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Richard C. Harris
Institute of Systematic Botany, The New York Botanical Garden, Bronx, New York

Erin A. Tripp
Department of Ecology and Evolutionary Biology, University of Colorado, Boulder

James C. Lendemer
Institute of Systematic Botany, The New York Botanical Garden, Bronx, New York

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ARTHOPYRENIA BETULICOLA (ARTHOPYRENIACEAE, DOTHIDIOMYCETES), AN UNUSUAL NEW LICHENIZED FUNGUS FROM HIGH ELEVATIONS OF THE SOUTHERN APPALACHIAN MOUNTAINS

Richard C. Harris,[1] Erin A. Tripp,[2] and James C. Lendemer[1,3]

[1]*Institute of Systematic Botany, The New York Botanical Garden, Bronx, New York 10458-5126;*
[2]*University of Colorado, Department of Ecology and Evolutionary Biology and CU Museum of Natural History, UCB 350, Boulder, Colorado 80309*
[3]*Corresponding author (jlendemer@nybg.org)*

ABSTRACT

The crustose pyrenolichen *Arthopyrenia betulicola* is described as new to science based on collections from high elevations of Great Smoky Mountains National Park in eastern North America. The species is hypothesized to be endemic to the southern Appalachian Mountains where it occurs only on the bark of mature yellow birch (*Betula alleghaniensis*). It is a somewhat unusual member of the genus *Arthopyrenia* s.l. in consistently having a conspicuous photobiont layer of *Trentepohlia*. It differs from *A. cinchonae*, with which it is allopatric, by this feature as well as in having differently shaped and narrower ascospores.

Key words: Great Smoky Mountains, lichen, new species, North Carolina, old growth, pyrenolichen, Tennessee.

INTRODUCTION

In 2006, we initiated our study of the lichen biota of Great Smoky Mountains National Park (hereafter abbreviated GSMNP), located in western North Carolina and eastern Tennessee, by inventorying a small transect (ca. four linear miles) of the northern slopes of Mount Sterling over a total time period of six person hours. To our initial surprise, despite this limited field time and geographical area, this effort yielded 141 species of lichens and allied fungi, including more than 50 species that had not yet been reported from the park and seven species that were previously unknown to science. At the time, only 463 lichens had been previously recorded from GSMNP (Bennett and Wetmore 2008).

Upon further consideration, however, our discovery of high levels of lichen alpha diversity (and new species) in such a limited area was not particularly surprising given that GSMNP is one of the world's most biologically rich temperate forests (Braun 1950; White 1982; Petranka 1998; Bartels and Nelson 2007; Carlton and Bayless 2007; O'Connell et al. 2007; Snyder 2008). For instance, the Park is home to nearly the same diversity of trees as is found in all of Europe. Further, numerous IUCN Red List (IUCN 2013) species of conservation concern occur in the Park including *Abies fraseri* (Pursh) Poir. (Fraser fir), *Ammodramus henslowii* (Henslow's sparrow), *Aneides aeneus* (green salamander), *Calamagrostis cainii* Hitchc. (Cain's reed grass), *Cryptobranchus alleganiensis* (hellbender), and *Contopus cooperi* (olive-sided flycatcher). Moreover, most regions of the United States are under-inventoried from a lichenological perspective. Indeed, past lichen research in GSMNP that was intended to be taxonomically comprehensive was limited to popular areas, high elevations, and/or macrolichens (Degelius 1941; Dey 1978).

Since our initial work in 2006, we have continued to make collections in GSMNP by conducting intensive surveys of exemplary habitats that span the Park's moisture and elevational gradients. These habitats include: cove hardwood and mixed mesophytic forest, northern hardwood-spruce forest, spruce-fir forests, beech gaps, chestnut oak ridge forest, ericaceous-pine heaths, grassy balds, and rock outcrops in each of these habitats (Whittaker 1956; MacKenzie and White 1998). Initially, we focused efforts on middle to low elevations because we deemed these areas to be less well studied than the charismatic higher elevations of the Park (e.g., where both Degelius and Dey focused their earlier efforts). Numerous new reports and new species were discovered as a result of our work at these lesser-explored elevations (Lendemer et al. 2013). Nonetheless, following a single collection trip to higher elevations of GSMNP in 2012, we encountered numerous species that either represented significant range extensions of more northerly taxa (e.g., *Arthonia byssacea* (Weigel) Almq., *A. cupressina* Tuck., *A. vinosa* Leight., *Cliostomum griffithii* (Sm.) Coppins and *Opegrapha gyrocarpa* Flot.) or were new to science (e.g., *Arthonia kermesina* R.C.Harris, E.Tripp & Lendemer and *Lecanora masana* Lendemer & R.C.Harris). These discoveries indicated to us that the higher elevations of GSMNP were considerably more poorly known than we had originally assumed, and as such, we began to survey these regions more thoroughly. The present paper reports on a new species of *Arthopyrenia*, currently known only from high-elevation northern hardwood-spruce forests of GSMNP. It adds to a growing number of interesting discoveries from upper Park elevations (Lendemer and Harris 2013*a,b*) that have come to light after our summary treatment of GSMNP lichens published in early 2013 (Lendemer et al. 2013).

