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Hornfels rocks as a habitat for saxicolous lichen biota. A case study from the Sudety Mountains (SW Poland)

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Abstract: The results of lichenological studies on hornfels outcrops in the Izerskie Mountains (Sudetes, SW Poland) are presented. This substrate is connected with the igneous intrusion into the country rocks and is characterized by a richer chemical and mineral composition than the surrounding rock bodies. In the six analyzed sites, a total of 48 saxicolous lichen species were found. Hornfels as a substrate for lichen vegetation is distinguished by the presence of lichens typical for rocks rich in metal compounds, in the study area represented by *Rhizocarpon oederi*, *Lecidea silacea* and *Porpidia melinodes*, and lichens that prefer mineral-enriched rocks, like *Lecanora campestris*, *L. rupicola*, *Lecidea fuscoatra*, *Porpidia cinereoatra* and *Rimularia gibbosa*. The three mentioned metallophilous species are some of the rarest components of the lichen biota in Poland, known from single localities. Other rare and locally endangered lichens recorded on hornfels include *Lambiella furvella*, *Stereocaulon dactylophyllum* and *Umbilicaria pustulata*.

Keywords: saxicolous lichens, biodiversity, Hercynian mountains, Central Europe, metallophytes

INTRODUCTION

Hornfels is a type of contact metamorphic rock formed at the junction of igneous intrusion with older rock layers. The process of metamorphism is accompanied by a change in the structure and texture of the rock mass, as well as the formation of new minerals characteristic of the hornfels facies, e.g. andalusite and cordierite (Butler, 1989). Outcrops of these rocks can be an attractive substrate for saxicolous lichens due to their increased content of minerals, especially iron compounds; however, they are quite difficult to colonize because of their dense structure and hardness (Bielczyk & Kossowska, 2015).

In Poland, hornfels rocks occur in the Sudety Mountains (SW part of the country), where they create, among others, a narrow and fragmented metamorphic aureole around the granite intrusion that builds up most of the Karkonosze (Giant) Mountains. The most widely known outcrops of these rock are located on the slopes and summit of Mt. Śnieżka (1603 m), where they are associated with a very rich and diverse high-mountain lichen biota (Kossowska, 2007). Apart from the Karkonosze Mountains, hornfels is also exposed in the adjacent highest ridge (Wysoki Grzbiet) of the Izerskie Mountains. The hornfels zone is located in the eastern part of the ridge (Fig. 1A) and builds, among others, the culmination of Mt. Wysoki Kamień (1058 m).

The locality of Mt. Wysoki Kamień (in German literature named Schreiberhauer Hochstein or Hochstein bei Schraeiberhau) has long been known for the presence of the rare metallophilous species *Lecidea silacea* and *Rhizocarpon oederi*, together with some other saxicolous lichens (Flotow, 1850; Körber, 1855; Stein, 1879). Moreover, in the 1970s unusual lichen thalli were recorded on the hornfels outcrop at the so-called Zakręt Śmierci (the Death Curve) on the eastern slope of the Wysoki Grzbiet ridge. They were originally identified as *Umbilicaria propagulifera* (Vainio) Llano (Topham et al., 1982; Seaward et al., 1983), and later renamed *U. dendrophora* (Poelt) Hestmark (Hestmark, 1993) (in all these publications, the site of the Death Curve was incorrectly located in the Karkonosze Mountains). This species is also considered to be metallophilous (Hestmark, 1993), and the hornfels rocks on the eastern slope of Mt. Wysoki Kamień remain the only known locality of this lichen in Poland (Fałtynowicz, 2003).

The rarity and specific mineral composition of hornfels rocks were the reason to undertake detailed studies on related saxicolous lichens. The presented results are another contribution to knowledge on the lichen biota inhabiting various types of rocks in the Sudety Mountains; the earlier ones concerned serpentinite (Kossowska, 2001), crystalline limestone (Kossowska, 2008)

