar primerno, lahko rečemo, da je posamezna hipoteza toliko boj zanesljiva, kolikor poskusov falzifikacije je že prenesla in kolikor bolj so bili ti poskusi agresivni, poglobljeni in natančni.

Zakaj ta uvod? Enostavno zato, ker še kako dobro ogovarja diskusijo o nekdanjem obstoju jezera na prostoru Ljubljanskega barja. Ni pomembno, kdo je sploh prvi interpretiral jezersko kredo na Barju kot sediment jezerskega okolja. Morda je bil to Karl Deschmann, morda še kdo pred njim, na primer inženirji, ki so sredi 19. stoletja projektirali železniško progo čez Barje. Domnevam, da so se ti prvi raziskovalci pri interpretaciji zanašali tako na sedimentne teksture in strukturo jezerske krede kot tudi na splošen geološki in geomorfološki kontekst Ljubljanskega barja. Do tega zaključka jih je vodil tudi princip aktualizma. Kasneje je bila njihova teza potrjena, saj je bil obstoj jezerskega okolja dokazan s fosilno vsebino v sedimentih (cf. Pavlovec 1967, 1973; Kroflič 2007). Hipoteza o nekdanjem jezerskem okolju na Barju ima trdne temelje in njene verodostojnosti ni ogrozil še noben poskus falzifikacije oziroma drugačne interpretacije terenskih opazovanj in laboratorijskih analiz. Pravzaprav je polemika le okoli Šifrerjeve (1984) interpretacije in tudi sam ne poznam drugih razprav, ki bi v osnovi zanikale obstoj zgornjepleistocenskega in holocenskega jezerskega sedimentacijskega okolja na Barju.

Teze in trditve v Šifrerjevem tekstu so brez primernih geoloških razlag in argumentov. Tako na primer piše (str. 36): "*Z vidika razvoja Barja v zadnji ledeni dobi je videti predvsem pomembno, da je bilo tu fluvioperiglacialno nasipanje izredno izdatno in da je tako vseskozi konkuriralo nasipanju ledeniške Save. Zato je tudi razumljivo, da je le ta samo lokalno prodrla proti Barju pa še to najbrž le tako daleč do koder ji je tedaj močno napet svet na Barju to dovoljeval. Zato povsem upravičeno domnevamo, da v poledenitvenih obdobjih na Barju ni bilo pogojev za izdatnejše zastajanje vode, kaj šele za ojezeritev, kot so to domnevali starejši raziskovalci tega sveta (Kramer 1905; Seidel 1912; Rakovec 1939, 1955; Melik 1946).*"

Zgornje trditve so na srečo preverljive in se izkažejo kot napačne. Za nastanek jezera ni pomembno, kako daleč Sava s svojimi naplavinami prodre na Barje v njegovo notranjost, pomembno je, da zapre površinski rečni iztok, nekdanjo Paleoljubljanico, na izhodu iz Barja (*sl. 1*). Najmlajši savski zasip v Ljubljani, zasip zadnje ledene dobe, je v obliki aluvialnega vršaja preko centra Ljubljane segal do Mirja, ob Grajskem hribu pa verjetno nekako do Šentjakobskega mostu. S severa se je dobesedno "zaletel" v Grajski hrib, ni dvoma, da je s tem Paleoljubljanici zaprl pot proti vzhodu. Te lokacije smo lahko opazovali pri gradbenih in arheoloških delih in so preverjene in dokumentirane. V citiranem odstavku je simptomatična tudi Šifrerjeva trditev: "*… do koder ji je tedaj močno napet svet na Barju to dovoljeval*". Od kod njegovo poznavanje nekdanjega napetega sveta na Barju, danes je to pokopan nivo pod jezersko kredo?

Kot naslednji argument za negiranje nekdanjega jezerskega okolja omenja, "*da ni prav nikjer opaziti deltaste sedimentacije, ki bi jo bilo pričakovati, če bi se izlivali ti potoki in reke v nekdanje jezero*" (str. 41). Pri tem ne navaja, kje je sploh lahko opazoval jezersko kredo, bodisi v vrtinah ali profilih, da lahko trdi, da take sedimentacije ni opaziti. V zadnjem času imamo nekaj nasprotnih opažanj: že pri izvedbi in popisu raziskovalnih vrtin na Špici (*sl. 1*) (Novšak et al. 2009) kot tudi kasneje pri geološki spremljavi arheoloških izkopavanj smo lahko dokaj podrobno sledili detritičnemu vnosu nekarbonatnih terigenih peščenih sedimentov v jezersko okolje, kjer se je sicer usedala jezerska kreda. Na razdalji dobrih sto metrov smo lahko določili bolj proksimalni in bolj distalni del majhne delte danes neznanega potoka, morda tistega iz erozijske zajede nad Rakovnikom. Jezerska kreda je bila odkrita tudi na območju ljubljanske Tribune, neposredno pod Grajskim hribom. Razen tega je bila v letu 2009 ugotovljena jezerska kreda ob gradbenih in arheoloških delih tudi ob Tržaški cesti pri nekdanji Tobačni tovarni. Tudi tam so med meljasto jezersko kredo peščene lamine. Prav ta ugotovitev nakazuje na nekdaj enotno jezersko sedimentacijsko okolje na celotnem Barju. Na območju Viča je bil kasneje pretežen del jezerske krede erodiran (Gradaščica, Mali graben). Sedimentacija v teh proksimalnih delih jezera je bila ob koncu pleistocena verjetno zelo hitra, zaradi vnosa detritičnega sedimentnega materiala savskega vršaja. Na hitro sedimentacijo v tem proksimalnem jezerskem okolju verjetno nakazuje tudi majhna volumska koncentracija peloda v jezerski kredi s Špice (Andrič 2010, ustna informacija; Culiberg 2010, ustna informacija).

Pravzaprav bi si kritično pripombo lahko zaslužila še marsikatera Šifrerjeva (1984) navedba. Recimo (str. 49): "*S tem pa se dobro ujemajo tudi ugotovitve, da se polžarica omejuje predvsem na bližino apniškega in dolomitnega zaledja*." V številnih primerih avtor neko tezo podpre z dvomljivim ali celo neobstoječim argumentom. Jezersko kredo smo namreč ugotovili na Špici, na Tribuni in pred nekdanjo Tobačno, zelo daleč od "*apniškega in dolomitnega zaledja*".

