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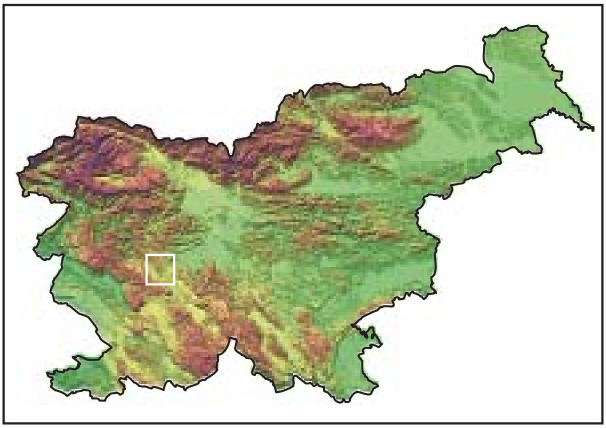
DOLOMITE RELIEF IN THE ŽIBRŠE HILLS

DOLOMITNI RELIEF NA OBMOČJU ŽIBRŠ

Blaž Komac

A typical dell in the Žibrše hills (photography Blaž Komac).
Značilen dolec na Žibršah (fotografija Blaž Komac).



Dolomite Relief in the Žibrše Hills

UDC: 551.435(497.4 Žibrše)
COBISS: 1.01

ABSTRACT: The paper describes the dolomite relief of the Žibrše hills where dells are a characteristic relief feature. It discusses the main geomorphological characteristics and genesis of the relief.
Carbonate rock covers almost one half of Slovenia's surface area, of which dolomite comprises about one quarter. Dolomite relief with dells, which cover a little less than one tenth of the dolomite areas, is particularly interesting. The relief with dells is neither typical fluviodenudational relief because there are no surface water streams nor typical karst relief because dells are linear relief features. Their occurrence and development have not previously been studied in detail.
The paper describes the principal characteristics of dolomite relief with dells in the Žibrše hills northeast of Logatec. Considered geomorphologically, the studies of the geological structure and chemistry studies indicate that the dells were formed by periglacial processes during the cold periods of the Pleistocene, and due to the carbonate nature of the rock, by karst processes as well.

KEYWORDS: geomorphology, dolomite, dell, Slovenia, Notranjska, Žibrše.

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Dolomitni relief na območju Žibrš

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IZVLEČEK: V prispevku je opisan dolomitni relief Žibrš, na katerem so nastali dolci kot značilna reliefna oblika. Razpravlja o poglavitnih geomorfnih značilnostih in genezi reliefa.
Karbonatne kamnine prekrivajo skoraj polovico površine Slovenije, od tega dolomitno površje približno četrtino. Na nekaj manj kot desetini dolomitnega površja so nastali dolci. Dolomitni relief z dolci je zanimiv. Relief z dolci ni niti tipično rečno-denudacijski, saj na njem ni površinskih vodnih tokov, niti tipično kraški relief, saj so dolci linearne reliefne oblike. Njihov nastanek in razvoj še nista bila podrobno preučena.
V prispevku so opisane poglavitne značilnosti dolomitnega reliefa z dolci na Žibršah, slemenu severozahodno od Logatca. Opravljene geomorfološke, geološko-strukturne in kemične raziskave kažejo, da bi ta oblika lahko nastala s periglacialnimi procesi v hladnih obdobjih pleistocena, po drugi strani pa je zaradi karbonatnosti kamnine pomemben kraški proces.

KLJUČNE BESEDE: geomorfologija, dolomit, dolec, Slovenija, Notranjska, Žibrše.

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Contents

Kazalo

1 Introduction

In Slovenia, dolomite covers 2,500 km^2 or 11.7% of the national territory. The majority was created through the dolomitization of limestone. Stratigraphically, we distinguish twelve types of dolomite, the most frequent being Mesozoic dolomite, particularly Triassic dolomite. The proportion of dolomite areas in Slovenia is greatest in the Dinaric karst region, where it covers one fifth of the surface, and in the alpine areas, where it covers one sixth of the surface. Dolomite relief is diverse. In alpine regions, walls and steep dolomite hillslopes with erosion gullies are frequent. Relief with dells occurs frequently in Slovenia, but there are few actual karst surfaces on dolomite (Gabrovec 1994).

Transition areas with characteristics of fluviodenudational and karst surfaces are frequent to which the term »fluviokarst« has been applied; however, this term is not appropriate from the genetic point of view.

The Žibrše hills lie at the contact of Rovtarsko hribovje hills to the north and the Notranjska valley system to the south. The hills are bordered by the valleys of the Reka stream to the east and the Žejski potok stream to the west. The southern part of the hills, which are named after a village near Logatec, is composed of main dolomite.

The relief is interesting because of its structural composition and the proximity of the Idrija fault, the transitional character of its lithological structure of alternating dolomite and marl, the hydrogeographical characteristics, and the diversity of geomorphological processes. Research has confirmed the undisputable geomorphological role of water or the corresponding relationship between erosion-denudational processes and corrosion. Several features of the dolomite relief indicate that today corrosion is a more significant feature-forming process than erosion or denudation. Its intensity is also influenced by the red-brown clay that is preserved on the bottoms of hollows and dells in the Žibrše hills. Dells are a characteristic relief feature of the area and numerous ravines dissect the slopes, but dolines are a rare feature in the Žibrše hills, with the exception of the upper edge of the slopes above the Reka stream.

Figure 1: The bottom of dell 2 meets the slope in a sharp bend (photography Blaž Komac).

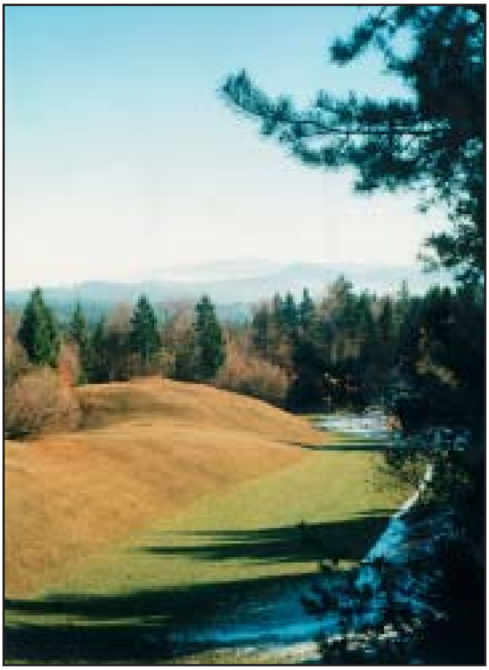


Figure 2: The dells in the Žibrše hills are several meters deep (photography Blaž Komac).

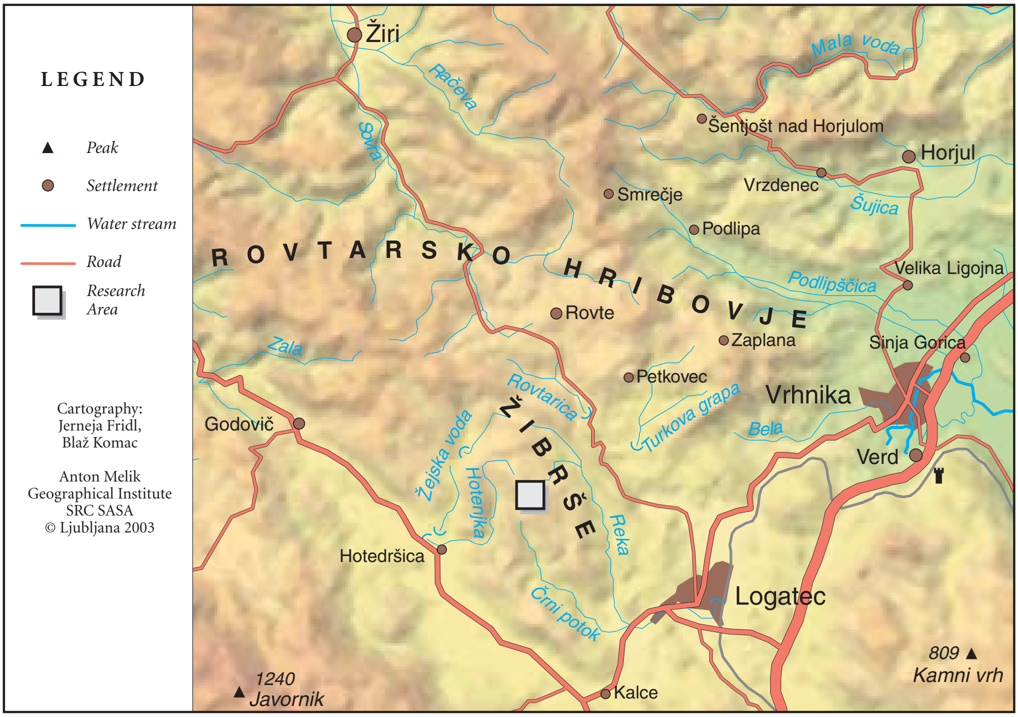
In addition to the geomorphological conditions and the characteristics of the rock, the development of the surface is also influenced by tectonics. Along the faults, the rock is tectonically fractured and crushed. Crushed dolomite is less permeable, and fluviodenudational relief forms on it. The distribution of dells depends on the routes of the internal zones of faults.

