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HABITAT PREFERENCES ON SOME SOIL-INHABITING *TONINIA* SPECIES WITH SPECIAL ATTENTION TO SOME SOIL-PARAMETERS

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The former *Toninia coeruleonigricans* now represents three almost equally frequent species in Hungary. *Toninia opuntioides*, *T. physaroides* and *T. sedifolia* were investigated in the same locality for comparison of various parameters of their microhabitats. Analysis of variance (ANOVA) was used to test the niche preferences of these species. More than two hundred soil samples were analysed in the respect of six soil parameters. Aspect and slope degree of the microsites, and the abundance of associated bryophyte and lichen species were also studied. ANOVA revealed that there are significant differences between the species in acidity, carbonate content, soil depth, aspect and slope degree.

Key words: habitat preferences, Hungary, terricolous, *Toninia*

INTRODUCTION

In Hungary the cover of vascular plants in open rocky grasslands is usually low, therefore the thalli of mosses and lichens might be dominant and conspicuous (Zólyomi 1942). In open limestone and dolomite grasslands the mosaic of different terricolous lichen species forms a xerothermic association of coloured lichens widely known as "Bunte Erdflechtengesellschaft" (*Fulgensietum fulgentis* or *Toninio-Psoretum decipientis*) (Reimers 1937, Bornkamm 1958, Marstaller 1968, Wirth 1980, Zólyomi 1987). In addition to *Fulgensia fulgens Toninia coeruleonigricans* [sic!] also has a dominant role in this association (Gallé 1977).

A taxonomic revision of the Hungarian *Toninia* species was carried out recently (Farkas and Lőkös 2002). The most frequent species was kept under

Toninia coeruleonigricans (Light.) Th. Fr. earlier and considered to be *T. caeruleonigricans* auct. non (Lightf.) Th. Fr. based on the monograph by Timdal (1991). Due to the revision of about two hundred specimens of this species, now they represent three almost equally frequent species: *T. opuntioides* (Vill.) Timdal, *T. physaroides* (Opiz) Zahlbr. and *T. sedifolia* (Scop.) Timdal. The effect of changes concerning to *Toninia coeruleonigricans* specimens was pointed out in respect of associations of higher plants and cryptogams (Farkas and Lőkös 2003). The main conclusion was that associations containing former *T. coeruleonigricans* need revision in the future.

The habitat preferences of these species are not well known. According to the herbarium data the habitat of the three species is slightly different. All the three species are distributed in the mountain region in Hungary, but only *T. physaroides* is known from the open sandy grasslands of the Great Hungarian Plain where the other two species are missing.

According to Timdal (1991), *Toninia opuntioides* grows on rock and soil, often among mosses, and apparently always associated with cyanolichens when young. It is most frequently found in fissures on rock walls, both exposed and in some shade. *Toninia physaroides* grows mainly on soil or sand in open habitats, often among mosses, and more rarely on rock walls. It is apparently also associated with cyanophilic lichens when young. *Toninia sedifolia* grows on soil and rock, often among mosses, and associated with cyanophilic lichens when young. This last one is the most commonly collected species of the genus, and known from all continents except Antarctica.

Our aim was to investigate habitat preferences of the three species in one locality to exclude the macroclimatic effects. Since these species grow together in some places in Hungary, we choose the study site there. First of all we concentrated on parameters measurements or investigations of which were technically more easily available for us (soil parameters, aspect, slope and associated cryptogams (lichens and bryophytes)), because we think that for soil-inhabiting lichens, parameters of the substrate is quite substantial. Nevertheless we think that climatic – especially microclimatic – conditions also might have an important role, and should be studied later.

MATERIALS AND METHODS

Both fresh material and herbarium specimens collected earlier were investigated from BP and VBI. Hungarian specimens were investigated with special attention for observation of substrate (soil/rock) and original habitat description of collectors. A database of locality data was set up.

In the case of investigation of herbarium specimens, locality descriptions are varied by authors and often contained very few details in the past. We prepared a database to summarise information accumulated on herbarium specimens: elevation, aspect, type of substrate, presence of associated lichen and moss species if mentioned on the labels. We also investigated each specimen to describe if they grow directly on the rock or on soil deposited on rock crevices. Our own observations were also included in the database.