Teza, ki postavlja obstoj jezerskega okolja na Barju pod vprašaj ali ga celo zanika (Šifrer, 1984), je strokovno neutemeljena. Ta teza je prvotno služila nekaterim avtorjem kot dodaten argument za interpretacijo, da koliščarske naselbine niso bile postavljene na jezeru ali ob njem, pač pa na poplavni ravnici (cf. Budja 1994). Pojavila se je predvsem zaradi pomanjkanja kritične naravoslovne presoje. Geologom je jasno, da Šifrerjeva (1984) teza za navedeno interpretacijo sploh ni potrebna.

V tem okviru so bistvena vprašanja, kdaj je jezero obstajalo, kako se je njegov obseg s časom spreminjal in v kakšno okolje je prehajalo jezersko okolje. In to so vprašanja, na katera imamo le zelo fragmentarne odgovore. Sicer obstaja bolj ali manj sprejeta splošna teza o bočnem zasipavanju jezerskega sedimentacijskega bazena z aluvilanimi (vršajnimi, deltnimi, …) naplavinami na eni strani in hkratnim vertikalnim prirastom jezerske krede bolj kot ne po celotnem območju jezera. Za bolj podrobne raziskave je na tem področju ogromno prostora in materiala, verjamem, da nas čakajo s tem v zvezi še številna presenečenja.

V preteklosti je prevladovalo mnenje, da je jezerska kreda izključno holocenski sediment. Verjetno so k takemu stališču, bolj kot rezultati analiz, prispevala nekatera splošna, načelna mnenja, na primer, da so šele v holocenu klimatski pogoji omogočali sedimentacijo jezerske krede (cf. Šercelj 1962, 1965, 1966). Podobne trditve zasledimo še v zadnjem obdobju (Pohar, Culiberg 2002; Brenčič 2007). Sicer pa v zadnjem času dobivamo drugačno sliko o stratigrafskem obsegu jezerske krede. Tako poznamo že štiri lokacije, kjer imamo, kot kaže, le pleistocensko jezersko kredo, holocenska pa je bila bodisi erodirana, bodisi sploh ni bila odložena. Te lokacije so Notranje Gorice (Šercelj 1976), Zalog pri Verdu (Culiberg 2006; Verbič 2006b), Hočevarica (Culiberg 2006) in Špica (v nadaljevanju). Sorazmerno dolg holocenski stratigrafski hiatus nad jezersko kredo je bil ugotovljen tudi pri Resnikovem prekopu (Šercelj 1963; Andrič 2006). Šercelj (1981–1982) bežno omenja rezultate sondiranj in palinoloških raziskav ob trasi ljubljanske južne obvoznice. Med Dolgim mostom in Ljubljanico omenja samo pleistocenske sedimente, vendar ne izrecno jezerske krede. Na podlagi odsotnosti holocenskih sedimentov sklepa, da kolišč na tem območju ne more biti. Dolg stratigrafski hiatus med pleistocenskimi in holocenskimi sedimenti (mlajšimi od kolišč) omenja na območju industrijske cone Rudnik. Podobno situacijo opisuje na območju avtocestne deteljice ob Dolenjski cesti. Ob vsem tem ni nepomembno, da je lokacija Na mahu (Andrič et al. 2008) do sedaj edina, kjer je prehod med jezerskim in močvirskim sedimentacijskim okoljem zvezen in hkrati časovno dobro dokumentiran. Pri številnih drugih lokacijah manjka geokronološka časovna kontrola.

Kako je s prostorskim obsegom jezerskega okolja? Preprosto sklepanje nam seveda narekuje, da je bilo v času največje ojezeritve pod vodo celotno območje Barja pod koto približno 297 m, to je kota, do katere je predvidoma segal savski zasip med Rožnikom in Grajskim hribom. Nekoliko nejasna je vloga sedla med Grajskim hribom in Golovcem. Nadmorska višina tega sedla pred gradnjo Gruberjevega kanala ni natančno znana, zdi pa se, da je bila višja od prehoda ob severozahodnem robu Grajskega hriba, saj na Poljanah nimamo sedimentnega zapisa, ki bi ga lahko povezovali s prelivanjem vode z barjanske strani. Če zgoraj opisana teza vsaj okvirno drži, potem so na območju med Rožnikom in Grajskim hribom, vsaj v času nastajanja savskega aluvialnega vršaja, obstajale zelo zanimive hidrološke razmere. Voda, ki se je stekala v jezero iz kraških izvirov in površinskih vodotokov na obrobju Barja, je morala iz njega tudi odtekati, in to prav preko savskega vršaja. Ni povsem jasno, kako je bila v takih pogojih urejena vodna bilanca. Verjetno je šlo za antagonizem dveh hidroloških sistemov v smislu, da savski vršaj v času svoje aktivnosti verjetno ni dopuščal hitrejšega vrezovanja aluvialnega odtoka, moderne Ljubljanice, iz jezera. Morda je šlo za izrazito sezonsko pogojen hidrološki režim. S tem v zvezi naj omenim dva debela horizonta drobnozrnatih usedlin, ki smo ju lahko opazovali med peščenim prodom pri gradnji garažne hiše pod Kongresnim trgom. Ta dva horizonta nakazujeta na sedimentacijo iz suspenzije, torej iz zastajajoče vode na aluvialnem vršaju.

Krčenje jezera je bilo povezano z zmožnostjo erozijskega vrezovanja odtoka iz jezera oziroma nižanjem lokalne erozijske terminante. Vendar moramo biti pri ocenjevanju tega krčenja pazljivi. To krčenje je nedvomno povezano z dinamiko posedanja dna jezera. S tem v zvezi so številna nerešena vprašanja. Kakšen je bil vpliv nenadne statične obremenitve tega prostora s približno 10 m visokim vodnim stolpcem na posedanje? Ni dvoma, da se je posedanje dna jezera zaradi tega pospešilo, problem pa je kvantifikacija tega pospeška. Ker je dinamika posedanja Barja vplivala na okoljske razmere, bom temu vprašanju v nadaljevanju namenil nekaj več stavkov.

LJUBLJANICA! OD KDAJ?

Na izjemnost Ljubljanskega barja kot sedimentacijskega okolja, seveda v smislu ekstremnih lastnosti, nakazuje tudi glavna odvodna žila Ljubljanskega barja Ljubljanica. Geomorfološka literatura se le redko nanaša na tako ekstremne reke, kot je Ljubljanica. Ljubljanica tudi z geomorfološkega stališča zaradi pomanjkanja ustreznih meritev še ni zadovoljivo opisana. Nekatere lastnosti so vseeno znane. Nastala je na območju nekdanjega jezera, napaja se pretežno iz kraških vodonosnikov, talnega sedimentnega tovora skoraj nima. Erozijska moč Ljubljanice je izredno majhna, še posebno če pogledamo bočno erozijo. Skoraj v celotni dolžini na Barju je še vedno vrezana v kohezivno jezersko kredo. Padec gladine Ljubljanice (*sl. 2*) vzdolž njenega toka med Vrhniko in Ljubljano (razdalja 22 km) je ob velikih pretokih (nad 100 m^3/s) res okoli 2 m, ob pretoku 20 m^3/s pa le 40 cm (Stojič 1994). Pri nižjih vodostajih se gladina Ljubljanice na celotnem obravnavanem odseku uravnava z višino zapornic v Ljubljani.