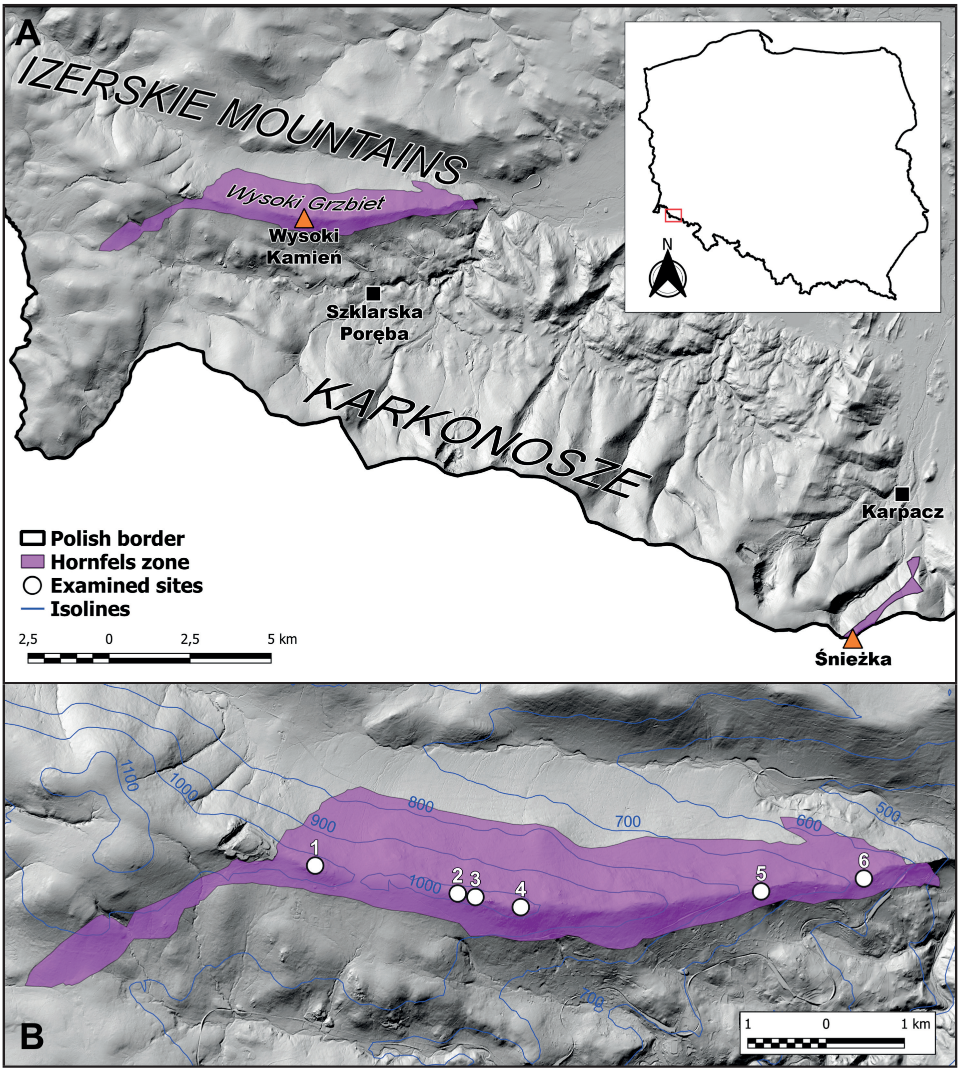

Fig. 1. A – Hornfels zones of the Izerskie and Karkonosze Mountains in SW Poland; B – Location of the examined sites. Numbers of the sites are consistent with description in the text. The base of the map: geoportal.gov.pl

and basalt (Kossowska & Szczepańska, 2020). The aim of this series is to recognize the richness and species diversity of saxicolous lichens in an old Hercynian mountain range, characterized by a complex history and geological structure, with particular emphasis on lichens of substrates other than the acidic silicate rocks, namely granites and gneisses, which are dominant in the Sudety Mountains.

MATERIAL AND METHODS

Field research was carried out in 2013 on 6 sites located in the hornfels zone of the Izerskie Mountains (Fig. 1B). The individual sites were separated from each other by 0.5–3 km and included exposed rocks (site 1, 2, 4, 6), boulder fields (site 1, 4), rock walls (site 5) and stones scattered among herbaceous vegetation (site 3). The collected lichens were identified with classical techniques, using a Nikon Eclipse E600 light