MATERIALS AND METHODS

This study is based entirely on material held in the herbarium of The New York Botanical Garden (NY), including all of the collections made by the authors in GSMNP as well as the sizeable herbarium of John P. Dey (ca. 35,000 specimens), which was recently donated to NY. Chemical and morphological investigations were carried out using the methods outlined in detail by Lendemer and Harris (2013*a*), and descriptive terminology largely follows Harris (1995).

TAXONOMIC SECTION

Arthopyrenia betulicola R.C.Harris, E.Tripp & Lendemer, sp. nov.—TYPE: USA. Tennessee, Sevier County: Great Smoky Mountains National Park, Appalachian Trail 0–1 mi E of False Gap, elev. 5530–5243 ft, shaded Anakeesta rock outcrops in *Abies-Picea-Betula alleghaniensis* forest with occasional stands of *Fagus* and *Sorbus*, 2 Aug 2013, on old *Betula alleghaniensis*, *J.C. Lendemer 37940* (holotype NY!). (Fig. 1–4).
Mycobank #805935.

Diagnosis.—Similar to *Arthopyrenia cinchonae* (Ach.) Müll.-Arg. (Fig. 5, 6) but differing in the shape of the ascospores (acute at both ends vs. both ends rounded or with lower end ± acute), the width of the ascospores (6–7.5 μm vs. 7–9.5 (–11) μm), by growing at high elevations, and in having a consistently lichenized thallus.

Description.—Thallus endophloeodal, white, with a conspicuous *Trentepohlia* photobiont. Ascomata perithecioid, black, mostly immersed, becoming emergent with age, hemispherical to ± applanate, 0.2–0.3 mm in diameter. Ostiole apical, often sunken. Wall colorless below. Asci cylindrical, ca. 95 × 15 μm. Ascospores 8/ascus, biseriate to irregularly uniseriate, colorless, fusiform with both ends acute, 1-septate, constricted at the septum, 20–26 × 6–7.5 μm, halonate. Pycnidia black, hemispherical, ca. 70 μm in diameter. Conidia bacillar, 4.5–5.5 × 1.0–1.2 μm.

Etymology.—The epithet "betulicola" refers to the fact that all of the known collections are from the phorophyte *Betula alleghaniensis* Britt.

Ecology and distribution.—*Arthopyrenia betulicola* is currently known from only a handful of sites in a relatively restricted portion of GSMNP (the central highlands south and east of Mt. Le Conte; Fig. 7) where it occurs in mature, mixed northern hardwood-spruce forests. In this region, the new species has been collected exclusively from older bark on drier (i.e., south-facing) surfaces of mature *B. alleghaniensis*, in particular, on large exposed roots or lowermost portions of tree boles. This association is unlikely to be spurious, as we have documented precisely the same association between old growth yellow birch and another lichen we recently described as new to science, *Graphis sterlingiana* E.Tripp & Lendemer (Lendemer et al. 2013). Since our initial collection of *G. sterlingiana* in 2006, we have subsequently collected it on several occasions in high elevation primary forests in the eastern portions of the Park. We similarly expect that *A. betulicola* will eventually be found in a broader region than that described above, but likely only in areas that host mature northern hardwood-spruce forest, which are rare in the southeastern United States.

Conservation status.—Although it is likely that *Arthopyrenia betulicola* will eventually be documented from a broader geographic area than described above, the limited extent of the type of habitat in which it occurs suggests that this species may genuinely represent a rare element of the North American lichen biota. Specifically, although *Betula alleghaniensis* is a dominant constituent of middle to high elevation forests of the southern Appalachians, this tree is most commonly encountered in middle-aged forest stands that originated following massive logging of the entire region in the early 20th Century (Abramson and Haskell 2006). That is, mature northern hardwood-spruce forests represent a very small fraction of the extent of this habitat, and virgin stands of this habitat type are even rarer. Given the fact that we have now documented not one but two (i.e., including *Graphis sterlingiana*) species of lichens that are apparently endemic to mature stands of yellow birch, current and future conservation plans must take into account the importance of these rare, albeit highly charismatic, montane habitats. We encourage others to search for *Arthopyrenia betulicola* and *Graphis sterlingiana* in mature yellow birch-spruce stands, particularly in forests outside of GSMNP where comparatively less lichenological inventory has been advanced.