2 Geomorphological processes and features of the dolomite in the Žibrše hills

The Žibrše hills are situated in the southern part of the Rovtarsko hribovje hills, where stratified Karnian and Noric main dolomite appears on the surface. It contains brown or grey dolomite marl at the bottom and is lighter at the top of the lithostratigraphic unit. The area belongs to the Idrija-Žiri thrust structure, which is characterized by numerous overlaps or nappes. In this area, the older faults run in the northeast-southwest direction, while the younger strike-slip faults run northwest-southeast. Individual blocks shifted vertically along the faults (Mlakar 1969; Gospodarič 1987).

As a carbonate rock, dolomite is subject to chemical weathering and to physical weathering as well due to its porosity, stratification, and fracturedness. The process of physical weathering was intensive during the colder periods of the Pleistocene, but in Slovenia today it is limited to higher elevations (Širfer 1963, Kunaver 1990) and areas of strongly crushed dolomite. In the colder periods of the Pleistocene, periglacial conditions dominated in the Žibrše hills (725 m). During these periods denudation processes removed the weathered rock, revealing the bedrock and the structural composition. Dells and denudation notches formed, and fans were created below the ridge (see Šifrer 1990).

In today's conditions, the surface is being transformed primarily by the chemical weathering that dolomite is particularly vulnerable to due to its fracturedness. Measurements of the water hardness and the volume of flow of the Predvratnica stream near Velike Lašče south of Ljubljana showed that the annu-



Map 1: Survey map of the area.

Figure 3: Dell 2a is found just below the ridge. The average inclination of its bottom is around 20° (photography Blaž Komac).

al corrosion between its sink in the Vratnica Cave and its 1,150-meters distant source in Peči totals as much as seventy-four tons of $CaCO_3$. In one year, water on average dissolves 27.4 m^3 of rock, carrying away 65 mg/l of carbonates in solution (Kogovšek and Kranjc 1992). Although the waters from dolomite regions are saturated or even supersaturated with dolomite, the dolomite is not deposited due to the slow kinetics or its greater chemical mobility compared with calcite (Lapanje 2000).

3 Dells

Along with erosion foci, denudation notches, saddles, dolomite mounds, pinnacles, dolines, and karst poljes, dells (»*dolec*« in Gabrovec 1994, 1996 or »*dolek*« in Gams 1968; Gams and Natek 1981; Gams 2003; »*die Delle*« in German) are a characteristic feature of dolomite relief.

On dolomite, a dell is rarely just a shallow depression on a slope. It is often a deep and narrow oblong relief form similar to a small river valley. The upper part starts with a shallow depression and widens and deepens downwards. A dell can be several hundred meters long and several dozen meters in depth at most. Although it has no permanent surface stream at the top, farther down it can transform into a ravine with a permanent water stream, which reflects the close dependence of the surface formation on hydrogeographical development on less permeable carbonate rock (Brenčič 2003). A dell can end hanging above a steep slope or run into a plain. Below Ravnik near Hotedršica along the dolomite-limestone contact, dells run into the dolines (Mihevc 1986). In cross-section, a dell has a concave dolomite bottom that continues to relatively steep slopes. The bottom can be level due to farming, in which case it meets the steep slopes at a distinctive edge. In places, the bottoms of dells were partitioned by stone walls and thus acquired some additional flat surface.

In employing the term »dell« to label a relief feature characteristic of dolomite, we must take care to distinguish this use from the usual meaning of »dell« (»dry valley«) in English or »*die Delle*« (»*die Tilke, das Muldentälchen*«) in German. While the genesis of dolomite dells has not yet been explained, the established use of the term in English and German defines a relief feature both descriptively and genetically. It must also be emphasized that genetically and morphologically a dolomite dell most probably differs from similar relief forms that occur in periglacial conditions on granite, limestone, chalk, marl, light soil, rubble terraces, and clay.

It has been established that this relief form did not originate through the activity of running water or wind but through periglacial processes such as freezing and thawing. The principal relief-forming processes in the formation of dells are periglacial processes, particularly pluvial-snow erosion, snow erosion, solifluction, and nivation (the weathering of rock near a patch of snow resulting from the alternating freezing and thawing of the rock, the permeation of water into the depths, and the occurrence of ice wedges in combination with slope processes; also »snow patch erosion« – Fairbridge 1968, 774).

A dell forms in two phases. An initial deepening of the surface appears first, followed by denudation and the deposit of material below the slopes at the bottom of the dells. In intervening warmer periods, it is also shaped by surface running water from melting snow. The formation and development of a dell is also influenced by the relative altitude differences of the area, the size of the catchment area (the length of the dell), and the length of dells's slopes (Fairbridge 1968, 251). While solifluction can occur on a slope of just two degrees, it becomes much stronger at six degrees. Denudation and erosion are also substantial on steeper hillslopes and cultivated fields (Demek et al. 1972). In the Žibrše hills, the dells are interconnected in an asymmetric treelike system, which indicates an origin in linear geomorphological processes. We can assume the long duration of their formation or the high intensity of the processes from the great width and depth of the dells compared with intervening ridges.

There are no traces of erosion by surface running water streams in the dells of the Žibrše hills. On the grassy bottoms, diffuse streams of water appear with intensive precipitation that carry away soil from surfaces with sufficient inclination. The upper section of the dells is steep with a shallow layer of weathered debris. In the central section the dells have a convex cross-section that slopes steeply. Downwards, the inclination decreases and the bottom becomes slightly concave toward the edges. This pattern appears regardless of the location of a dell in the system.

In colder climate conditions, weathering and denudation quickly transformed the relief. In dolomite areas the varying resistance of the rock depending on its structure and lithological composition becomes evident. Early Triassic dolomite is shaped into polyhedrons and is fractured along faults, and the fracturedness reduces permeability and resistance. Since the dolomite surface in the Žibrše hills is covered with soil and weathered debris, we can only deduce the direction of faults and the degree of fracturedness of the rock from the density and direction of fissures in nearby outcroppings. The rock strata in the Žibrše hills are inclined toward the southwest from 20° to 40°. The great depth of dells on dolomite in Slovenia compared with dells described elsewhere as typical (Fairbridge 1968) can be explained by their good state of preservation due to the relatively more resistant dolomite and the corrosion on their bottoms.

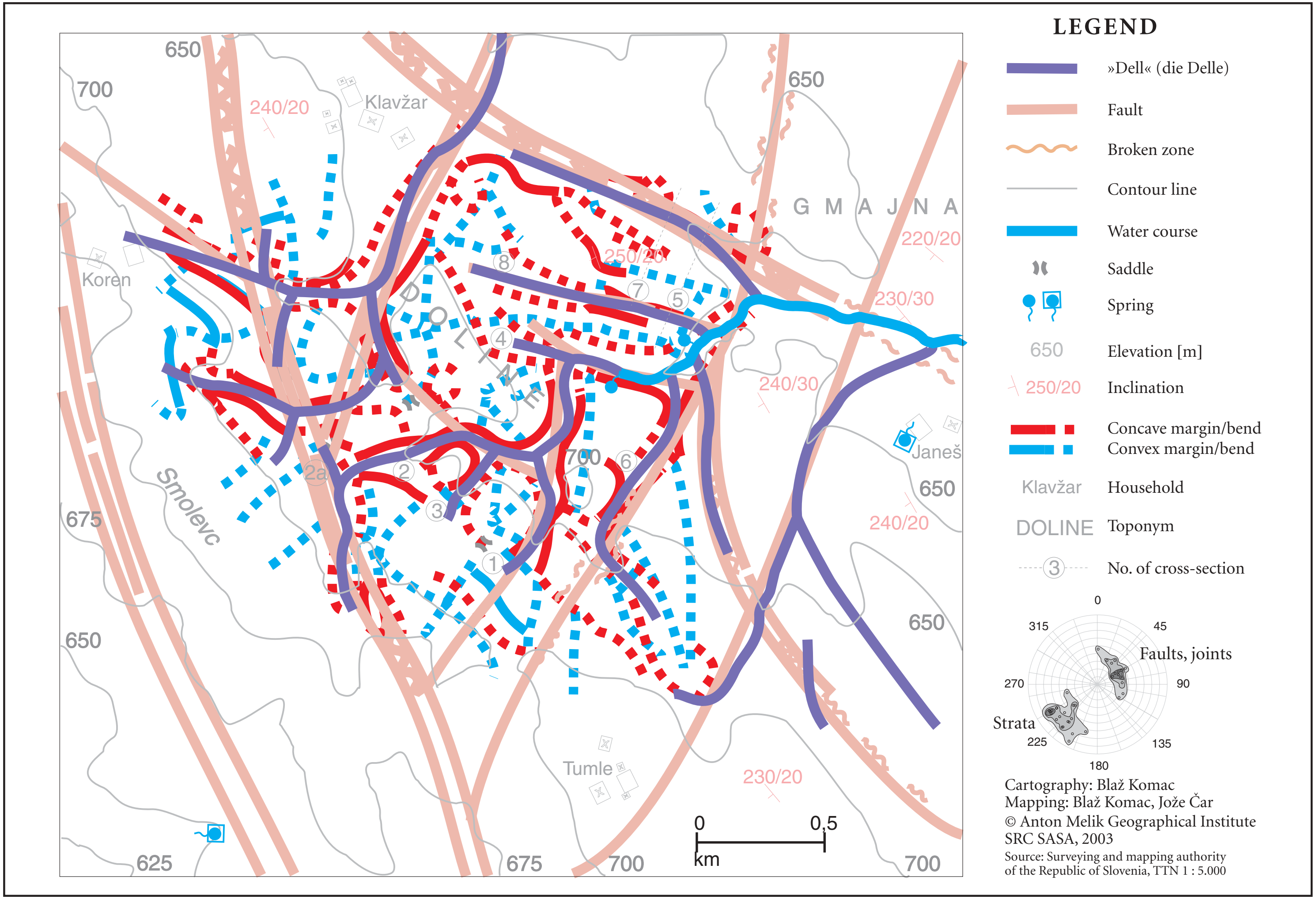
Table 1: Number of distances on individual cross-sections relative to the average inclination of the surface measured with a 1.5-meter pantometer, average inclination of the bottom of dells, lowest and highest measured inclinations, length of cross-section in meters. Cross-sections 5 and 7 are crosswise; the rest are lengthwise.

