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The saxicolous and terricolous lichens of northeastern Brazil, with special reference to the Vale do Catimbau in Pernambuco

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Abstract: The saxicolous and terricolous lichen biota of the Vale do Catimbau in Pernambuco state (Brazil) was studied and with 74 species found to be relatively rich. Most species are new to the state and five are new to Brazil, *viz. Andreiomyces obtusatica* (Tønsberg) B.P. Hodk. & Lendemer, *Caloplaca brittonii* (Zahlbr.) Aptroot, *Candelariella rosulans* (Müll. Arg.) Zahlbr., *Clavascidium antillarum* (Breuss) Breuss, and *Stromatella bermudana* (Riddle) Henssen. In addition, some new state records were found of corticolous and lignicolous lichens. A comparison is made with all other places in northeastern Brazil where saxicolous lichens have been studied. For this, the Serra de Itabaiana in Sergipe state was revisited too, and many additional species were recorded there. All places differ markedly in species composition. This seems to be correlated to altitude, biome, and rock type (sandstone versus granite), with the biome mostly influencing the species composition and the altitude the species richness. Some of the species newly reported from Brazil are so far known from the Antilles and there seems to be some resemblance between these lichen biotas.

Keywords: *Andreiomyces*, *Caloplaca*, *Candelariella*, *Clavascidium, Cladonia, Stromatella*, new records, species list, lichenized fungi

INTRODUCTION

The study of lichens in northeastern Brazil started relatively late. There are no reports from the 19th century, and only a few from the 20th century, mainly on macrolichens from Recife (e.g., Moreira de Barros Barros & Xavier, 1972; Xavier Filho & Marix, 1972; Britto et al., 1984), on foliicolous lichens by Batista and coworkers, and on *Cladonia* P. Browne (Ahti, 2000). In the present century, studies about taxonomy and ecology of corticolous microlichens was conducted by Cáceres (2007), her work was continued by many of her students (e.g., Menezes et al., 2011, 2013, 2018; Cavalcante, 2012, 2020; Rodrigues, 2012; Menezes, 2013; Xavier-Leite et al., 2013, 2015; Alves, 2014; Alves et al., 2014a, b; Aptroot & Cáceres, 2014; Cáceres et al., 2014; Mendonça, 2014; Andrade, 2015, 2020; Sobreira, 2015; Dantas, 2016; Santos et al., 2016, 2019; Dantas et al., 2017; Andrade et al., 2020; Nascimento et al., 2021). One of the areas that was studied in detail was the archaeological reserve Vale do Catimbau in inland Pernambuco, from which many new species were described (Aptroot et al., 2013, 2015; Cáceres et al., 2013; Lima, 2013; Lima et al., 2013a, b, c).

The study of saxicolous lichens in northeastern Brazil started with publications about the results of excursions to the Pedra da Galinha in Ceará (Aptroot & Cáceres, 2016; Cáceres et al., 2017), the Serra de Itabaiana in Sergipe (e.g., Cáceres et al., 2016; Aptroot et al., 2022), the Chapada Diamantina in Bahia (Aptroot & Cáceres, 2018a,2018b), the Pedra Talhada in Alagoas (Nusbaumer et al., 2015; Aptroot et al., 2019; Oliveira Junior et al., 2020), and the Poço Redondo in inland Sergipe (Aptroot et al., 2021c). These publications include additional records of *Cladonia* species and other terricolous lichens too, when present. The aspect of the lichen vegetation in these places is somewhat similar: *Xanthoparmelia* (Vain.) Hale species are often dominant (sometimes replaced by the members of the genus *Parmotrema* A. Massal.), and many species belong to *Caloplaca* Th.Fr. s. lat., also some with black apothecia or with brown *Lecanora*-like apothecia; cyanophilic

lichens are locally present, and many crusts belong to *Buellia* De Not.; true *Lecidea* Ach. or *Rhizocarpon* Ramond ex DC. species are absent. The lichen biotas of these areas however differ widely, both in diversity and in species composition. Saxicolous lichens were so far not studied in the Vale do Catimbau, or elsewhere in Pernambuco, except for the foliose Parmeliaceae (Buril, 2015).

