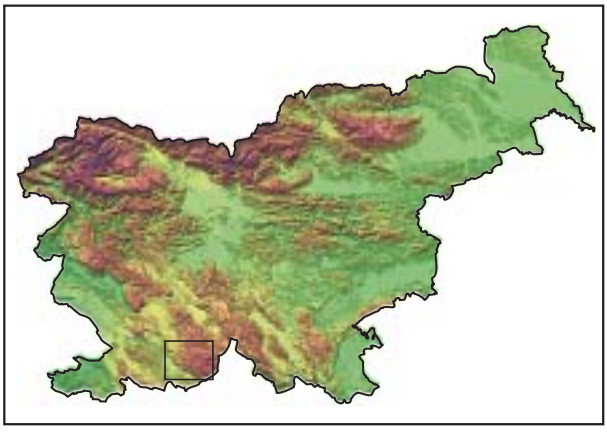
Acta geographica Slovenica, 46-1, 2006, 33–55

RELIEF EVOLUTION IN THE HINTERLAND OF THE PIVKA RIVER

RAZVOJ POVRŠJA V POVIRJU PIVKE

Gregor Kovačič

A view across the Petelinsko jezero in the Upper Pivka region (photograph: Marjan Garbajs).
Pogled prek Petelinskega jezera v Zgornji Pivki (fotografija: Marjan Garbajs).



Relief evolution in the hinterland of the Pivka river

UDC: 911.2:551.4(497.4)
COBISS: 1.01

ABSTRACT: The article discusses relief evolution in the catchment area of the highest situated permanent spring of the Pivka river – the Pivšce karst spring near the village Zagorje. The discussed landscape, which lies on the southernmost edge of the Upper Pivka valley, shows several geomorphological particularities, which are the result of different geomorphogenetic processes in the past. The basic characteristics of the present relief were shaped in the Pliocene when also the original valley of the Pivka river was formed. The region was more profoundly transformed by Pleistocene processes, which strongly altered the surface. Apart from karstic relief forms, there are several small dry stream channels on the land surface, which were carved by torrents. The two most distinctive relief features are the karst polje situated between the villages Koritnice, Bač and Knežak, which is covered with rubble and gravel-like clastic sediments, and the dry valley of the former Pivka river lying southwest from Koritnice.

KEY WORDS: geomorphology, relief, karst, Pleistocene, Pivka, Knežak, Snežnik, Slovenia.

The article was submitted for publication on March 24, 2006.

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Contents

1 Introduction

The Pivka basin is a large depression surrounded by the high karst plateaus Nanos, Hrušica, Javorniki, Snežnik and Slavenski ravnik and the flysch basin of the Reka river. The southern part – the Upper Pivka valley – is a depression, about 16 km long and 4–5 km wide, which stretches upstream from the settlement Prestranek and is mainly composed of Cretaceous limestone (Mulec et al. 2005). The landscape is given its character by the Pivka river with its unstable course. Due to the presence of the fine-grained river alluvia which cover the riverbed of the Pivka and the bottoms of larger karst depressions, and given the fact that the rocks are, in some places, less permeable and underground flowing is relatively poor, the prevailing karst relief is, in some places, combined with the elements of fluvial relief. This is reflected in the many intermittent karst lakes, the unstable course of the Pivka and nearby flooding.

The Pivka rises from the Pivšca karst spring (555 m) near the village Zagorje. The catchment area of this highest situated permanent spring of the Pivka covers the southernmost part of the Upper Pivka valley, which, towards the south and east, continues into the deeply karstified plateau Snežnik, which forms the watershed between the Adriatic (the karst springs Podstenjšek and Bistrica) and Black (the Pivka river) Seas. To the west, the upper part of the basin of the Pivka is bounded by the Taborski hrbet ridge (Gora), which forms a geological and relief boundary between limestone regions and the flysch regions of Brkini and the Reka valley.

The upper part of the basin of the abovementioned spring abounds with special geomorphological features, as some elements of fluvial relief are also present in the area with prevailing karst relief, especially in those parts where flat land converges into the slopes of the Snežnik plateau. These elements are the result either of a different bedrock (a flysch tectonic window near Knežak) or different geomorphogenetic processes in the past, especially in the Pleistocene, which have left traces in the surface stream of the former Pivka and other torrents. Today, this is evidenced by dry valleys and many fossil ravines. With the exception of the mainly flat, rubble and gravel-covered karst polje situated between the villages Koritnice, Knežak and Bač, karst relief with dolines of different shapes and sizes prevails. Most of these dolines are shallow and have inconspicuous edges, which gradually continue into somewhat higher and flatter land. In some places there are conical-shaped hills.

Figure 1: The karst polje between Koritnice, Knežak and Bač. View from the slope above Koritnice to the west (photograph: Gregor Kovačič, 1. 3. 2000).

There is no recent literature regarding relief evolution in the discussed area; therefore, the article is based on a critical review of existing investigations, which, however, are not supported by the latest geomorphological methods and knowledge about the karst relief evolution. The author has conducted detailed field mapping of the area, giving most emphasis to the study of the processes of relief transformation in the Pleistocene. He has undertaken to integrate field observations and results into the theories of relief evolution in the discussed area. These theories still need to be confirmed by other geomorphological methods, possibly through examination of sediments.

2 Geological setting

Medium to well permeable Upper Cretaceous limestones prevail in the region (Figure 2). The dry valley above Koritnice and the upper parts of its margins are composed of dolomite-limestone breccia, which is somewhat more resistant to weathering. In the valley and its surroundings also grained dolomite can be found, which weathers very fast. The presence of well tectonically crushed dolomite (the valley is developed along the Selce fault) probably contributed to the faster deepening of the former Pivka river dry valley above Koritnice, especially in the Pleistocene, when strong mechanical weathering was taking place (Šikić et al. 1972; Šikić and Pleničar 1975; Krivic et al. 1983).

The Taborski hrbet ridge is built mostly of Upper Cretaceous light crystalline limestone, as well as of less permeable Paleogene dark limestone, and somewhere marly limestone characterized by karstic and karst-fissured porosity can be found. In the tectonic window near Knežak, Eocene flysch rocks outcrop to the surface (Pleničar 1959). In the tectonic sense, the flysch rocks are a fraction of the recumbent fold of the Komen thrust sheet, which lies underneath the overthrust of the Snežnik thrust sheet, built mostly of Upper Cretaceous limestone (Placer 1981). The flysch barrier in the base of this area prevents karst water from flowing away underground from the discussed region towards the Reka river and directs the ground waters into the Pivka river basin. The Podstenjšek karst spring is an exception. The presence of underlying flysch rocks, which outcrop in the tectonic windows near Knežak and Zagorje and whose existence is additionally evidenced by a well near Zagorje situated only 2300 m from the thrust edge, at a depth of 100 m, is probably the reason for the formation of a shallow karst aquifer, which enables the rise of karst groundwater to the surface during high waters.

Flysch rocks near Knežak cover an area of 0.2 km^2 and are an exception in the discussed area. The flysch surface is altered by several small streams, which have short channels. Some of the streams are even captured for local drinking water supply. At the foothill, the streams converge into an uplifted artificial ditch, which is inundated only in rainy season. At the end of the ditch, the stream sinks into the ponor Kneške ponikve, where underground water connection with the intermittent Videmščica karst spring near Zagorje has been proved (Habič 1975).

The karst depression between Koritnice, Bač and Knežak is covered with unconsolidated rubble and gravel clastic sediments, which in some places exceed 10 m of depth. In the Pleistocene, the material was accumulated by the former Pivka river in an alluvial fan at the exit of its source valley. According to its morphology, the abovementioned karst depression can be classified as a karst polje since it has the main characteristics of karst poljes as defined in Slovenian karst terminology) (Gams 1973), less distinctive being only its shape. In addition, Quaternary sediments cover the bottoms of other larger karst depressions.

Beside the abovementioned well-defined thrusting deformation of the Snežnik thrust sheet over the Komen thrust sheet, the discussed area is dissected also by several other, less distinctive faults. The source valley of the former Pivka river is formed along the Selce fault. Southwest from the lake Šembijsko jezero is the Šembije fault. Frequent earthquakes that occur along the faults at a depth from 7–17 km (Vidrih et al. 1996; Cecić et al. 1999) confirm that the area is tectonically still very active.

3 Relief evolution in the Pliocene

The elongated Pivka basin was predominately shaped by the erosional activity of the Pliocene Pivka river, which formed a 3–4 km wide valley extending from the village Koritnice towards the town Postojna (Melik 1951; 1955). In the east, it is surrounded by the Javorniki plateau (1268 m asl), whereas its upper part lies on the slopes of the Snežnik plateau (1796 m asl). The western side of the basin is bounded by the