DISCUSSION

The discovery of this new species at high elevations of the Great Smoky Mountains was quite unexpected. Indeed, the species puzzled us for some time as it clearly seemed to belong to the genus *Arthopyrenia* s.l. but differed from most members of that genus in having a thallus that was consistently lichenized with *Trentepohlia* (Harris 1995). The latter feature is more typical of members of superficially similar genus *Anisomeridium* (Müll.Arg.) R.C.Harris s.l. (Harris 1995). While the aspect of the ascospores of *A. betulicola* strongly resembles that of some species of *Anisomeridium*, the bacillar conidia readily distinguish it from that genus, which has globose to elliptical microconidia (Harris 1973, 1995). Additionally, the presence of a well developed halo on the ascospores of the new species indicates that placement in *Arthopyrenia* s.l. rather than *Anisomeridium* is warranted.

It should be noted that herein we refer to *Arthopyrenia* in a broad sense following Harris (1995). Indeed, a recent molecular study found the genus to be polyphyletic as currently circumscribed (Nelsen et al. 2011). Unfortunately an evolutionarily accurate circumscription of the genus remains out of reach because only three of the approximately 117 known *Arthopyrenia* species (Kirk et al. 2008) were included in the above study and these did not include the type species, *A. cerasi* (Schrad.) A.Massal. In the absence of a well supported phylogeny with broad sampling of *Arthopyrenia* and its relatives, including the type species of relevant genera, we prefer to refrain from further speculation as to the evolutionary relationships within the genus.

The asci of *Arthopyrenia betulicola* are very similar to those of *A. cinchonae* (cf. Fig. 4, 5), a common species of the Coastal Plain of southeastern North America (Harris 1995; and see Fig. 7 herein). The new species can be distinguished from *A. cinchonae* primarily by its narrower ascospores that are acute at both ends (vs. only one end in *A. cinchonae*). Although *A. cinchonae* has been reported from a low elevation site in GSMNP (Lendemer et al. 2013), the two species appear to be allopatric, with *A. betulicola* restricted to spruce-fir forests that occur only at high elevations. During the peer review of this manuscript, it was indicated that South American material of *A. cinchonae* is lichenized and that this species is probably polyphyletic. Indeed, there is *Trentepohlia* present in some South American specimens of *A. cinchonae* that we have examined, and thus some populations of that species may be considered to be lichenized. This observation is consistent with