Here, we present the preliminary results, however not all specimens could be identified, and some are still under study, especially of the genera *Lecanora* Ach., *Parmotrema*, *Tephromela* M. Choisy, and *Xanthoparmelia*.

MATERIAL AND METHODS

In April 2022, we made a collecting trip to the Vale do Catimbau in the Pernambuco state (Fig. 1), concentrating on saxicolous lichens on the sandstone. We also revisited the Serra de Itabaiana in Sergipe state, concentrating on sites rich in *Cladonia* species. All specimens are preserved in ISE and CGMS herbaria. Numbers are ISE herbarium numbers; the collectors are A. Aptroot and L.A. Santos. Specimens were observed with an Olympus SZX7 and pictures were taken with Nikon Coolpix 995. Hand-made sections of ascomata and thallus were studied in water, 5% KOH (K), and/or Lugol's reagent (1% I_2) after pre-treatment with KOH (IKI). Microscopic photographs were prepared using an Olympus BX50 with Nomarski interference contrast and Nikon Coolpix 995. Chemical spot reactions used were K (5% KOH), C (commercial bleach), KC (K followed by C), P (paraphenylenediamine), and UV refers to fluorescence at 365 nm. Thin-layer chromatography (Orange et al., 2010) has been undertaken by A. Aptroot in solvent A. Only one representative specimen is mentioned for each relevant species in the tables.

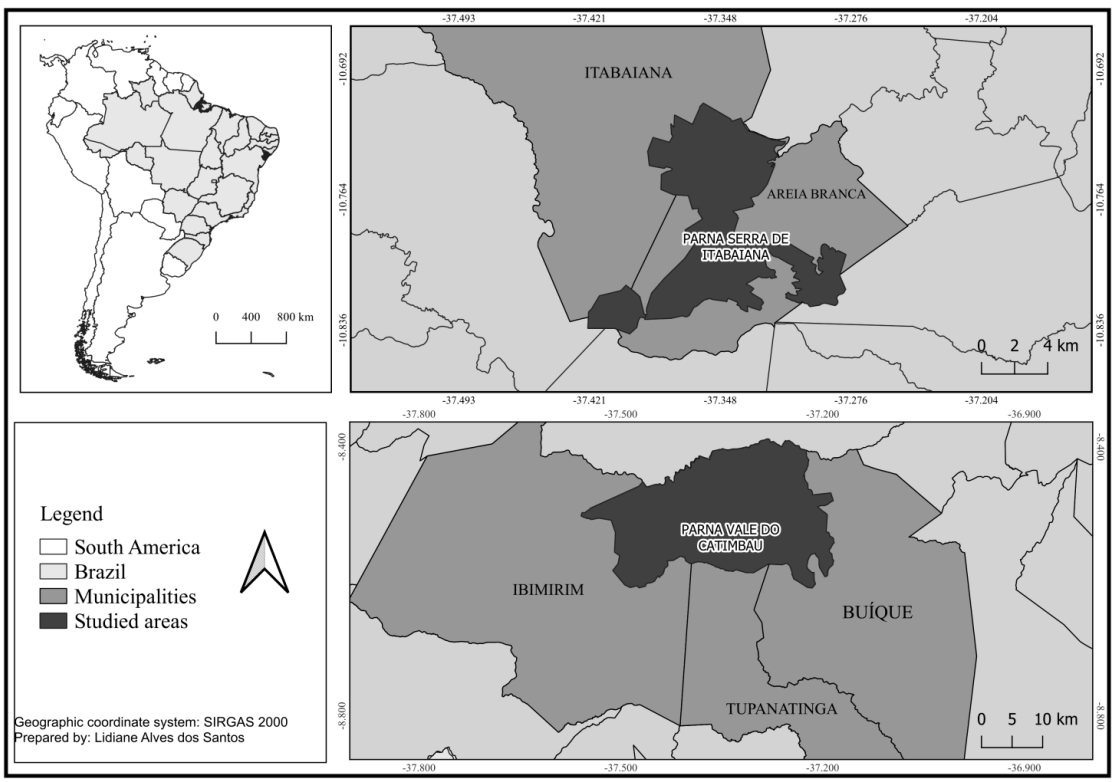

Fig. 1. Map with location of the Vale do Catimbau.