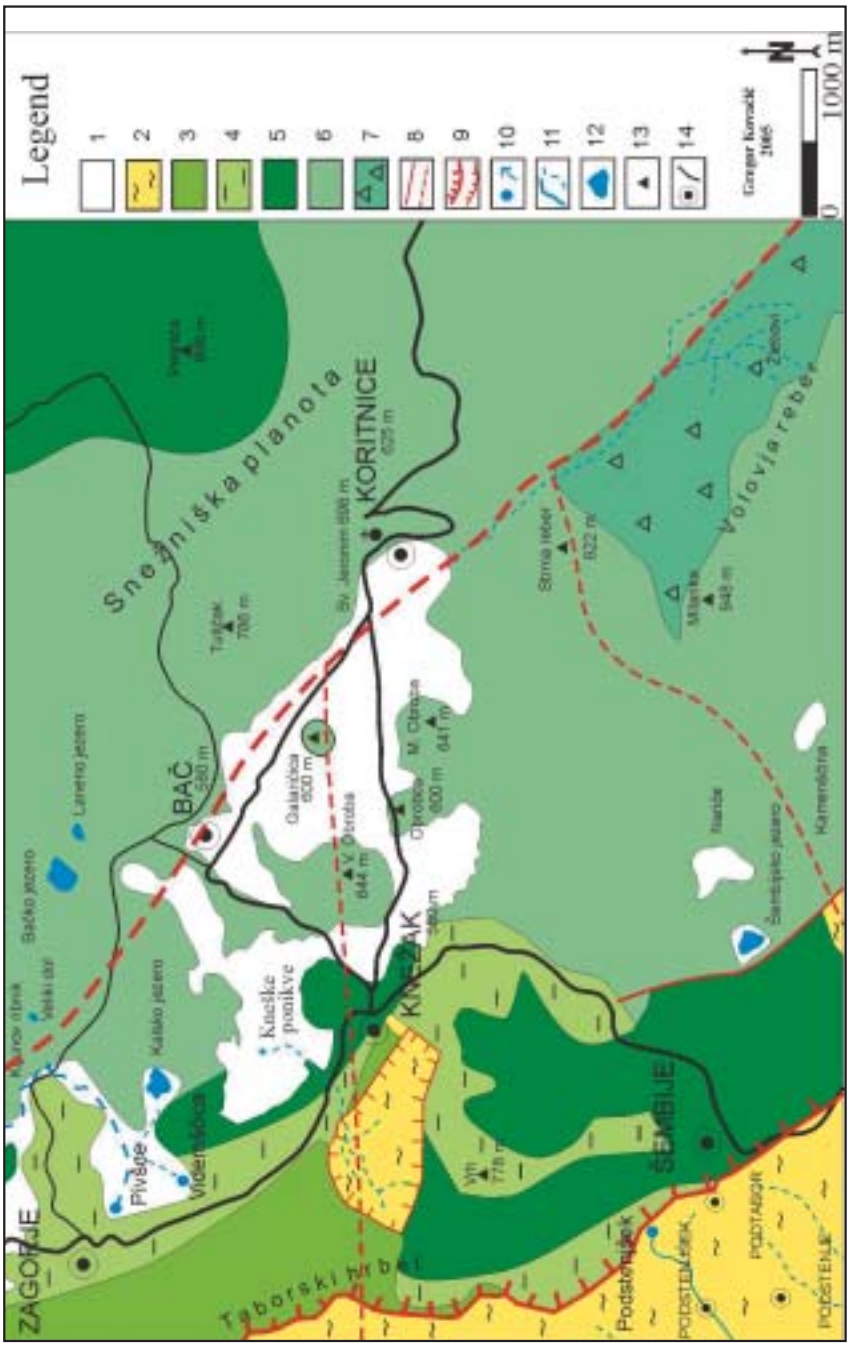

Figure 2: Geological setting of the southern part of Upper Pivka, compiled by the author (after Pleničar 1959; Šikić et al. 1972; Placer 1981; Krivic et al. 1983; Ravbar and Šebela 2004). Legend: 1 – alluvium (Quaternary); 2 – flysch (Eocene); 3 – brown and dark grey limestones (Paleogene); 4 – dark and marly limestones (Paleogene); 5 – light grey and white crystalline limestones (Upper Cretaceous); 6 – light limestones (Upper Cretaceous); 7 – dolomite-limestone breccia (Upper Cretaceous); 8 – established and covered fault; 9 – stronger and weaker thrust fault; 10 – karst spring, ponor; 11 – permanent, periodical water flow; 12 – karst periodical lake; 13 – hill with indication of elevation (above sea level); 14 – settlement, road.

Volovja reber ridge with the peak of Velika Milanja (1099 m asl), which is part of the Snežnik plateau, and by the Taborski hrbet ridge stretching between the settlement Šembije and the hill Primož (718 m asl) above the settlement Pivka. According to Melik, this is a long normal valley of the Pliocene Pivka, which once ran from the upper part of the basin situated in the elevated Snežnik plateau underneath the peaks of Velika Milanja and Devin (1028 m asl) towards Postojnska vrata (the Postojna Gap) and onwards to the basin of the Ljubljanica river. This is evidenced by a terrace stretching eastwards from the settlements Pivka, Zagorje and Knežak, and featuring wide, levelled ridges and smaller round-shaped peaks lying at an elevation of between 610 and 630 m. Today, the surface stream of the Pivka is preserved only in the lowest parts of Upper Pivka.

The orographic watershed between the Pivka river basin and the Reka river basin in the south is about the same age. It is well expressed with a relief barrier extending from the hill Osojnica across the Taborski hrbet ridge and onwards across the lower surface around Šembijsko jezero towards the Volovja reber ridge. In the carbonate bedrock, karstic runoff has developed, with groundwater running towards the basins of the Adriatic and Black Seas (Habič 1968).

On the southern side of Volovja reber is a dry hanging valley, created by a onetime stream, which probably flowed into the Reka river basin during the Pliocene. Since it was less subjected to erosion in the past, and, on the other hand, also strongly modified by recent karstification, the discussed valley is, compared with the dry valley above Koritnice, less markedly incised into the surrounding surface. According to the morphology of the area, it can be presumed that the former tributary of the Reka joined its basin (flysch bedrock) somewhere in the area called Žlebovi lying to the north of Ilirska Bistrica. Žlebovi is an erosional gap in the thrust edge, where the flysch bedrock indents for about 700 m inwards into the limestone bedrock of the Snežnik plateau. Similar limestone erosional gaps can be observed along the entire thrust edge, however the discussed one is the most evident one. It was formed by the faster erosional lowering of flysch rocks, which caused headward erosion and the prolongation of the valley into the limestone on the flysch-limestone joint. Later, the surface runoff was interrupted and groundwater circulation developed.

Similar dry and hanging valleys are also found in other parts of Upper Pivka, showing the existence of Pliocene surface streams flowing into the Pivka river valley. Vlačno and the valley between Jurišče and Palčje are the most obvious (Habič 1968).

The formation of surface drainage on carbonate rocks was possible due to the impermeable layers of Tertiary rocks, which, in the Pliocene, on all sides bounded limestones, which, as a result, lied in a lower position and were blocked (Radinja 1972). Such conditions hindered the process of vertical corrosion. Therefore, groundwater circulation did not develop.

The Pliocene fluvial phase was followed by the karstification period in the conditions of subtropical and tropical climate (Melik 1951; Habič 1968). This can be deduced from the preserved land features and the processes which are nowadays in progress in tropical karst areas in the world (Radinja 1972). The erosional activity of the Pivka, its tributaries and the tributaries of the Reka, which developed a regular surface drainage pattern in the discussed area, was replaced by the corrosion activity of aggressive precipitation

Figure 3: The source valley of the Pliocene Pivka river has been modified by torrents in the Pleistocene. View from the Volovja reber ridge to the east (photograph: Gregor Kovačič, 1. 3. 2000).

water, which exhausted its strength soon after it had started to flow underground. A series of hanging terraces on different elevations on the western side of the Javorniki indicates the multi-stage lowering of the surface as well as the deepening of the Pivka valley (Habič 1968). The older, higher terrace of the Pivka river lying at elevations of 600–650 m was intensively transformed by karst processes, which is evidenced by a somewhat dissected surface where several dolines have developed.

The former valley on the southern side of Volovja reber also transformed into a hanging valley, which is now situated 100 m above the depression of Šembijsko jezero. This former valley was transformed by subsequent karstification. Therefore, many dolines are present mainly at the bottom of the valley, while, due to inclination, fewer of them are found on the slopes. The latter are usually also of less regular shapes.

In contrast with the other valleys in Upper Pivka, the source valley of the Pliocene Pivka above Koritnice is opened towards the karst polje between Koritnice, Bač and Knežak. It seems that its evolution and deepening have not been interrupted.

As was probably the case with the other fossil valleys, the discussed one was also hanged above the lower surface in the first phase of karstification. However, due to the intensive erosional activity of Pleistocene torrents, it was re-deepened to the level of the already mentioned karst polje, and the load of the torrents accumulated in the form of an alluvial fan at the end of the valley. The former bottom of the source valley of the Pliocene Pivka could be the pass (750 m asl) on the western side of the conical peak Strma reber (822 m asl). Following this explanation, the ending part of the valley on the eastern part of the abovementioned peak would only be the result of very intensive erosional deepening during the Pleistocene.

One of the most probable explanations is that, through the entire Pliocene period, the surface flow of the Pivka was preserved at the bottom of Upper Pivka. Subsequent karstification lead to the formation of a system of karst springs in the area around Koritnice, which hindered the fossilification of the mountain valley above Koritnice. At that time, karst springs, which created a pocket valley called Raša and a less pronounced pocket valley under the church of St. Hieronymus (698 m asl), were active. The size of the Raša pocket valley shows that the valley must have been created by a water-abundant spring. The catchment area of the abovementioned springs was the higher positioned karstified part of the Snežnik plateau with already developed karst drainage. In such conditions, it was possible that there was a sinking river at the bottom of a more or less homogeneous karst polje, which probably extended from the springs near Koritnice to the ponors in the Postojnska jama cave, but there is no solid evidence to confirm this theory.

The bottom of the dry Raša valley is several metres wide and on the western side reaches up to 50 m. The spring lies at an elevation of 740 m. At the spring, the valley is deeply cut into the surrounding surface for about 20 m. Somewhat downstream, it is even deeper and wider. The valley is approximately 600 m long and its starts with a 10 m high wall. The erosional power of the former flow must have been considerable, since it formed such a remarkable relief feature in the relatively undissected surrounding surface. There is a lot of rubble on the slopes, collected in small screes. The edge of the valley is in some places bounded by 8 m high walls. Slightly above the ending wall of the Raša valley there is a 1 km long shallow and dry stream channel cut into the rocky bottom of the surface. Its creation is related to one of the previous karstification phases in the region, when several karst springs on different elevations were active in Upper Pivka. With the lowering of the water table, the karst spring in the Raša valley became active and created a deep valley, while the channel of the higher situated karst spring hanged above it and remained preserved until today. Habič (1968) also writes about pocket valleys on different elevations that were created along karst tributaries under the Snežnik and Javorniki plateau. Morphologically, the dry channel above the Raša valley is very similar to the shallow trough-shaped stream channels in the hinterland of Šembijsko jezero, which are of much younger origin. I do not exclude the possibility that the intensive deepening of the Raša valley also dates to the Pleistocene period.