Inclination in degrees	Cross-section 1	Cross-section 2	Cross-section 2a	Cross-section 3	Cross-section 4	Cross-section 6	Cross-section 8	Cross-section 5	Cross-section 7	Proportion of measurements (%)
0–4.9	88	41	1	10	3	94	47	7	5	28.82
5–9.9	82	146	3	32	8	2	102	8	4	37.68
10–14.9	32	21	16	44	17	1	9	8	8	15.19
15–19.9	20	7	7	18	17	0	8	1	0	7.59
20–24.9	15	1	13	23	5	0	3	3	2	6.33
25–29.9	3	0	17	3	5	0	0	0	0	2.73
30–34.9	1	0	2	2	5	0	0	0	1	1.07
35–39.9	0	0	2	0	2	0	0	0	0	0.39
40–44.9	2	0	0	0	0	0	0	0	0	0.19
Average inclination of dell	8.56	6.91	20.13	10.97	16.94	8.6	6.39	11.65	14.58	11.64
Lowest value	0.0	0.0	1.5	0.0	3.5	0.0	0.0	0.0	0.0	0.56
Highest value	41.0	21.0	39.0	36.5	36.5	32.0	22.0	26.5	42.0	32.94
Length of cross-section in m	364.5	334.5	91.5	210.0	93.0	234.0	262.5	109.5	94.5	TOTAL 1,794 m

The majority of dells in the Žibrše hills are oriented along faults or crushed zones where corrosion and denudation occur, as well as the subcutaneous washing away of particles. Hollows and saddles formed at the intersections of faults, the larger of which mostly have the southeast-northwest Dinaric orientation. Ravines, denudation gullies, and saddles also run along the faults.

Some dells are oriented relative to the stratification structure and follow less resistant few-decimeter to several-meter thick layers of marl, schistose marl, and schistose claystone. In places where weathering is less intensive and where carrying away is still stronger than in the surroundings, a hollow-mound relief occurs. In their upper part, some of the dells end almost imperceptibly in a mounded surface. It is characteristic that smaller mounds follow the stratification or the lithographical structure, and larger mounds follow fault structures.

The dells in the Žibrše hills can be placed into two classes according to the inclinations of their bottoms. In the first class are dells 1, 2, 6, 8, 3, 2a, and 4, and in the second, dells 5 and 7. This classification, made using Ward's method and the *SPSS* computer program which calculates similarity using squared Euclidean distances is expected since the cross-sections of dells 5 and 7 are crosswise and the rest are lengthwise. In the same way, we classified the dells with lengthwise cross-sections into three further subgroups. The first subgroup includes the longer dells (1, 2, 6), while the second includes dell 3, whose upper part begins in a cultivated field, and dell 8, whose upper part ends in a mounded surface. In the third subgroup are dells 2a and 4, which occur on a steep slope.



Map 2: Relief features in the Žibrše hills.

Figure 4: In its upper part, dell 8 starts with a shallow depression (photo) and narrows and deepens farther down (photography Blaž Komac).

4 Recent development of dells

At the bottom of dell 1, we measured the depth of the soil or the weathered debris in six cross-sections. Beneath the soil is red-brown clay or dolomite rubble. In places, the clay, which is poorly permeable for water, is about ten centimeters deep but we usually found it at a depth of forty and fifty centimeters, seldom more. The weathered debris on the bottom at the higher end of the dell is shallower than lower down the dell, the consequence of the transport of clay downwards along the bottom of the dell.

Where there is clay at the bottom of dells, the dells have a convex cross-section. Along the sides of the dells, the clay layer ends in a wedge shape, the consequence of erosion by the water flowing down the slopes. At the junction between the bottom and the slopes, the water joins and to a large degree flows away on the surface but also partly permeates into the weathered debris and flows beneath the surface along the contact with the bedrock, corroding its surface. However, due to the fracturedness of the rock, a small proportion of the water flows in the karstic fashion. Corrosion depends on the quantity of corrosion-active water and is greatest at the contact between the weathered debris and the bedrock at the bottom of the dell where the main subcutaneous water flow is joined by side tributaries from the slopes (Zámbó 1989). This supposition about the corrosion effect of the »accelerated corrosion of combined subcutaneous currents« deepening the dells is also asserted by Gams (2003, 39).

Today, the deepening of dells is probably a more important process than their linear transformation. This is proven by the more rapid deepening of dells with a large catchment area compared with dells that have smaller catchment areas and by the existence of structural levels at the bottom of dells. In the Žibrše hills, for example, two dells (4 and 8) with smaller catchment areas overhang the system of interlinked dells. They remained in a higher position than the other dells and are separated from them by an almost four-meter high step. The convexity in the lower section of their long profiles indicates that denudation processes did not follow the deepening of the other dells or that its deepening occurred quickly. Presuming that

Figure 5: Above dell 1 (background), the convex bend in the lower part of dell 4 appears at the foreground of the photograph (photography Blaž Komac).

Figure 6: The bottom of a dell is the deepest at the contact with the slopes, as we can see in the foreground (photography Blaž Komac).

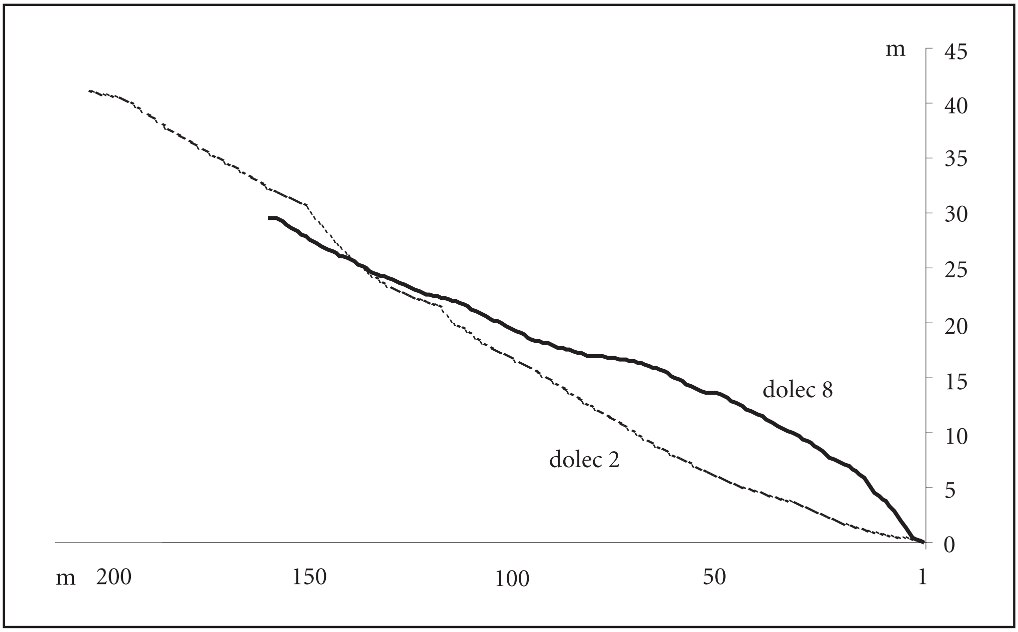


Figure 7: Comparison of the profiles of dells 2 and 8, the latter being characterized by convex lower sections (Distances are expressed in meters).