RESULTS & DISCUSSION

We identified 74 saxicolous species (including species on soil and termitaria) in the material from the Vale do Catimbau (Table 1), almost all new records for Pernambuco and some for Brazil; a few dozen more remain unidentified at this moment, including one or a few undescribed species. Only two species of terricolous *Cladonia* were found by us. We also collected corticolous lichens and lichens on wood, and e.g., recollected many species that were described from the place, but also some additional records, which are mentioned at the end of Table 1.

Table 1. Terricolous and saxicolous lichens in the Vale do Catimbau, with some new corticolous and lichenicolous species mentioned at the end, with one ISE collection number of 2022 collection.

Genus	Species	Author	ISE #	Substratum	New to
Acarospora	*chrysops*	(Tuck.) H. Magn.	54555	sandstone	PE
Agonimia	*tristicula*	(Nyl.) Zahlbr.	54513a	sandstone	PE
Andreiomyces	*obtusatica*	(Tønsberg) B.P. Hodk. & Lendemer	54414	sandstone	Brazil
Brianaria	*lutulata*	(Nyl.) S. Ekman & M. Svenss.	54447	sandstone	PE
Buellia	*halonia*	(Ach.) Tuck.	54428	sandstone	PE
Buellia	*mamillana*	(Tuck.) W.A. Weber	54412	sandstone	PE
Buellia	*subtabacina*	(Müll. Arg.) Malme	54520	sandstone	PE
Buellia	*xanthinula*	(Müll. Arg.) Malme	54664	sandstone	PE
Caloplaca	*arenaria*	(Pers.) Müll. Arg.	54517	sandstone	PE
Caloplaca	*brittonii*	(Zahlbr.) Aptroot	54408	sandstone	Brazil
Caloplaca	*chapadensis*	(Malme) Zahlbr.	54572	sandstone	PE
Caloplaca	*cinnabarina*	(Ach.) Zahlbr.	54559	sandstone	PE
Caloplaca	*crenularia*	(With.) J.R. Laundon	54410	sandstone	PE
Caloplaca	*cupulifera*	(Vain.) Zahlbr.	54430	sandstone	PE
Caloplaca	*decipioides*	Arup	54612	sandstone	PE
Caloplaca	*isidiosa*	(Vain.) Zahlbr.	54443	sandstone	PE
Caloplaca	*lecanorocarpa*	Aptroot & M. Cáceres	54431	sandstone	PE
Caloplaca	*lecapustulata*	Aptroot & M. Cáceres	54406	sandstone	PE
Caloplaca	*leptozona*	(Nyl.) Zahlbr.	54516	sandstone	PE
Caloplaca	*subsoluta*	(Nyl.) Zahlbr.	54520a	sandstone	PE
Candelariella	*rosulans*	(Müll. Arg.) Zahlbr.	54589	sandstone	Brazil
Catillaria	*chalybeia*	(Borrer) A. Massal.	54459	sandstone	PE
Chrysothrix	*xanthina*	(Vain.) Kalb	54416	sandstone	
Clavascidium	*antillarum*	(Breuss) Breuss	54621	sandstone	Brazil
Coccocarpia	*erythroxyli*	(Spreng.) Swinscow & Krog	54584	sandstone	
Cryptothecia	*isidioxantha*	Aptroot & M. Cáceres	54433	sandstone	PE
Cryptothecia	*lichexanthonica*	E.L. Lima, Aptroot & M. Cáceres	54659	sandstone	
Dendrographa	*austrosorediata*	Aptroot & Gumboski	54654	sandstone	PE
Diploschistes	*actinostomus*	(Ach.) Zahlbr.	54555a	sandstone	PE
Endocarpon	*pallidullum*	(Nyl.) Nyl.	54448	sandstone	