For the soil investigations a study area was selected where all the three species grow naturally close to each other. In this way, the influence of the different land use history, the macroclimate of the different areas was excluded. The study area (Szénás Hills) is located in Buda Hills, ca 20 km NW of the centre of Budapest, in the northern part of Hungary. It belongs to Duna–Ipoly National Park. The sampling sites are situated on S–SW aspect at 450–500 m elevation range. The maximum distance between investigated microsites (where the sampled lichen thalli of the three species occurred) was *ca* 1 km. The climate is characterised by 1,800 hours annual sunshine and 7.5–9.0 °C mean annual temperature. The mean annual rainfall is 650 mm. Years with sub-Mediterranean rainfall are the most frequent. Areas of lower elevation are covered with snow on average 40–45 days, areas of higher elevation on 50–55 days. The prevailing wind is of NW direction similarly with the surrounding areas. The base rock is *Diplopora*-dolomite (Middle Triassic) of weak karst development, due to the warm and dry microclimate. The varied surface and microrelief of the dolomite hills resulted in a microclimate changing within even 2 meters distance. This so-called "dolomite-phenomenon" can be so strong that macroclimatic effects remain in the background of the microclimatic effects (Zólyomi 1942). On the dolomite Pleistocene loess was deposited. The erosion by wind and water are continuous and remarkable, therefore the soil development is arrested at an early stage. The most common soils are thus rendzina, with an AC profile. The bulk (20–60%) of dolomite granules have high (85–95%) [$CaMg(CO_3)_2$] level and it causes a high soil pH (7.4–7.8). The humus content is about 3.3% (in rock cavities it may be higher) (Zólyomi 1958). The vascular vegetation of open rocky grasslands (*Seselio leucospermi-Festucetum pallentis*, *Stipa eriocauli-Festucetum pallentis*) is dominated by *Festuca pallens*, *Stipa* species and *Carex humilis* (Zólyomi 1942).

Sampling was carried out in 2004–2005. For soil investigations at least 10 g samples of soil was necessary to collect at each site for investigating five parameters, but the general soil sample size was bigger (20–30 g). Since *T. opuntioides* often grows directly on rock surface, it is difficult to collect sufficient soil samples under its thalli, especially for hygroscopicity, because its analysis requires larger amount of soil (*ca* 5 g) than investigation of other parameters. Data of hygroscopicity were measured for *T. physaroides* and *T. sedifolia* in more samples, because the amount of soil samples collected under *T. opuntioides* was not enough for the investigation. 20–20 microsites by species were sampled randomly. Small parts of lichen thalli were collected for identification (by microscopic and HPTLC investigations). Aspect, slope degree, soil thickness and the occurrence of bryophyte and lichen species (without further identification) were recorded right at the spot.

Our investigation was carried out following Paus *et al.* (1997). We recorded partly the same parameters. We could analyse smaller amount of soil (a few gram only), because the soil of our investigated area is a shallow rendzina. We decided to investigate the following parameters for each species: six soil variables, such as humus content, carbonate content, acidity, water adsorption capacity (hygroscopicity), thickness, size-distribution of soil-grains, furthermore three substrate and other features, like aspect, slope degree, associated cryptogams (lichens and bryophytes).

For identification of specimens a Zeiss and an Olympus SZX9 stereo dissecting microscope, a Zeiss Ergaval stereo microscope, and a BX50 stereo research microscope was used. Hand sections and squashed samples were investigated in water. For identification the monograph of Timdal (1991) was used. The lichen substances were examined by high performance thin layer chromatography (HPTLC) as described in Arup *et al.* (1993).

Soil investigations were carried out according to the methods detailed in Bellér and Varjú (1986). Soil samples were dried at room temperature for several days. Then they were sifted. For measuring the organic matter content (%) Tyurin method was applied. Soil pH was measured in two different solutions: in soil : distilled water (1 : 5) and in soil : KCl solution (1 : 5). For the electrometric method we used "Corning Checkmate 90" pH meter equipment. For the comparison carbonate content (%) 0.3–0.7 g of soil samples were applied to react with 10% HCl. The volume of produced gaseous CO_2 was measured in a Scheibler calcimeter, the amount of carbonate was calculated from this and expressed as percentage of $CaCO_3$. Carbonate content was also checked in the field applying 10% HCl directly on the rock surface to justify the presence of chalk on the surface of dolomite rock indicating the direction of the water movement. Higroscopicity characterises the water-adsorption capacity of soils. The amount of hygroscopicity was determined by placing soil samples in exsiccator containing 50% sulphuric acid (1.399 g cm^{-3}). After 5 days samples were dried at 105 °C to permanent weight for c. 24 hours. [The value "hy%" is the ratio of the adsorbed water and dry soil (dried at 105 °C)]. Size distribution of soil grains was measured by laser analyser in the Department for Physical Geography, Geographical Research Institute of the Hungarian Academy of Sciences.