Isolated hills (»humi«), which are situated within the karst polje between Koritnice, Bač and Knežak and on its margins, give evidence of the Pliocene karst phase. Viewed from above, the conical-shaped hills have the shape of a more or less regular circle. The hills gently rise above the surrounding levelled surface. Such hills are Velika Obroba (644 m asl), Mala Obroba (641 m asl) and the neighbouring hill situated at an elevation of 644 m. Their almost identical elevation testifies to their common origin. Well noticeable are also Galaričica and Obrobca (both 600 m asl). In the vicinity there are also some other isolated hills on higher elevations. The karstified base of the bottom of the karst polje between Koritnice, Bač and Knežak

has been confirmed by investigations conducted in wells (Krivic et al. 1983). Small karst caves filled with clay can be seen on different depths, while closer to the surface some of the conduits are also filled with limestone debris.

At the same time, the Pliocene karst surface of the Pivka basin was altered by erosion-denudation and corrosion morphogenetic processes with intensive corrosion planation. Both processes supplemented each other and led, on the one hand, to the development of dolines, which became increasingly deeper due to the lowering of gradient, and on the other hand, to the development of terraces on different elevations.

4 Relief evolution in the Pleistocene

In his study of Slovenian karst poljes, Melik (1955) established that, during the Pleistocene, the mechanical weathering and disintegration of carbonate rocks on the surface intensified due to very frequent fluctuation in air temperature around zero and intensive freezing, which occurred mainly on higher elevations. Therefore, a lot of rock debris accumulated on the surface, which was either denuded to lower positions by solifluction or washed away by running water. Due to the filling up of caves, shafts and ponors, surface drainage was re-established and the dry valleys became active again. Among the factors contributing to the interruption of the karstification process was also the frozen ground, whereas, due to the impoverished soil and vegetation coverage, corrosion mainly took place in fractures.

In periglacial regions (the discussed area), chemical weathering was therefore rather weak, which, geomorphologically speaking, means a weakening of the karstification process. The predomination of mechanical weathering, solifluction and denudation led to the filling up of existing swallow holes. A clear example is the karst polje Grobničko polje above the city of Rijeka in Croatia, where Pleistocene torrents incised some deep and narrow gorges and thickly filled the karst polje with debris. Moreover, the structure of accumulated material suggests that the karst polje was subject to periodical inundation (Šikić and Pleničar 1975).

There is a similar assumption, according to which there was a Pleistocene lake lying between Koritnice, Bač and Knežak (Cumin 1929; Melik 1955) and extending in two branches from Koritnice to Knežak and Bač, but no solid evidence is available to confirm this. The presence of fine-grained lake sediments has not been proven by wells (Krivic at al. 1983). Therefore, it is difficult to speak about a long lasting inundation of the karst polje. On the other hand, we cannot exclude the possibility of periodical inundations in the Pleistocene, similar to the present-day flooding of karst poljes, during which the debris fills up the narrower parts of swallow holes, disabling them to swallow all the incoming water and other load. During the raining period, the karst polje between Koritnice, Bač and Knežak is in its lowest parts regularly inundated, while during extremely high waters extensive flooding of short duration occurs, causing flood damage (Kovačič 2005).

A slightly different explanation of morphogenesis in the Pleistocene is offered by Radinja (1972), who argues that climate changes caused the selective lowering of different types of rock, which changed hypsographic relations between them and led to the creation of gradient and deep karst circulation, which, due to the bandage of impermeable rocks around carbonates, had not been able to develop during the previous period. Therefore, corrosion dynamics transformed from Pliocene surface and planation corrosion into deep (point-like) karstification, as aggressive water, with the climate being colder and the vegetation and soil coverage poorer, lost its power of dissolving not until much further on its path. According to Radinja (1972), the predominant morphogenetic processes are point-like karstification and erosion, the effects of the latter being more pronounced on the surface of the discussed area.

4.1 Effects of Pleistocene geomorphogenesis on the present relief structure

Pleistocene geomorphic processes have left many traces in the discussed area. In the area above Koritnice, well noticeable traces of very intensive erosional activity of the Pivka, which sprang under the peaks Devin and Velika Milanja, are present. At the exit from the mountain valley, the river accumulated a huge alluvial fan, composed of rubble and gravel-like debris. The fan is inclined from Koritnice (625 m asl) towards Bač (580 m asl) and Knežak (580 m asl). The material was transported from the nearby slopes, where strong mechanical weathering and solifluction took place in periglacial conditions. By its structure, the debris

is more similar to rubble than it is to gravel, which proves that it was transported only for a short period and on a short distance. In order to make farming easier, local farmers arranged some terraces on the more inclined slopes of the alluvial fan near Koritnice.

The highest situated springs of the former Pivka river are those in the Žlebovi area (950 m asl), situated directly at the foot of the Volovja reber ridge. On a very steep slope with an inclination of more than 22°, torrents created several deep and steep gullies.

At Žlebovi, gullies are abundant and they are generally orientated towards the northwest, with the exception of the gullies under Velika Milanja. In their upper part, they are orientated towards the north, but as soon as they reach the lower parts of the valley they turn towards the northwest. Žlebovi is the left and upper source branch of the Pleistocene Pivka river. From the right, the other branch of the Pivka runs in a 1 km long channel. The spring of this branch lies at an elevation of 740 m. Here, the Pivka created a 10 m high pocket valley, which is separated from the surrounding surface. Above the ending wall of this pocket valley, there are several gullies, which are most noticeable under Devin, where, according to our assumptions, there were the highest positioned springs of the right branch of the Pleistocene Pivka. Under Devin, the surface is not as strongly dissected as it is in the Žlebovi area. In the Pleistocene, torrents under Devin most probably also sprang at an elevation of 950 m.

At the convergence of both branches, approximately 1 km before the hill Strma reber (822 m asl), the channel of the Pleistocene Pivka becomes somewhat wider. Since the gradient decreases, some accumulation of unconsolidated rubble-like material mixed with soil can be observed in the area. In the Holocene, running water formed some very small and narrow, 0.5 m deep channels in these deposits. The latter are probably a result of one of the last phases of Pleistocene accumulation. Where these sediments are not denuded, their depth can exceed several metres.

At the foothill of Strma reber, the channel of the former Pivka river is 1.5 m deep and more than 3 m wide. It is developed in unconsolidated material. An interesting shape of the Pivka riverbed can be observed shortly ahead of Koritnice. In this 350 m long section of its path, the Pivka river incised a narrow, 4 m deep channel (chut), which has given the name to the nearby settlement of Koritnice (»korito« = »chut«).

Figure 4: The dry riverbed of the former Pivka river northwest from Koritnice (photograph: Gregor Kovačič, 7. 10. 2005).

Further from Koritnice towards the northwest, the Pivka riverbed gradually becomes shallower and, only after a few hundred metres, disappears. The position of fossil riverbeds indicates that the Pivka has changed its course several times. Dry riverbeds can be observed along the road leading from Koritnice to Bač and Knežak. Especially well developed is a dry riverbed at the foothill of Tuščak (786 m asl) on the right side of the Koritnice–Bač road (Figure 4), where some interesting meanders can be observed. Its bottom is 2 m deeper than the surface of the alluvial fan above it. This confirms the assumption that the majority of accumulation ended in the Pleistocene and that in the Holocene some weak incision activity took place. During the extreme precipitation events of November 2000, the abovementioned dry riverbed was filled up with water in its lower part and a surface stream appeared, which flooded the settlement Bač (Kovačič 2005).

The Pleistocene Pivka was, measured from the springs at Žlebovi to the dry riverbeds under Tuščak, more than 4 km long. On this relatively short course, its gradient was relatively steep. A steeper gradient means more erosional power as well as easier and faster transportation of the mechanically weathered and disintegrated material, which formed an alluvial fan at Koritnice. The thickness of the accumulated material, which in spots exceeds 10 m, is therefore not surprising.

The structure of the material can be examined on several spots in the abovementioned dry riverbed below Tuščak and in some of the excavations alongside the Koritnice–Bač road. In this dry riverbed, the 2 m deep profile is composed of material of different sizes. In the uppermost part of the profile, there is a 20 cm thick layer of dark soil mixed with gravel. The size of individual fragments differs, however, those with a diameter of 1–6 cm prevail, and some of them reach the size of 25 cm. The material is not well rounded and resembles more rubble than gravel. There is also some sand in it. With the exception of the upper part of the profile, where some thin layers of sorted material can be observed, the fragments are usually irregularly spread in the mixture of fragments of different sizes, which proves the torrent character of the Pleistocene Pivka river.

Figure 5: Structure of the alluvial cover in the karst polje between Koritnice, Knežak and Bač in the excavation alongside the Koritnice–Bač road (photograph: Gregor Kovačič, 7. 6. 2006).