Genus	Species	Author	ISE #	Substratum	New to
Fulgogasparrea	*intensa*	Aptroot & M. Cáceres	54665	sandstone	PE
Heterodermia	*obscurata*	(Nyl.) Trevis.	54487	sandstone	
Heterodermia	*speciosa*	(Wulfen) Trevis.	54531	sandstone	PE
Lecanora	*oreinodes*	(Körb.) Hertel & Rambold	54557	sandstone	PE
Lecanora	*sulfurescens*	Fée	54415	sandstone	PE
Lecidella	*enteroleucella*	(Nyl.) Hertel	54411	sandstone	PE
Lepra	*ventosa*	(Malme) Lendemer & R.C. Harris	54434	sandstone	PE
Micarea	*squamulosa*	Aptroot, Lücking & M. Cáceres	54513	sandstone	PE
Neoprotoparmelia	*brasilisidiata*	Garima Singh, M. Cáceres & Aptroot	54581	sandstone	PE
Neoprotoparmelia	*saxicola*	(Aptroot & M. Cáceres) L.A. Santos, M. Cáceres & Aptroot	54435	sandstone	PE
Opegrapha	*lithyrgiza*	Vain.	54574	sandstone	PE
Parmotrema	*flavescens*	(Kremp.) Hale	54491	sandstone	
Parmotrema	*mellissii*	(C.W. Dodge) Hale	54407	sandstone	
Parmotrema	*mirandum*	(Hale) Hale	54409	sandstone	
Parmotrema	*mordenii*	(Hale) Hale	54512	sandstone	PE
Parmotrema	*rampoddense*	(Nyl.) Hale	54444	sandstone	
Peltula	*euploca*	(Ach.) Poelt	54618a	sandstone	
Physcia	*sinuosa*	Moberg	54616	sandstone	PE
Physcia	*sorediiconvexa*	Aptroot & Cáceres	54488	sandstone	PE
Pseudoparmelia	*arida*	(Lynge) Elix & T.H. Nash	54563	sandstone	
Pseudoparmelia	*harrisiana*	Elix & T.H. Nash	54564	sandstone	PE
Pyxine	*albovirens*	(G. Mey.) Aptroot	54486	sandstone	PE
Pyxine	*coralligera*	Malme	54455	sandstone	PE
Pyxine	*obscurascens*	Malme	54413	sandstone	PE
Pyxine	*simulans*	Kalb	54619	sandstone	PE
Pyxine	*subcinerea*	Stirt.	54615	sandstone	PE
Ramboldia	*heterocarpa*	(Fée) Kalb, Lumbsch & Elix	54432	sandstone	PE
Relicina	*abstrusa*	(Vain.) Hale	54577	sandstone	PE
Stromatella	*bermudana*	(Riddle) Henssen	54603	sandstone	Brazil
Thermutis	*velutina*	(Ach.) Flot.	54441	sandstone	PE
Usnea	*amblyoclada*	(Müll. Arg.) Zahlbr.	54439	sandstone	PE
Usnea	*densirostra*	Taylor	54440	sandstone	PE
Verrucaria	*macrostoma*	DC.	54602	sandstone	PE
Xanthoparmelia	*neocumberlandia*	T.H. Nash & Elix	54429	sandstone	
Xanthoparmelia	*neopropaguloides*	Hale	54660	sandstone	PE
Xanthoparmelia	*subplittii*	Hale	54442	sandstone	
Xanthoparmelia	*subtinctina*	T.H. Nash & Elix	54522	sandstone	PE
Cladonia	*ceratophylla*	(Sw.) Spreng.	54482	soil	PE
Cladonia	*verticillaris*	(Raddi) Fr.	54483	soil	