Soil depth was measured directly in the field. A large sewing needle was stuck into the soil in right angle to the surface of the lichen thalli (in its approximate centre) reaching the surface of base rock. An elastic band fastened around the needle was adjusted at soil surface among lichen squamules to indicate the thickness of the soil. The distance between the point of the needle and the elastic band was measured in mm. Aspect and slope degree of substrates under thalli were measured by geologist compass of Freiberg.

For data analysis we used analysis of variance (ANOVA) to examine the environmental difference of the three *Toninia* species. Assumptions of the ANOVA were checked byy QQ-plot of residuals. Log-transformation was applied for slope degree data to solve heterogeneity of variances. For the comparison of species pairs we used the Tukey-test. For the statistical analysis and also for checking the assumptions of the test program STATISTICA 7.1 (StatSoft 2005) was applied.

RESULTS

The analysis of the database on herbarium data had tentative or doubtful and insufficient results to mention here. Therefore we concentrate on the results gained in the field and laboratory.

In our investigated area the soil was generally characterised by high calcium carbonate content (18.9–43.6%), high organic matter level (8.5–10.5%) and pH ranging from 7.0–7.7 (measured in distilled water). The microtopography of the area is very variable of different slopes and soil depth. Most of the substrates are south-facing. According to the results there are no differences between the size distributions of soil grains under the three species on the Atterberg scale. The 20–60 µm dimensions are above 40%, revealing that the substrata are loess in all investigated cases.

Significant differences were found between species in acidity (measured in KCl extraction), in carbonate content level, in soil depth and in slope degree of substrata. The organic matter content of soil under *T. sedifolia* (Fig. 1A) seems to be higher than that of the other two species, but due to the high within a species variation, the difference was not significant ($p = 0.088$). Further investigation with higher sample size would be necessary to reveal the possible difference in organic matter content. The mean pH in distilled water was around 7.6 under each investigated *Toninia* species, but significant differences were recorded among species in pH measured in KCl solution. Samples under *T. physaroides* showed higher values than those of the two other species (Fig. 1B). The carbonate content was the lowest under *T. sedifolia* (18.9±7.9%) and the highest under *T. opuntioides* (43.6±6.6%) (Fig. 1C). For the examination