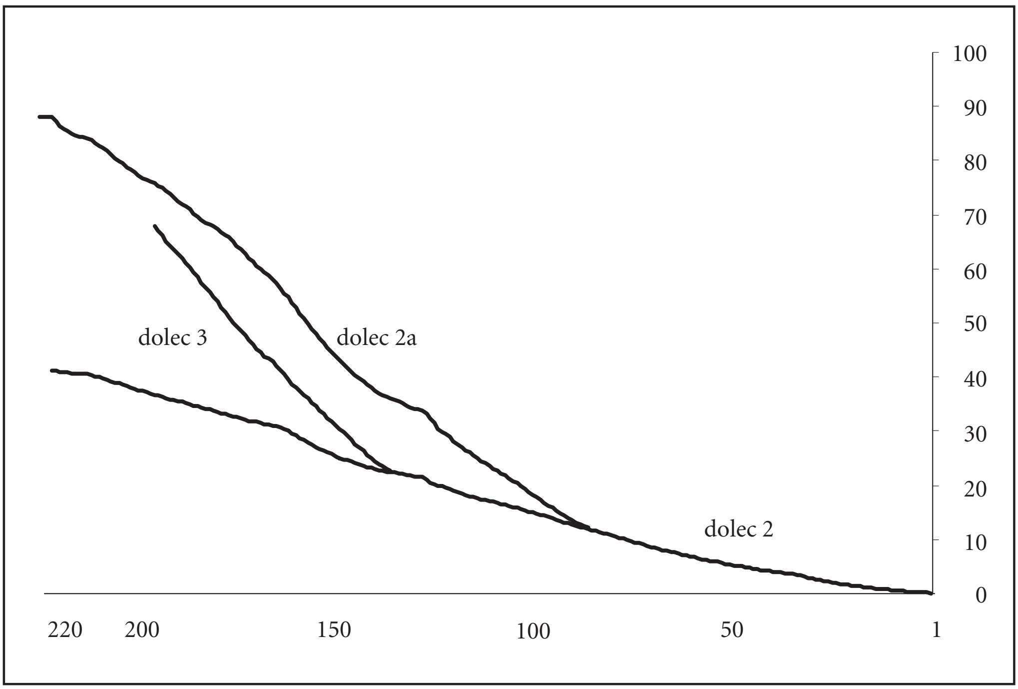


Figure 8: Comparison of the long profiles of dells 2a and 3 that meet the bottom of the longer dell 2. The difference in the slope of dell bottoms most probably arose from different extension of cathcment areas, lithological-tectonical structure and intensity of geomorphic processes. Distance is expressed in meters.

corrosion was focused primarily on the bottom of the dells, such a step could have been formed in the Holocene. We did not find any proof of the possible influence of lithological or structural differences on the development of this relief form.

5 Water conditions and intensity of corrosion

Karst dolomite land is an important water collector (Verbovšek 2003). The hydrogeographical properties of dolomite depend on its fracturedness, the location of dolomite in relation to other lithological units, the production of rubble by weathering, and the relief (Zogović 1966).

In the Žibrše hills, a spring developed at Doline at the junction of three dells close to the contact between the dolomite and the less permeable marl. The fault running along the bottom of the dell also contributed to its location.

The water from the upper parts of the Žibrše hills collects in numerous springs that feed the Žejski potok, Hotenjka, Črni potok, and Reka streams and also feeds the Ljubljanica River, the Podroteja stream, and Divje jezero lake. The Žejski potok, Hlevišarka, and Hotenjka streams flood the Hotenjsko polje while the Reka, into which water flows from the spring at Doline along the Gričarska grapa ravine, causes flooding in Logatec (Gospodarič and Habič 1976; Mihevc 1992).

The annual precipitation in the Žibrše hills amounts to about 1,800 mm, evapotranspiration totals about 600 mm (Kolbezen and Pristov 1998), and the specific outflow is 38 $l/s/km^2$. Habič's (1968) calculations for the nearby Hotenjka stream give a figure of 50 $l/s/km^2$. According to Habič (1970), the usual outflow coefficient on dolomite is 0.5, while in the Žibrše hills it is a higher 0.7, which is probably linked to the inclination of the surface and its northern facing location (Komac 2003).

Figure 9: Due to the deepening of the dells, steep ridges up to several meters high and overgrown with forest formed between them (photography Blaž Komac).

The average volume of flow of the spring (0.2 l/s), considering the specific outflow, indicates that water flows to the spring from an area of about 0.5 hectares. This is a five times smaller area than the area of the bottom of the dells around the spring (2.45 ha) or barely a fortieth of the total outflow from the hypsographically limited area around the spring (23.52 ha). Field observations showed that after heavy precipitation, the water runs off quickly on the surface or just under it, which Habič (1968) and others state is characteristic for dolomite areas. Due to high fracturedness of the rock we did not trace water streams in the weathered debris (*piping*) or found any proof of the subcutaneous washing away of particles.

Magnesium and total hardness are very high due to the completely dolomite surroundings and the unbroken soil blanket. The magnesium hardness (129.1 mg/l) encompasses as much as 51% of the total hardness (251.9 mg/l), while the carbonate hardness is 221.6 mg/l.

Specific electroconductivity is the measurement of ions dissolved in water from which we can deduce the hardness of the water, as well as its pollution. On May 29, 2001, it was relatively high in the Gričarski potok stream, into which water runs from the spring, as the consequence of the high hardness and sulfate content (about 90 mg/l). The specific electroconductivity increases downstream. The spring at Doline had 430–460 μS/cm and a temperature of 9.5–10.2 °C. The daily oscillation in the temperature and electroconductivity is the consequence of the small volume of flow and the shallow water flow in the catchment area of the spring. After 100 meters of flow, we measured 400 μS/cm and 20.9 °C, and at a small spring just beside the stream, 560 μS/cm and 9.6 °C. Below the waterfalls, the electroconductivity dropped due to the deposits of travertine. At the springs from dolomite near Logatec, the specific electroconductivity of the water was similarly high (350–490 μS/cm and 11.3 °C).

Given the value of the specific outflow, around 40 l/s/km^2, and the hardness of the water, we calculated the speed of the corrosion lowering of the surface, which in the Žibrše hills totals 121 m^3/km^2/year or 0.12 mm/year. For the Hotenjka catchment area, Habič (1968, 216) states a value of 126 m^3/km^2/year. These calculated values are some four times higher than the previously mentioned calculations made by Kogovšek and Kranjc (1992), which is probably connected with the fact that the water from dolomite also carries away rock in suspension, that is, in an undissolved form.

6 Red-brown clay on dolomite

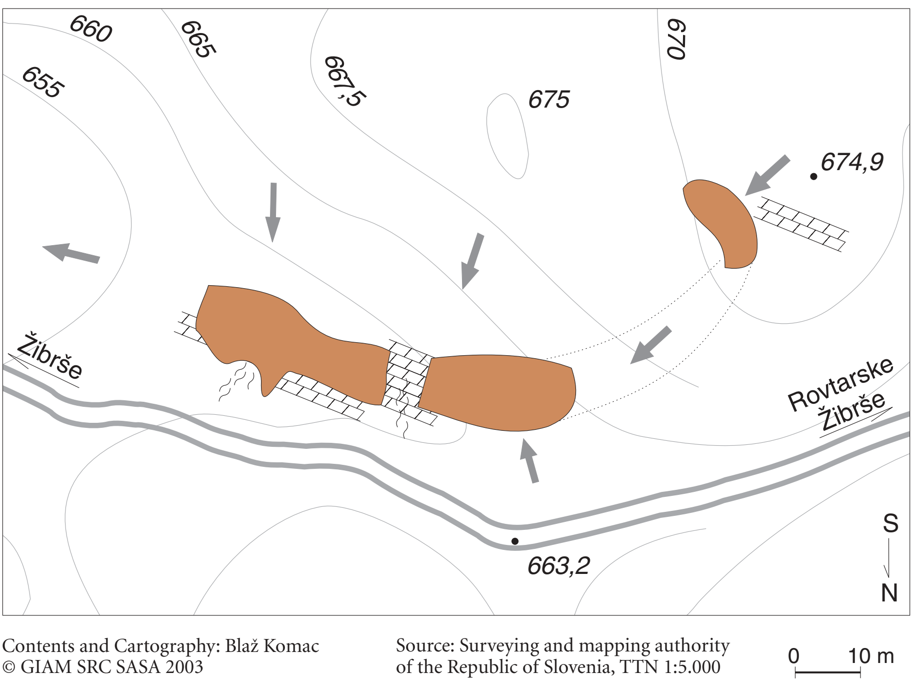
On dolomite areas, red-brown clay frequently covers the surface in an unbroken layer or lies at the bottom of hollows and pockets. In the Dolenjska valley system, for example, it stretches from Šmarje to Trebnje in a flat, half-meter to ten-meter deep and five- to ten-kilometer wide belt. It has not been found farther north. Some speculate that part of this sediment was brought to this area from the Posavje hills and covered the primary red clays, while others speculate that it is Pleistocene sediment, the insoluble remains of the dissolving bedrock. For red-brown clay to occur, a very large amount of rock must have been dissolved (Hrovat 1953; Gregorič 1964; Buser 1974; Habič 1988).