Aluvialni odtok iz Ljubljanskega barja je bistven element, ki je skozi zgodovino opredeljeval hidrološke razmere na njem. Seveda so na te razmere vplivale tudi številne druge okoljske spremenljivke, pa vendar je vodni režim prvenstveno pogojen z zmožnostjo odtekanja vode iz sedimentacijskega bazena, torej od višine lokalne erozijske terminante. V času nasipavanja savskega aluvialnega vršaja je bila ta na njegovi površini, po umiku Save proti severu pa je začela Ljubljanica vrezovati svoje korito v savski vršaj. Najstarejši odsek moderne Ljubljanice je v tem okviru prav odsek pod Grajskim hribom, od Šentjakobskega mostu dolvodno proti vzhodu do izliva v Savo.

Na Barju je Ljubljanica povsod mlajša. Oprijemljivih geoloških podatkov, na podlagi katerih bi lahko vsaj posredno sklepali na čas nastanka Ljubljanice na posameznih odsekih, trenutno skoraj ni. Zato lahko le ponovim arheološke argumente, da je do srednje bronaste dobe Ljubljanica nedvomno oblikovala svoje korito vsaj na nekaterih delih Barja (Gaspari 2009a, 38).

Lahko pa postavimo ohlapen fizikalno-geološki okvir nastanka Ljubljanice brez časovne dimenzije. Kot sem omenil, je Ljubljanica na Barju skoraj v celotni dolžini vrezana v kohezivno jezersko kredo. Zaradi pretežno kraškega porečja in kohezivnih bregov je njen talni tovor količinsko zelo omejen. Talni tovor je tisti faktor, ki šele omogoča nastajanje alternirajočih sipin, ki potem lahko injicirajo meandriranje samo (cf. Leopold et al. 1964; Schumm 1981, 1985). Tretja pomembna lastnost, ki opredeljuje Ljubljanico, je njen ekstremno nizek padec. Meandriranje reke je v takih pogojih (kohezivni bregovi, skoraj brez talnega tovora, ekstremno majhen padec) običajno zelo omejeno.

S tem v zvezi sta zanimivi smer in premočrtnost odseka Ljubljanice pred Podpečjo, kjer se povsem približa obrobju Barja. Kljub navidezni nelogičnosti je ta smer morda pogojena s povsem naravnimi razmerami. Severno od Podpeči, na dvorišču bivšega obrata Hoja na levem bregu Ljubljanice, je bila že leta 1953 izvrtana vrtina, v kateri je bil po mojih podatkih ugotovljen do sedaj najdebelejši horizont jezerske krede, 17,5 m (Grimšičar, Ocepek 1967). Posledično bi utegnili sklepati, da se je na tem območju zaradi hitrejšega posedanja jezero ohranilo dalj časa in se je Ljubljanica iz zahodnega dela Barja izlivala v tamkajšnje jezero preprosto zato, ker je sledila največjemu gradientu. Podoben izliv Ljubljanice v jezero nekoliko gorvodno omenjata tudi Turk in Horvat (2009). Ta sicer širok pas z debelim horizontom jezerske krede se nadaljuje proti Črni vasi. Morda je to pokazatelj, da se je jezero med Podpečjo in Črno vasjo ohranilo dalj časa kot drugod na Barju. V tem kontekstu bi bilo zanimivo ponovno raziskati lokacijo najdbe antičnega *pontoniuma* pri Lipah (Gaspari 1998). Morda ta najdba neposredno na jezerski kredi kaže na nekdanje zelo plitve in široke kanale napajanja nižjih delov Barja z vodo iz Ljubljanice in hkrati odtekanja poplavne vode nazaj proti Ljubljanici, pač odvisno od hidroloških razmer.

LJUBLJANSKO BARJE V ČASU KOLIŠČ

Čas kolišč na Barju je le eno izmed obdobij v razvoju krajine, za njeno pravilno razumevanje moramo poznati okolje tako v obdobjih pred kolišči kakor tudi kasneje. Kljub vsemu je težišče znanstvene arheološke radovednosti prav na okolju v času kolišč. Pričakujemo lahko, da okolje tedaj na Barju ni bilo monotono, razlike med posameznimi predeli so bile verjetno večje kot danes. Postavlja se vprašanje, ali res lahko pri vseh koliščih pričakujemo enak sedimentološki kontekst. Različna sedimentološka okolja imajo lahko posamezne podobne lastnosti. Poenostavljeno se je polemika v zadnjem času ustavila na nivoju *pro et contra* v smislu razlage koliščarskih naselbin na robu jezera ali na poplavni ravnici, predvsem na primeru kolišča Maharski prekop (cf. Budja, Mlekuž 2008a; Velušček 2009a). Na neprimernost polemike v tem okviru je opozorila že Andričeva (2009). Obstaja še vrsta drugih vmesnih okolij, ki sicer niso navedena v osnovnih sedimentoloških učbenikih. Ta vmesna okolja so običajno težje razpoznavna. Za njihovo razpoznavo in interpretacijo je potrebno več podatkov, opazovanj in analiz.

Kolišča ob jezeru?

Interpretacija, ki je postavila kolišča ob jezera, naj bi imela svoj izvor v sredini 19. stoletja, v času idealiziranja preteklosti, tudi v obliki romantičnih podob (Grajf 1997). Iz tistega obdobja res izhajajo nekatere idealizirane upodobitve kolišč sredi jezer. Vendar so bile že tedaj poznane tudi moderne, povsem realne analogije. Hkrati ta interpretacija sloni tudi na sklepanju, pravzaprav na odgovoru na vprašanje, kakšno okolje (v okvirih, ki jih je Barje tedaj ponujalo) naj bi nekdanjim prebivalcem najbolj ustrezalo. Vendar se ob tem upravičeno vprašamo, ali je "smotrnost" izbire lokacije z naše perspektive res edino vodilo, na podlagi katerega sklepamo na nekdanje koliščarsko okolje. Grajfova je zapisala (1997, str. 12): "*S poudarjanjem le določenih aspektov, ki so vplivali na razvoj koliščarskih naselbin, zlahka zapademo v determinizem in poenostavljene razlage*."