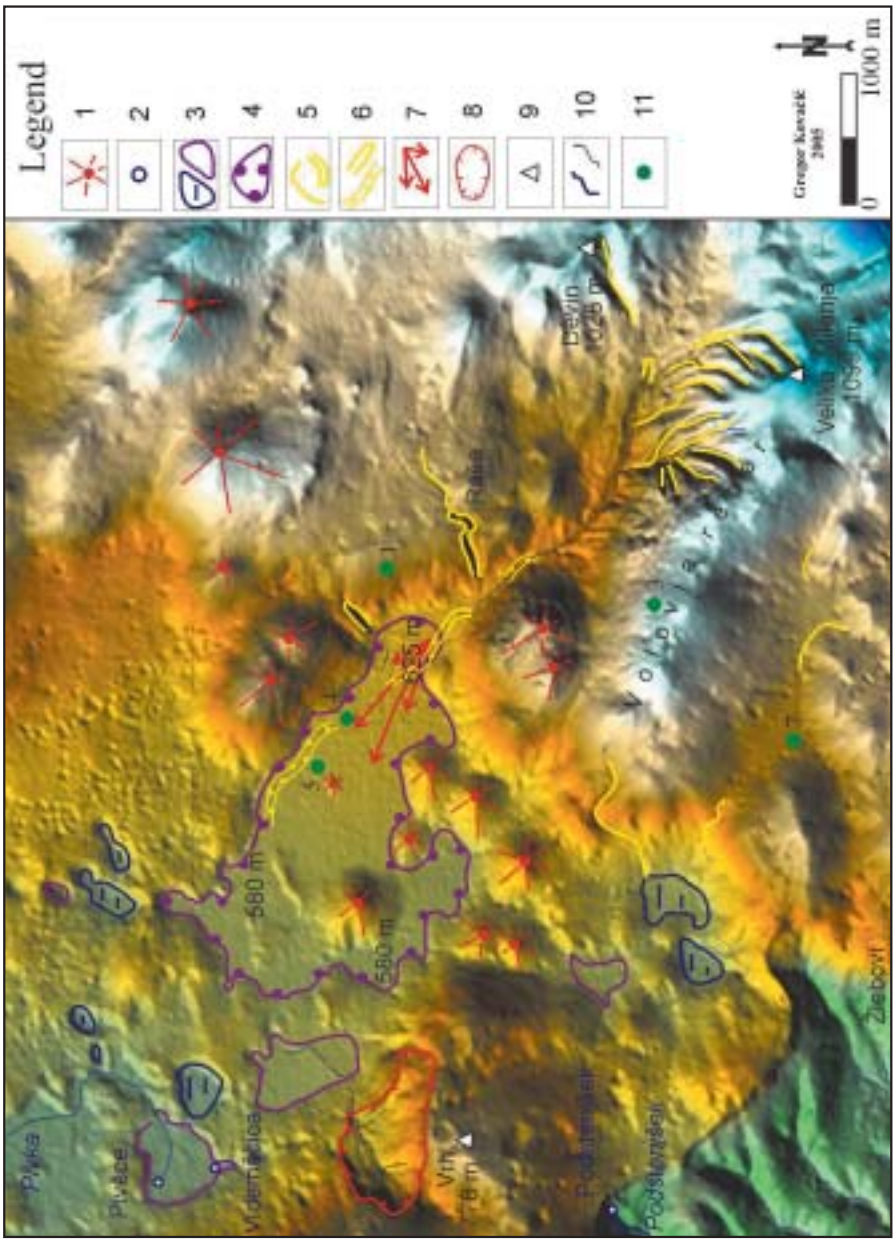

Figure 6: Geomorphological map of the discussed area, drawn on the basis of a digital elevation model (25×25 m). Legend: 1 – conical-shaped hill; 2 – karst spring; 3 – intermittent karst lake depression, bigger karst depression; 4 – karst polje; 5 – narrow, wider dry trough-shaped stream channel; 6 – dry stream channel formed in alluvium, pocket valley; 7 – directions of the Pleistocene Pivka accumulation; 8 – tectonic window; 9 – hill with indication of elevation (above sea level); 10 – surface flow (permanent or temporary); 11 – figure location.

In the excavation alongside the Koritnice–Bač road (Figure 5), situated about 700 m away from the first profile, the conditions are similar. Here, the size of individual fragments is slightly smaller; fragments with a diameter of less than 2 cm prevail. The biggest fragments do not exceed 16 cm in diameter. Also here, there is a lot of sand mixed among the fragments. A slightly more rounded are the smaller fragments.

The material is irregularly spread in the profile and there is no trace of stratification. At the bottom of this 2.5 m deep profile, the onetime surface of the karst polje is exposed to the surface, which is reflected in subcutaneous rocky relief features and the presence of red clay inside the pockets.

Traces of Pleistocene activity can also be found in a hanging valley on the southern side of the Volovja reber ridge. At the end of the valley, on a flat area (Kamenščina) above the depression of Šembijsko jezero, material of different sizes is deposited. The material was accumulated by a Pleistocene stream, as well as by solifluction processes, which transported the weathered material from the slopes to the lower parts of the valley. Compared with the material in the karst polje between Koritnice, Bač and Knežak, the fragments at Kamenščina are much smaller.

The material structure can be studied on the basis of excavations in three dolines. In the examined profile (Figure 7), layers of various materials can be seen in one of the excavated dolines. Beneath a 25 cm thick layer of dark soil there is a 0.5 m thick layer of unconsolidated and irregularly spread rubble mixed with soil. Individual fragments in this layer do not exceed 2 cm in diameter. Beneath this layer, there is a 0.9 m thick layer of brown clay containing some isolated larger pieces of rubble, followed by a 0.8 m thick layer of well-calcified, fine-grained rubble, which is lithified into the breccia. In the breccia, some stratification of fragments of different sizes can be observed. Beneath the breccia layer, there is a layer of unconsolidated fine-grained rubble, which is stratified in thin layers. The thickness of this layer cannot be established, however, it is estimated that this figure is higher than 0.8 m. In the examined 4 m deep profile, the size of individual fragments in the breccia as well as in the layer of rubble beneath it does not exceed 5 cm in diameter, which indicates small transport capacity of surface flow in the valley in the past. The shape of the fragments indicates that the origin of the material is in the nearest hinterland. The rocky bottom of the doline is not noticeable, and there are no fragments of dripstone found in the material. The sediments in the other two excavations have a similar structure, however rocky basement is well noticeable at the bottom and margins of these two dolines filled up with earth and other material.

In the middle part of the valley, there is a small dry channel, 200 m long, which was created as a result of the erosion activity of a small surface stream, which was fed with water from melting snow below the Volovja reber ridge. The stream probably flowed onwards across the edge of the valley into the depression of Šembijsko jezero, where a small channel incised into the rock above it can be observed. The channel carried surface waters and fine-grained material to the bottom of the present depression of Šembijsko jezero and to a hollow depression called Nariče, which was also flooded during the extreme precipitation events of November 2000. A similar, but somewhat longer channel runs from the northwesternmost slopes of the Volovja reber ridge and is initially orientated towards the northwest. Afterwards, it turns to the west and ends at Nariče. The channel is very narrow and shallow and has a rocky bottom.

5 Conclusion

The study of present relief features in the discussed area has revealed that the fluvial relief features have been heavily transformed by the recent lowering of the surface due to the corrosion of precipitation water. Nevertheless, some elements of the erosional activity of surface running waters from previous periods in the hinterland of today's Pivka river karst spring are still well preserved. Moreover, these elements are the most recognizable ones in the discussed area.

The basic features of karst relief in the hinterland of the present Pivka river were developed in the period of warm and humid Pliocene climate.

The previously developed karst features were altered by Pleistocene processes. Due to increasing mechanical weathering of limestone, gradual slopes were formed and the surface became well dissected.

While the hanging valley on the southern side of the Volovja reber ridge was largely transformed by more recent karstification processes, the elements of fluvial relief are still predominant in the dry valley of the former Pivka river. This is evidence of the great erosional power of Pleistocene running waters, causing more intense deepening of this tectonically crushed area compared with the surrounding areas. Thus, most of the effects of Pleistocene morphogenetic activity are still noticeable and are prevailing on the surface. Therefore, several small dry gullies and trough-shaped stream channels are still preserved.

Rubble and gravel-like clastic debris, which had been transported by Pleistocene running waters from the foothills of Devin and Velika Milanja, thickly covered the depression of the karst polje between Korit-

nice, Bač and Knežak. It can be concluded from the structure of deposits and the presence of dry riverbeds that the majority of accumulation ended in the Pleistocene, while in the Holocene some weak incision activity took place. Except in the area of the abovementioned karst polje, deposits from the Pleistocene period and some of later origin can also be found in other depressions.

Today, dispersed point-orientated corrosion is a prevailing geomorphic process in the discussed region. In the upper parts of the Volovja reber ridge and in the Žlebovi area, the mechanical weathering of rocks is also strong, especially in the colder part of the year. Relief evolution in the region is, to a great extent, conditioned by the groundwater level. The water table in the karst polje between Koritnice, Bač and Knežak is usually 30–40 m below the surface and is inclined from Koritnice, where it reaches 560 m asl, towards Bač, where it reaches 540 m asl (Krivic et al. 1983). Hydrologically, the area under review is a bifurcation zone between the Adriatic and Black Seas. Groundwater flows away from the karst polje mainly towards the Pivka spring, whereas the depression of Šembijsko jezero and its catchment area belong to the Reka river basin, as the water table is inclined towards the Podstenjšek karst spring.

If we integrate the geomorphogenetic evolution of the discussed area into the broader context of relief evolution in the entire Pivka basin or at least in its upper part (Upper Pivka), the question of further gemorphogenetic development of this very interesting region arises. In their study of intermittent lakes in the Pivka basin as well as in their comparison between hydrological conditions in Upper Pivka and those in the Cerknica karst polje, Ravbar and Šebela (2004) establish that the Pivka basin is currently in the preliminary development phase of a »typical« karst polje, where karst depressions deepen to the level of karst groundwater, as is the case with the intermittent lakes of Upper Pivka.

However, another explanation is possible. According to the results of hydrogeological investigations, the groundwater gradient in the Javorniki area is orientated towards the Malni karst springs (Habič 1968). Strong, deep groundwater circulation towards the northeast is present, which has been proved by tracer

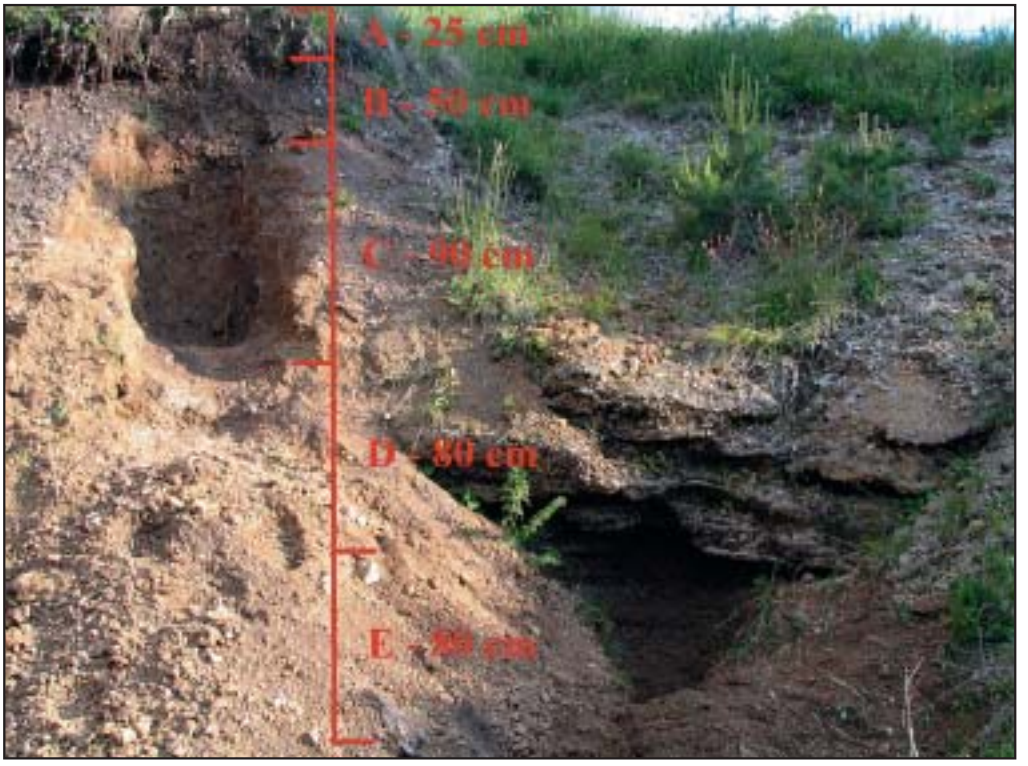

Figure 7: Profile through sediments in one of the excavated dolines situated at Kamenščina (photograph: Gregor Kovačič, 7. 6. 2006). Legend: A – soil; B – fine-grained rubble; C – clay; D – breccia; E – fine-grained rubble in layers.