We conclude that the clay originally covered a larger part of the surface because there are individual clay areas in smaller depressions in very diverse locations. While it is found most frequently at the bottom of dells, it is also found in hollows at the top of ridges. Today's locations of clay are most probably the denudational remains of a larger unbroken blanket. Because the clay was subject to solifluction during the colder periods of the Pleistocene, (Fairbridge 1968), it was mostly removed from convex relief forms while remaining in concave forms. From just the morphological features on the surface, we often can not tell whether the foundation is bedrock or clay. Geomorphic processes frequently shape the surface without regard to the properties of its foundation.

We can indirectly judge the thickness of the clay by the vegetation because the vegetation is richer where the clay is thicker. Forest and grass grow on dolomite areas covered with shallow brown soil that has a low retention capability, while on flat surfaces it makes an agricultural soil. In dolomite karst regions, land use and settlement are bound to such areas, which is why there are more meadows, pastures, and to some extent cultivated fields in dolomite areas in Slovenia in comparison with limestone areas. There is also less forest on dolomite than on other carbonate rock (Gabrovec 1995; Roglić 1958).

The *in situ* occurrence of clay indicates an up to 0.5-meter thick clayey transitional belt at the contact with the bedrock containing chunks of weathered rock with a powdery surface. Here, individual minerals have leached from the rock, while others remain in it. Its crystal structure becomes increasingly porous and less stable (see Zupan Hajna 2002). On the surface of the rock particles and in their surrounding, a dust-like coating of corroded rock particles accumulates, which can be removed by rubbing with the fingers and which extends up to 1.5 mm deep in the rock. Chemical weathering is also proven by the corrosion of the strongly dissected subcutaneous surface. The weathering front between the clay and the bedrock indicates the penetration of water along the fissures and small channels that occur through the activities of plants and animals. Otherwise, the clay is not particularly permeable (see Gros 1999).

In a hollow on the Klavžar farm, there was a three-meter thick layer of clay or about 16,000 m^3. Dolomite contains only a small percentage of insoluble material at most. If the rock is homogenous, about 100 m^3 of the rock must dissolve for 2.5 m^3 of clay to occur (Gregorič 1964). If we assume a hypsographical catchment area of 500 m^2 and the equivalent dissolving of 0.12 mm/year, almost 640,000 m^3 of rock would have to dissolve to produce such a quantity of clay, which would take a million years. This is a long period given the significant changes in geomorphological conditions at that time, so we can conclude that the clay was brought into the hollow by denudation, creeping, or solifluction. It is clear that the clay was formed from the insoluble remains of the rock, but without more detailed analyses the question of its local origin or its age remains open.



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Map 3: Red-brown clay in three-meter deep hollows in the shallow upper part of a dell near the Klavžar farm.

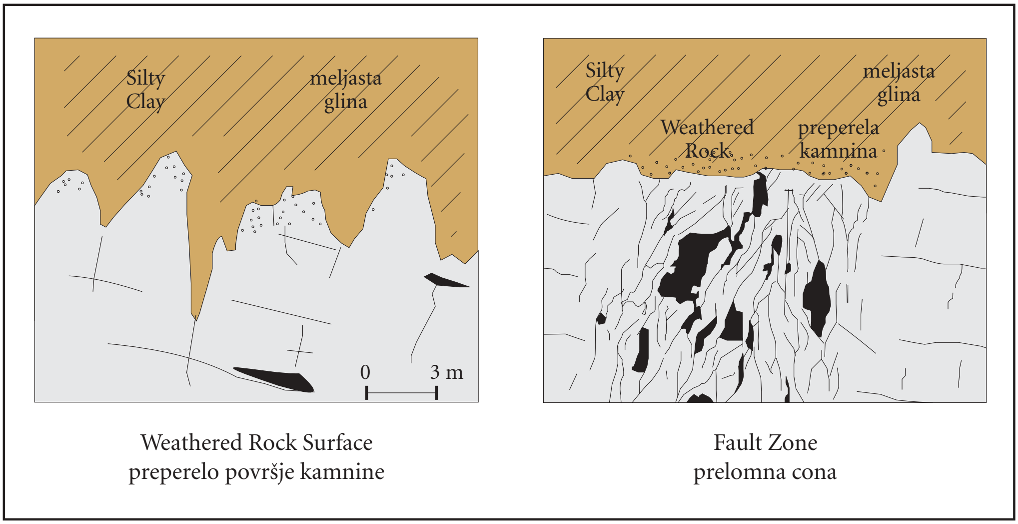

Figure 10: Weathering of dolomite beneath clay.

Figure 11: Shallow soil developed on red-brown clay (photography Blaž Komac).

7 Conclusion

The results of the research indicate the intensive geomorphological transformation of dolomite areas. On gently sloping relief with thicker layers of clay or soil, corrosion plays an especially important role, while on steep dolomite hillslopes with shallow soil, denudation and erosion dominate. Corrosion is an important process at the bottom of dells and other hollows. The geomorphological effect of individual processes depends on the lithological properties of the rock, the fracturedness of dolomite, and the location of individual relief feature in the geomorphological system. The dells in the Žibrše hills originated along faults and less resistant lithological units composed of marl, schistose marl, and schistose claystone.

The dolomite surface with dells in the Žibrše hills is organized in an asymmetric treelike system. The intensity of the transformation of individual parts of the surface is very diverse and depends on the lithological and structural conditions. Denudation is intensive primarily in places where the rock is fractured and not covered thickly with vegetation. One-year measurements of the denudation on the steep, bare, fractured dolomite in the Žibrše hills indicated a low degree of denudation (12 t/ha). The low value is most probably the consequence of the (too) small size (1.5 m^2) of the measuring site. The denudation mainly occurs during rains and the thawing of the frozen surface. In the observation period, 26.3 kg of material accumulated in the measurement field, or about 25 g/m^2 per »precipitation event.« Simultaneous measurements done at the larger (45 m^2) measurement field in the Polhov Gradec Hills indicated a greater intensity of geomorphological processes on steep dolomite slopes (175 t/ha/year; Komac 2003).

Measurements and geomorphological analyses indicate that in the Žibrše hills, corrosion is a more important process than denudation or erosion. Corrosion is important at the bottom of dells and on less dolomitized areas. Along with numerous small karst springs, doline-like surfaces that developed because the dolomite is only fissured and not fractured also reflect karstification. Dolines developed at the contact between two fissured zones. It appears that the morphology of the wider surroundings influences the karstification of dolomite and karst phenomena (Zogović 1966). Dolines occurred at bends in the surface where the ridge turns into a steep slope above the valley of the Reka stream.

Figure 12: In the background are two dells cut into the hillslope surface by denudation that occurred beneath the ridge. The origin of the hillslope terrace is probably linked to lithological factors since rock strata run across the hillslope (photography Blaž Komac).

8 References

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1 Uvod

Dolomit na Slovenskem prekriva 2500 km^2 ali 11,7 % državnega ozemlja. Večinoma je nastal z dolomitizacijo apnenca. Stratigrafsko razlikujemo dvanajst vrst, najpogostejši je mezozojski oziroma triasni dolomit. Delež dolomitnih območij je največji na dinarskem krasu, kjer obsega petino površine ter v alpskih in predalpskih pokrajinah, kjer obsega šestino površine. Dolomitni relief je raznolik. V alpskih pokrajinah so pogoste stene in strma dolomitna pobočja z erozijskimi jarki. V Sloveniji je pogost relief z dolci, malo pa je na dolomitu kraškega površja (Gabrovec 1994).

Pogosta so prehodna območja z značilnostmi rečno-denudacijskega in kraškega površja, za katere se je uveljavil izraz fluviokras, ki z genetskega vidika ni primeren.

Žibrše ležijo na stiku Rovtarskega hribovja na severu in Notranjskega podolja na jugu. Sleme obdajata dolini Reke na vzhodu in Žejskega potoka na zahodu. Južni del slemena, imenovanega po kraju blizu Logatca, gradi glavni dolomit.

Relief je zanimiv zaradi strukturne zgradbe oziroma bližine idrijskega preloma, prehodnosti litološke zgradbe oziroma menjavanja dolomita z laporovcem, hidrogeografskih značilnosti in pestrosti geomorfnih procesov. Raziskave so potrdile nesporno geomorfno vlogo vode oziroma na spremenljivo razmerje med erozijsko-denudacijskimi procesi in korozijo. Nekatere značilnosti dolomitnega reliefa kažejo, da je korozija danes pomembnejši oblikotvorni proces kot erozija oziroma denudacija. Na njeno intenzivnost vpliva tudi rdeče-rjava ilovica, ki je na Žibršah ohranjena v dnu kotanj in dolcev. Dolci so značilna reliefna oblika na slemenu, v njena pobočja pa so vrezane številne grape. Na Žibršah so vrtače redka oblika z izjemo zgornjega dela pobočij nad dolino Reke.

