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PERIODICALLY INUNDATED UVALAS AND COLLAPSE DOLINES OF UPPER PIVKA, SLOVENIA

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Palško Jezero is one of the largest intermittent lakes of Upper Pivka.

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ABSTRACT: Within the area of Upper Pivka there is a number of intermittent lakes because of oscillation of water table level close to the surface i.e. shallow karst. Our survey was focused on morphogenetic interpretation of depressions hosting intermittent lakes by means of classic morphographic mapping and sediment analyses that was supported by electrical resistivity tomography. We can interpret at least two different morphogenetic types of depressions. One type are depressions which are periodically inundated uvalas positioned in-between conical hills. The second type are circular depressions within karst plain that are collapse dolines filled with extensive flood deposits up to several metres thick.

KEY WORDS: geophysics, electrical resistivity tomography (ERT), geomorphology, collapse doline, uvala, shallow karst, karst, Slovenia

Periodično poplavljene uvale in udornice na območju Zgornje Pivke

IZVLEČEK: Na območju Zgornje Pivke so zaradi nihanja gladine podtalnice blizu površja (tj. plitvega krasa) številna presihajoča jezera. Raziskava se osredotoča na morfogenetsko razlago kotanj s presihajočimi jezeri na podlagi klasičnega morfografskega kartiranja in analiz sedimentov, podprtih z električno upornostno tomografijo. Na proučevanem območju lahko določimo vsaj dva morfogenetska tipa kotanj: periodično poplavljene uvale, umeščene med kopaste vzpetine, in okrogle udornice na kraških uravnavah, zasute z do več metrov debelo plastjo poplavnih sedimentov.

KLJUČNE BESEDE: geofizika, električna upornostna tomografija (ERT), geomorfologija, udornica, uvala, plitvi kras, kras, Slovenija

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1 Introduction

The region of Upper Pivka is a part of the Karstic Ljubljanica River catchment, positioned within the Classical Karst of Slovenia (Gospodarič and Habič 1976; Šušteršič 1994; Gams 2003; Mihevc 2010; Stepišnik 2010). The highest sections of the catchment consist of high karst plateaus (Mihevc 2010) where surface drainage pattern is completely absent. In contrast, periodical surface drainage occurs on eight major poljes surrounded by high karst plateaus. The Karstic Ljubljanica River catchment drains towards the north-eastern boundary of the Classical Karst where it emerges in several karst springs. This complex hydrologic system is accompanied by a great variety of karst features, which makes the whole area an exceptional example of karst landscape (Ferk and Stepišnik 2011; Stepišnik and Repe 2015; Stepišnik and Trenchovska 2016). One of the most studied sections of the catchment is the Upper Pivka region that has particularly diverse hydrologic and hydrogeologic settings (Ravbar and Šebela 2004). This is a region of shallow karst where the water table level is positioned close to the relatively levelled surface (Habič 1985–1986; Habič 1989). During high water levels, several streams appear on the surface; their flow is directed northwards to the Postojna Cave. At these conditions, seventeen larger karst depressions within surrounding karst become inundated. The intermittent lakes are an important geoheritage of Slovenia. They were extensively studied and are considered as unique karst phenomena (Mulec, Mihevc and Pipan 2005; Stepišnik and Trenchovska 2016).

Previous literature is predominantly revising morphographic settings and hydrologic function of those lake depressions (Pleničar 1959; Habič 1975; Kranjc 1985; Habič 1985–1986; Habič 1989; Gams 2003; Ravbar and Šebela 2004; Habič 2005; Kovačič and Habič 2005; Kovačič 2006). They were simply described as periodically inundated karst depressions lacking systematical interpretation of their origin. Modern geomorphological research approach is concerned mainly by morphogenesis of surface features (Pavlopoulos, Evelpidou and Vassilopoulos 2009). The morphogenesis of the lake depressions has not yet been interpreted since interpretation would require more in-depth analysis than the simple morphographic, morphometric, and morphodynamic approaches that have been used so far.

Understanding the morphogenesis of relief features is actually an understanding of the formation, development and functioning of relief in a particular area. It enables the further interpretation of paleogeographic and paleoenvironmental conditions within the study area. Comprehensive understanding of geomorphological settings of the area enables possibilities of proper nature interpretation (Smrekar et al. 2014). This is important for enhancing geoturistical and geoeducational potential of protected areas, such as the Upper Pivka region. Furthermore, it enables more expedient and prudent management of geosites. Thus, morphogenetic assessment gives us possibilities for more appropriate measures for the nature protection and more efficient spatial management.

The aim of the study is to interpret morphogenesis of enclosed karst depressions hosting intermittent lakes of Upper Pivka. As a principal tool for interpretation we applied electrical resistivity tomography (ERT) that is a non-invasive geophysical analysis. We set the following goals: (1) general morphographic analysis and morphographic mapping of the wider area of the lakes, (2) detailed morphographic and morphometric analysis of lake depressions, (3) electrical resistivity tomography of selected section within the depressions, and (4) morphogenetic interpretation.

2 Regional settings

The Karstic Ljubljanica River catchment occupies an area of about 1,100 to 1,200 km^2 (Habič 1976). The highest sections of the area are high karst plateaus, the lower sections are mainly karst plains (or corrosion plains) and poljes. The total number of poljes within the area are eight, all of them have periodical streams, and they are inundated during high water levels (Habič 1976). The waters from poljes submerge to the underground through a number of ponors. The subsurface drainage system is diverted to a series of major springs of the Ljubljanica River at the edge of the Ljubljana Basin. This hydrologic system is accompanied by a great variety of surface and sub-surface karst features, which makes the whole area an exceptional example of karst diversity (Gams 1966; Gospodarič and Habič 1976; Zupan Hajna et al. 2008; Ferk et al. 2019).