experiments (Habič 1989). Considering these facts, we can assume that the deepening of karst depressions has not been interrupted and is still in progress. Today, the relief of the Pivka basin, with its many periodically inundated karst depressions and the unstable course of the Pivka river, can be characterized as a dissected karst polje. As an interesting detail, I would like to mention the structure of the karst depression of the lake Malo Drskovško jezero, which is reminiscent of a classical overflow karst polje, with the spring on one side and the ponor on the other.

The Pivka basin (Pivka, the Pivka karst polje) (Kranjc 1987) is one of the most spectacular and most interesting regions of the Slovenian classical karst. This article, based on critical review of literature and fieldwork, sets out to explain relief evolution in the southeasternmost part of the basin. The region has gone through different geomorphogenetic phases, with many different processes interchanging with one another. Today, the relief structure is predominantly characterized by the effects of Pleistocene processes.

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Razvoj površja v povirju Pivke

UDK: 911.2:551.4(497.4)
COBISS: 1.01

IZVLEČEK: Prispevek obravnava razvoj površja v povirnem zaledju najvišje ležečega stalnega izvira reke Pivke, kraškega izvira Pivšce pri Zagorju. Obravnavana pokrajina na skrajnem južnem robu Zgornje Pivke izkazuje številne geomorfološke posebnosti, ki so rezultat različnih geomorfogenetskih procesov v preteklosti. Osnovne poteze današnjega površja so bile začrtane v času pliocena, ko se je tudi izoblikovala prvotna dolina Pivke. Pokrajino so izraziteje preoblikovali pleistocenski procesi, ki so površju dali poseben pečat. Poleg kraških reliefnih oblik, so v reliefu prisotne številne manjše suhe struge nekdanjih hudourniških tokov. V površju izstopata kraško polje med Koritnicami, Knežakom in Bačem, ki je nasuto z gruščnato-prodnatim drobirjem ter suha dolina nekdanje Pivke jugovzhodno od Koritnic.

KLJUČNE BESEDE: geomorfologija, relief, kras, pleistocen, Pivka, Knežak, Snežnik, Slovenija.

Uredništvo je prejelo prispevek 24. marca 2006.

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Vsebina

1 Uvod

Pivška kotlina je velika depresija med visokimi kraškimi planotami Nanosom, Hrušico, Javorniki, Snežnikom, Slavenskim ravnikom ter flišnim povodjem reke Reke. Južni del, Zgornja Pivka, je okrog 16 km dolga in 4–5 km široka depresija, ki se razteza gorvodno od Prestranka in je izoblikovana pretežno v apnencih kredne starosti (Mulec in ostali 2005). Pokrajini daje pečat reka Pivka s svojim nestanovitnim tokom. Prevladujoče kraško površje se zaradi prisotnosti drobnozrnatih rečnih naplavin, ki prekrivajo dno struge Pivke in dna večjih kraških depresij, ter mestoma slabše prepustnih kamnin in omejenega podzemeljskega pretakanja, ponekod prepleta z elementi fluvialnega površja. To se odraža v številnih presihajočih kraških jezerih, nestalnem toku Pivke ter poplavah ob njej.

Pivka izvira v izviru Pivšce (555 m) pri Zagorju. Zaledje tega najvišje ležečega stalnega izvira Pivke obsega najjužnejši del Zgornje Pivke, ki proti jugu in vzhodu prehaja v globoko zakraselo planoto Snežnik, kjer poteka razvodnica med jadranskim (kraška izvira Podstenjšek in Bistrica) in črnomorskim (reka Pivka) povodjem. Proti zahodu povirje Pivke omejuje Taborski hrbet (Gora), ki predstavlja geološko in reliefno mejo s flišno pokrajino Brkinov in doline Reke.

Povirje omenjenega izvira se ponaša s številnimi geomorfološkimi posebnostmi, saj se na območju s prevladujočim kraškim značajem površja, zlasti na prehodih uravnanega sveta v vzpeti svet Snežniške planote, pojavljajo tudi elementi fluvialnega površja. Ti so bodisi rezultat drugačne kamninske podlage (flišno tektonsko okno pri Knežaku) bodisi delovanja različnih morfogenetskih procesov v preteklosti, zlasti v pleistocenu, ki so v pokrajini pustili sledove o površinskem toku nekdanje Pivke in drugih hudourniških vod. To dokazujejo današnje suhe doline ter številne fosilne grape. Z izjemo pretežno ravnega nasutega dna kraškega polja med Koritnicami, Bačem in Knežakom, prevladuje zakraselo površje z vrtačami raznih oblik in velikosti. Največ je plitvih vrtač z neizrazitimi robovi, ki v blagih pregibih prehajajo v nekoliko višji in bolj uravnan svet med njimi, ponekod so kopaste vzpetine.

Novejše literature o razvoju reliefa na omenjenem območju nimamo, zato članek temelji na kritičnem pregledu obstoječih raziskav, ki pa niso podprte z novejšimi geomorfološkimi metodami in znanjem o razvoju kraškega površja. Avtor je opravil podrobno terensko kartiranje območja, pri čemer je največji poudarek namenil preučitvi procesov preoblikovanja površja v pleistocenu. Terenska spoznanja in izsledke je skušal uokviriti v hipotezo o razvoju površja na omenjenem območju. Hipotezo bi bilo potrebno potrditi še z drugimi geomorfološkimi metodami, možnosti se nakazujejo zlasti pri preučevanju sedimentov.

Slika 1: Kraško polje med Koritnicami, Knežakom in Bačem. Pogled s pobočja nad Koritnicami proti zahodu (fotografija: Gregor Kovačič, 1. 3. 2000).
Glej angleški del prispevka.

2 Geološka sestava

Na območju prevladujejo srednje do dobro vodoprepustni apnenci zgornjekredne starosti (slika 2). Na območju suhe doline nad Koritnicami in na njenih vršnih robovih je apnenčasto-dolomitna breča, ki je nekoliko bolj odporna na preperevanje. V suhi dolini in v njeni okolici naletimo tudi na vložke zrnatega dolomita, ki hitro prepereva. Prisotnost tektonsko močno pretrtega dolomita, dolina je namreč izoblikovana ob Selškem prelomu, je najverjetneje prispevala k hitrejšemu poglabljanju suhe doline nekdanje Pivke nad Koritnicami, še posebej v pleistocenu, ko je potekalo močno mehanično preperevanje

Slika 2: Geološka sestava južnega dela Zgornje Pivke, sestavil avtor (po Pleničar 1959; Šikić in ostali 1972; Placer 1981; Krivic s sodelavci 1983; Ravbar in Šebela 2004. Legenda: 1 – aluvij (kvartar), 2 – fliš (eocen), 3 – rjavi in temnosivi apnenci (paleogen), 4 – temni in lapornati apnenci (paleogen), 5 – svetlosivi in beli prekristalizirani apnenci (zg. kreda), 6 – svetli apnenci (zg. kreda), 7 – dolomitno-apnena breča (zg. kreda), 8 – ugotovljen in prekrit prelom, 9 – močnejši in šibkejši nariv, 10 – kraški izvir, ponor, 11 – stalni, občasni tok vode, 12 – presihajoče jezero, 13 – vzpetina z nadmorsko višino, 14 – naselje, cesta.
Glej angleški del prispevka.

Taborski hrbet gradijo poleg svetlih prekristaliziranih apnencev zgornjekredne starosti še za vodo manj prepustni temni apnenci in ponekod lapornati apnenci paleogenske starosti s kraško in kraško-razpoklinsko poroznostjo. V tektonskem oknu pri Knežaku izdanja na površje fliš eocenske starosti (Pleničar 1959).

Flišne kamnine so v tektonskem pogledu del prevrnjene gube Komenske narivne grude, ki leži pod narivom Snežniške narivne grude, zgrajene pretežno iz zgornjekrednih apnencev (Placer 1981). Flišna zapora v podlagi narivnega območja preprečuje podzemni odtok kraške vode z obravnavanega območja proti Reki in usmerja podzemne vode v porečje Pivke. Izjema je kraški izvir Podstenjšek. Spodaj ležeče flišne kamnine, ki so razen v tektonskih oknih pri Knežaku in Zagorju dokazane tudi z vrtino pri Zagorju 2300 m od narivnega roba v globini 100 m (Krivic in ostali 1983), so najverjetneje vzrok za obstoj plitvega kraškega vodonosnika, kar omogoča ob visokih vodah dvig kraške podtalnice na površje.

Flišne kamnine pri Knežaku, ki izdanjajo na približno 0,2 km^2 površine, so posebnost obravnavanega območja, saj jih s svojimi kratkimi strugami preoblikujejo številni manjši potoki. Nekateri med njimi so celo zajeti za lokalno vodooskrbo. Studenci se ob vznožju pobočja združijo v izgonsko strugo manjšega potoka, ki teče izključno v deževnem obdobju. Potok ponika v Kneških ponikvah, od koder je bila dokazana podzemeljska zveza z občasnim kraškim izvirom Videmščica pri Zagorju (Habič 1975).