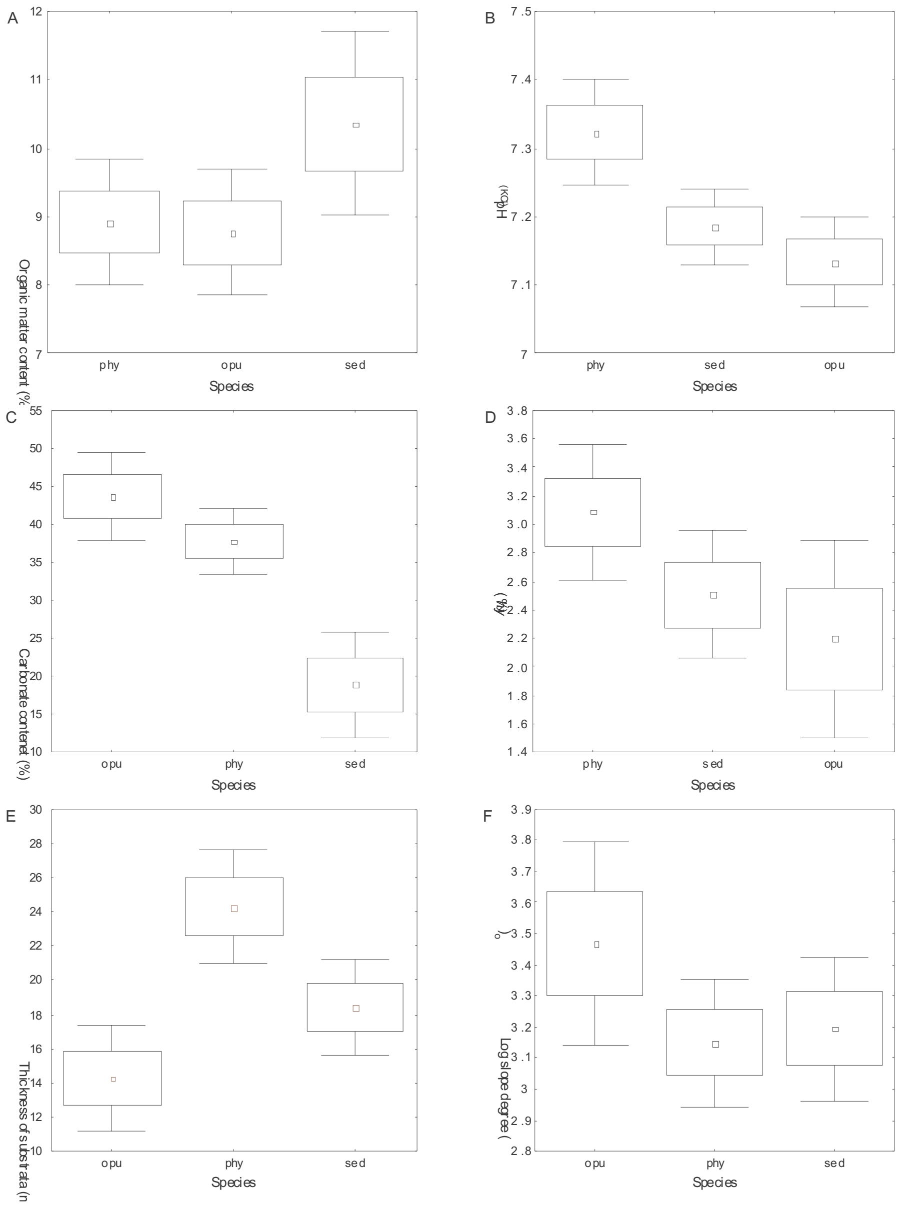

Fig. 1. The measured soil parameters under thalli of *Toninia opuntioides*, *T. physaroides* and *T. sedifolia*. A = organic matter content; B = hydrogen-ion concentration (measured in KCl solution); C = carbonate content; D = hygroscopicity ("hy"); E = soil depth; F = slope degree (opu = *T. opuntioides*, phy = *Toninia physaroides*, sed = *T. sedifolia*, ? = mean, ? = mean ± SE, T = Mean ± 1.96*SE)

Table 1

Summarised results of field and laboratory investigations referred to the three *Toninia* species. (Figures are averages for continuous variables)

	T. opuntioides	*T. physaroides*	*T. sedifolia*
Exposition	S	S	S
Position	in vertical rock crevices	on plateau	on plateau, in rock cavities
Soil parameters			
type, thickness (mm)	loess, 14.3	loess, sand, 24.3	loess, 18.4
carbonate content (%)	43.6 (high)	37.9 (high)	18.9 (medium)
content of organic matters (%)	8.9	8.9	10.4
acidity (pH_{KCl})	7.1 (basofrequent)	7.3 (basofrequent)	7.2 (basofrequent)
hygroscopicity (%)	2.2*	3.1	2.5
associated cryptogams	lichens, mosses	mosses	lichens, mosses

* measured in 4 samples only

of water adsorption capacity of soil under *T. opuntioides* there was only a few grams of samples available and therefore the results are considered to be as tentative values and *T. physaroides* and *T. sedifolia* did not show significant differences for this variable (Fig. 1D). Among field parameters difference was found between soil depths, where *T. opuntioides* usually occurred on the shallowest substrate (14.3±3.2 mm), *T. sedifolia* on medium thick soil (18.4±2.9 mm) and *T. physaroides* was abundant on the thickest substrata (24.3±3.4 mm) of the three investigated ones (Fig. 1E). Thalli of *T. opuntioides* occurred mainly on vertical rock crevices with average slope degree 43.7±7.7°, the other two *To-*