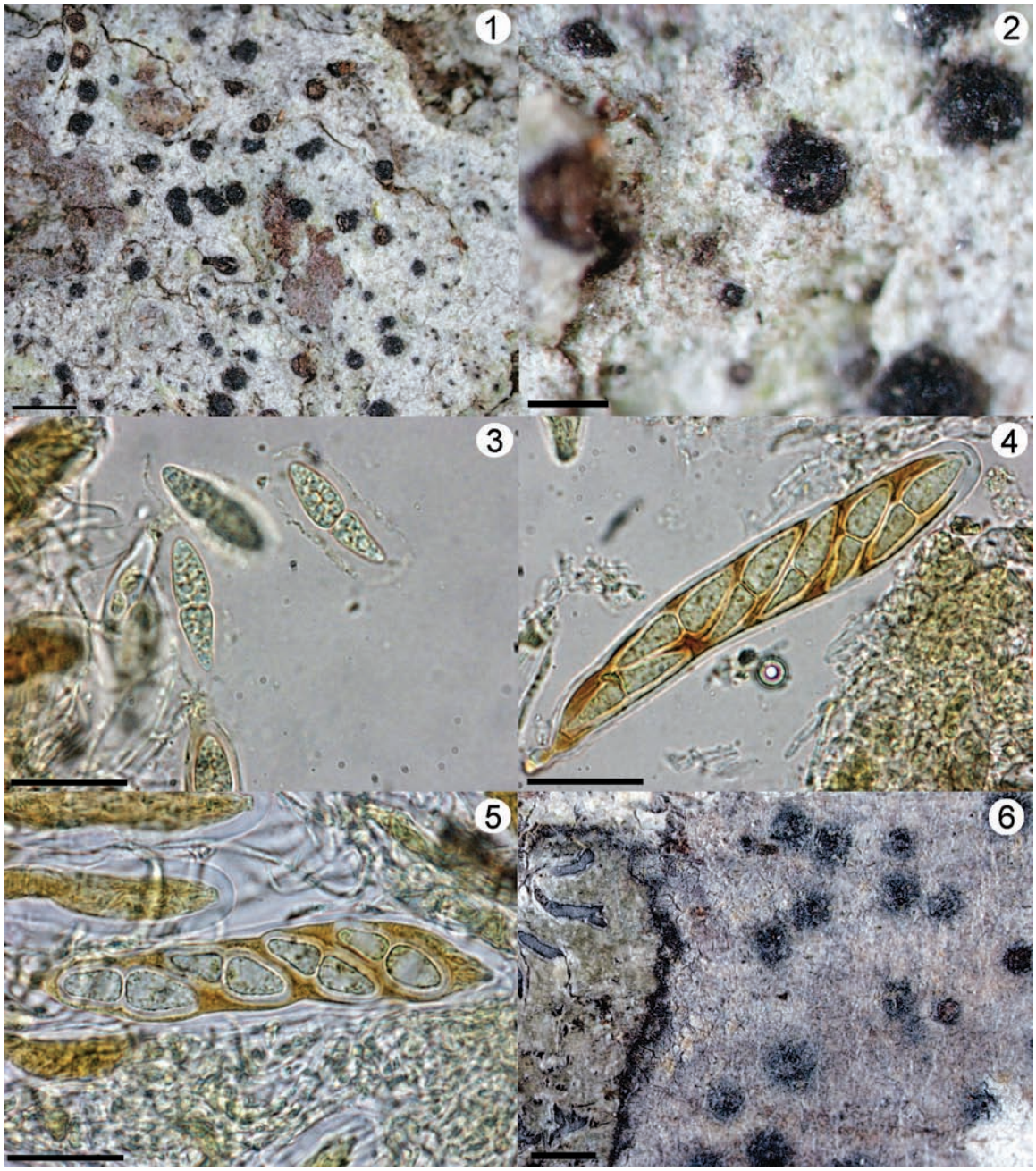

Fig. 1–6. *Arthopyrenia betulicola* (Fig. 1–4 from *Lendemer 37940*) and *A. cinchonae* (Fig. 5 from *Buck 22504*; Fig. 6 from *Lendemer 37940*).—1. Gross morphology of thallus and perithecia of *A. betulicola*.—2. Detail of a perithecium of *A. betulicola*.—3. Halonate ascospores of *A. betulicola* mounted in iodine.—4. Ascus of *A. betulicola* mounted in iodine.—5. Ascus of *A. cinchonae* mounted in iodine.—6. Gross morphology of thallus and perithecia of *A. cinchonae.* Scales = 1.0 mm in Fig. 1–6; 0.25 mm in Fig. 2; 20 µm in Fig. 3–5.

the reviewer's comment. However, the *Trentepohlia* is sparse in these populations and detected only with careful staining (unlike in *A. betulicola*, where it forms an obvious layer). The North American material of *A. cinchonae* that we examined was not obviously lichenized, but further detailed study is required to confirm that this is the case.

Arthopyrenia lyrata R.C.Harris is another species that, like *A. betulicola*, has a ± well developed photobiont layer (Harris 1995). *Arthopyrenia lyrata* is sympatric with *A. cinchonae* in the southeastern Coastal Plain of North America and the two are likely related. *Arthopyrenia lyrata* is nevertheless easily distinguished from *A. betulicola* and *A. cinchonae* in having ascospores wherein the cells are pinched (vs. ± even) and the walls are finely ornamented (vs. smooth). Considering the differences in ascospore morphology we do not believe that it is likely that *A. lyrata* is closely related to *A. betulicola*.

Additional specimens examined.—USA. North Carolina, Haywood County: Great Smoky Mountains National Park, Appalachian Trail 0–1.1 mi E of Laurel Top, 2 Aug 2013, on root of large *Betula alleghaniensis*, *J.C. Lendemer 37879* (NY); Gunter Fork Trail between junction Balsam Mountain Trail