Kraško kotanjo med Koritnicami, Bačem in Knežakom prekrivajo nesprijeti gruščnato prodnati klastični sedimenti, ki so ponekod globoki več kot 10 m. Gradivo je v obliki vršaja ob izhodu iz povirne doline v času pleistocena nasula tedanja Pivka. Po morfologiji lahko kotanjo označimo kot kraško polje, saj izkazuje bistvene značilnosti kraških polj po Slovenski kraški terminologiji (Gams 1973), nekoliko neznačilna je zgolj njena oblika. Kvartarni sedimenti pokrivajo tudi dna ostalih večjih kraških kotanj.

Razen že omenjenega izrazitega narivnega preloma Snežniške narivne grude na Komensko narivno grudo sekajo obravnavano območje še številni drugi, manj izraziti prelomi. Povirna dolina nekdanje Pivke je izoblikovana ob Selškem prelomu, jugozahodno od Šembijskega jezera poteka Šembijski prelom. Območje je tektonsko aktivno še danes, kar dokazujejo pogosti potresi, ki nastajajo ob prelomih na globini 7–17 km (Vidrih in ostali 1996; Cecić in ostali 1999).

3 Razvoj površja v pliocenu

Melik (1951; 1955) navaja, da je Pivško podolje rezultat erozijskega delovanja pliocenske Pivke, ki je od Koritnic proti Postojni izoblikovala 3–4 kilometre široko dolino. Na vzhodu jo obdajajo Javorniki (1268 m), v zgornjem delu pa je izoblikovana na obronkih Snežniške planote (1796 m). Na zahodni strani dolino obdaja gorski hrbet Volovje rebri z Veliko Milanjo (1099 m), ki je del Snežniške planote, in Taborski hrbet med Šembijami in Primožem (718 m) nad naseljem Pivka. To je po njegovem mnenju dolga normalna dolina pliocenske Pivke, ki je tekla od povirja v visokem svetu Snežniške planote pod Veliko Milanjo in Devinom (1028 m) proti Postojnskim vratom v porečje Ljubljanice. To dokazuje terasni nivo, ki se razprostira vzhodno od Pivke, Zagorja in Knežaka. Povsod je izražen s širokimi, uravnanimi hrbti in manjšimi zaobljenimi vrhovi v nadmorskih višinah 610–630 metrov. Površinski tok Pivke je danes ohranjen le v najnižjih delih Zgornje Pivke.

Enako stara kot dolina Pivke naj bi bila tudi orografska razvodnica med Pivko in porečjem Reke na jugu, ki je danes opazna po markantni pregradi od Osojnice čez Taborski hrbet in dalje prek nižjega sveta v zaledju Šembijskega jezera na Volovjo reber. Na karbonatni podlagi je razvit kraški odtok z raztekanjem voda v jadransko in črnomorsko povodje (Habič 1968).

Slika 3: Izvirna dolina pliocenske Pivke je preoblikovana zaradi delovanja hudournikov v času pleistocena. Pogled z grebena Volovje rebri proti vzhodu (fotografija: Gregor Kovačič, 1. 3. 2000).
Glej angleški del prispevka.

Na južni strani Volovje rebri je suha in obvisela dolina nekdanjega vodotoka, ki je verjetno v pliocenski fluvialni fazi pritekal v porečje Reke. V primerjavi s suho dolino nad Koritnicami je omenjena dolina manj izrazito vrezana v okoliški svet, saj je v erozijskem procesu nekoliko zaostajala, močno pa jo je preoblikovalo tudi recentno zakrasevanje. Glede na izoblikovanost površja lahko sklepamo, da se je nekdanji vodotok vključeval v flišno porečje Reke nekje na območju Žlebov severno od Ilirske Bistrice. Žlebovi so erozijska vrzel v narivnem robu, kjer se flišna podlaga približno 700 m zajeda v notranjost apnenčastega sveta Snežniške planote. Podobne apnenčaste erozijske vrzeli lahko opazujemo vzdolž celotnega narivnega roba v okolici Ilirske Bistrice, omenjena pa je najizrazitejša. Njen nastanek lahko razlagamo z izrazitejšim erozijskim zniževanjem flišnih kamnin, ki je povzročilo zadenjsko erozijo in podaljševanje doline na stiku fliša v apnenčasti svet, dokler ni prišlo do prekinitve površinskega toka in prestavitve odtoka v podzemlje.

Podobne suhe in obvisele doline, ki kažejo na prisotnost pliocenskih površinskih tokov usmerjenih v dolino Pivke, so tudi drugje na Zgornji Pivki, v površju pa najbolj izstopata Vlačno in dolina med Jurišči in Palčjem (Habič 1968).

Razvoj površinske rečne mreže na karbonatnih tleh je po mnenju Radinje (1972) omogočila odeja neprepustnih terciarnih kamnin, ki je v pliocenu na široko obdala apnence, da so bili ti v nizki legi in zaprti. To je onemogočalo globinsko korozijo, zaradi česar se ni razvila globinska cirkulacija.

Pliocenski fluvialni fazi je sledilo obdobje zakrasevanja, ki je potekalo v subtropski oziroma tropski klimi (Melik 1951; Habič 1968). To sklepamo po ohranjenih oblikah in procesih, ki potekajo danes v kraških tropskih pokrajinah (Radinja 1972). Korozijsko raztapljanje agresivne padavinske vode, ki je svojo moč izčrpala že na začetku svoje poti, je zamenjalo predhodno izrazitejše erozijsko delovanje reke Pivke in njenih pritokov ter pritokov Reke, ki so na obravnavanem območju začrtali linearno strukturo površja. Različni nivoji obviselih teras na območju zahodnih Javornikov nakazujejo večstopenjsko zniževanje površja oziroma poglabljanja doline Pivke (Habič 1968). Kraški procesi so zelo izrazito preoblikovali nekdanjo starejšo teraso Pivke v višinah 600–650 m, saj je razčlenjena s številnimi vrtačami.

Obvisela je tudi nekdanja dolina na južni strani Volovje rebri, ki v 100 m stopnji visi nad kotanjo Šembijskega jezera. Kasnejše zakrasevanje je preoblikovalo nekdanjo dolino, številne vrtače so zlasti na dnu, zaradi večjih nagibov pa so na pobočjih manj pogoste in nepravilnih oblik.

V nasprotju z ostalimi dolinami na Zgornji Pivki, je povirna dolina pliocenske Pivke nad Koritnicami odprta proti kraškemu polju med Koritnicami, Bačem in Knežakom in ne kaže, da bi bila njen razvoj in poglabljanje kakorkoli prekinjena.

Morda je tako kot ostale fosilne doline tudi omenjena gorska dolina v prvi fazi zakrasevanja sicer obvisela, vendar je zaradi intenzivnega hudourniškega erozijskega delovanja v pleistocenu prišlo do ponovne poglobitve doline do ravni že omenjenega kraškega polja, gradivo pa se je na izhodu iz doline v obliki vršaja odložilo v dnu polja. Dno obvisele povirne doline pliocenske Pivke bi lahko bilo preval na zahodni strani kopastega vrha Strma reber (822 m) v višini 750 m, ter da je spodnji del doline izoblikovane na vzhodni strani omenjene vzpetine rezultat zgolj zelo intenzivnega erozijskega poglabljanja v času pleistocena.

Zelo verjetna je tudi razlaga, da se je v dnu Zgornje Pivke ves čas pliocena ohranil površinski tok Pivke. Kasneje je z zakrasevanjem nastal sistem kraških izvirov na območju Koritnic, kar je zavrlo fosilizacijo gorske doline nad Koritnicami. Takrat so bili aktivni kraški izviri, ki so izoblikovali izrazito zatrepno dolino Raše in nekoliko manj izrazito in krajšo suho dolino, ki se vije izpod cerkve Sv. Jeronima (698 m) skoraj do Koritnic. Velikost zatrepne doline Raše nakazuje, da je šlo za precej vodnat izvir. Napajalno zaledje omenjenih izvirov je bil višje ležeči zakraseli svet Snežniške planote z že izoblikovano kraško drenažo. V takšnih razmerah bi imeli opraviti z reko ponikalnico v dnu dokaj homogenega kraškega polja, ki se je morda raztezalo od Koritnic do ponorov v Postojnski jami, vendar pa o smereh odtekanja vode nimamo pravih dokazov.

Dno suhe doline Raše je široko nekaj metrov, na zahodu pa doseže 50 m. Izvirni del doline je v nadmorski višini 740 m. Dolina je že pri izviru globoko vrezana v okoliški svet za približno 20 m. Nižje je še bolj vrezana, vendar je tu dno doline že širše. Raša je dolga približno 600 m. Zatrepni del je 10 m visoka stena. Erozijska moč nekdanjega vodotoka je morala biti zelo velika, da je lahko izoblikoval tako markantno zajedeno dolino v ne preveč razčlenjeno površje. Na pobočjih se je nabralo veliko grušča, ki tvori manjša melišča. Rob doline ponekod obdajajo tudi do 8 m visoke stene. Neposredno nad zatrepom Raše se slab kilometer v notranjost Snežniške planote vije plitva struga, vrezana v živoskalno dno. Njen nastanek povezujemo z eno od starejših faz zakrasevanja, ko so bili na Zgornji Pivki aktivni kraški izviri v višjih nadmorskih višinah. Z znižanjem piezometra je postal aktiven izvir v Raši, ki se je izrazito poglobil v okoliški svet, suha struga višjega izvira pa je obvisela nad njim in se ohranila do danes. O zatrepih, ki si v stopnjah slede z višjih v nižje uravnave in so nastali ob kraških pritokih izpod Snežniške planote in Javornikov, piše tudi Habič (1968). Seveda so možne še druge razlage, ki jih lahko povezujemo s pleistocenskimi procesi, saj je zlasti suha struga nad zatrepom Raše po morfologiji zelo podobna plitvim koritastim strugam v zaledju Šembijskega jezera, ki jim pripisujem kasnejši nastanek. Ne izključujem možnosti, da je tudi do izrazite poglobitve suhe doline Raše prišlo v času pleistocena.