Genus	Species	Author	ISE #	Substratum	New to
Collemopsidium	*argilospilum*	(Nyl.) Coppins & Aptroot	54672	soil	Brazil
Lepraria	*finkii*	(B. de Lesd.) R.C. Harris	54521	soil	PE
Lepraria	*sipmaniana*	(Kümmerl. & Leuckert) Kukwa	54578	soil	PE
Arthrorhaphis	*citrinella*	(Ach.) Poelt	54462	termitarium	PE
Lecidea	*termitophila*	Malme	54556	termitarium	PE
Amandinea	*efflorescens*	(Müll. Arg.) Marbach	54540	tree bark	PE
Arthonia	*spadicea*	C. Knight	54629	tree bark	PE
Astrothelium	*pulcherrimum*	(Fée) Aptroot & Lücking	54647	tree bark	PE
Biatora	*kalbii*	(Brako) S.Y. Kondr.	54634	tree bark	PE
Caloplaca	*granularis*	(Müll. Arg.) Zahlbr.	54609a	tree bark	PE
Constrictolumina	*planorbis*	(Ach.) Lücking, M.P. Nelsen & Aptroot	54427	tree bark	PE
Enterographa	*quassiicola*	Fée	54473	tree bark	PE
Gyalecta	*nana*	Tuck.	54630a	tree bark	PE
Haematomma	*flexuosum*	Hillmann	54479	tree bark	PE
Haematomma	*fluorescens*	Kalb & Staiger	54474	tree bark	PE
Hyperphyscia	*mobergii*	Kalb	54594	tree bark	PE
Hypotrachyna	*bahiana*	(Nyl.) Hale	54501	tree bark	PE
Lecanactis	*elaeocarpa*	(Nyl.) Tehler	54538	tree bark	PE
Lecanographa	*illecebrosula*	(Müll. Arg.) Egea & Torrente	54597	tree bark	PE
Lepra	*tropica*	(Vain.) Lendemer & R.C. Harris	54475	tree bark	PE
Lepraria	*sipmaniana*	(Kümmerl. & Leuckert) Kukwa	54404	tree bark	PE
Neoprotoparmelia	*brasilisidiata*	Garima Singh, M. Cáceres & Aptroot	54518	tree bark	PE
Neoprotoparmelia	*capitata*	(Lendemer) Garima Singh, Lumbsch & I. Schmitt	54496	tree bark	PE
Nigrovothelium	*inspersotropicum*	Aptroot & Diederich	54480	tree bark	PE
Parmotrema	*melanochaetum*	(Kurok.) O. Blanco, A. Crespo, Divakar, Elix & Lumbsch	54626	tree bark	PE
Parmotrema	*nyasensis*	(C.W. Dodge) R.S. Egan	54539	tree bark	PE
Polymeridium	*corticatum*	A.A. Menezes, M. Cáceres & Aptroot	54424	tree bark	PE
Pyrenula	*guianensis*	Sipman & Aptroot	54635	tree bark	PE
Pyxine	*albovirens*	(G. Mey.) Aptroot	54458	tree bark	PE
Pyxine	*mantequeirensis*	Marcelli & Jungbluth	54449	tree bark	PE
Rinodina	*sipmanii*	Aptroot	54650	tree bark	PE
Synarthonia	*ferruginea*	(Vain.) Van den Broeck & Ertz	54499	tree bark	PE
Tylophoron	*moderatum*	Nyl.	54670	tree bark	PE
Usnea	*brasiliensis*	(Zahlbr.) Motyka	54467	tree bark	PE
Usnea	*cornuta*	Körb.	54532	tree bark	PE
Usnea	*parvula*	Motyka	54506	twig bark	PE
Sculptolumina	*serotina*	(Malme) Marbach	54526	wood	PE
Xylographa	*parallela*	(Ach.) Fr.	54596	wood	PE