The Pivka Basin represents the westernmost part of the Karstic Ljubljanica River catchment. The basin is enclosed by high karst plateaus. Waters are discharging in different directions towards the boundaries of the basin where they sink into the karst underground. The Upper Pivka is encompassing the southern part of the Pivka basin. The region is engulfed between high karst plateaus, while the northern part is merged with the rest of the Pivka Basin. The Upper Pivka is 15 km long and up to 5 km wide. The southernmost areas are located at an elevation of 640 m and gradually lower towards north to the elevation of 520 m. Within the area, bedded Cretaceous limestone prevail, with some Cretaceous dolomite breccia in the southern sections (Buser et al. 1967; Šikić, Pleničar and Šparica 1972). On the western edge of the area a buried fold of Eocene flysch that crops out at two separate tectonic windows is located (Pleničar 1959). The flysch fold is an active hydrogeologic barrier that is blocking westward drainage of susbsurface drainage diverting it towards east and north-east (Šikić and Pleničar 1975).

The topography of the northern part of the Upper Pivka comprises a karst plain dissected with numerous conical hills, dolines and other smaller karst features. The central part is almost a completely levelled karst plain dissected solely by dolines. The whole area of the Upper Pivka characterized by a number of large karst depressions which floors extend into the watertable oscillation level causing them to be periodically inundated. Within the western part of the karst plain the Pivka River and its short tributaries are positioned. The wide valley floor is covered by fine-grained alluvial deposits and at some stretches engulfed within narrow and up to 10-metre-deep canyon.

The wider area hosting intermittent lakes is proclaimed in 2014 as Pivka Lakes Nature Park due to its large biodiversity and habitat for many endangered species. The area is also included in the Natura 2000 network.

3 Materials and methods

Geomorphological analysis of karst depressions hosting intermittent lakes was accomplished through analytic geomorphological methods (Pavlopoulos, Evelpidou and Vassilopoulos 2009). Field morphographic analyses and mapping that included identification and spatial documentation of geomorphological features within the depressions and the surrounding slopes was supported by remote sensing data (Državna topografska karta … 2018; Lidar 2019;). Detailed field investigations were conducted after the remote sensing analyses. Field investigations were focused on karst depressions hosting intermittent lakes and their surroundings. Electronic surveying devices (GPS Garmin Oregon 600, laser distance meter Leica Disto, photo camera and drone) were used to support field morphographic and morphometric survey.

To establish subsurface structure of depressions the geophysical method of Electrical Resistivity Tomography (ERT) (also Electrical resistivity imaging (ERI)) was applied. The method is appropriate for subsurface tomography of karst terrains as the high contrast in resistivity values between carbonate rock and clayey material can easily be detected. It is particularly useful for determining the boundary between bedrock and overburden (Zhou, Beck and Stephenson 2000).

Five ERT measurements were conducted in five separate depressions. The data were collected using a SuperSting R1/IP resistivity meter developed by Advanced Geosciences Inc. A multi-core cable of 20 electrodes spaced at 5 m intervals was used. A dipole-dipole array, which is utilized in cases where vertical depth penetration and high resolution are paramount, was applied. The dipole-dipole array has been widely used in morphogenetic studies of dolines, collapse dolines and denuded caves (Zhou, Beck and Adams 2002; Stepišnik 2006; Stepišnik and Mihevc 2008; Kaufmann, Deceuster and Quinif 2012; Mihevc and Stepišnik 2012; Yeboah-Forson, Comas and Whitman 2014). The depth penetration of dipole-dipole array is approximately 15% of total spread length of profiles where the roll-along method has not been used (Herman 2001). The depth penetration in the measured profiles varies from 20.1 to 20.6 m in the profile centres.

The apparent resistivity data were inverted using AGI EarthImager 2D software. The root mean square error (RMS) quantifies the difference between the measured resistivity values and those calculated from the true resistivity model. A small RMS value indicates small differences (Zhou, Beck and Adams 2002; Zhou, Beck and Stephenson 2000). In the measurements, presented in this paper, 3–8 iterations were run to achieve the RMS errors from 2.05% to 7.70%. Contact resistance testing showed no outliers.

4 Results

Upper Pivka can be divided into two typical sections based on the relief features. The northern section is not a characteristic karst plain as it is dissected by numerous conical hills and in-between relief hollows. The floors of some hollows are within groundwater oscillation zone and accommodate intermittent lakes.

Detail investigation was conducted within two depressions within this area that are occasionally inundated. The first depression is of the northernmost intermittent lake named Jeredovce, and the second one is towards south named Krajnikov Dol.

Even though the Jeredovce depression is rarely inundated, it is referred by literature as an intermittent lake (Habič 2005; Kovačič and Habič 2005). The depression is elongated in the south-west – north-east direction. Its widest part is in the south-west, while it is gradually narrowing in the north-east direction. The floor is uneven and dissected by dolines. In some parts it is covered with flood loam. The length of the floor is ~1800 m, while the width on the southwest is ~600 m. The lowest altitude of the floor is in the south-western part at 538 m asl, while the north-western part is slightly higher at 540 m asl. The slopes of the depression are dissected by some dolines. The transition between the slopes and the surrounding karst

Figure 1: Locations of ERT profiles: A – Jeredovce, B – Krajnikov Dol, C – Veliko Zagorsko Jezero, D – Udor, E – Bačko Jezero.

surface is gradual. This depression is a part of a larger elongated lowland located in between the surrounding conical hills. The floor of the Jeredovce is flooded only in cases of the highest water levels. The highest recorded altitudes of flooding in this depression are 542 m (Habič 2005; Kovačič and Habič 2005).