O pliocenski kraški fazi pričajo kopaste vzpetinice, ki se dvigajo v obrobju in znotraj kraškega polja med Koritnicami, Bačem in Knežakom. Kopaste vzpetinice imajo tloris v obliki skoraj pravilnega kroga. Humi se z blagim nagibom dvigajo iz sosednjega večinoma ravnega sveta. Lepo so opazne zlasti vzpetinice Velika Obroba (644 m), Mala Obroba (641 m) ter sosednji hum višine 644 m. Njihova skoraj enaka

nadmorska višina priča o skupnem nastanku. Dobro opazni sta še vzpetinici Galaričica in Obrobca, ki sta v nadmorski višini 600 m, v okolici so še druge kopaste vzpetine v višjih nadmorskih višinah. Zakraselost podlage v dnu kraškega polja med Koritnicami, Bačem in Knežakom dokazujejo vrtine (Krivic in ostali 1983). Na različnih globinah naletimo na manjše kraške jame zapolnjene z glino, bližje površju pa so nekateri rovi delno zapolnjeni tudi z apnenim gradivom.

Pliocensko kraško površje Pivke sta istočasno preoblikovala tako erozijsko-denudacijski kot korozijski morfogenetski proces z močno ploskovno korozijo. Procesa sta se medsebojno dopolnjevala. Tako so nastajale doline, ki so se zaradi zniževanja gradienta vedno bolj poglabljale, in terase na različnih višinah.

4 Razvoj površja v pleistocenu

Melik (1955) je s preučevanjem slovenskih kraških polj ugotovil, da se je v pleistocenu povečalo mehansko preperevanje ter razpadanje karbonatnih kamnin na površini kot učinek izredno pogostega kolebanja temperatur okoli ničle in intenzivnega zmrzovanja, kar se je dogajalo zlasti v višjih predelih. Tako se je na površju nabiralo veliko kamninskega drobirja, ki ga je močna denudacija, bodisi v obliki soliflukcije, bodisi s fluvialnim odnašanjem transportirala v nižje predele. Zaradi zatrpavanja jam, brezen in ponikev je prišlo do obnovitve površinskih vodotokov in do oživljanja suhih dolin. K prekinitvi kraškega procesa je pripomogla tudi zamrznjenost tal, osiromašena pedološka in vegetacijska odeja pa je korozijo vezala predvsem na razpokanost tal.

Kemično preperevanje je bilo v periglacialnih predelih (obravnavano območje) torej zelo šibko, kar v geomorfološkem smislu pomeni oslabitev procesa zakrasevanja. Prevlada mehaničnega razpadanja, soliflukcije ter denudacije je povzročila zasipavanje že obstoječih kraških požiralnikov. Zelo nazoren primer je Grobničko polje nad Reko na Hrvaškem, kjer so pleistocenski potoki v pobočja vrezali prave soteske, polje pa na debelo nasuli z drobirjem. Sestava sedimentov kaže celo na občasno ojezeritev (Šikić in Pleničar 1975).

Podobne so tudi domneve o pleistocenskem jezeru med Koritnicami, Bačem in Knežakom (Cumin 1929; Melik 1955). Jezero naj bi se raztezalo v obliki dveh krakov od Koritnic proti Knežaku in Baču, vendar pa pravih dokazov o njegovem obstoju nimamo. Vrtine v polju (Krivic in ostali 1983) niso dokazale prisotnost drobnejših jezerskih sedimentov, zato težko govorimo o daljši ojezeritvi. Ne moremo pa izključiti možnosti, da je v pleistocenu kljub vsemu prihajalo do občasnih ojezeritev, ko je nasuti drobir zadelal pretesna grla požiralnikov in ponikve niso mogle več sproti sprejemati vse vode, plavja ter nanosa, podobno kot so današnje poplave na kraških poljih. Kraško polje med Koritnicami, Bačem in Knežakom je v najnižjih predelih zalito ob vsakem daljšem deževnem obdobju, ob izjemno visokih vodah pa prihaja tudi do obsežnejših kratkotrajnih poplav, ki povzročajo škodo (Kovačič 2005).

Nekoliko drugačno razlago morfogenetskega dogajanja v času pleistocena ponuja Radinja (1972), ki navaja, da je s podnebnimi spremembami usmerjeno diferencirano zniževanje različnih kamnin spremenilo hipsografska razmerja med njimi, kar je omogočilo nastanek gradienta in globinske kraške cirkulacije, ki se zaradi zajezenosti karbonatnih kamnin z vododržnimi kamninami v prejšnjem obdobju ni mogla razviti. Prišlo je do spremembe korozijske dinamike, ki je prešla iz pliocenske površinske, usmerjene in ploskovne korozije v razpršeno in globinsko (točkasto) korozijo, saj so agresivne vode ob hladnejši klimi in skromnejši vegetacijski in pedološki odeji izčrpale svojo moč šele na daljši poti. Kot prevladujoča morfogenetska procesa navaja globinsko korozijo in erozijo. V površju obravnavanega območja izstopajo predvsem učinki slednjega.

4.1 Učinki geomorfnega dogajanja v pleistocenu na današnjo izoblikovanost površja

Geomorfni procesi so v pleistocenu obravnavano območje močno zaznamovali. V terenu nad Koritnicami so dobro opazni sledovi zelo intenzivnega erozijskega delovanja reke Pivke, ki je izvirala izpod Devina in V. Milanje. Ob izhodu iz gorske doline (grape) je reka nasula ogromen gruščnato-prodnati vršaj, ki je nagnjen od Koritnic (625 m) proti Baču (580 m) in Knežaku (580 m). Drobir so dobavljala tudi sosednja pobočja, na katerih sta v periglacialnih razmerah vladala močno mehansko preperevanje kamnine ter solifluk-

cija. Drobir je bolj podoben grušču kot produ, kar dokazuje, kako malo časa so ga valile vode. Da bi si olajšali kmetovanje, so domačini v bolj nagnjenih predelih vršaja pri Koritnicah uredili manjše terase.

Najvišji izviri nekdanje Pivke segajo v Žlebovih do nadmorske višine 950 m in so neposredno pod slemenom Volovje rebri. V strmem pobočju z nakloni prek 22° so hudourniki izdolbli globoke in strme grape.

Hudourniške grape v Žlebovih so zelo številne, na splošno pa so usmerjene proti severozahodu. Izjema so hudourniške grape pod Veliko Milanjo, ki so v vrhnjem delu usmerjene bolj proti severu, vendar se potem ko pridejo v nižji svet, obrnejo proti severozahodu. Žlebovi so levi, višji povirni krak pleistocenske Pivke. Z desne pa Pivka priteka po slab kilometer dolgi strugi. Izvir tega povirnega kraka je približno na višini 740 m. Pivka je tu izoblikovala 10 m globok zatrep, ki dolino loči od okolice. Nad zatrepom so hudourniške grape, ki so najbolj opazne pod Devinom, kjer je bil predvidoma najvišji izvir desnega kraka Pivke. Pod Devinom površje ni tako močno razjedeno kot v Žlebovih. Podobno kot v Žlebovih so tudi pod Devinom hudourniške vode v pleistocenu najverjetneje izvirale na višini okoli 950 m.

Struga pleistocenske Pivke se po združitvi obeh krakov približno 1 km pred Strmo rebrijo (822 m) nekoliko razširi. Strmec se zmanjša, zato na površini zasledimo sipko gradivo, sestavljen iz drobnega grušča, pomešanega s prstjo. V to naplavino je voda v holocenu izoblikovala zelo majhne in ozke struge, 0,5 m globoke. Ti predeli so najverjetneje rezultat ene od zadnjih faz rečnega zasipavanja v Pleistocenu. Kjer ni denudirano, debelina tega gradiva ponekod znaša tudi več metrov.

Ob vznožju Strme rebri je poldrugi meter globoka in nekaj več kot 3 m široka struga v kratkem odseku nastala v drobirju, ki ga je prinesla Pivka iz zaledja. Zelo zanimivo obliko dobi tik pred Koritnicami. Tu je Pivka s svojo razdiralno močjo na razdalji 350 m v živoskalno podlago izdolbla do 4 m globoko in ozko strugo (korito), kar je pripomoglo k imenu Koritnice (Melik 1955). Struga Pivke postaja od Koritnic proti severozahodu vedno plitvejša, dokler je po nekaj 100 m ni več opaziti. Položaj nekdanjih strug nakazuje, da je Pivka večkrat preusmerjala svoj tok. Suhe struge lahko opazujemo ob cesti, ki vodi od Koritnic proti Baču in proti Knežaku. Zlasti je lepo izdelana suha struga pod Tuščakom (786 m), ki se v meandrih vije desno od ceste Koritnice–Bač (slika 4). Njeno dno je do 2 m globlje od hrbtov vršaja nad njimi, kar dokazuje, da se je večji del nasipavanja zaključil v pleistocenu, v holocenu pa se je vršilo šibko vrezovanje. Ob izjemnih padavinah novembra 2000 se je struga v spodnjem delu zapolnila in pojavil se je površinski vodotok, ki je poplavil naselje Bač (Kovačič 2005).

Slika 4: Suha struga nekdanje Pivke severozahodno od Koritnic (fotografija: Gregor Kovačič, 7. 10. 2005).
Glej angleški del prispevka.

Pleistocenska Pivka je od izvirov v Žlebovih do območja suhih strug pod Tuščakom v dolžino merila nekaj več kot 4 km. Pivka je imela na tej razmeroma kratki poti relativno velik strmec. Večji strmec pa pomeni večjo erozijsko moč ter lažji in hitrejši transport mehanično preperelega in razpadlega gradiva, ki se je nasul v vršaj pod Koritnicami. Debelina nasutega gradiva, ki ponekod presega 10 m, zato ni presenetljiva.

Sestavo drobirja je moč preučevati na več mestih v že omenjeni suhi strugi ter v posameznih izkopanih jamah vzdolž ceste Koritnice–Bač. 2 m globok prerez v suhi strugi sestavlja drobir različne velikosti. V zgornjem delu prereza je do 20 cm temne prsti, ki je pomešana z drobirjem. Velikost posameznih delcev je različna. Prevladujejo delci, ki v premeru merijo 1–6 cm, največji med njimi pa do 25 cm. Drobir je slabo zaobljen in bolj podoben grušču kakor produ. Med drobirjem je veliko peska. Z izjemo gornjega dela prereza, kjer lahko v zelo omejenem obsegu opazujemo sortirano gradivo v tankih slojih, so delci razporejeni kaotično, tako da je med seboj pomešano gradivo različne velikosti. To dokazuje hudourniški značaj pleistocenske Pivke.