Although still only a small portion of the country has been investigated lichenologically, it is possible to compare between the investigated areas. The saxicolous lichen biota of the Vale do Catimbau is markedly different from any other area we investigated. It shares only relatively few species with the geographically closest investigated area, the Pedra Talhada mountains. These are composed of granite outcrops inside an Atlantic Rainforest remnant. Its lichen biota is dominated by *Parmotrema*, and it shares many species with the Chapada Diamantina, and other investigated granite areas in the Atlantic Rainforest biome, more to the South, like the Serra do Caraça in Minas Gerais (Aptroot, 2002) and Pedra Azul in Espírito Santo. Still further South, the lichen biota on the investigated rock outcrops in Mato Grosso (Aptroot & Souza, 2021), Mato Grosso do Sul (Aptroot & Spielmann, 2020; Aptroot et al., 2021b), Paraná (Aptroot et al., 2022), Santa Catarina (Aptroot et al., 2017a) and Rio Grande do Sul (Aptroot et al., 2012a, 2022) shows many similarities with that on Pedra Talhada in Alagoas. There are differences of course; for instance, *Stereocaulon* Hoffm. is absent in the North-East, and the genus *Hypotrachyna* (Vain.) Hale is much more diverse in the South and South-East.

At almost the same distance as Pedra Talhada from Vale do Catimbau is the Poço Redondo. It is also an inland Caatinga area, differing mainly because it is low elevation (c. 25 m) and granite. It is poor in diversity, with only 23 species (Aptroot et al., 2021c). Although the aspect of the lichen vegetation is similar, the two areas share only few species, notably *Fulgogasparria intensa* Aptroot & M. Cáceres, which was newly described and is a locally common species, while it was only found once in Vale do Catimbau.

Somewhat further away is the Serra de Itabaiana in Sergipe. We (and others researchers) visited this are before (e.g., Cáceres et al., 2016; Aptroot et al. 2022) but we revisited it in April 2022 too and found especially many *Cladonia* species, half of which were new to the state, notwithstanding that we and others, in cluding Ahti, previously collected here (Table 2). This includes the northernmost records of species that were described from Bahia (*Cladonia bahiana* Ahti and *C. lichexanthonica* Aptroot & M. Cáceres) or even from South Brazil (*C. gumboskii* Aptroot, M.F. Souza & A.A. Spielm.). For the latter species it is a range extension of c. 1200 km. Incidentally, two of the above *Cladonia* species are not terricolous but strictly saxicolous, which strengthens our opinion that they should be seen as one ecological element. The saxicolous lichen biota of this area is not species-rich; there are more *Cladonia* species. It shows, mostly because of the *Cladonia* species, some resemblance to the biota of Pedra Talhada, but is markedly poorer. The reason may be that the bedrock is often rather soft sandstone and the surrounding forest is transitional/patchy Caatinga and Atlantic Rainforest. Incidentally, it should be noted here that some of the terricolous lichens are ephemerous. During a previous visit, an unidentifiable and probably undescribed *Gyalideopsis* was frequently found on places where it was absent now. Some of the *Cladonia* species that were recorded earlier could also not be found, while we now found 19 species, eight of which being new records to Sergipe state. The same is true for some corticolous lichens. A tree that was investigated many times before now yielded *Swinscowia griseonitens* (R.C. Harris) S.H. Jiang, Lücking & Sérus., another new state record and only the second record in the southern hemisphere. It was absent before.

Further away, c 400 km to the North West is the investigated granite outcrop area of the Pedra da Galinha in Ceará (Aptroot & Cáceres, 2016; Cáceres et al., 2017). It is not very rich in species, but many of them are actually in common with the Vale do Catimbau, especially the many *Caloplaca* species found, including the two species with *Lecanora*-like apothecia that were originally described from the Pedra da Galinha in Ceará state, but which have been found in the mean time almost all over Brazil.

Another large area of rocky outcrops in the North East from which we have saxicolous lichen data is the Chapada Diamantina in Bahia, sandstone table mountains c. 600 km to the South West (Aptroot & Cáceres, 2018a, b). It shares almost no species with the Vale do Catimbau. Its lichen biota is equally similar to Pedra Talhada to the North West and to Serra do Caraça to the South.

The last investigated area in the North East we can compare with is Poço Azul in Maranhão (Aptroot et al., 2017b), c. 1000 km West of Vale do Catimbau. The lichen biota shows little resemblance to other areas in the North East.

Table 2. Terricolous and saxicolous lichens in the Serra de Itabaiana, with one ISE collection number of 2022 collection. Abbreviations: PE = Pernambuco SE = Sergipe.