A B C D

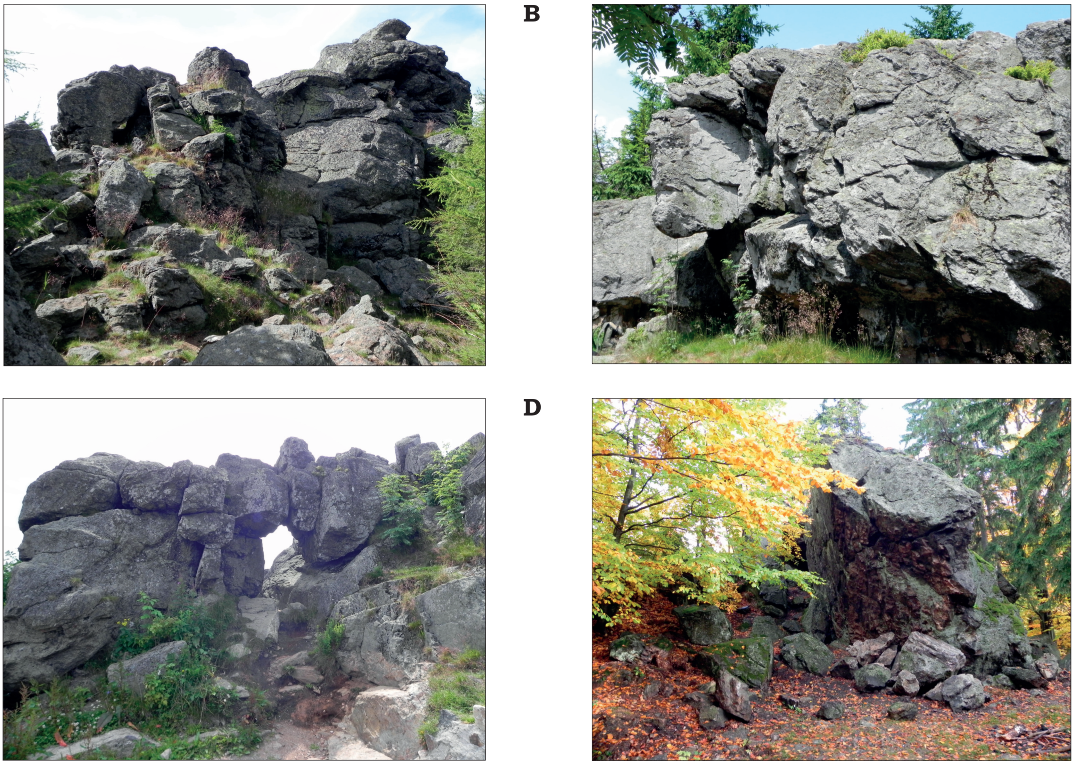

Fig. 2. Outcrops of hornfels rocks in the Izerskie Mountains. A – Wieczorny Zamek rocks on Zwalisko Mt.; B – Zawalidroga rock; C – part of the outcrop on Wysoki Kamień Mt.; D –Zbójeckie Skały rocks.

microscope, a Nikon SMZ-U stereoscopic microscope and standard chemical reagents: 10% potassium dioxide (K), sodium hypochlorite (C), p-phenylenediamine in ethanol (Pd) and Lugol's iodine (I). The content of secondary metabolites was determined by thin layer chromatography (Orange et al., 2001). The herbarium material was deposited in the private collection of the author (Hb. Kossowska). Names of lichens follow Fałtynowicz & Kossowska (2016), except for *Lambiella furvella* (see Resl et al., 2015) and *Umbilicaria pustulata* (see Davydov et al., 2017).

List of the localities. (1) Mt. Zwalisko (1047 m), a summit in the central part of the Wysoki Grzbiet ridge, with a vast rock complex (Wieczorny Zamek rocks, Skarbki rocks; Fig. 2A), 50°50'56.9"N 15°27'14.2"E, coll. date: 19.07.2013; (2) Zawalidroga rock, a single rock (7 m) on the Wysoki Grzbiet ridge at the height of 999 m (Fig. 2B), 50°50'48.2"N 15°28'48.1"E, coll. date: 18.07.2013; (3) stones between Zawalidroga rock and Mt. Wysoki Kamień, 50°50'47.1"N 15°28'59.8"E, coll. date: 18.07.2013; (4) Mt. Wysoki Kamień (1058 m), a summit in the eastern part of the Wysoki Grzbiet ridge, with a vast rock complex (up to 30 m) at the top (Fig. 2C), 50°50'43.8"N 15°29'29.7"E, coll. date: 17.07.2013; (5) Zakręt Śmierci (Death Curve), rock walls up to 12 m high by the Szklarska Poręba – Świeradów Zdrój road on the eastern slope of the Wysoki Grzbiet ridge at the height 775 m, 50°50'55.0"N 15°32'06.1"E, coll. date: 20.07.2013; (6) Zbójeckie Skały rocks, a rock group in the forest at a height of ca. 600 m, at the eastern end of the Wysoki Grzbiet ridge (Fig. 2D), 50°51'02.3"N 15°33'12.8"E, coll. date: 11.10.2013.