V izkopu vzdolž ceste Koritnice–Bač (slika 5), ki je 700 m oddaljen od prvega prereza, so razmere podobne. Velikost posameznih delcev je nekoliko manjša, saj prevladujejo delci, ki v premeru merijo do 2 cm, največji drobir pa v premeru ne presega 16 cm. Tudi tu je med slabo zaobljenim drobirjem veliko peska. Nekoliko bolj zaobljeni so zlasti manjši delci. Drobir je razporejen brez reda, slojevitosti ni opaziti. V dnu 2,5 m globokega prereza je razkrita nekdanja površina kraškega polja, ki se odraža v oblikah podtalnega skalnega reliefa in prisotnosti rdeče ilovice v žepih.

Slika 5: Sestava naplavine v kraškem polju med Koritnicami, Knežakom in Bačem v izkopu poleg ceste Koritnice–Bač (fotografija: Gregor Kovačič, 7. 6. 2006).
Glej angleški del prispevka.

V obviseli dolini na južni strani Volovje rebri tudi naletimo na sledove delovanja pleistocena. Ob zaključku doline, na uravnanem svetu Kamenščine nad kotanjo Šembijskega jezera, je odloženo gradivo različne velikosti. Akumulacija gradiva je posledica delovanja pleistocenskega potoka v dolini ter soliflukcijskih procesov, ki so omogočali transport preperelega gradiva po pobočjih v nižje predele. Velikost drobirja je v primerjavi z gradivom na kraškem polju med Koritnicami, Bačem in Knežakom veliko manjša.

Vpogled v sestavo gradiva nam omogočajo izkopi v treh vrtačah. V preučevanem prerezu (slika 7) v eni izmed izkopanih vrtač lahko opazujemo sloje raznovrstnega gradiva. Pod 25 cm slojem temne prsti je sloj 50 cm nesprijetega in kaotično razporejenega drobnozrnatega grušča, ki je pomešan s prstjo. Velikost kamninskih delcev v tem sloju ne presega 2 cm. Pod slojem grušča je 90 cm debel sloj rjave ilovice, v kateri so tudi posamezni večji kosi grušča. Sledi 80 cm debel sloj dobro kalcificiranega drobnozrnatega grušča, ki je sprejet v brečo. V breči so opazni posamezni sloji različno velikega gradiva. Pod brečo je nesprijeti drobnozrnati grušč, ki je tudi sortiran v tanke sloje. Debelina tega sloja ni znana, v prerezu pa meri približno 80 cm. V preučevanem 4 m globokem prerezu velikost posameznih delcev v breči in sloju grušča pod njo ne presega 5 cm, kar priča o majhni transportni moči nekdanjega vodotoka v dolini, oblika delcev pa nakazuje, da je izvor drobirja zelo bližnje zaledje. Živoskalno dno v vrtači ni opazno, med gradivom ni sige. Podobna sestava sedimentov je tudi v sosednjih dveh izkopih, vendar pa je živoskalna osnova dna in robov zasutih vrtač tam dobro vidna.

V srednjem delu doline je 200 m dolga manjša suha struga, ki je rezultat erozijskega delovanja vodotoka, ki se je v času pleistocena napajal s snežišč izpod Volovje rebri. Vodotok je najverjetneje odtekal tudi prek roba doline v kotanjo Šembijskega jezera, kjer je v pobočju nad njo v skalo vrezana manjša hudourniška grapa. Hudourniška grapa je odvajala površinske vode in drobnozrnato gradivo v dno današnje kotanje Šembijskega jezera in v kotanjo Nariče, ki je bila ob izjemnih padavinah novembra 2000 tudi zalita z vodo. Podobna, vendar daljša hudourniška grapa, se vleče s skrajnih severozahodnih pobočij Volovje rebri in je sprva usmerjena proti severozahodu, nato pa zavije na zahod, kjer se na Naričah konča. Omenjena hudourniška grapa je ozka in plitva z živoskalnim dnom.

Slika 6: Geomorfološka karta obravavanega območja izrisana na podlagi digitalnega modela reliefa (25 × 25 m). Legenda: 1 – kopasta vzpetina, 2 – kraški izvir, površinski vodotok (stalen ali občasen), 3 – kotanja presihajočega kraškega jezera, večja kraška kotanja, 4 – kraško polje, 5 – ozka, široka suha koritasta struga, 6 – suha struga oblikovana v naplavini, zatrepna dolina, 7 – smeri nasipanja pleistocenske Pivke, 8 – tektonsko okno, 9 – vzpetina z nadmorsko višino, 10 – površinski vodotok (stalen ali občasen), 11 – lokacija slike.
Glej angleški del prispevka.

5 Sklep

Študij današnjih površinskih oblik je pokazal, da je fluvialni relief na tem območju že povsem zabrisalo recentno zniževanje površja zaradi korozije padavinske vode. Toda nekateri elementi erozijskega delovanja površinskih voda iz prejšnjih obdobji v zaledju današnjega izvira reke Pivke so zelo dobro ohranjeni. Še več, obravnavanemu območju dajejo prepoznaven pečat.

Osnovne oblike kraškega površja v zaledju današnje Pivke so nastale med toplim in vlažnim pliocenskim podnebjem. Pleistocenski procesi so spremenili prejšnje kraške oblike. Zaradi povečanega mehaničnega razpadanja apnencev so nastala položna pobočja, kasneje pa se je površje drobno razčlenilo.

Slika 7: Prerez skozi sedimente v eni od izkopanih vrtač na Kamenščini (fotografija: Gregor Kovačič, 7. 6. 2006). Legenda: A – prst, B – drobnozrnati grušč, C – ilovica, D – breča, E – drobnozrnati grušč v slojih.
Glej angleški del prispevka.

Medtem ko je obviselo dolino na južni strani grebena Volovje rebri precej preoblikovalo mlajše korozijsko delovanje, v suhi dolini nekdanje Pivke še danes močno prevladujejo poteze fluvialnega površja. To je dokaz o izjemni erozijski moči pleistocenskih voda, ki so tektonsko dobro pretrto območje hitreje poglabljale od sosedstva. Učinki pleistocenskega morfogenetskega dogajanja zaradi kasnejše korozije tako večinoma niso bili zabrisani, zato so v površju dominantni. Tako so v površju ohranjene tudi številne manjše hudourniške grape in koritaste struge.

Gruščnato-prodnati drobir, ki so ga pleistocenske vode prenašale izpod pobočij Devina in Velike Milanje, je na debelo prekril kotanjo kraškega polja med Koritnicam, Bačem in Knežakom. Tako lahko po

naplavinah in suhih strugah sklepamo, da se je večina akumulacije zaključila v pleistocenu, v holocenu pa je potekalo rahlo vrezovanje. Razen na območju omenjenega polja zasledimo naplavine pleistocenskega in deloma kasnejšega izvora še v drugih kotanjah.

Danes je prevladujoči geomorfni proces razpršena točkovna korozija, v vršnih predelih Volovje rebri in v Žlebovih pa je zlasti v hladni polovici leta intenzivno tudi mehansko razpadanje kamnin. Razvoj površja je v veliki meri pogojen z gladino podtalnice na območju, ki se v polju med Koritnicami, Bačem in Knežakom običajno nahaja nekje na globini 30–40 m pod površjem in je nagnjena od Koritnic, kjer dosega 560 m, proti Baču (540 m) (Krivic in ostali 1983). V hidrološkem smislu je obravnavano območje bifurkacijska cona med jadranskim in črnomorskim povodjem. Podzemne vode s kraškega polja odtekajo večinoma proti Pivki, medtem ko kotanja Šembijskega jezera in njegovo hidrografsko zaledje pripada porečju Reke, saj gladina podtalnice visi v smeri kraškega izvira Podstenjšek.

Če poskušamo geomorfogenetsko dogajanje obravnavanega območja povezati v širši kontekst razvoja površja v Pivškem podolju ali vsaj njegovega zgornjega dela (Zgornje Pivke) naletimo na vprašanje, v kakšni smeri gre nadaljnji geomorfološki razvoj te nadvse zanimive pokrajine. Ravbar in Šebela (2004) v okviru preučevanja Pivških presihajočih jezer ter medsebojne primerjave hidroloških razmer na Zgornji Pivki in Cerkniškem polju ugotavljata, da je Pivško podolje trenutno v predhodni fazi razvoja »pravega« kraškega polja, ko se kraške kotanje poglabljajo do nivoja kraške podtalnice, kot je to primer v presihajočih jezerih na Zgornji Pivki.

Možna pa je tudi drugačna razlaga. Iz hidrogeoloških raziskav je razvidno, da je gradient podzemne vode pod Javorniki usmerjen v izvire Malnov (Habič 1968), prisotna je močna globinska cirkulacija proti severovzhodu, kar je dokazano tudi s sledenji (Habič 1989). Iz tega lahko sklepamo, da proces poglabljanja kraških kotanj ni zavrt, temveč se nadaljuje. V tem pogledu bi lahko današnjo reliefno podobo Pivškega podolja s številnimi občasno poplavljenimi kraškimi kotanjami in občasno površinsko tekočo Pivko razložili kot razpadajoče kraško polje. Kot zanimivost omenjam zgradbo kotanje Malega Drskovškega jezera, ki je manjše izvorno-ponorniško polje s kraškim izvirom na eni in ponorom na drugi strani.

Pivško podolje (Pivka, Pivško polje) (Kranjc 1987) se uvršča med najzanimivejše in najslikovitejše pokrajine slovenskega klasičnega krasa. Prispevek, ki temelji na kritičnem pregledu literature in terenskih raziskavah, skuša razložiti razvoj površja v njenem skrajnem jugovzhodnem predelu. Območje je prešlo skozi različne geomorfogenetske faze razvoja, izmenjevali so se številni procesi preoblikovanja pokrajine. V današnji podobi površja nedvomno izstopajo učinki delovanja pleistocenskih procesov.

6 Viri in literatura

Glej angleški del prispevka.