Karst denudation measurements on North Dalmatian plain using rock tablet method

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Introduction

Weathering processes affect carbonate rocks exposed to natural environment (on surface or buried under soil cover), resulting in formation of different karst morphologies, and controlling surface denudation. It is a key component of the rock cycle that transforms rocks in sediments, soils and/or dissolves minerals to ions, and plays an important role in landforms development and landscape evolution. Different methodological approaches can be used to quantify these processes (e.g., the use of micro-erosion meters on rock surfaces, measuring the concentration of cosmogenic radionuclides on exposed rocks, measuring water hydrochemistry to infer amount of carbonates being dissolved, quantifying the differential erosion on bare-rock surfaces of known age), among which rock tablet method is one of the most comprehensive.

North Dalmatian plain is one of the most emblematic parts of Dinaric karst and its development has been attributed to corrosional planation process. However, it has not been measured locally. Thus, to get an **insight in rock weathering process and** denudation rates in this area we used rock tablets method.

Fig. 1. North Dalmatian plain.

Study site

The study site (43°47’39'' N, 16°00'08'' E; 200 meters above sea level) is located in the Dalmatian region of Croatia (Fig. 1A), within Krka National park. It is a part of Sjevernodalmatinska zaravan (North Dalmatian plan), built up from Upper Cretaceous limestones and Eocene limestones and carbonate conglomerates that have been intensively faulted and folded forming structures having Dinaric orientation (i.e., NW–SE) and later levelled over a long period of denudation by corrosion planation in the level of the karst water. Regional tectonics caused uplift to its present state and entrenchment of major allogenic through-rivers. The terrain is dominated by natural rock exposures, with karst features such as karren and kamenitzas developed on the surface.

Calcocambisol on limestone is developed in top of carbonate bedrock and is the most dominant soil type in the area. The depth of this soil varies greatly over small distances, but mostly is shallow (< 35 cm) with large rock outcrops interrupting the continuity of the soil cover. Calcocambisols are silty clayey or clayey soils, characterized by high internal drainage, acid soil reaction and variable humus content depending on land use/vegetation.

Local meteorological conditions are recorded in a station installed in a proximity of study site. Here the mean annual temperature recorded during 2019 was 14.97 °C, while annual amount of precipitation was 1222 mm, having clear seasonal pattern.

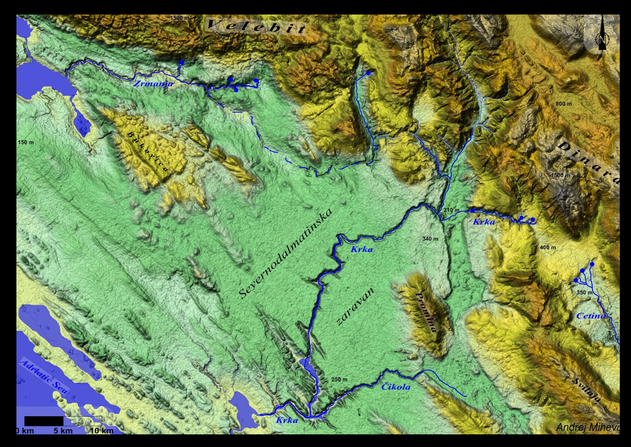

Fig. 2. Digital elevation model of North Dalmatian plain (Mihevc, 2010).

Methodology

55 rock tablets have been exposed to natural environment at the surface, but as well buried in cambic soil profile at 50 cm depth for a period of one year. Actual weathering was measured using rock tablets of local lithologies (i.e., foraminiferal limestone and promina conglomerates), while “standard” Lipica rock tablets were used to measure potential weathering rate.

These circular rock tablets were 30 to 41 mm in diameter, while their thickness varied from 3.3 to 13.9 mm. In order to recreate a rough surface more similar to natural conditions, rock tablets were exposed to 10% HCl solution for 3 min. Preparation of rock tablets also included rinsing in distilled water, cleaning in ultrasonic bath (in distilled water, 2 times per 5 min), drying in laboratory oven for 24 h at 50 °C and weighing on an analytical scale with 10−5 g precision. Upon removal from the oven, tablets were placed in desiccator to cool down in order to minimize possible influence of moisture content prior to weighing.

Rock tablets were placed horizontally in a 0.7 × 0.4 m pit dug up to a depth of 50 cm. The pits was covered back with the original sediment taking care that the surface horizon of the soil was set back as similar as possible to the original conditions. As well, rock tablets were exposed at the surface in horizontal position. All rock tablets were enclosed in elongated (line) mash bag, separated by plastic ties to ease tablet retrieval and identification. Nylon was selected in order to avoid possible interactions between the cord and the tablets affecting their weathering. After investigation period, the tablets retrieved from the field were carefully cleaned following the same procedure (rinsing, cleaning, drying and weighing).
Percentage of weight loss was calculated for all tablets. Denudation rate was calculated according to Krklec et al. (2021), but size correction factor was not applied. To account for the control of inter-sample variability, weathering results from similar lithologies were averaged, differentiating exposure setting.

Fig. 3. Bedrock sampling for rock tablets.

Fig. 4. Rock tablets preparation.

Fig. 5. Setting in the field.

Fig. 6. Rock tablets prior to cleaning.

Fig. 7. Drying of rock tablets.

Results and discussion

Average value of actual weathering rate measured on the surface during one year period were 6.16 μm/a for Promina conglomerates and 6.45 μm/a for foraminiferal limestones. At the same time average potential weathering rate measured using Lipica limestones was slightly higher (3-8%; 6.63 μm/a).

For rock tablets buried in the soil actual weathering rate were 2.68 μm/a for rock tablets made of Promina conglomerates and 1.88 μm/a for those made of foraminiferal limestones. Potential weathering rate measured using Lipica limestones rock tablets was 35-43% higher (3.61 μm/a).

Although, results shown here provide an insight in rock weathering process on North Dalmatian plain, they should not be extrapolated over time or distances since they are site specific.

Actual vs. potential weathering

Results of this study show clear difference between actual and potential weathering rates. Although research of potential weathering is important when comparing weathering rates across in a region or even worldwide, for local studies like one presented here actual weathering rates provide much better estimation of rate of landforms development.

However, due to inter-annual as well as long-term changes of environmental conditions (e.g., climate, soil and vegetation cover) and the complex stress histories of natural rocks, weathering rates are not constant. Therefore, extrapolation of the results over long time periods should be avoided when measuring actual weathering.

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