Konec leta 2009 in v začetku 2010 so na Špici potekala arheološka izkopavanja. Po odkritem tlorisu in profilu s stikom jezerske krede in kulturne plasti na severnem delu najdišča (*sl. 3*) sem podal predhodno interno mnenje, da naj bi se nekdanji prebivalci naselili prav na rob jezera. Mnenje sem utemeljil na podlagi sledečih terenskih opazovanj:

– odsotnost talnih horizontov ali vsaj začetka pedogeneze neposredno na jezerski kredi;

– odsotnost erozijskih oblik na površini jezerske krede (poševnih erozijskih rezov, korit, žlebov, ...), ki bi jih utemeljeno pričakovali, če bi teren pred nastankom kulturne plasti zajela (aluvialna) erozija;

– odsotnost aluvialnih sedimentov neposredno nad jezersko kredo, ki bi hkrati dokazovali tudi morebitno erozijo in/ali sedimentacijski hiatus;

– laminiranost jezerske krede, ki smo jo lahko sledili preko celotnega profila in ugotovili rahlo nagnjenost proti Barju, vendar je enako nagnjenost izkazovala tudi sama meja med jezersko kredo in kulturno plastjo.

Opisane lastnosti profila bi lahko razlagali kot prehod jezerskega sedimentacijskega okolja v antropogeno pogojeno močvirsko okolje na prehodu med obrežjem in jezerom. Zakaj antropogeno pogojeno: med navpičnimi koli smo namreč lahko opazovali neposredno nad jezersko kredo lečasto (cm in dm dimenzij) plavljenje tako klastičnega mineralnega sedimenta kot tudi rastlinskega detritusa, lupin moluskov ter fragmentov keramike. To plavljenje, ujeto med vertikalne kole, bi lahko bilo tako posledica valovanja jezerske vode kot tudi občasnega in skromnega aluvialnega plavljenja iz zaledja. Dotedanja opazovanja so se stekala v povsem sprejemljivo interpretacijo. Vendar napačno! Celotna situacija se je izrazito spremenila že med samimi izkopavanji.

Pred koncem izkopavanj so bili v južnem delu izkopnega polja odprti profili s slabo izraženo erozijsko površino med jezersko kredo in kulturno plastjo, skoraj hkrati pa sem dobil dve ustni informaciji, da je glede na pelodno vsebino jezerska kreda pleistocenska in ne holocenska. Luminiscenčne analize vzorca jezerske krede so nekoliko kasneje dale bolj natančen rezultat: starost krede je približno 18.000 let BP, torej je nastala v obdobju zadnjega glacialnega viška (Johanna Lomax, elektronsko sporočilo 27. 1. 2011).

Ta nova opazovanja oziroma analize je potrebno združiti z zgoraj opisanimi in poskusiti razložiti stratigrafski hiatus v kontekstu sedimentacijskih, erozijskih in pedoloških procesov. Je bilo v času poselitve na Špici oziroma v neposredni bližini jezero? Verjetno ne. Sicer bomo težko razložili približno štirinajsttisočletni stratigrafski hiatus evidentiran med jezersko kredo in kulturno plastjo brez sledu pedogeneze, s slabo izraženo erozijsko površino. Če odmislimo jezersko sedimentacijsko okolje, s kakšnim naj ga nadomestimo? Vprašanja, ki v tem trenutku še nimajo odgovorov. V zvezi s tem se vsekakor moramo strinjati s trditvijo, da navpični koli v jezerski kredi sami za sebe niso dokaz za naselbino na robu jezera (Budja, Mlekuž 2008a).

Kolišča na poplavnih ravnicah?

Teza, da so bila kolišča postavljena na poplavnih ravnicah ob vodotokih, verjetno izhaja iz interpretacije letalskih posnetkov Maharskega prekopa in okolice (Bregant 1975, 49), ki so jih kasneje dopolnili (izvrstni!) posnetki LIDAR skupaj z interpretacijo radiometričnih datacij polnila v koritih nekdanjih vodotokov (Mlekuž et al. 2006; Budja, Mlekuž 2010). Hkrati se avtorji te hipoteze v veliki meri naslanjajo tudi na interpretacijo geoloških oziroma sedimentoloških podatkov. Povsem jasna je njihova želja narediti korak naprej pri razumevanju nekdanjega okolja prav z interpretacijo geoloških procesov. Teza je zanimiva, vendar je dosedanji podatki in rezultati arheoloških izkopavanj večinoma ne podpirajo, včasih ji celo nasprotujejo. Kot se zdi, v sedanji obliki zahaja v slepe ulice in pušča nekaj odprtih splošnih ter lokalno pogojenih naravoslovnih vprašanj. Omejil se bom na dve.

Gledano na splošno, pri tej interpretaciji najbolj moti odsotnost aluvialnih klastičnih sedimentov, ki naj bi bili povezani z nekdanjo poplavno ravnino in – v skladu s to tezo – tudi s kulturnimi horizonti. Kulturna plast na Maharskem prekopu je vezana na organske sedimente, gyttjo,[1] in je ponekod odložena neposredno na površino jezerske krede (Bregant 1975). Tako zatečeno stanje implicitno zahteva interpretacijo, da je bila poplavna ravnica v času poselitve prekrita izključno z gyttjo. Ta podmena

[1] Tu sicer uporabljam izraz gyttja v smislu Bregantove (1974, 1974), čeprav v nadaljevanju v zvezi s tem izražam dvom, ki ga pojasnjujem v nadaljnjem besedilu.

pa spet pogojuje okoljsko interpretacijo: ohranitev organskih sedimentov, tudi gyttje, je povezana z bolj kot ne stalnim *vodnim telesom,* kakorkoli ga že imenujemo. V sedimentološkem smislu ga ne moremo opredeliti kot poplavno ravnico.

Morda bi tu opozoril, da zagovorniki te hipoteze (Mlekuž et al. 2006, 257) izrecno omenjajo domnevni talni aluvialni tovor, ki naj bi bil celo vzrok za spremembo rečnega režima. Vendar pri arheoloških izkopavanjih in sondiranjih tak tovor, razen seveda organskih sedimentov, ni bil nikjer ugotovljen.