ERT profile of Jeredovce was measured in the central part of the depression floor at an elevation of about 541 m throughout the entire profile. Five iterations were made to achieve RMS of 7.70%. The inverted resistivity for this profile show undulating carbonate bedrock with values from 500 to 1,500 ohm-m starting at depth from 4 to 14 m. At some parts, the carbonate bedrock reaches the surface, e.g. at electrode No. 13. The carbonate bedrock is covered by a sediment or regolith with resistivity about 200 ohm-m. Individual patches of sediments show lower resistivity values of about 100 ohm-m, probably owing to its loamy character.

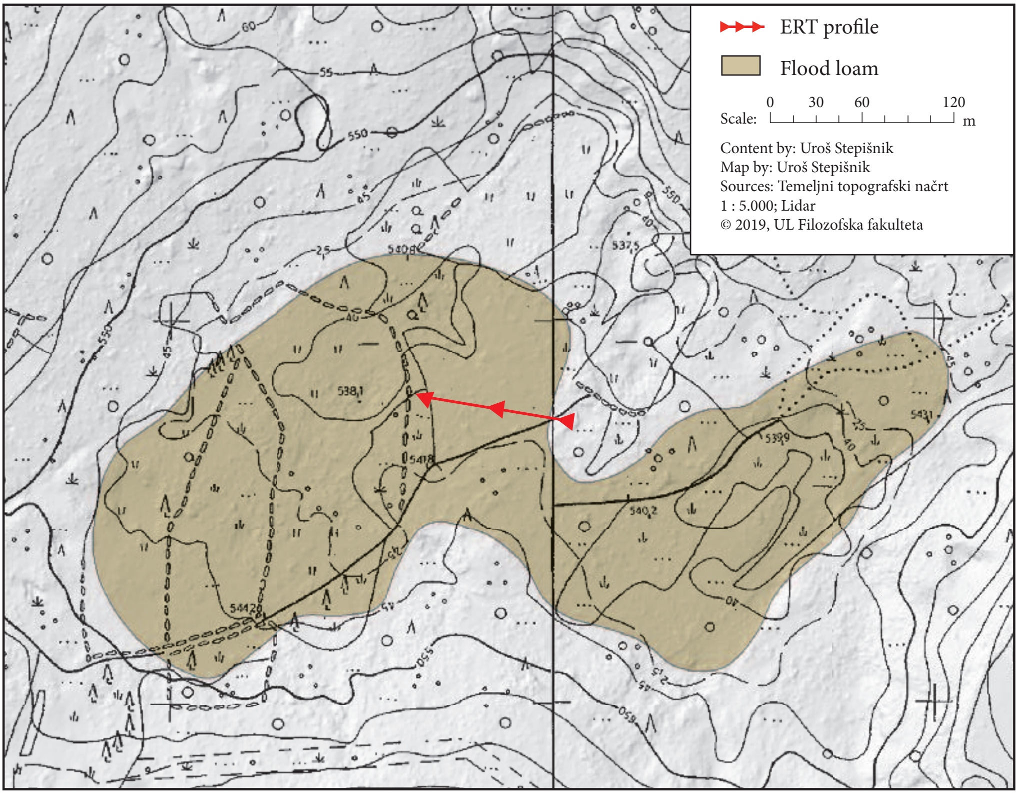

Figure 2: ERT profile location within Jeredovce depression.

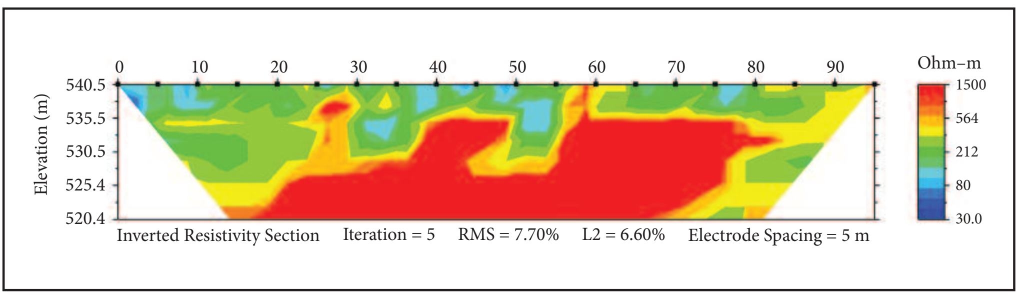

Figure 3: ERT profile of the Jeredovce depression.

Around one kilometre to the south of Jeredovce the depression Krajnikov Dol is located. The floor is flattened by flood loam at an altitude of 537 m. The levelled floor is elongated in south-west – north-west direction and has a length of 140 m and a width of 60 m. The elevation of the lake, which occasionally fills the depression floor, can be as high as 540 m (Habič 2005; Kovačič and Habič 2005). The slopes sourrounding the floor are gentle and dissected by shallow gullies. The rim of the depression is not distinct but it gradually transfers into sourrounding karst surface. The depression is not completely rounded but has an irregular shape in ground plan.