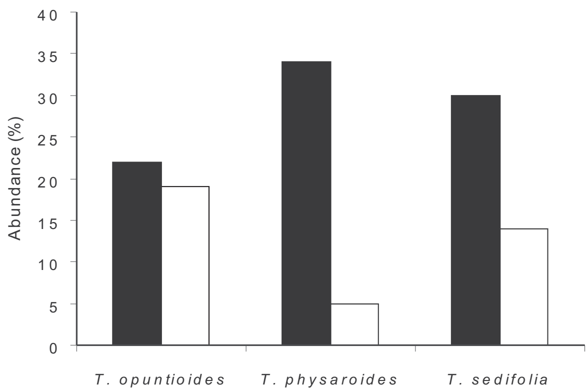

Fig. 2. The abundance of associated bryophyte and lichen species. Abundance is expressed as a percentage value of thalli with associated cryptogams in the number of total investigated thalli (black = moss, white = other lichen)

ninia species usually grew on plateau between average sample values of 27.8±5.1° (*T. physaroides*) and 29.5±5.5° (*T. sedifolia*) (Fig. 1F). Most of the substrata of the investigated thalli were south-facing at each species.

In the field we recorded that other lichen species only a few times occur together with *T. physaroides* (5%), but bryophyte thalli were more frequently observed (35%). Associated bryophyte and lichen thalli were equally frequent in sites of *T. opuntioides* (20–20%). *T. sedifolia* was more frequently (30%) associated with bryophytes than with other lichen species (15%) (Fig. 2). Our results are summarised in Table 1.

DISCUSSION

The habitat preference of the studied species has not been studied yet. Therefore in our discussion we can hardly refer to papers where values for some parameters also investigated by us are available for comparison or some aspects are common in our investigation. Some papers treat soil or habitat data of large areas (e.g. Eldridge and Tozer 1997) where macroclimatic effects have major influence on the distribution of species. Though the study of Alexander and Calvo (1990) is based on terricolous lichen communities different from our one, the results based on investigation of those communities where "*T. caeruleonigricans*" also occurs, help to explain the mechanisms in our study site.

Our investigated area characterised with diverse microtopography makes it possible for lichens with different tolerance to colonise special microhabitats. Microtopography has a major role in the effect on microclimate and in the small scale variability in soil parameters, such as pH or calcium carbonate content, and these may affect lichen distribution (Hawksworth and Hill 1984).

In the present study carried out in one and the same locality, the results indicate differences in habitats preferred by three species earlier regarded as one species. The most important differences between species habitat preference were in acidity, carbonate content, and depth of soil, and the slope degree of the substrate.

In the case of acidity, our measurements showed a good agreement with the literature data. Wirth (1995) also mentions that these species prefer substrate soil of pH = 7.5–7.7. Data referring to associations including *Toninia coeruleonigricans* also characterised by similar soil acidity: Gallé (1977) considered as "basophilous"; Gams (1938) found *Fulgensietum fulgentis* on soils of pH = 7.2–8.0.

In the study area the carbonate content of soil under *Toninia* species reached high values typical for the rendzina developed on dolomite. Carbonate content of the soil is dissolved in rainwater temporarily, but it is soon precipitated. The way of rainwater is indicated by the calcium carbonate deposit on open rock surfaces.

Lichens gain water passively from the surrounding air and from their substrate. Differences in water adsorption capacity of soil may result in different life conditions for lichens. In this respect there was no significant difference among the two better investigated species (*T. physaroides* and *T. sedifolia*).

Various components with different size occur in the solid phase of soils. Their quantity and proportion control the physical and physicochemical properties of the soil. The hygroscopicity and adsorption properties of soil are determined by the surface of small particles. Granules of sand have only a small specific surface and in consequence they do not form aggregates because of the weak adhesiveness. Between the small particles the tight interspaces can conduct water, and thus it is not retained in soil. In the clay fraction the specific surface of grains is large. Aggregates are formed where the space between the granules are thin thus the water retaining capacity is important. The most frequent adhesive matters in soil are humus components, iron- and aluminium oxides and hydroxides and $CaCO_3$ (Juhász 1987). According to the laser size-distribution analysis the proportion of fractions is very similar in all samples collected under the three *Toninia* species. Since *T. physaroides* grows also on sand we expected that soil under its thalli might contain larger granules in higher percentages also among low mountain grassland conditions. This hypothesis could not be justified. In the study of Alexander and Calvo (1990) rainfall simulation tests were carried out in badlands to investigate the influence of lichens on surface processes. In terms of their physiognomy lichens were divided into four groups, which appear to differ in their influence on water and sediment movement. One of the groups (A) contains *Toninia caeruleonigricans* too. Group A lichens form continuous patches of thin, porous crust which are likely to provide some degree of surface binding. The results show that on sites with moderate slopes and group A lichens only, the presence of a porous but binding lichen crust increases the infiltration rate, thereby causing slow ponding and surface runoff and also a low sediment concentration. Similar effects might occur in our study site.