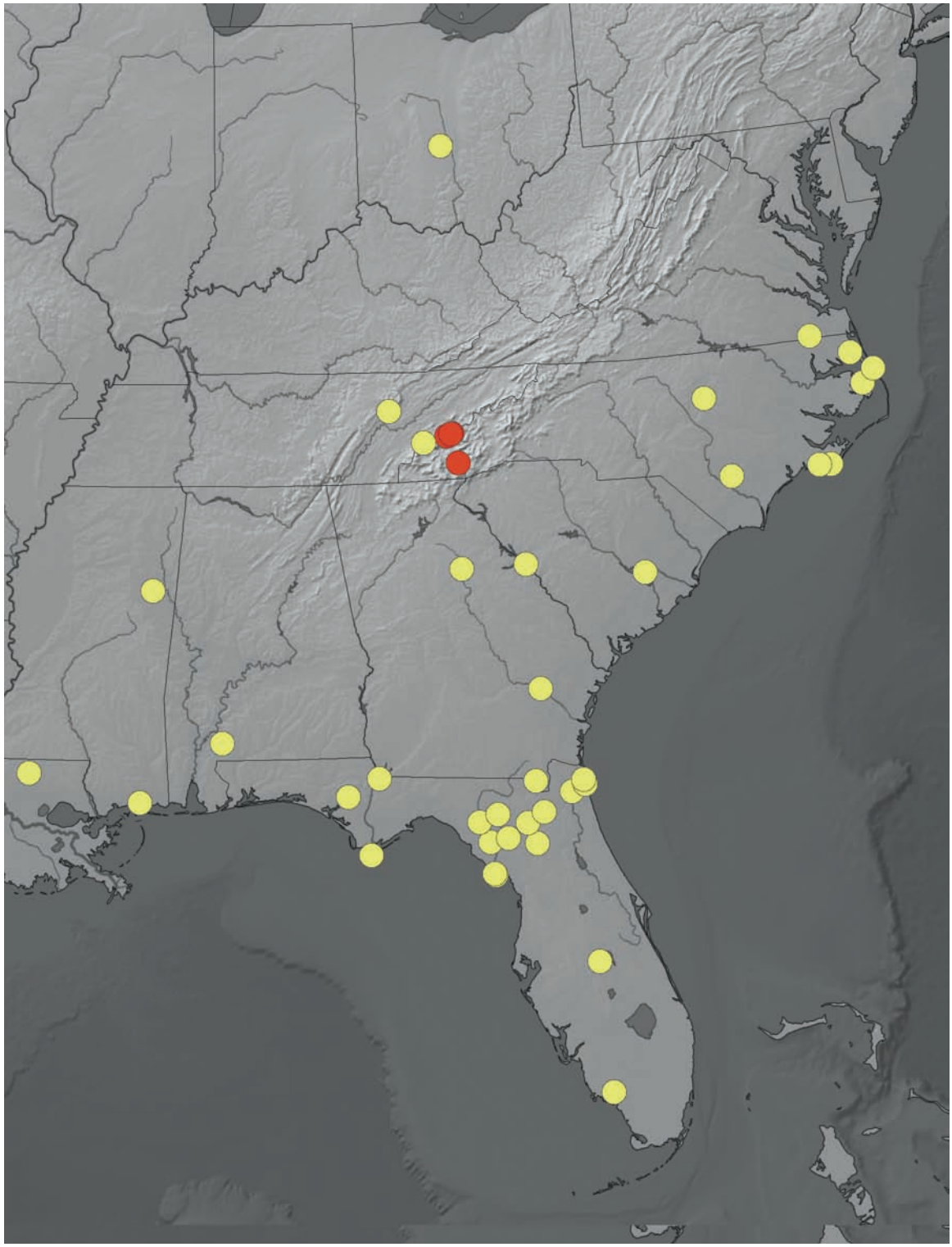

Fig. 7. Known geographic distribution of *Arthopyrenia betulicola* (red dots) compared to that of *A. cinchonae* in North America (yellow dots) based on specimens at the NY Herbarium. Note that all records of *A. cinchonae* are from low to middle elevations while those of *A. betulicola* are from high elevations.

and Walnut Bottoms, 13 Oct 2012, on *Betula alleghaniensis*, *E. Tripp 3894 & J.C. Lendemer* (NY). Swain County: Great Smoky Mountains National Park, Appalachian Trail between Clingmans Dome and junction with Goshen Prong Trail, 25 July 2011, on old *Betula*, *J.C. Lendemer 29651 & N. Davoodian* (NY). Tennessee, Cocke County: Great Smoky Mountains National Park, Snake Den Trail between junction with Maddron Bald Trail and Inadu Knob, 26 July 2011, on old *Betula alleghaniensis*, *J.C. Lendemer 29750* (NY), *J.C. Lendemer 29817* (NY). Sevier County: Great Smoky Mountains National

Park, Anakeesta Knob to The Jumpoff spur along Boulevard Trail, 7 Aug 2012, on *Betula alleghaniensis* base, *E. Tripp 3476 & J.C. Lendemer* (NY), *E. Tripp 3483 & J.C. Lendemer* (GSMNP, NY).

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