ERT profile of Krajnikov Dol was assessed from the east slope trough the floor with orientation 300 degrees. Elevation at the beginning and the end of profile was about 540 m. Seven iterations were made to achieve

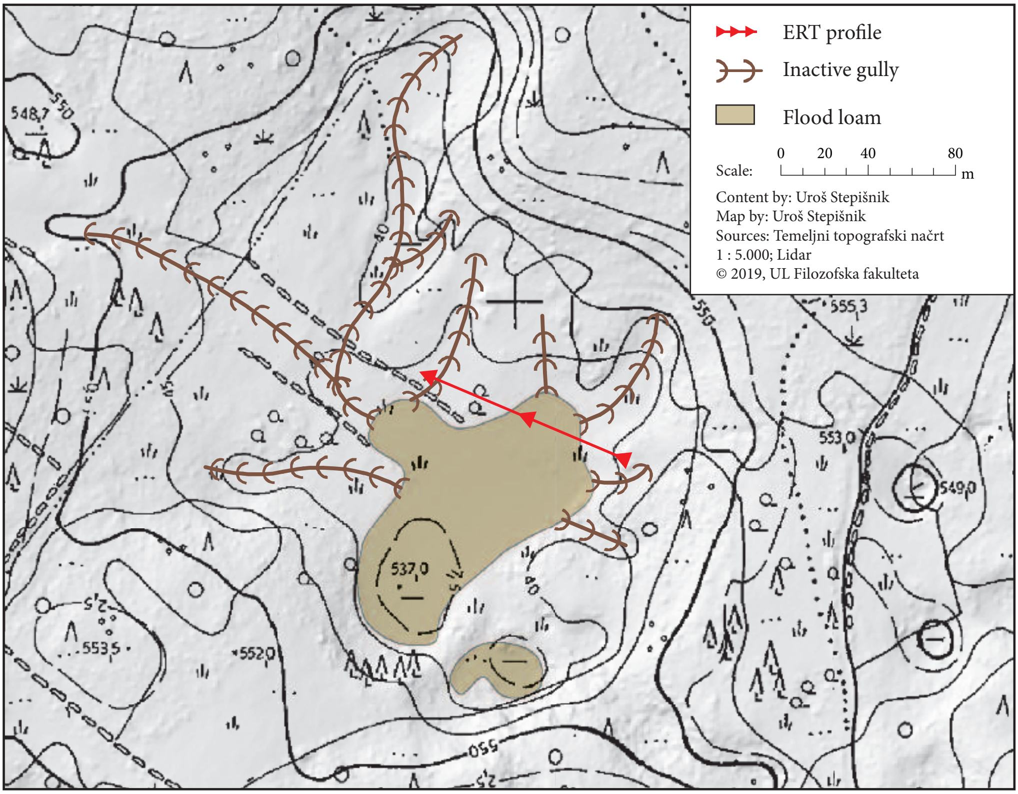

Figure 4: ERT profile location within Krajnikov Dol depression.

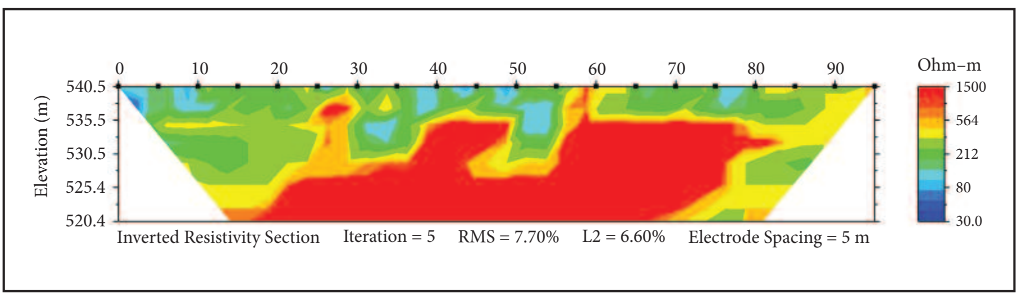

Figure 5: ERT profile of Krajnikov Dol.

RMS of 3.43%. Inverted resistivity of the east slopes exceed 500 ohm-m (electrodes 1–7), which means the slopes are built of carbonate bedrock. The resistivity at 5–8 m depth are lower – 200–400 ohm-m, which is probaby due to higher water content within the bedrock pores or due to regolith mantle. The middle part of the profile (electrodes 8–13) is located at approximately 538m asl. There, the resistivity values were below 100 ohm-m, which is due to the presence of loamy sediments with lower electrical resistivity. The depth of loamy fills does not exceed 5 m in the central part. Carbonate bedrock with resistivity values from 500 to 1,500 ohm-m is located below the loamy fills. On the western slopes (electrodes 14–20) the measured inverted resistivity exceed 500 ohm-m, which indicate the presence of carbonate bedrock. Resistivity at the final part of the profile (electrodes 18–20) are below 150 ohm-m at depths up to 10 m. This part of