Drugo vprašanje, na katero hipoteza o koliščarskih naselbinah na poplavni ravnici ni dala ustreznega odgovora, se nanaša na stratigrafsko zaporedje dogodkov ob Ižici, kjer sta avtorja vzorčila in datirala polnila aluvialnih korit (Budja, Mlekuž 2008b, 2010). V vseh petih vrtinah in po njihovi celotni globini sta pod vrhnjim talnim horizontom naletela izključno na temni vlaknati organski sediment, pod njim pa na jezersko kredo. Nobena od petih vrtin ni prevrtala kakršnegakoli klastičnega sedimenta. Podobno situacijo so odkrili tudi na delu izkopnega polja ob izkopavanjih na Maharskem prekopu, le da je na profilih med jezersko kredo in gyttjo ponekod interpretirana tanka kulturna plast (Bregant 1975). Take razmere je avtorica interpretirala kot z organskim sedimentom zapolnjena aluvialna korita, sočasna z naselbino (Bregant 1975). Izven teh korit je stratigrafsko zaporedje bolj pestro. Nad jezersko kredo je odložena gyttja (pred gradnjo kolišča), ki je prekrita s kulturno plastjo (njena osnovna sestavina je gyttja), nad njo pa je večinoma svetlo sivorumena mastna glina. To glino v sedimentološkem kontekstu verjetno lahko interpretiramo le kot poplavni sediment, kar je menila tudi Bregantova (1975). Ta je seveda mlajši kot kulturna plast, vendar nas bolj zanima njegov stratigrafski odnos do korit kot erozijskih oblik in do polnila v koritih. Verjetno je odveč razlaga, da so poplavni sedimenti odloženi ploskovno neprekinjeno, če razmere dopuščajo zvezno razlitje vode s suspenzijskim sedimentom. Kaj bi lahko oviralo nastanek poplavnega sedimenta nad obstoječimi koriti, slednja so namreč na topografsko nižjih legah kot t. i. poplavna ravnica?

Razlaga, da naj bi bila korita časovno istočasna s poselitvijo, ni samoumevna, še več, ne ustreza stratigrafskim načelom in sedimentološkim razmeram. Bolj ustrezna, verjetno edina smiselna razlaga[2] za opisane stratigrafske razmere je, da so korita mlajša od kulturne plasti in tudi od svetle sivorumene mastne gline. Aluvialna korita na tej lokaciji so se verjetno zarezala v že naplavljeno svetlo sivorumeno mastno glino in nato poglabljala navzdol skozi kulturno plast in gyttjo pred gradnjo kolišča, tudi v samo jezersko kredo (*sl. 4*). Da bi to utegnila biti verjetnejša interpretacija, nakazujejo tudi z risbo nakazani stratigrafski odnosi (Bregant 1975, pril. 3; Bregant 1974, pril. 1).[3] Bolj trden odgovor na to vprašanje pa bi podala numerična datacija tega poplavnega sedimenta.

Avtorji hipoteze o kolišču na poplavni ravnini se bodo morda sklicevali na radiometrične datacije gyttje oziroma vlaknatega organskega sedimenta iz teh korit (Budja, Mlekuž 2008b, 2010). Opozoriti je potrebno, da obstaja samo ena datacija iz vsakega jedra vrtine. Morda gre za resedimentiran starejši organski material. Podobno resedimentacijo morda

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[2] Pod specifičnimi pogoji bi lahko razlagali tudi istočasnost potočnih korit in kulturne plasti. V tem primeru bi morala biti vsa korita stabilna skozi daljše časovno obdobje, ne samo v času nastanka kulturne plasti in morda pred njo, pač pa tudi kasneje, ko je nastajala gyttja nad kulturno plastjo in v času nastanka svetle sivorumene mastne gline, torej poplavnega sedimenta. Če neko korito ne bi bilo aktivno v času nastanka omenjene gline, bi ga le-ta morala prekrivati, kar pa ne drži. Tako nam za razmislek ostaja še možnost, da bi se voda z glinastim suspenzijskim materialom razlila na poplavno ravnino prav iz teh korit. To je precej nepremišljena teza, saj bi v tem primeru pričakovali poplavni sediment tudi v sklopu starejših plasti (v kulturni plasti in gyttji pred poselitvijo), ki naj bi nastajale v obdobju aktivnosti potočnih korit. V tem primeru ne bi bilo razloga za odsotnost poplavnih sedimentov v sklopu teh starejših plasti. Razmere na Maharskem prekopu so nasprotne: poplavni sediment je vezan praktično na eno samo plast v krovnini kulturne plasti. Kakorkoli poskušamo evidentirane stratigrafske razmere razložiti z modelom sočasnosti korita in kulturne plasti (Bregant 1975, 13; Mlekuž et al. 2006, Budja, Mlekuž 2010), nam to ne uspe. Zato se ta razlaga ne zdi smiselna. Zdi se, da je prvotni argument za ta model interpretacija zgoščenih vertikalnih kolov v smislu valobrana, kar pa naj ne bi bila edina možna razlaga (Velušček 2009a, 305).

[3] V posameznih delih izrisanih profilov (severni profil kvadranta IX, zahodni profil kvadranta XXIII in severni profil kvadranta XV) je Bregantova ob robovih nekaterih korit interpretirala svetlo sivorumeno mastno glino na način, da v ozkem pasu prekriva gyttjo, kot da so zapolnitve korit v teh delih starejše od svetlo sivorumene mastne gline. Menim, da gre pri omenjenih robovih lahko za spiranje te gline, morda pa tudi za manjše netočnosti pri izrisu posameznih stratigrafskih odnosov. V veliki večini na izrisanih profilih (v skupni dolžini okoli 80 m) gyttja v koritih ni prekrita s svetlo sivorumeno mastno glino, taka interpretacija je izrisana na vsega treh mestih v skupni dolžini okoli 4 m (Bregant 1975, pril. 3 in 4; Bregant 1974, pril. 1).

lahko razberemo tudi iz profilov Bregantove (1975, pril. 3 in 4) pri tanki kulturni plasti v koritih neposredno nad jezersko kredo (glej tudi *sliko 4f*).

V zvezi z Maharskim prekopom moram omeniti še eno zanimivost, in sicer pahljačasto geometrijo trajektorijev kolov in lego ter usmerjenost z njimi povezanih hiš ob domnevnem vodotoku (Bregant 1975, pril. 2, 3; Mlekuž et al. 2006, sl. 5, 7, 8), ki bi lahko nakazovale nekdanjo aluvialno dinamiko. Kot poskus interpretacije te geometrije sem te trajektorije prekril s posnetkom LIDAR, ki ga navajajo Mlekuž s sodelavci (2006, sl. 4) ter Budja in Mlekuž (2010, sl. 4). Rezultat je na videz osupljiv. Pahljačasti trajektoriji kolov se dobro ujemajo z domnevnim vodotokom 1. faze, vendar le, če je ta tekel od severa proti jugu, kjer se je v obliki pahljače (vršaja) iztekal v nižje ležeča korita 3. faze. Ne trdim, da je ta interpretacija točna, nasprotno, menim, da je to opazovanje morda pokazatelj, da samo daljinsko zaznavanje lahko pripelje tudi do napačnih domnev, na podlagi teh pa lahko naprej konstruiramo le napačne interpretacije.