RESULTS

As a result of the conducted research, 48 species of saxicolous lichens were found (Table 1). The richest lichen vegetation covered the vast rock outcrop at the top of Mt. Wysoki Kamień. On this site the presence of both metallophilous species known from this place since the 19th century, i.e. *Rhizocarpon oederi* and *Lecidea silacea* (Körber, 1855) was confirmed. In addition, another species associated with rocks rich in iron compounds, *Porpidia melinodes*, was recorded in numerous localities along the ridge from Mt. Wysoki Kamień up to Mt. Zwalisko (Kossowska, 2014). However, during this study, no specimens of *Umbilicaria dendrophora* were found, neither at the known site on the Death Curve (Topham et al., 1982; Seaward et al., 1983), nor at the other analyzed outcrops. This species has probably become extinct in Poland.

Among the recorded lichen species, the majority are typical for silicate rocks in general, with a fairly wide range of tolerance to the mineral composition of the substrate, like *Acarospora fuscata*, *Lecanora intricata*, *L. polytropa*, *Rhizocarpon geographicum*, etc. These species were found on all or almost all the analyzed rock outcrops and constitute the core of the lichen biota. However, at all sites a greater or lesser share of lichens with specific habitat requirements was noted. Lichens considered metallophilous (Purvis & Halls, 1996; Bielczyk & Kossowska, 2015) included *Porpidia melinodes*, *Lecidea silacea* and *Rhizocarpon oederi*. These three species were recorded together exclusively at the locality of Mt. Wysoki Kamień, and only *Porpidia melinodes* was more widely distributed. This indicates an increased concentration of iron ions in the rocks of Mt. Wysoki Kamień. Mineraliphilous lichens, i.e. species with a slightly wider spectrum of habitat requirements than strictly metallophilous ones and favoring mineral-rich rocks (Bielczyk & Kossowska, 2015), were represented by *Lecanora campestris*, *L. rupicola*, *Lecidea fuscoatra*, *L. plana*, *Porpidia cinereoatra* and *Rimularia gibbosa*.

Additionally, the sites located in the highest, western part of the hornfels zone in the Izerskie Mountains were distinguished by the presence of several high-mountain species (according to Wirth et al., 2013) which are widespread in the neighboring Karkonosze Mts. These are: *Lambiella furvella*, *Lecidea confluens*, *L. lactea*, *Melanelia hepatizon*, *Miriquidica leucophaea*, *Schaereria fuscocinerea*, and *Umbilicaria cylindrica*. However, all these species were recorded at only 1–2 sites and none of them was represented in large numbers.

DISCUSSION

As mentioned in the introduction, hornfels is a metamorphic rock that accompanies igneous intrusions. It usually creates contact aureoles of varying widths around plutonic rocks; however, these metamorphic zones can be fragmented and rocks are not always exposed on the Earth's surface. Probably due to the dispersion and local nature of hornfels occurrences, this rock substrate has not yet become the subject of detailed lichenological studies, as was the case with another unusual type of rock, serpentinite (Ritter-Studnická & Klement, 1968; Sirois et al., 1988; Hafellner, 1991; Kossowska, 2001; Brackel, 2007; Paukov, 2009; Rajakaruna et al., 2012 etc.). In lichenological studies, hornfels is usually not distinguished as a substrate different from granite, or is simply referred to as a "silicate rock". However, its rich mineral composition and increased content of metal compounds make it suitable for a lichen biota with specific properties, and it is worth paying attention to this substrate.