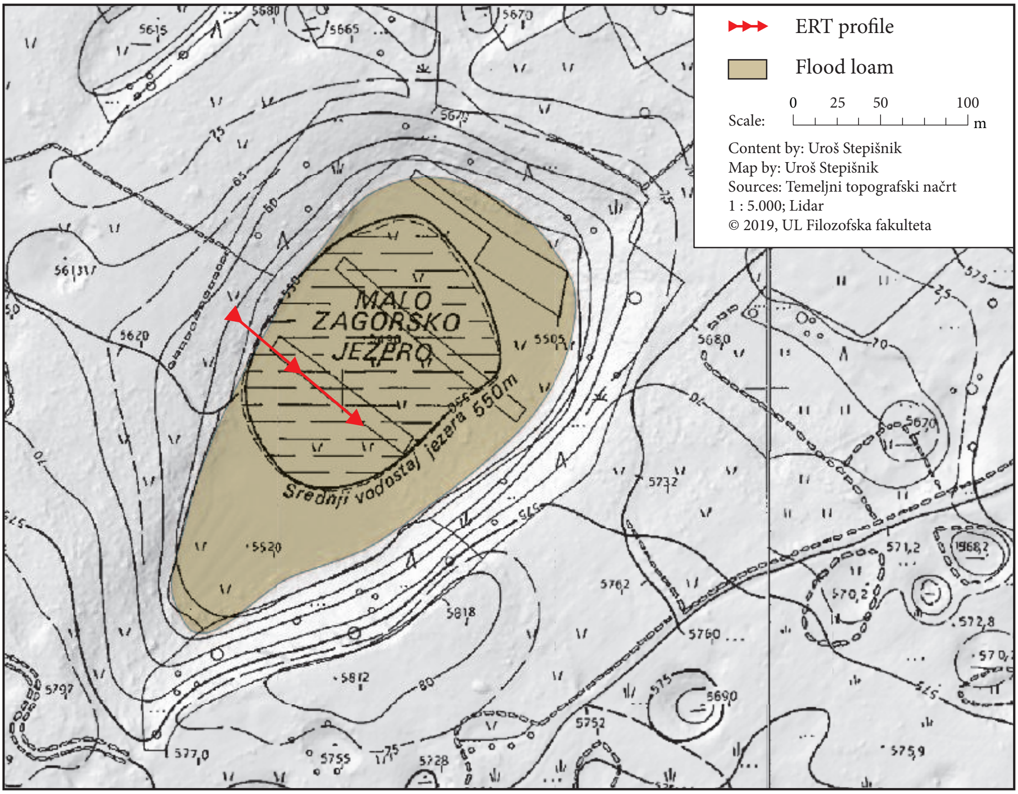

Figure 6: ERT profile location within Veliko Zagorsko Jezero depression.

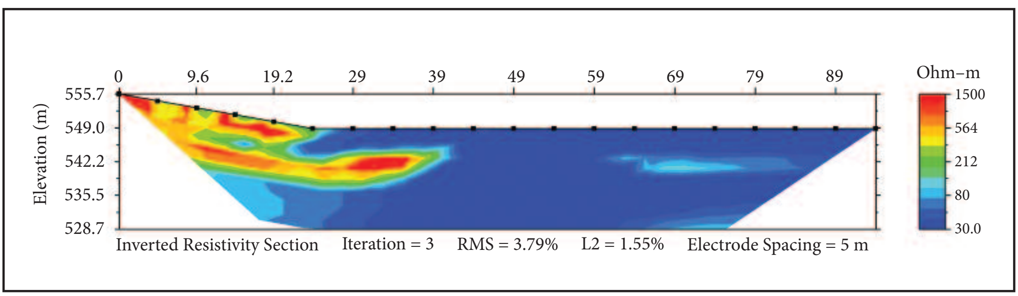

Figure 7: ERT profile of Veliko Zagorsko Jezero.

the profile crosses an inactive gully on the slope that is filled by weathered bedrock and sandy-loamy sediment located at its floor.

Towards the south the Upper Pivka karst plain is positioned. Within this section of the study area the largest number of depressions hosting intermittent lakes is located. Unlike the northern section, this area is completely levelled, dissected solely by dolines, while conical hills are completely absent. Unlike the northern part of the karst plain, the hollows of the intermittent lakes are in plan view of circular shape, contrary to the star-shaped depressions in the northern part. Moreover, the area of these circular depressions is smaller than the large depressions of the north. The largest group of circular depressions is located along the valley floor of the Pivka River. Detail investigation of thickness of flood loam

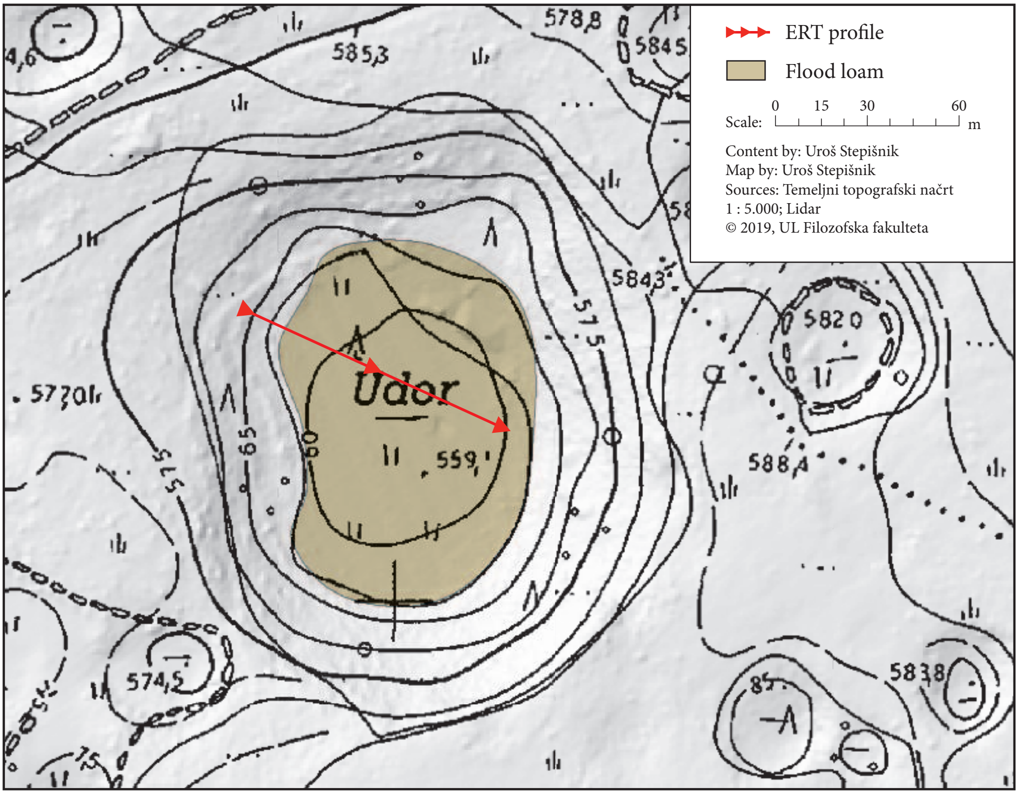

Figure 8: ERT profile location within Udor depression.