POSEDANJE BARJA IN VPLIV NA SEDIMENTACIJSKO OKOLJE

Krajinski park Ljubljansko barje danes obsega zatečeno, antropogeno degradirano krajino, ki jo z barjanskim sedimentacijskim okoljem povezuje le zgodovina. Redkokje je človekov vpliv na okolje tako izrazit kot na Barju. V geološkem smislu je vpliv antropogenih posegov na Barju največji v zvezi z dinamiko posedanja oziroma sesedanja tal. Ocena posedanja v posameznih obdobjih, torej poznavanje dinamike posedanja, bi lahko pripomogla k razumevanju preteklih okoljskih sprememb na Barju. Prav tako pa posedanje tal lahko v prihodnosti bistveno vpliva tudi na urbanistični razvoj in poselitveni vzorec Barja.

Verjetno je posedanje tal danes najbolj kompleksen naravni geološki proces na Barju, hkrati pa delno tudi antropogeno vsiljen. Že brez antropogenega vpliva je posedanje na Barju sestavljeno vsaj iz dveh neodvisnih procesov: naravne kompakcije nelitificiranih sedimentov in tektonskega posedanja. Osuševanje Barja vpliva na nove procese: posedanje oziroma kompakcija tal zaradi nižanja talne vode, sesedanje tal zaradi rezanja, požiganja in preperevanja šote ter propadanja organskih sedimentov oziroma tal. Seveda se lahko tudi sprašujemo, kakšen je vpliv recentne razbremenitve barjanskih tal zaradi zgoraj navedenih posledic osuševanja. Razen tega v zadnjih desetletjih prihaja na Barju do inženirskih posegov, ki pa imajo na posedanje sicer izrazit, vendar lokalen vpliv (na primer vodarna Brest).

Obstajajo številni poskusi kvantificiranja posedanja, različni predvsem v metodološkem smislu. Najbolj uspešni so poskusi geodetskega spremljanja recentnih posedkov, predvsem na manjših antropogeno degradiranih območjih, kjer se posedanje spremlja zaradi tehničnih razlogov (cf. Ježovnik, Jakljič 2003; Ježovnik 2009). Pri teh meritvah je metodologija jasna, napake opredeljene, težava pa je, da izmerjene vrednosti posedkov predstavljajo kumulativni seštevek različnih vzrokov posedanja (lokalno antropogeno pogojeno posedanje, posedanje zaradi naravne kompakcije sedimentov, posedanje zaradi propadanja organskih tal, tektonsko posedanje, …). Rezultatov teh meritev nikakor ne moremo prenesti ne v (geološko) preteklost ne v prihodnost (urbanistično planiranje) in tudi ne na druge lokacije na Barju. Posedki zaradi konstrukcijskih antropogenih vplivov so namreč večinoma neprimerno večji od naravnega posedanja. Na drugi strani obstaja nekaj poskusov kvantifikacije posedanja na Barju po posameznih vzrokih (Breznik 2000; Bračič Železnik et al. 2003). Nasprotno kot pri geodetskih meritvah je metodologija pri teh ocenah precej nejasna, napake pa nedefinirane. V tehničnem smislu so te ocene večinoma vprašljive vrednosti.

To stanje je z dokaj originalno metodologijo želel izboljšati Brenčič (2007). Na podlagi ugotovljene linearne regresije med globino in starostjo sedimentov v vrtinah BV-1 in BV-2 je ugotovil, da se je Barje na teh dveh lokacijah v holocenu posedalo dokaj enakomerno s hitrostjo 1,235 ± 0,011 mm/leto oziroma 1,357 ± 0,005 mm/leto. Na numerične starosti sedimenta je sklepal le na podlagi korelacije pelodnih diagramov, kar rezultate postavlja pod vprašaj, saj gre za precej nenatančno in tudi nezanesljivo metodo. Bolj pa bode v oči konceptualna napaka pri tem izračunu. Izhodiščna premisa pri njegovem modelu je bila vseskozi sedimentacija na nivoju tal. To seveda v primeru Ljubljanskega barja ne drži, saj v tem primeru ignoriranje globine sedimentacijskega bazena implicitno negira nekdanje jezersko okolje, kjer je nastala večina sedimentov. Na *sliki 5* sta ob sicer enakem končnem stanju, predstavljena dva konceptualna modela nastanka 10 m debelega sedimentnega zaporedja, ki je nastalo v 10.000 letih. Prvi primer (*sl. 5a*) ponazarja Brenčičev (2007) model, kjer sediment vseskozi nastaja na relativnem nivoju 0 m, recimo na površini tal. Posedanje je v tem primeru res 1 mm/leto, enako kot hitrost same sedimentacije. Ta hitrost bi se marsikomu zdela kar realna, čeprav ta model sloni na povsem nerealni premisi negiranja jezerskega sedimentacijskega okolja.

Drugi primer (*sl. 5b*) izhaja iz zapolnjevanja sedimentacijskega bazena (recimo jezera), globokega 10 m, ki se enakomerno polni s hitrostjo 1 mm/leto. V tem primeru se sedimentacijski bazen sploh ne poseda, ampak se samo polni (*sl. 5b*). Vhodni podatki za ta drugi primer so v grobem velikostnem razredu podobni razmeram na Barju po zadnjem glacialnem višku: 10.000 let sedimentacije, 10 m sedimenta (jezerska kreda), začetna globina jezera 10 m. Ko smo torej vključili v model nek dokaj realen parameter (začetno globino jezera 10 m), dobimo kot rezultat povsem nerealno hitrost posedanja. Ta je v tem primeru posledica pomanjkljivosti še vedno izrazito poenostavljenega modela, saj ne upošteva interakcij med posameznimi spremenljivkami. Ne, nikakor ne trdim, da posedkov na Barju v tem času ni bilo.