Genus	Species	Author	ISE #	new to
Buellia	*halonia*	(Ach.) Tuck.	54719	
Buellia	*mamillana*	(Tuck.) W.A. Weber		
Buellia	*ocellata*	(Flörke ex Flot.) Körb.		
Buellia	*subdisciformis*	(Leight.) Jatta		
Buellia	*trachyspora*	Vain.		
Caloplaca	*boergesenii*	(Vain.) Zahlbr.		
Caloplaca	*cinnabarina*	(Ach.) Zahlbr.		
Caloplaca	*diplacia*	(Ach.) Riddle		
Caloplaca	*ochraceofulva*	(Müll. Arg.) Jatta		
Cladia	*aggregata*	(Sw.) Nyl.	54679	
Cladonia	*bahiana*	Ahti	54699	SE
Cladonia	*clathrata*	Ahti & L. Xavier	54714	
Cladonia	*confusa*	R. Sant.	54678	
Cladonia	*didyma*	(Fée) Vain.	54727	SE
Cladonia	*furfuracea*	Vain.	54724	
Cladonia	*gumboskii*	Aptroot, M.F. Souza & Spielmann	54723a	SE
Cladonia	*kalbii*	(Ahti) Ahti & DePriest	54689	
Cladonia	*lichexanthonica*	Aptroot & Cáceres	54723	SE
Cladonia	*megaphylla*	Ahti & Marcelli	54697	SE
Cladonia	*miniata*	G. Mey.	54698	SE
Cladonia	*ochracea*	L. Scriba	54693	SE
Cladonia	*parvipes*	(Vain.) S. Stenroos	54701	
Cladonia	*pityrophylla*	Nyl.	54691	
Cladonia	*polyscypha*	Ahti & L. Xavier	54684	
Cladonia	*polystomata*	Ahti & Sipman	54690	SE
Cladonia	*rugicaulis*	Ahti	54677	
Cladonia	*subminiata*	S. Stenroos	54686	
Cladonia	*subradiata*	(Vain.) Sandst.	54682a	
Cladonia	*subsquamosa*	Kremp.	54682	
Cladonia	*substellata*	Vain.	54688	
Dimelaena	*tenuis*	(Müll. Arg.) H. Mayrhofer & Wippel	54721	
Diploschistes	*hypoleucus*	Zahlbr.	54707	
Lecanora	*sulfurescens*	Fée		
Lecanora	*pseudistera*	Nyl.		
Lepra	*subventosa*	(Malme) I. Schmitt & Lumbsch	54717	SE
Lepra	*ventosa*	(Malme) Lendemer & R.C. Harris		
Micarea	*squamulosa*	Aptroot, Lücking & M. Cáceres	54705	SE
Pterygiopsis	*atra*	Vain.		
Sulzbacheromyces	*caatingae*	(Sulzbacher & Lücking) B.P. Hodk. & Lücking	54708	
Trapeliopsis	*granulosa*	(Hoffm.) Lumbsch	54726	SE
Xanthoparmelia	*substenophylloides*	Hale	54720	SE

If anything, it is closer to those of investigated rock outcrops in Mato Grosso (Aptroot & Souza, 2021). They have in common that they are at the border of the Amazon forest.

One problem with the study of such areas that were never explored before is how to interpret the adaptation of species to the special habitat. The soft sandstone in combination with the often high temperatures makes that many species only make scanty or no thallus. Although this is an ancient landscape, we did not find more than one clearly undescribed species. We do however report several species as new to Brazil, mostly from the Antilles, but also from Europe.

Concluding, we are gradually getting to know the saxicolous lichen biota of northeastern Brazil. It varies much from place to place, depending on altitude, surrounding vegetation and bedrock type. Altogether, the lichen biota is considerably rich, and it (probably) contains local endemics. Part of the species are (probably) widespread but there is also a sizeable element of Brazilian endemics like many of the *Cladonia, Hypotrachyna, Parmotrema* and *Xanthoparmelia* species and *Trapeliopsis studerae* Aptroot & M. Cáceres.

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