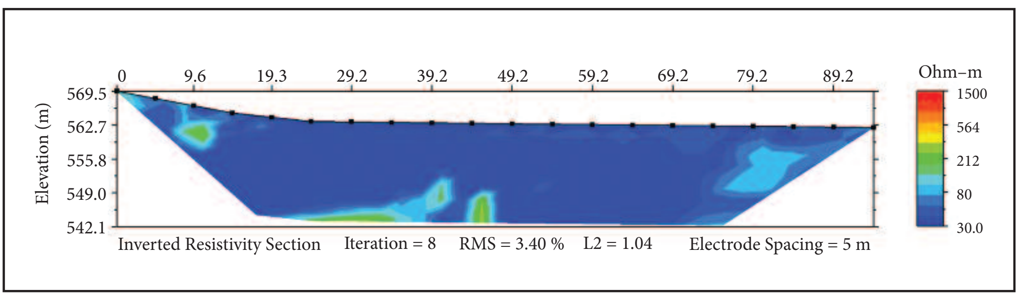

Figure 9: ERT profile of Udor.

deposits within floors was conducted within three depressions: Veliko Zagorsko Jezero, Udor and Bački Dol.

The depression of Veliko Zagorsko Jezero is positioned in the western part of the plain. It is oval in shape with a longer axis in the south-west-north-east direction. The length of the floor is ~300 m and the width is about ~150 m. Flood loam levels the floor at the altitude of 549 m. The floor of the depression passes sharply into the surrounding slopes. Almost all of the slopes are active, partly consist of steep rocky walls with collapse blocks below them. Only a part of the eastern slope is balanced (Stepišnik and Kosec 2011). Intermittent inundations within the Veliko Zagorsko Jezero depression reach elevations of 550 m, during extreme watertable levels even 551 m (Habič 2005; Kovačič and Habič 2005).

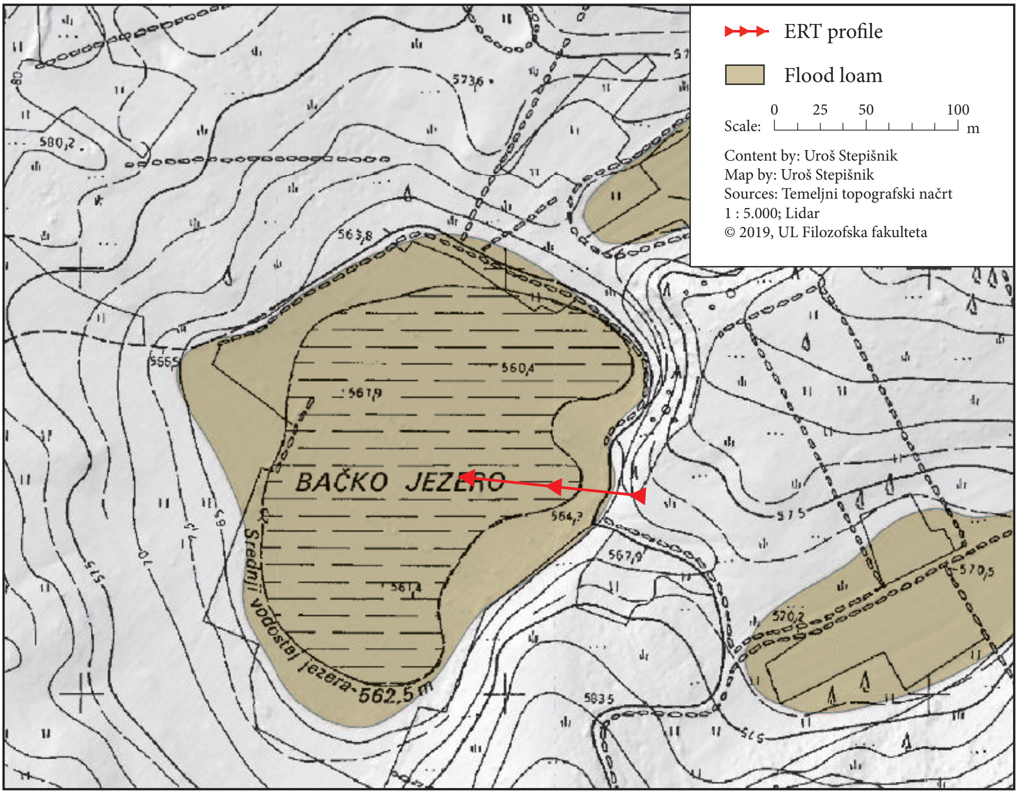

Figure 10: ERT profile location within Bačko Jezero depression.

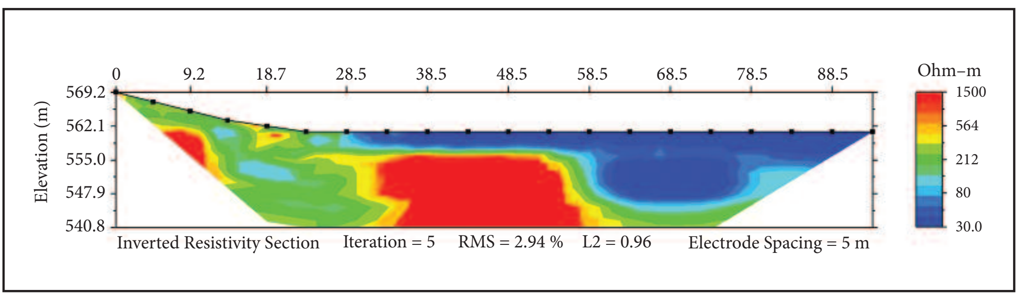

Figure 11: ERT profile of Bačko Jezero.