Ta primer dokazuje, da moramo pred kakršnokoli kvantifikacijo najprej razumeti model in vse spremenljivke ter njihove medsebojne odvisnosti. Model, ki je bil predstavljen pred kratkim (Verbič, Andrič 2010), nakazuje vse prej kot na linearno dinamiko posedanja na Barju od zadnjega glacialnega viška do danes. Nelinearnost je v posedanje Barja prav gotovo prinesla nenadna statična obremenitev tal s približno 10 m visokim vodnim stolpcem ob nastanku jezera. Predvsem bo v prihodnje potrebna kvantitativna ocena vpliva te obremenitve na posedanje dna tedanjega jezera. Še bolj kompleksno pa je recentno pogrezanje oziroma sesedanje tal zaradi posameznih prej navedenih razlogov. Avtorji ocen posedanja do sedaj večinoma niso upoštevali preteklega in predvsem tudi prihodnjega posedanja zaradi propadanja organskih tal. Ta komponenta posedanja je na nekaterih mestih morda še danes največja. Propadanje organskih sedimentov in tal, kjer so seveda prisotna, se bo ob trenutnem vodostaju talne vode na Barju še nadaljevalo (Hacin 2004).

S tem v zvezi sta interpretativno izpovedni krivulji višin obeh bregov Ljubljanice (*sl. 2*). Ti krivulji, vključno s krivuljo dna Ljubljanice, sta bili konstruirani na podlagi prečnih topografskih profilov (skupaj 96 profilov med Vrhniko in Špico; Stojič 1994). Višine obeh obrežnih nasipov vzdolž Ljubljanice (*sl. 2:* krivulji c in d) nakazujejo na pospešeno posedanje ozemlja med Podpečjo in Črno vasjo, seveda v primerjavi z okolico dol- in gorvodno. Na tem odseku sta krivulji vidno upognjeni, zdi se, da sama sedimentacija ni dovolj hitra, da bi to upognitev v reliefu zapolnila z naplavinami. Podatki so stari že skoraj 20 let, zato z zanimanjem čakamo na nove meritve.

SEDIMENTI IN SEDIMENTACIJSKO OKOLJE

Po pregledu dela objavljenih razprav v zvezi s kolišči na Barju bi najprej rad opozoril, da podatki nakazujejo, da so bila kolišča postavljena v različna sedimentacijska okolja. Na to je opozorila že Bregantova (1984, 23). Če se na hitro ozremo samo na štiri kolišča: na Špico, Maharski prekop (Bregant 1975), Notranje Gorice (Harej 1976) in Parte (Harej 1981–1982), lahko med njimi opazimo kar nekaj razlik, ki so posledica različnih sedimentoloških in erozijskih okvirov.

V tem trenutku obstaja dovolj argumentov, ki kažejo, da bi morali biti raziskovalci v prihodnje previdni glede obeh prevladujočih interpretacij, vsaj v delu, ki se tiče posploševanja enega modela na vsa kolišča (npr. Budja, Mlekuž 2009, 366). Odsotnost poplavnih sedimentov v kontekstu kulturnih plasti na Maharskem prekopu in hkratna ohranjenost organskih sedimentov ne podpirata modela kolišč na poplavni ravnini. Dvom o pravilnosti te hipoteze izkazujejo tudi evidentirane stratigrafske razmere na tem najdišču. Nasprotno bi sedimentološke razmere na kolišču Notranje Gorice, kakor jih lahko rekonstruiramo iz poročila Hareja (1976), lahko nakazovale na bistveno manj močviren teren. Dovoljevale bi morda tudi gradnjo na suhem. Najbolj kompleksno litostratigrafsko zaporedje je evidentirano na lokaciji Parte (Harej 1981–1982). Značilno je plavljenje različnega materiala v kulturni plasti (pesek, lupine moluskov, keramika, rastlinski ostanki) kakor tudi v plasteh navzgor. Taka situacija nekoliko spominja na sedimentološke lastnosti v sami kulturni plasti na Špici, hkrati pa med obema lokacijama obstajajo številne razlike (debelina kulturne plasti, količina siliciklastične mineralne in karbonatne komponente, razmere v krovnini kulturne plasti, …).

Razmere na Maharskem prekopu kažejo, kakorkoli se to zdi neprijazno do nekdanjih prebivalcev, bolj na močvirsko okolje z zelo hitrim prirastom organskih sedimentov. Zelo pomembna se zdi Stritarjeva (1975) analiza kulturne plasti, ki je pokazala prisotnost kalcijevega karbonata. Poročila nikjer ne navajajo jasne notranje stratifikacije (na primer laminacije), zato predpostavljam, da je kalcijev karbonat dokaj enakomerno dispergiran po kulturni plasti. To bi pomenilo, da se je poleg organskih sedimentov istočasno odlagal tudi (avtigen) karbonat, kar bi nakazovalo na rob jezerskega okolja. V tem kontekstu ima trditev, da je bila pred koliščem Maharski prekop *čistina jezera* (Velušček 2009a), vsekakor jasno podporo. Podobno bi lahko interpretirali s karbonatom bogato kulturno plast na Partih (Stritar, Lobnik 1985), le da to lokacijo opredeljujejo številne sedimentološke strukture, povezane s klastičnimi sedimenti (Harej 1981–1982). Morda so te oblike povezane z lokacijo ob dotoku mineralne komponente v jezersko okolje, morda s plavljenjem ob jezerski obali. Sicer bi za neposredno potrditev hipoteze kolišč na robu jezera na primer lahko šteli numerično datacijo jezerskega sedimenta pod *istočasno* kulturno plastjo na najdišču, brez vmesnega stratigrafskega hiatusa, ali pa prekritje kulturne plasti z jezerskimi sedimenti.

Močvirsko okolje na robu jezera omenja tudi Velušček (2009b) v okviru najdišča Stare gmajne. Turk in Horvat (2009) omenjata možnost ohranjenega zveznega sedimentnega zapisa ob prehodu iz jezerskega v močvirsko okolje pri Blatni Brezovici, vendar hkrati opozarjata, da ne moreta izključiti stratigrafske vrzeli, saj jezerska kreda ni datirana.