The closest occurrence of hornfels to the studied area is in the neighboring Karkonosze Mountains, where this rock builds the highest peak of the massif, Mt. Śnieżka (1603 m). Because of the elevation of rocky outcrops high above the treeline, the size of the area they occupy, and different climatic conditions, the saxicolous lichen biota of Mt. Śnieżka and its surroundings is much richer than that found in the Izerskie Mountains. It is distinguished primarily by the presence of high-mountain species and glacial relics, including numerous lichens with an arctic-alpine range type (Kossowska, 2007; 2019). However, the proportion of metallo- and mineraliphilous taxa in the saxicolous lichen biota of Mt. Śnieżka is also distinct (Kossowska, 2019 and unpubl. data). Despite the significant difference in the number of species, the total share of the discussed group of species in the biota of hornfels in both mountain ranges is similar and amounts to approx. 20%. The presence of species preferring metal- and mineral-enriched rocks seems to be a characteristic trait of hornfels as a substrate for lichen vegetation, which distinguishes it from granite and brings it closer to serpentinite and basalt (Kossowska, 2001; Kossowska & Szczepańska, 2020). However, the two latter bedrocks share the presence of basi- and neutrophilous lichens (according

Table 1. List of lichens found on individual sites in the hornfels zone of the Izerskie Mountains.

No.	Species	1	2	3	4	5	6
1.	*Acarospora fuscata* (Nyl.) Arnold	+	+	.	+	+	+
2.	*Baeomyces rufus* (Huds.) Rebent.	.	.	.	.	.	+
3.	*Buellia aethalea* (Ach.) Th. Fr.	+	+	.	.	.	+
4.	*Candelariella coralliza* (Nyl.) H. Magn.	+	.	.	+	.	.
5.	*Candelariella vitellina* (Hoffm.) Müll. Arg.	.	.	.	+	.	.
6.	*Chrysotrix chlorina* (Ach.) J.R. Laundon	.	.	.	.	+	+
7.	*Circinaria caesiocinerea* (Nyl. ex Malbr.) A. Nordin, Savić & Tibell	.	.	.	.	+	.
8.	*Diploschistes scruposus* (Schreb.) Norman	.	+		+	+	+
9.	*Gyrographa gyrocarpa* (Flot.) Ertz & Tehler	.	.	.	.	+	+
10.	*Hypogymnia physodes* (L.) Nyl.	.	.	.	.	.	+
11.	*Lambiella furvella* (Nyl. ex Mudd) M. Westb. & Resl	.	+	.	.	.	.
12.	*Lecanora campestris* (Schaer.) Hue	.	+	.	+	.	.
13.	*Lecanora intricata* (Ach.) Ach.	+	+	+	+	+	+
14.	*Lecanora polyropa* (Ehrh. ex Hoffm.) Rabenh.	+	+	+	+	+	+
15.	*Lecanora rupicola* (L.) Zahlbr.	.	+	.	.	.	.
16.	*Lecidea confluens* (Weber) Ach.	+	.	.	+	.	.
17.	*Lecidea fuscoatra* (L.) Ach.	.	.	.	+	+	+
18.	*Lecidea lactea* Flörke ex Schaer.	+	.	.	.	.	.
19.	*Lecidea lithophila* (Ach.) Ach.	.	.	.	+	.	.
20.	*Lecidea plana* (J. Lahm ex Körb.) Nyl.	+	.	.	.	.	.
21.	*Lecidea silacea* Ach.	.	.	.	+	.	.
22.	*Melanelia hepatizon* (Ach.) Thell	.	+	.	+	.	.
23.	*Melanelixia fuliginosa* (Fr. ex Duby) O. Blanco & al.	.	.	.	.	+	+
24.	*Miriquidica leucophaea* (Flörke ex Rabenh.) Hertel & Rambold	+	.	+	.	.	.
25.	*Montanelia disjuncta* (Erichsen) Divakar & al.	.	.	.	.	+	.
26.	*Parmelia saxatilis* (L.) Ach.	.	.	.	+	+	+
27.	*Porpidia cinereoatra* (Ach.) Hertel & Knoph	+	.	.	.	.	.
28.	*Porpidia macrocarpa* (DC.) Hertel & Schwab	+	.	.	.	.	+
29.	*Porpidia melinodes* (Körb.) Gowan & Ahti	+	.	+	+	.	.
30.	*Protoparmelia badia* (Hoffm.) Hafellner	+	+	.	+	+	.
31.	*Pseudevernia furfuracea* (L.) Zopf	.	.	.	.	.	+
32.	*Rhizocarpon geographicum* (L.) DC.	+	+	+	+	+	
33.	*Rhizocarpon lecanorinum* Anders	.	+	.	+	+	+
34.	*Rhizocarpon oederi* (Weber) Körb.	.	.	.	+	.	.
35.	*Rhizocarpon polycarpum* (Hepp) Th. Fr.	.	.	.	+	+	.
36.	*Rhizocarpon reductum* Th. Fr.	.	.	+	.	.	.
37.	*Rimularia gibbosa* (Ach.) Coppins, Hertel & Rambold	.	.	+	.	+	.
38.	*Schaereria fuscocinerea* (Nyl.) Clauzade & Cl. Roux	.	.	+	+	.	.
39.	*Scoliciosporum umbrinum* (Ach.) Arnold	.	.	.	.	+	+
40.	*Stereocaulon dactylophyllum* Flörke	+	.	.	+	.	.
41.	*Trapelia obtegens* (Th. Fr.) Hertel	.	.	.	+	+	.
42.	*Umbilicaria cylindrica* (L.) Delise ex Duby	+	.	.	+	.	.
43.	*Umbilicaria deusta* (L.) Baumg.	.	+	.	+	+	.
44.	*Umbilicaria hirsuta* (Sw. ex Westr.) Hoffm.	.	.	.	+	+	+
45.	*Umbilicaria polyphylla* (L.) Baumg.	+	.	.	+	+	.
46.	*Umbilicaria pustulata* (L.) Hoffm.	.	.	.	.	.	+
47.	*Xanthoparmelia conspersa* (Ach.) Hale	.	.	.	+	+	+
48.	*Xanthoparmelia loxodes* (Nyl.) O. Blanco & al.	.	.	.	.	+	.
Total:		17	13	8	27	23	19