ERT profile of Veliko Zagorsko Jezero was measured from western slopes at an elevation of ~556 m towards the central part of the flattened floor (azimuth of profile: 115 degrees). Three iterations were made to achieve RMS of 3.79%. Inverted resistivity of the slope (electrodes 1–6) exceed 500 ohm-m, which means that the slope is built of carbonate bedrock. At the depth of around 10 m (elevation 545 m) is a zone with resistivity below 80 ohm-m, indicating cavernous spaces filled with loamy sediment. Below the possible sediment-filled cavity, the resistivity values reach up to 1,500 ohm-m, which means that the underlying layer consists of carbonate bedrock. The floor of the depression is filled with loamy sediment with resistivity between 30 and 80 ohm-m. The measured depth of the sediment exceeds 20 m in the central part of the profile.

The depression Udor is positioned ~500 m east of Veliko Zagorsko Jezero. It is almost circular in ground plan. Its floor is levelled by flood loam at an altitude of 559 m asl. The width of the floor is ~70 m and the length is ~100 m. Within the central part of the floor two suffusion dolines are formed. Levelled floor sharply transits into surrounding slopes that are active (Stepišnik and Kosec 2011). Parts of the north-eastern slopes are rocky walls with scree and collapse blocks below them. The intermittent lake within this depression is not mentioned in the literature, however the local inhabitants report occurrence of occasional inundations.

ERT profile of Udor was measured from the north-western slope, starting at 570 m asl crossing the entire floor with its final part at the foot of the south-east slope (azimuth of profile: 130 degrees). Eight iterations were made to achieve RMS of 3.40%. The north-west slopes show relatively low inverted resistivity values, which only exceed 200 ohm-m a few metres below the surface. Only the upper parts of the slopes are covered with carbonate rock debris, which is underlain by loamy sediments. The floor of Udor depression is filled with loamy sediments with resistivity below 50 ohm-m. The measured depth of the sediment exceeds 20 m in the south-east part of the floor.

Bačko Jezero is the most south-eastern depression of the Upper Pivka karst plain and is positioned about one kilometre south of Udor. Its ground plan is irregularly shaped, it is elongated in the south-west – north-east direction. Flood loam is levelling the floor at an elevation of about 560 m. The levelled floor is ~270 m long and ~160 m wide. The floor's transit to the western and northern slopes is very gradual. These slopes are fully balanced (Stepišnik and Kosec 2011). Regular inundation of this depression extends to an altitude of 562 m. At extremely high levels of karst waters, the elevation of the floods reaches up to ~568 m (Kovačič and Habič 2005).

ERT profile of depression Bačko Jezero was measured from its east slope (elevation of about 750 m) towards the central part of the flattened floor (azimuth of profile: 270 degrees). Five iterations were made to achieve RMS of 2.94%. The inverted resistivity of the east slope are between 200 and 500 ohm-m, with sections of higher resistivity values (500–1500 ohm-m) at a depth of 1 to 10 m. Resistivity values of the slopes may be interpreted as a result of weathered carbonate rock. The floor of the depression consists of two morphologically different sections. The first one (electordes 7–13) shows low resistivity values of the upper 5 m (30 to 50 ohm-m), underlain by a section that has resistivity values up to 1500 ohm-m. According to the measurements, this part of the floor consists of 5 m of loamy sediments, deposited over carbonate bedrock. The central part of the depression (electrodes 13–20) exhibits 16m of thick loamy sediments with low resistivity values ~50 ohm-m, underlain by sediments with resistivity up to 200 ohm-m reaching depth of over 20 m.

5 Discussion

The area of Karstic Ljubljanica River catchment is one of the most diverse areas of the Dinaric Karst (Gospodarič and Habič 1976; Gams 2003; Mihevc 2010; Ferk 2016). The uppermost of its drainage basin represents the region of Upper Pivka, which is well-known for its shallow karst and a number of intermittent lakes (Habič 1975; Habič 2005; Mulec, Mihevc and Pipan 2005). Our survey was focused on systematic geomorphologic analysis and morphogenetic interpretation of those depressions which have floors in water table oscillation levels by means of morphographic and sediment analyses and non-invasive geophysical examination.

Our analyses show that the region of Upper Pivka is hosting several different mophogenetic types of large karst depressions. Previously, the authors described them simply as depressions that are regularly inundated, (Pleničar 1959; Habič 1975; Kranjc 1985; Habič 1985–1986; Habič 1989; Gams 2003; Ravbar and Šebela 2004; Habič 2005; Kovačič and Habič 2005; Kovačič 2006) disregarding their morphogenesis. Although morphogenetic interpretation is of uttermost importance for the interpretation of nature, for understanding the functioning of the entire hydrological system and for the protection of nature, it has not been interpreted so far.

Throughout our systematic morphographic survey of selected features, we identified equifinality within all intermittent karst depressions of Upper Pivka. It means that even though they exhibit similar morphology they differ in their morphogenesis. We established that large karst depressions of Upper Pivka can be divided into two distinct morphogenetic types. The first type of depressions are areas of lowered relief in-between surrounding conical hills. The second type are closed depressions which are circular in a ground-plan and surrounded by levelled karst surface.