The investigated *Toninia* thalli were predominantly situated at south-facing aspect, such as it was mentioned for instance by Zólyomi (1942), Marstaller (1968) or Wirth (1980). According to Verseghy (1975) *Toninia coeruleonigricans* is a boreal-montane species, since the majority (63%) of specimens was found at 200–400 m elevation, 14% in lowlands and only 10% in mountain region. The mean annual rainfall of their habitat is 500–600 mm. They occur in warm and dry grasslands or in detritus soil where the microclimate and microtopography have a more important role. According to Verseghy's measurements this species is basofrequent.

Though there is no significant difference between the organic matter content of soil samples under the thalli of the three *Toninia* species, nevertheless, our data (8.5–9.0% for soil under *T. opuntioides* and *T. physaroides*, and 10.0–10.5% for soil under *T. sedifolia*) contribute to the characterisation of the habitat of those species. We could declare certain conclusion by the investigation of more samples.

Toninia opuntioides often grows in vertical south-facing rock crevices where after rain small water flows wash away the soluble component of soil (organic and inorganic matters) and thallus fragments have a good chance to spread. In these places calcium carbonate get precipitated on the rock surface due to frequent water flow. High carbonate content was detected in the soil of these rock crevices (43.6±6.6%). Because of flows only a little soil can develop in fissures (14.3±3.2 mm). It is characterised with a lower pH (7.1±0.1) and organic matter content (8.9±1.3%). Herbarium specimens were often collected from rock surface. This fact was confirmed by our investigation, too.

Herbarium data showed that only the thalli of *T. physaroides* were collected from calcareous sand, where the organic matter content is low. The specimens of this species occur in low mountain grasslands too. Specimens often were collected from horizontal, south-facing, 24.3±3.4 mm thick substrata. *T. physaroides* prefer substrate soil with pH of 7.3±0.1 and humus content of 8.9±1.0%. As *T. physaroides* grows among the poorest nutrient conditions (cf. lowest measured humus content values) of the three species. Possibly the nutrients are not available in suitable concentration on sand for the other two species. The carbonate content of soil under this species is lower than under the previous species (37.8±5.0%). Water adsorption capacity of soil under *T. physaroides* is 3.1±0.5%. In the field we recorded only a few thalli of other lichen species occurring together with *T. physaroides*, but bryophyte thalli were more frequently observed.

We often collected thalli of *Toninia sedifolia* from rock cavities on medium thick soil (18.4±2.9 mm) with slope degree of 29.5±5.5°, where humus matters are accumulated and the organic and inorganic soluble component of soil cannot be easily washed away after rain. The pH (measured in KCl solution) of soil under *T. sedifolia* is 7.2±0.05. The lowest carbonate content of soil was recorded under *T. sedifolia* (18.9±7.9%). Hygroscopicity value is 2.5±0.5%. Bryophytes associated *T. sedifolia* more frequently than other lichen species.

In the present study habitat differences of three species of *Toninia coeruleonigricans* (*T. opuntioides*, *T. physaroides* and *T. sedifolia*) was investigated in the same locality. In respect of the eight examined variables, significant differences were found in the case of soil acidity, carbonate content, soil depth and slope degree of substrate under the different thalli of the species. The thalli of *Toninia opuntioides* were abundant in vertical rock crevices, where a little amount of soil can develop only because of the frequent small water flows. This soil is characterised by lower pH and organic matter content than those measured in other microhabitats. The specimens of *Toninia physaroides* were often collected from horizontal substrates with the highest soil pH among the three species. *Toninia sedifolia* often occurs in horizontal rock cavities, where humus matters can be accumulated and the carbonate content is lower than that of the other two species.

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