Poleg geomorfnih razmer in značilnosti kamnine vpliva na razvoj površja tudi tektonika. Vzdolž prelomov je kamnina razpokana in zdrobljena. Pretrt dolomit je manj prepusten, na njem je nastal rečno-denudacijski relief. Razporeditev dolcev je odvisna od poteka notranjih con prelomov.

Slika 1: Dno dolca 2 preide v pobočje v ostrem pregibu (fotografija Blaž Komac).
Glej angleški del prispevka.

Slika 2: Dolci na Žibršah so globoki nekaj metrov (fotografija Blaž Komac).
Glej angleški del prispevka.

2 Geomorfni procesi in reliefne oblike na dolomitu Žibrš

Žibrše ležijo v južnem delu Rovtarskega hribovja, kjer prihaja na površje skladovit karnijski in norijski glavni dolomit, ki je zgoraj svetlejši, spodaj pa vsebuje rjav ali siv dolomitni laporovec. Ozemlje pripada idrijsko-žirovski narivni zgradbi, za katero je značilnih več obsežnih narivov oziroma pokrovov. Na tem območju potekajo starejši prelomi v smeri SV–JZ, mlajši pa so zmični SZ–JV smeri. Vzdolž njih so bili posamezni bloki vertikalno premaknjeni (Mlakar 1969; Gospodarič 1987).

Dolomit je kot karbonatna kamnina podvržen kemičnemu preperevanju, zaradi poroznosti, plastovitosti in pretrtosti pa tudi fizikalnemu preperevanju. Proces je bil intenziven v hladnih obdobjih pleistocena, v Sloveniji je danes omejen na višje lege (Šifrer 1963; Kunaver 1990) in območja močno pretrtega dolomita. V hladnih obdobjih pleistocena so na Žibršah (725 m) vladale periglacialne razmere. Denudacijski procesi so sproti odstranjevali preperelo kamnino, kar je razkrilo kamninsko oziroma strukturno zgradbo. Nastali so dolci in denudacijske zajede, pod slemenom pa vršaji (prim. Šifrer 1990).

V današnjih razmerah površje preoblikuje kemično preperevanje, ki mu je dolomit podvržen zaradi zdrobljenosti. Meritve trdote vode in pretoka potoka Predvratnica pri Velikih Laščah so pokazale 74 t $CaCO_3$ letne korozije med ponorom v jamo Vratnico in 1150 m oddaljenim izvirom v Pečeh. Voda v enem letu raztopi povprečno 27,4 m^3 kamnine oziroma v raztopini odnese 65 mg/l karbonatov (Kogovšek in

Kranjc 1992). Čeprav so vode z dolomitnih ozemelj nasičene ali prenasičene z dolomitom, se ta ne odlaga zaradi počasne kinetike obarjanja oziroma večje kemične mobilnosti napram kalcitu (Lapanje 2000).

Karta 1: Pregledna karta območja.
Glej angleški del prispevka.

Slika 3: Dolec 2a je nastal tik pod slemenom. Povprečni naklon njegovega dna je kar 20° (fotografija Blaž Komac).
Glej angleški del prispevka.

3 Dolec

Dolec (Gabrovec 1994, 1996) oziroma dolek (Gams 1968; Gams in Natek 1981; Gams 2003) je poleg erozijskih žarišč, denudacijskih zajed, sedel, dolomitnih grbin, samotarjev, vrtač in kraških polj značilna oblika dolomitnega reliefa.

Na dolomitu je dolec redko le plitva ulegnina na pobočju. Pogosto je podolgovata, ozka in globoka, dolini podobna reliefna oblika, ki se zgoraj začne s plitvo ulegnino, navzdol pa se širi in poglablja. Je do nekaj sto metrov dolg in največ nekaj deset metrov globok. Je brez stalnega površinskega vodnega toka. Navzdol lahko preide v grapo s stalnim vodnim tokom, kar kaže na tesno odvisnost oblikovanja površja od hidrogeografskega razvoja na manj prepustnih karbonatnih kamninah (Brenčič 2003). Dolec lahko tudi obvisi nad strmim pobočjem ali se izteče v ravnini. Pod bližnjim Ravnikom dolci na stiku z apnencem prehajajo v vrtače (Mihevc 1986). V prečnem prerezu je konkaven, dno zvezno prehaja v strmo pobočje. Zaradi obdelave je dno uravnano in preide v pobočja v izrazitem pregibu. Ponekod so dno dolca pregradili s kamnitimi zidovi in tako dobili nekaj ravne površine.

Dolec je reliefna oblika, ki je značilna za dolomit. Ker njegova geneza še ni bila pojasnjena, moramo previdno, z zadržkom uporabljati primerljive izraze, kot sta *dell (dry valley)* v angleškem jeziku ali *die Delle (die Tilke, das Muldentälchen)* v nemškem jeziku. Ustaljena raba omenjenih tujih ustreznikov namreč opisno in genetsko določa reliefno obliko. Velja poudariti, da se zaradi dolec genetsko, zato pa tudi morfološko, do neke mere razlikuje od podobnih reliefnih oblik, ki so v periglacialnih razmerah nastale na granitu, apnencu, kredi, laporovcu, puhlici, prodnih terasah ali glini.

Ugotavljajo, da ta reliefna oblika ni nastala z delovanjem tekoče vode ali vetra, temveč s periglacialnimi procesi, zamrzovanjem in odtaljevanjem. Poglavitni reliefotvorni procesi pri nastanku dolca so periglacialni procesi, zlasti pluvialno-snežna erozija, snežna erozija in soliflukcija. Pomembna naj bi bila zlasti *erozija snežnih krp* oziroma *nivacija* (angleško *nivation* oziroma *snow patch erosion*), ki pomeni preperevanje kamnine v okolici krpe snega zaradi izmeničnega zmrzovanja in odtaljevanja kamnine, prodiranja vode v globino in nastanka lednih klinov v kombinaciji s pobočnimi procesi (Fairbidge 1968, 774).

Dolec nastaja v dveh fazah. Najprej pride do začetnega poglabljanja površja, ki mu sledita denudacija in odlaganje gradiva pod pobočji oziroma v dnu dolcev. V vmesnih toplejših obdobjih ga ob taljenju snega oblikuje tudi površinska tekoča voda. Na nastanek in razvoj dolca vplivajo tudi relativna višinska razlika območja, velikost zaledja oziroma dolžina dolca in dolžina njegovih pobočij (Fairbridge 1968, 251). Soliflukcija lahko poteka že pri 2 stopinjah naklona, pri 6 stopinjah pa nastopi intenzivno odnašanje gradiva, zlasti soliflukcija, intenzivni pa sta tudi denudacija in erozija na njivah (Demek s sod. 1972).

Na Žibršah so dolci med seboj povezani v asimetrično razvejen dendritični sistem, kar kaže na nastanek z linearnimi geomorfnimi procesi. Na dolgotrajnost njihovega oblikovanja oziroma na intenzivnost procesov sklepamo po veliki širini in globini dolcev v primerjavi z vmesnimi hrbti. V dolcih ni sledov erozije površinskih vodnih tokov. Na travnatem dnu se ob intenzivnih padavinah pojavi nekoncentriran vodni tok, ki na dovolj nagnjenih površinah odnaša prst. Dno dolcev je zgoraj strmo s konveksnim vzdolžnim prerezom. Naklon dna se navzdol zmanjšuje, zato dno postaja v vzdolžnem prerezu rahlo konkavno. Takšen vzorec se pojavlja ne glede na to, kje v sistemu je dolec.

Preperevanje in denudacija sta v hladnejših podnebnih razmerah hitro preoblikovala relief. Na dolomitnih območjih je prišla do izraza spremenljiva odpornost kamnine v odvisnosti od strukturne in litološke zgradbe. Zgornjetriasni dolomit se poliedrično kroji in je vzdolž prelomov pretrt, pretrtost pa zmanjša prepustnost in odpornost. Dolomitno površje na Žibršah je prekrito s prstjo in preperino, zato o poteku prelomov in stopnji pretrtosti kamnine lahko sklepamo le iz usmerjenosti razpok v bližnjih izdankih. Kamninske plasti vpadajo proti jugozahodu z naklonom od 20 do 40 stopinj, kar lahko opazujemo le v razpoklinski coni. Veliko globino dolca na dolomitu pri nas v primerjavi z dolcem, ki ga drugje opisujejo kot tipičnega (Fairbridge 1968), lahko razlagamo z njegovo dobro ohranjenostjo zaradi relativno odpornejšega dolomita in korozijo v njegovem dnu.