The first type of depressions is typical for the area where the corrosion plain is dissected by conical hills in the northern section of Upper Pivka. Those topographic hollows are not circular in ground-plan, but they are diverging in-between conical hills and are star-shaped. Topography and orientation of those depressions are largely affected by local geologic structure. Their slopes are covered by karren and balanced (Stepišnik and Kosec 2011; Godard et al. 2016) while floors are covered by thicker layer of regolith. Floors that are periodically inundated are partially levelled by fine grained loamy deposits. Thickness of deposits reaches up to 5 m, but generally it is shallower. From the morphographic perspective they are comparable to karst hollows of tropical karst that are termed cockpits (Brook and Hanson 1991; Gams 2003; Day and Chenoweth 2004; Ford and Williams 2007). Yet they differ from cockpits in much gentler inclination of encircling slopes (Brook and Hanson 1991; Day and Chenoweth 2004). Additionally, cockpits are characteristic for karst of tropical climates and not for the humid temperate climatic zone of the study area.

The most appropriate term used for the first type of depressions would be uvalas. Cviji(1893) introduced uvalas into karstological literature, as a term describing karst depressions smaller than poljes and larger than dolines (Gams, Kunaver and Radinja 1973). Primarily their formation was explained as a result of merging of adjoining dolines (Cvijić 1893). Contemporary interpretation of the karst processes rejects its traditional use of the term and its morphogenetic interpretation (Ćalić 2011). The term uvala should apply solely to relief depression in-between conical hills. In a ground plan, these are circular relief forms that slightly extend in-between the gaps of surrounding conical hills. Their margins are not clearly recognisable in the relief. In a cross section, they are bowl-shaped with a flat bottom that regularly hosts dolines. Their dimensions differ as they depend on spatial distribution of sourrounding conical hills. Uvalas are formed by accelerated vertical denudation along tectonically deformed zones (Čar 1982; Ćalić 2011). Therefore, we can define the first type of depressions as periodically inundated uvalas.

The second type of depressions is typical for the central part of the corrosion plain that is almost completely levelled and not dissected by conical hills. These depressions are circular in ground-plan; most of them are lengthened in various directions. Most of the hollows have well expressed boundaries between slopes and surrounding karst plain. Their slopes are regularly steep, rocky and active (Stepišnik and Kosec 2011; Godard et al. 2016). Scree and boulders regularly cover lower sections of these slopes. Floors of those depressions are completely filled and levelled by fine-grained deposits. The latter indicate inundation phases and consequent deposition of suspended material from stagnant water bodies. The measured depths of fine-deposit fills exceed10 metres. Therefore, these hollows cannot be perceived as bowl-shaped features like uvalas from the northern section of the Upper Pivka. Additionally, we can deduce, that they were not formed by a process of lateral corrosion at watertable level as indicated in previous literature (Mulec, Mihevc and Pipan 2005).

According to their morphographic and morphometric characteristics, and according to the sediment bodies within their floors we can conclude that they are collapse dolines in a morphogenetic perspective.

The term collapse doline is applied for all landforms whose genesis is related to the removal of material due to specific geological structures and hydrological processes in the subsurface. Due to the gradual material removal in the underground, a depression termed collapse doline is formed on the surface (Stepišnik 2010). The size of those depressions depends on the dynamics and duration of the subsurface material removal processes. The shape of the collapse dolines depends on many factors, especially on their age and on the dynamics of the removal processes. Their floors are filled with large collapse blocks and scree. Over time, the rocky walls disappear, and the proportion of scree increases. At the last stage of development, all slopes of the collapses are gentle and balanced (Stepišnik and Kosec 2011; Godard et al. 2016), and floors are concave and covered by sediment (Stepišnik 2010). Collapse dolines in the hinterland of major karst ponors or springs where occasional inundation at the local watertable level within their floors takes place, have the same topography and shape of sediment bodies as those hollows in the region of Upper Pivka (Waltham, Bell and Culshaw 2005; Stepišnik 2006; Stepišnik 2008; Stepišnik 2010; Stepišnik 2011; Lipar, Stepišnik and Ferk 2019).

6 Conclusion

The Upper Pivka is part of the Karst Ljubljanica River catchment. This is one of the northernmost parts of the Dinaric Karst. Complex hydrological system is accompanied by a series of various karst phenomena, making this area known as an outstanding example of geomorphological and hydrological diversity of karst.

The study area of Upper Pivka is built predominantly of carbonates with watertable level oscillating close to the surface. High watertable levels are controlled by a hydraulic barrier of flysch bedrock on the western outskirts of the area and by the elevation of surface runoff of the Pivka River towards the north. A number of depressions within the karst plain of the Upper Pivka are being inundated at high water levels. Our morphogenetic interpretations of the intermittent depressions of Upper Pivka reject the preliminary characterisingthat they were created as swallow holes in a former polje (Habič 1975), or that they were formed by lateral corrosion during temporary inundations (Habič 1985–1986; Mulec, Mihevc and Pipan 2005). We established trough morphographic mapping, sediment analysis and electrical resistivity tomography that there are at least two different morphogenetic types of depressions formed in the Upper Pivka. The first type are depressions positioned in-between conical hills within the northern section of the study area. They are irregular in shape, with gentle and balanced slopes and with thin sediment cover within their floors. We morphogenetically interpreted them as periodically inundated uvalas. The second type are depressions positioned within the karst plain in the southern section of the study area. They are circular to semi-circular in ground plan with steep and regularly rocky slopes. Flood loam deposits within their floors can reach thickness of several tens of metres. According to their morphographic and morphometric characteristics, and according to the sediment bodies within their floors we can conclude that they are collapse dolines in a morphogenetic perspective.

New insights into the geomorphological development of the Upper Pivka periodically inundated depressions will enable a better understanding of the past and present processes of the wider area. At the same time, the new morphogenetic interpretation may be taken into account in nature protection measures and in the interpretation of the abiotic natural heritage of the protected area, which has not been properly emphasised so far.

7 References

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