1 – Zwalisko Mt., 2 – Zawalidroga rock, 3 – boulders between Zawalidroga rock and Wysoki Kamień Mt., 4 – Wysoki Kamień Mt., 5 – Zakręt Śmierci, 6 – Zbójeckie Skały rocks.

to Wirth, 1995; Wirth et al., 2013), which are absent on hornfels.

The three above-mentioned metallophilous lichens, *Rhizocarpon oederi*, *Lecidea silacea* and *Porpidia melinodes*, are undoubtedly the most interesting and the most valuable of species found on hornfels rocks in the Izerskie Mountains. In Poland, these species are found only in the Sudety Mountains (Jabłońska, 2012; Bielczyk & Kossowska, 2015) and are known from single locations. Outside the Izerskie Mountains, *R. oederi* and *L. silacea* have been found at a single site on iron shales in the Rudawy Janowickie Mountains (Leśniański, 2008), while *P. melinodes* has so far been recorded only on hornfels of Mt. Śnieżka (Jabłońska, 2012). This makes them one of the rarest components of the lichen biota in Poland.

Another species that deserves attention is *Rimularia gibbosa*. It is a rare crustose lichen with a sub-Atlantic range type, associated with substrates rich in minerals (Wirth et al., 2013). In Poland, this species is known from the Sudety and Tatra Mountains; however, records of it are mainly of a historical nature (Fałtynowicz, 2003). It is worth adding that the information provided by Wirth at al. (2013) about the type location of *R. gibbosa* on Mt. Wysoki Kamień in the Izerskie Mountains (Hochstein bei Schreiberhau) is probably a mistake. It seems that the specimen collected by Mosig came from Upper Lusatia (Hochstein bei Königshain; Körber, 1855; Zahlbruckner, 1928).

Among the lichens found on hornfels rocks in the Izerskie Mountains, there are also several other species that are rare in Poland and considered endangered (category EN on the red list of lichens, Cieśliński et al., 2006), namely *Lambiella furvella*, *Stereocaulon dactylophyllum* and *Umbilicaria pustulata*. The former two species are known from dispersed localities throughout the country (Fałtynowicz, 2003), while the localities of *U. pustulata* are clearly concentrated in the Sudety Mountains (Fałtynowicz & Bylińska, 1999). The presence of these species additionally confirms the great value of hornfels as a substrate for lichen vegetation.

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