Presenetljiv je ugotovljen približno 14.000 let dolg stratigrafski hiatus med jezersko kredo in kulturno plastjo na Špici. Soočamo se s podobnim problemom kot na Resnikovem prekopu (Andrič 2006). Trenutno še postavljamo različne hipoteze, ki bi lahko pojasnile na eni strani dolg stratigrafski hiatus in na drugi zelo slabo izraženo diskordanco (v pedološkem, erozijskem in sedimentološkem smislu). Še vedno ostaja plavljenje materiala med koli v kontekstu kulturne plasti eno od poglavitnih opazovanj, ki določajo tedanje sedimentacijsko okolje. Zdi se, da je to plavljenje lahko povezano tako s tekočo vodo kot tudi z valovanjem na robu stoječe vode. Ta stoječa voda seveda ne bi imela neposredne povezave z nekdanjim jezerom iz časa zadnjega glacialnega viška, ko se je odlagala talnina kulturne plasti na Špici. Vmesnih dogodkov ne poznamo, morda je ta lokacija v času kolišča povezana z brežino Ljubljanice. Ta je dalj časa v holocenu verjetno funkcionirala podobno kot odtoki iz presihajočih jezer, seveda le v smislu, da njen pretok ni dopuščal sprotnega odtekanja vode iz Barja v posameznih sezonskih obdobjih. S tem v zvezi lahko pričakujemo tudi znatno sezonsko nihanje nivoja površinske vode na Barju. Hkrati so bile možne motnje odtekanja vode iz Barja zaradi različnih naravnih procesov, morda tudi pobočnih zdrsov zemljine z Grajskega hriba ali podobno. Take, sicer težko predvidljive razmere bi za krajše obdobje, recimo za nekaj desetletij ali celo več, lahko znatno spremenile razmere na Barju. Sedimentni zapisi takih dogodkov pa so redki in običajno zelo težko ter tudi dvomljivo čitljivi. Vendar so to v tem trenutku le hipotetična razmišljanja.

Za zadnji del tega teksta je primerno, da nakažem smer, v kateri vidim iskanje odgovora glede okoljske interpretacije v času koliščarskih poselitev na Ljubljanskem barju. V prvi vrsti menim, da je nujno v prihodnosti natančno opisati in tudi analizirati vse sedimente v kontekstu arheoloških najdišč na Barju, ne samo kulturne plasti, pač pa tudi njeno talnino in krovnino. Ob tem še posebno izpostavljam organske sedimente, gyttjo (Hansen 1959) in tudi jezersko kredo (*Seekreide,* Merkt et al. 1971). Raziskave naj bi obsegale sedimentološke, mineraloške, kronološke in geokemične analize, pa seveda tudi druge (cf. Andrič et al. 2008; Turk, Horvat 2009). Te analize naj pokažejo predvsem razlike med organskimi sedimenti in tudi jezersko kredo na različnih lokacijah na Barju. Razlike zelo verjetno obstajajo, vendar niso evidentirane. Menim, da bodo lahko pomembna informacija v smislu okoljske interpretacije. Poglejmo, kako oba sedimenta razumemo danes in kakšno razumevanje bi želeli v prihodnje.

Z izrazom gyttja običajno razumemo sediment, ki ga lahko opišemo kot organsko blato, osnova je organski sediment, prisotne pa so lahko tudi avtigena, biogena in/ali detritična mineralna komponenta (Hansen 1959). To pa je bolj ali manj tudi vse. Torej je to zelo ohlapen izraz, z njim lahko opisujemo različne usedline tako po strukturi kot tudi po kvantitativni sestavi. Razen tega so temu izrazu v preteklosti različni avtorji dodajali različne pridevnike, na primer apnena gyttja. Podobno širok ali celo širši je spekter uporabe izraza gyttja v tujini (glej primere v Schnurrenberger et al. 2003). Zato je že pred štirimi desetletji prišla pobuda, da se je potrebno temu izrazu izogniti in sediment bolj natančno opisati (Merkt et al. 1971). Podobnim smernicam sta verjetno sledila tudi Budja in Mlekuž (2010), ki sta sediment v koritih na Maharskem prekopu opredelila kot "*dark organic fibrous deposit*". Verjamem, da je ta sediment drugačen, kot je organski sediment z lokacije na Špici. Zanimivo bi bilo na podlagi različnih analiz primerjati organske sedimente z lokacije ob Ižici: gyttjo pred poselitvijo, med kulturno plastjo in nad njo (Bregant, 1975) ter "*dark organic fibrous deposit*" (Budja, Mlekuž 2010) v koritih. Prav tako še nisem zasledil podatkov o vrsti vegetacije, ki sestavlja te sedimente.

Jezerska kreda je v Sloveniji dobro uveljavljen izraz, po svetu pa manj, kar naj bi bila posledica dejstva, da so bili originalni prispevki na to temo (cf. Merkt et al. 1971) objavljeni le v nemščini (Schnurrenberger et al. 2003). V slovenski geološki terminologiji se ta izraz uporablja v širokem smislu, tako za biokemične kot tudi za klastične (pretežno) karbonatne usedline, nastale v jezerskem okolju, in tako le deloma opisuje facies. Izraz na primer ne pove količine karbonata v celotnem sedimentu niti ali gre za detritični ali za avtigeni karbonat, kar vse pa lahko bistveno vpliva na interpretacijo sedimentacijskega okolja. Glede na model zapore iztoka Paleoljubljanice iz Barja proti vzhodu bi pričakoval zelo intenzivno sedimentacijo, tudi detritičnega karbonata. Še posebno v proksimalnem, severovzhodnem delu jezera, vse dokler je bil vršaj med Rožnikom in Grajskim hribom aktiven, saj je Sava tedaj poleg proda verjetno prenašala tudi ogromno suspenzijskega materiala. To pričakovanje podpira tudi luminiscenčna datacija jezerske krede s Špice, ki nakazuje, da se je že med zadnjim glacialnim viškom ta del jezera intenzivno zapolnjeval z jezersko kredo. Lokacija na Špici, enako kot lokacija ob nekdanji Tobačni tovarni, je pravzaprav distalni del zgornjepleistocenskega savskega aluvialnega vršaja, ki je s prodnato sedimentacijo proti jugu segal nekako do Mirja. Kot kažejo nove kronološke analize (OSL), lahko začetek zadnje ojezeritve Barja postavimo v obdobje zadnjega glacialnega viška.

Kasneje, predvsem v holocenu, bi pričakovali da se je vnos detritičnega materiala bistveno zmanjšal, sedimenta s savske strani ni bilo več, sedimentacija naj bi bila počasnejša, večjo vlogo naj bi prevzel avtigen karbonat. Avtigen karbonat se (bio)kemično obarja iz prenasičene jezerske vode, vanjo je voda dotekala predvsem preko kraških izvirov. Seveda je to v tem trenutku le model, konstruiran na podlagi razpoložljivih podatkov, potrebne pa so analize, ki ga bodo ali potrdile ali ovrgle, najbolj verjetno pa dodatno osvetlile.

Zahvala

Za informacije v zvezi s stratigrafsko in kronološko opredelitvijo jezerske krede na Špici se zahvaljujem Meti Culiberg, Maji Andrič in Johanni Lomax.

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