Preglednica 1: Število z 1,5 m dolgim pantometrom izmerjenih razdalj na posameznih prerezih glede na naklon površja, povprečni naklon dna dolca, najnižji in najvišji izmerjeni naklon, dolžina prereza v metrih. Prereza 5 in 7 sta prečna, ostali vzdolžni.

naklon v stopinjah	Prerez 1	Prerez 2	Prerez 2a	Prerez 3	Prerez 4	Prerez 6	Prerez 8	Prerez 5	Prerez 7	delež meritev (%)
0–4,9	88	41	1	10	3	94	47	7	5	28,82
5–9,9	82	146	3	32	8	2	102	8	4	37,68
10–14,9	32	21	16	44	17	1	9	8	8	15,19
15–19,9	20	7	7	18	17	0	8	1	0	7,59
20–24,9	15	1	13	23	5	0	3	3	2	6,33
25–29,9	3	0	17	3	5	0	0	0	0	2,73
30–34,9	1	0	2	2	5	0	0	0	1	1,07
35–39,9	0	0	2	0	2	0	0	0	0	0,39
40–44,9	2	0	0	0	0	0	0	0	0	0,19
Povprečni naklon dna dolca	8,56	6,91	20,13	10,97	16,94	8,6	6,39	11,65	14,58	11,64
Najnižja vrednost	0,0	0,0	1,5	0,0	3,5	0,0	0,0	0,0	0,0	0,56
Najvišja vrednost	41,0	21,0	39,0	36,5	36,5	32,0	22,0	26,5	42,0	32,94
Dolžina prereza v metrih	364,5	334,5	91,5	210,0	93,0	234,0	262,5	109,5	94,5	SKUPAJ 1794 m

Večina dolcev na Žibršah je usmerjena vzdolž prelomov oziroma pretrtih con, kjer potekata korozija in denudacija, morebiti tudi podzemno spiranje delcev. Na sečiščih prelomov, večji so večinoma dinarske usmerjenosti, so nastale kotanje in sedla. Vzdolž prelomov potekajo tudi grape, erozijski žlebovi in sedla.

Nekateri dolci so usmerjeni glede na stratigrafsko zgradbo in se ravnajo po manj odpornih nekajdecimetrskih do nekajmetrskih plasteh laporovca, skrilavega laporovca in skrilavega glinavca. Kjer je preperevanje manj intenzivno, odnašanje pa je še vedno močnejše kot v okolici, nastane kotanjasto–grbinast relief. V grbinasto površje se v zgornjem delu iztečejo tudi nekateri dolci. Značilno je, da se manjše grbine ravnajo po plastovitosti oziroma litostratigrafski zgradbi, večje pa sledijo prelomnim strukturam.

Slika 4: Dolec 8 se zgoraj začenja s plitvo ulegnino (na fotografiji), navzdol pa se oži in poglablja (fotografija Blaž Komac).
Glej angleški del prispevka.

Dolce na Žibršah lahko glede na naklone njihovega dna razvrstimo v dva razreda. V prvega spadajo dolci 1, 2, 6, 8, 3, 2a, 4, v drugega pa 5, 7. Razvrstitev, opravljena z Wardovo metodo in računalniškim orodjem *SPSS*, ki podobnost računa s kvadratom evklidske razdalje, je pričakovana, saj sta prereza 5 in 7 prečna, ostali pa podolžni. Podolžne prereze smo na isti način razvrstili v dva razreda, v prvem so daljši dolci (1, 2, 6), v drugem dolec 3, ki se zgoraj začne z njivo, in dolec 8, ki se zgoraj izteče v grbinasto površje. V tretji skupini sta dolec 2a in dolec 4, ki sta na strmem pobočju.

Karta 2: Reliefne oblike na Žibršah.
Glej angleški del prispevka.

4 Recentni razvoj dolcev

V dnu dolca 1 smo v šestih prečnih prerezih izmerili globino prsti oziroma preperine. Pod prstjo sta rdeče-rjava ilovica ali dolomitni grušč. Ponekod je ilovica, ki slabo prepušča vodo, že v globini 10 cm, običajno pa nanjo naletimo v globini med 40 in 50 cm, redkeje globlje. V višjih legah v dnu dolca je preperina plitvejša kot nižje, kar je posledica transporta ilovice po dnu dolca navzdol. Kjer je v dnu dolca ilovica, ima dolec v prečnem prerezu konveksno obliko. Ilovnata plast se namreč na stiku dna s pobočji izklini, kar je posledica spiranja vode, ki doteka po pobočjih. Voda se na stiku dna in pobočij združuje in v večji meri površinsko odteka, deloma pa ponikne v preperino in odteka pod površjem vzdolž stika s kamnino. Zaradi pretrtosti kamnine le manjši del vode odteka kraško. Korozija je odvisna od količine korozijsko aktivne vode in je največja na stiku preperine in matične kamnine na dnu dolca, kjer se poglavitnemu podtalnemu vodnemu toku po dnu dolca pridružijo stranski dotoki s pobočij (Zámbó 1989). Opisano predpostavko o korozijskem učinku 'pospešene korozije podtalnega združenega toka' zagovarja tudi Gams (2003, 39).

Slika 5: Nad dolcem 1 (zadaj) je na fotografiji v ospredju konveksen pregib v spodnjem delu dolca 4 (fotografija Blaž Komac).
Glej angleški del prispevka.

Slika 6: Dno dolca je najgloblje na stiku s pobočjem, kar vidimo v ospredju fotografije (fotografija Blaž Komac).
Glej angleški del prispevka.

Danes je poglabljanje dolcev najverjetneje pomembnejši proces kot njihovo linearno preoblikovanje. To dokazujeta hitrejše poglabljanje dolcev z večjim zaledjem v primerjavi z dolci, ki imajo manjše zaledje, in obstoj strukturnih stopenj v dnu dolcev. Na Žibršah sta na primer dva dolca (dolec 4 in dolec 8) z manjšim zaledjem obvisela nad omenjenim sistemom med seboj povezanih dolcev. Od preostalih dolcev ju loči približno štiri metre visoka stopnja. Konveksni spodnji del kaže na to, da denudacijski procesi niso sledili poglabljanju dolca oziroma je to potekalo hitro. Če predpostavimo, da bi bila korozija osredotočena predvsem na dna dolcev, bi takšna stopnja lahko nastala že v holocenu. Dokazov o morebitnem vplivu litoloških ali strukturnih razlik na takšen razvoj reliefa nismo ugotovili.

Slika 7: Primerjava prerezov dolca 2 in dolca 8, za katerega je značilen konveksen spodnji del (Razdalje so prikazane v metrih).
Glej angleški del prispevka.

Slika 8: Primerjava vzdolžnih prerezov daljšega dolca 2 ter dolcev 2a in 3, ki se iztekata vanj. Razlika v naklonih dna dolcev je najverjetneje posledica različne velikosti zaledja dolcev, litološko-tektonske zgradbe in intenzivnosti geomorfnih procesov. Razdalje so v metrih.
Glej angleški del prispevka.

5 Vodne razmere in intenzivnost korozije

Kraška dolomitna ozemlja so zelo pomemben vodni kolektor (Verbovšek 2003). Hidrogeografske lastnosti dolomita so odvisne od pretrtosti, lege dolomita napram drugim litološkim členom, produkcije grušča s preperevanjem in od reliefa (Zogović 1966).

Na Žibršah je v Dolinah nastal izvir na stiku treh dolcev in blizu stika med dolomitom in slabše prepustnim laporovcem. K njegovi legi je pripomogel tudi prelom, ki poteka po dnu dolca.

Voda z ovršja Žibrš se sicer zbira več izvirih, ki se združijo v Žejskem potoku, Hotenjki, Črnem potoku in Reki, napaja pa tudi Ljubljanico, Podrotejo in Divje jezero. Žejski potok s Hlevišarko in Hotenjko poplavlja Hotenjsko polje, Reka, v katero po Gričarski grapi odteka voda iz izvira v Dolinah, pa povzroča poplave v Logatcu (Gospodarič in Habič 1976; Mihevc 1992).

Na Žibršah pade letno približno 1800 mm padavin, evapotranspiracija pa znaša približno 600 mm (Kolbezen in Pristov 1998). Specifični odtok znaša približno 38 l/s/km^2. Habičev (1968) izračun za bližnjo Hotenjko daje vrednost 50 l/s/km^2. Po Habiču (1970) je odtočni količnik na dolomitu 0,5, na Žibršah pa je višji (0,7), kar je verjetno povezano z naklonom površja in s severno ekspozicijo (Komac 2003).

Povprečen pretok izvira (0,2 l/s) ob upoštevanju specifičnega odtoka kaže, da naj bi voda pritekala v izvir s približno 0,5 ha velikega območja. To je pet krat manjša površina, kot je površina dna vseh dolcev

(2,45 ha) ali komaj štiridesetina skupnega odtoka (9 l/s) s hipsografsko omejenega zaledja izvira (23,52 ha). Terenska opazovanja so pokazala, da voda po nalivih hitro odteče po površju ali tik pod njim, kar ugotavljajo za dolomitna območja že drugi avtorji (Habič 1968). Zaradi pretrtosti kamnine v dolcih nismo zasledili vodnih tokov v preperini (*piping*) oziroma dokazov za podtalno spiranje delcev.

Magnezijeva in skupna trdota sta zelo visoki zaradi povsem dolomitnega zaledja in sklenjene odeje prsti. Magnezijeva trdota (129,1 mg/l) obsega kar 51 % skupne trdote (251,9 mg/l), karbonatna trdota pa je 221,6 mg/l.

Specifična elektroprevodnost je mera v vodi raztopljenih ionov in po njej lahko sklepamo na trdoto vode, pa tudi na njeno onesnaženost. Dne 29. 5. 2001 je bila v Gričarskem potoku, v katerega se steka voda iz izvira, razmeroma visoka, kar je posledica visoke trdote in vsebnosti sulfatov (približno 90 mg/l). Specifična elektroprevodnost po toku navzdol narašča. Izvir v Dolinah je imel 430–460 μS/cm in temperaturo 9,5–10,2 °C. Dnevno nihanje temperature in elektroprevodnosti je posledica majhnega pretoka in plitvega zaledja izvira. Po 100 m toka smo namerili 400 μS/cm in 20,9 °C, v manjšem izviru tik ob strugi pa kar 560 μS/cm in 9,6 °C. Pod slapovi je elektroprevodnost upadla zaradi odlaganja lehnjaka. Podobno visoka je bila specifična elektroprevodnost vode v izvirih iz dolomita pri Logatcu (350–490 μS/cm in 11,3 °C).

Glede na vrednost specifičnega odtoka približno 40 $l/s/km^2$ in trdoto vode smo izračunali hitrost korozijskega zniževanja površja, ki znaša na Žibršah 121 m^3/km^2/leto (0,12 mm/leto). Za porečje Hotenjke navaja literatura 126 m^3/km^2/leto (Habič 1968, 216). Izračunane vrednosti so kar štirikrat višje od že omenjenih izračunov Kogovškove in Kranjca (1992), kar je morda povezano z dejstvom, da voda z dolomita odnaša kamnino tudi v suspenzijski, to je neraztopljeni obliki.

Slika 9: Zaradi poglabljanja dolcev so med njimi nastali strmi, do nekaj metrov visoki hrbti, ki jih prerašča gozd (fotografija Blaž Komac).
Glej angleški del prispevka.

6 Rdeče-rjava ilovica na dolomitu

Na dolomitnih območjih je pogosta rdeče-rjava ilovica, ki pokriva površje v sklenjeni plasti ali pa je ostala le v dnu kotanj in žepov. V Dolenjskem podolju se na primer razprostira od Šmarja do Trebnjega v ravnem, 0,5–10 m globokem in 5–10 km širokem pasu. Severneje je ne najdemo. Nekateri domnevajo, da je bila deloma na to območje prenesena s Posavskega hribovja in je prekrila primarne rdeče gline. Drugi menijo, da gre za netopni ostanek pri raztapljanju matične kamnine pleistocenske starosti. Za nastanek rdeče-rjave ilovice je morala biti raztopljena velika količina kamnin (Hrovat 1953; Gregorič 1964; Buser 1974; Habič 1988).

Karta 3: Rdeče-rjava ilovica v 3 m globokih kotanjah v plitvem zgornjem delu dolca pri kmetiji Klavžar.
Glej angleški del prispevka.

Sklepamo, da je ilovica prvotno prekrivala večji del površja, saj so posamezna ilovnata območja v manjših kotanjah v zelo različnih legah. Najpogostejša je v dnu dolcev, najdemo pa jo tudi v kotanjah na vrhu slemen. Današnja nahajališča ilovice so najverjetneje denudacijski ostanek večje sklenjene odeje. Ker je bila ilovica v hladnih obdobjih pleistocena podvržena soliflukciji (Fairbirdge 1968), je bila s konveksnih reliefnih oblik večinoma odstranjena, v konkavnih pa se je lahko ohranila. Zgolj po morfoloških značilnostih na površju pogosto ne moremo sklepati, ali je v podlagi matična kamnina ali pa ilovica. Geomorfni procesi površje pogosto preoblikujejo ne oziraje se na lastnosti podlage.

O debelini ilovice pa lahko sklepamo posredno, saj je rastje bujnejše, kjer je ilovica debelejša. Sicer dolomitna območja prekriva plitva rendzina, ki ima nizko retencijsko sposobnost in jo na strmih pobočjih poraščata gozd in trava, na ravnem površju pa je poljedelska prst. Na dolomitnem krasu se na takšna območja vežeta kmetijska raba zemljišč in poselitev, zato je v Sloveniji na dolomitnih območjih v primerjavi z apnenčastimi ozemlji več travnikov, deloma tudi njiv. Manj kot na drugih karbonatnih kamninah je na dolomitu le gozdov (Gabrovec 1995; Roglić 1958).

Na *in situ* nastajanje ilovice kaže do 0,5 m debel prehodni pas na stiku s kamnino. V njem so kosi preperele kamnine s porozno površina zaradi izluževanja mineralov, povečane poroznost in zmanjšane stabilnost kristalne strukture kamnine (prim. Zupan Hajna 2002). Na površini kamninskih delcev nastaja do 1,5 mm debela plast preperele kamnine. Kemično preperevanje dokazuje tudi korozijsko močno razčlenjeno subkutano površje. Voda doteka pod površje po razpokah v ilovici in cevčicah, ki nastanejo z delovanjem rastlin in živali. Sicer je ilovica slabo prepustna (prim. Gros 1999).

Slika 10: Preperevanje dolomita pod ilovico.
Glej angleški del prispevka.

V kotanji pri Klavžarju je bilo približno 16.000 m^3 ilovice. Ob nekaj odstotkih netopnih snovi v kamnini in predpostavljeni homogenosti, bi se moralo raztopiti približno 100 m^3 kamnine, da bi nastalo 2,5 m^3 ilovice (Gregorič 1964). Raztapljanje ustrezne količine kamnine bi ob predpostavljenih 500 m^2 hipsografskega zaledja in ekvivalentu raztapljanja 0,12 mm/leto trajalo kar milijon let. To je dolgo obdobje glede na občutne spremembe geomorfnih razmer v tem času, zato lahko sklepamo, da je ilovica bila prenesena v kotanjo s polzenjem ali soliflukcijo. Jasno je, da je ilovica nastala iz netopnega ostanka kamnine, vendar brez natančnejših analiz ostaja odprto vprašanje njenega krajevnega izvora oziroma starosti.

Slika 11: Na rdeče-rjavi ilovici je nastala plitva prst (fotografija Blaž Komac).
Glej angleški del prispevka.

7 Sklep

Rezultati preučevanj kažejo na intenzivno geomorfno preoblikovanje dolomitnih območij. Na položnem reliefu z debelejšo plastjo ilovice ali prsti je pomembna zlasti korozija, na strmih dolomitnih pobočjih s plitvo prstjo pa prevladujeta denudacija in erozija. Korozija je pomemben proces v dnu dolcev in drugih kotanj. Geomorfni učinek posameznega procesa je odvisen od litoloških značilnosti kamnine, od pretrtosti dolomita in lege posamezne reliefne oblike v geomorfnem sistemu. Dolci so na Žibršah nastali vzdolž prelomov in manj odpornih litoloških členov (lapornati dolomit, laporovec).

Dolomitno površje z dolci na Žibršah je organizirano v obliki dendritične mreže. Intenzivnost preoblikovanja posameznih delov površja je zelo raznolika ter odvisna od litoloških in strukturnih razmer. Denudacija je intenzivna predvsem na mestih, kjer je kamnina pretrta in ni porasla z rušo. Enoletne meritve odnašanja gradiva na strmem neporaslem pretrtem dolomitu na Žibršah so pokazale nizko odnašanje (12 t/ha). Nizka vrednost je najverjetneje posledica premajhne velikosti merilnega polja (1,5 m^2). Odnašanje večinoma poteka ob padavinah in odtaljevanju zamrznjenega površja. V času opazovanj se je v merilnem polju nabralo 26,3 kg gradiva, oziroma približno 25 g/m^2 na ‘padavinski dogodek’. Istočasne meritve na 45 m^2 velikem merilnem polju v Polhograjskem hribovju so pokazale večjo intenzivnost geomorfnih procesov na strmih dolomitnih pobočjih (175 t/ha/leto; Komac 2003).

Meritve in gemorfološke analize kažejo, da je na Žibršah korozija pomembnejši proces od denudacije oziroma erozije. Korozija je pomembna v dnu dolcev in na manj dolomitiziranih območjih. Na zakrasevanje kaže poleg številnih manjših kraških izvirov tudi vrtačasto površje, ki je nastalo, kjer je dolomit zgolj razpokan, ne pa pretrt. Vrtače so nastale na stiku dveh razpoklinskih con. Vse kaže, da vpliva na zakraselost dolomita in kraške pojave tudi morfologija njihove širše okolice (Zogović 1966). Vrtače so nastale na pregibu površja, kjer se sleme prevesi v strmo pobočje nad dolino Reke.

Slika 12: V ozadju sta dva dolca, poglobljena v pobočno uravnavo, ki je nastala pod grebenom. Njen nastanek je najverjetneje povezan z litološkimi dejavniki. Kamninske plasti vpadajo v pobočje, od desne proti levi (fotografija Blaž Komac).
Glej angleški del prispevka.

8 Literatura

Glej angleški del prispevka