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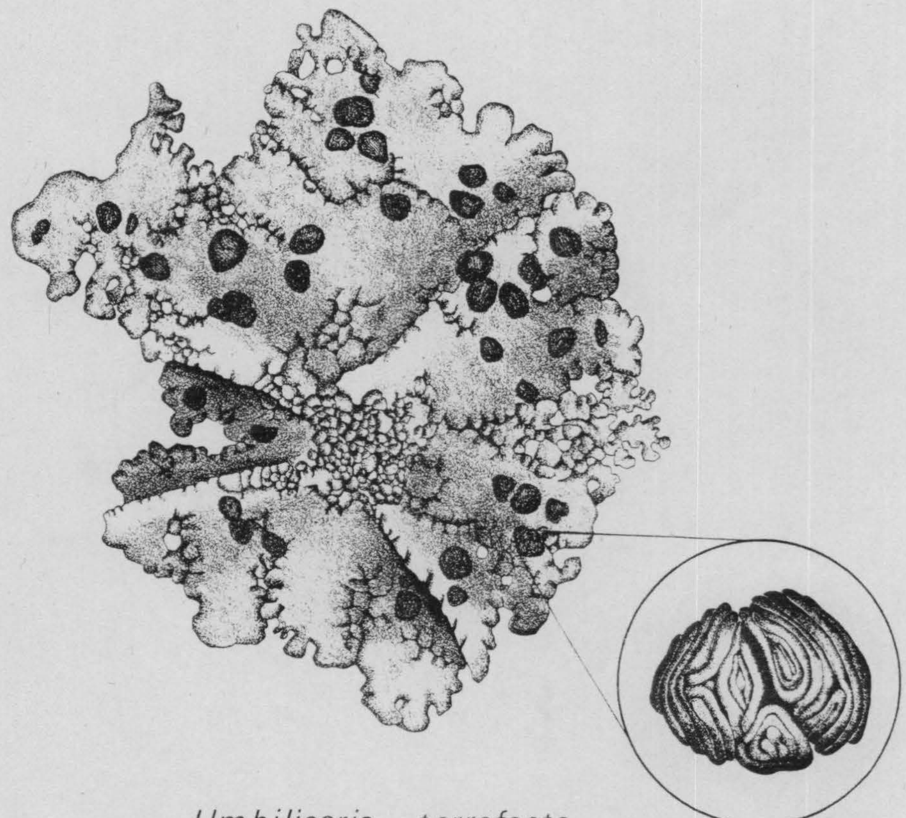
LICHENS AND AIR QUALITY IN

WHITE MOUNTAIN NATIONAL FOREST WILDERNESS AREAS

FINAL REPORT

USDA 40-1484-7-614



Umbilicaria torrefacta

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LICHENS AND AIR QUALITY

IN

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by

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LICHENS OF WHITE MOUNTAINS WILDERNESS AREAS

PREFACE

Under a grant from the U. S. Forest Service a lichen study was to be performed in the Presidential Dry River and the Great Gulf Wilderness Areas of the White Mountain National Forest. This study was to survey the lichens of the areas, produce a lichen flora, collect and analyze lichens for chemical contents and evaluate the lichen flora with reference to the air quality. This study is to establish baseline data for future restudy and determine the presence of any air quality problems as might be shown by the lichens at the time of the study. All work was done at the University of Minnesota with consultation with Randy Ferrin, Laconia, NH and with other U. S. Forest Service personnel.

The forest personnel have been very helpful during the field work with assistance and transportation which has contributed significantly to the success of the project. The study was made possible by funds from the U. S. Forest Service. The assistance of all of these is gratefully acknowledged.

INTRODUCTION

Lichens are composite plants composed of two different types of organisms. The lichen plant body (thallus) is made of fungi and algae living together in a symbiotic arrangement in which both partners are benefited and the composite plant body can grow in places where neither component could live alone. The thallus has no protective layer on the outside, such as the epidermis of a leaf, so the air in the thallus has free exchange with the atmosphere. Lichens are slow growing (a few millimeters per year) and remain alive for many years and so must have a habitat that is relatively undisturbed in order to survive. Lichens vary greatly in their ecological requirements but almost all of them can grow in places that only receive periodic moisture. When moisture is lacking they go dormant until the next rain or dew-fall. Some species can grow in habitats with very infrequent occurrences of moisture while others need high humidity and frequent wetting in order to survive. This difference in moisture requirements is very important in the distribution of lichens.

Lichens are known to be very sensitive to low levels of many atmospheric pollutants. Many are damaged or killed by levels of sulfur dioxide, nitrogen oxides, fluorides or ozone alone or in various combinations. Levels of sulfur dioxide as low as 13 ug/cubic meter (annual average) will cause the death of some lichens (LeBlanc et al., 1972). Other lichens are less sensitive and a few can tolerate levels of sulfur dioxide over 300 ug/cubic meter (Laundon, 1967, Trass, 1973). The algae of the thallus are the first to be damaged in areas with air pollution and the first indication of damage is discoloring and death of the algae causing bleached lobes, which quickly leads to the death of the lichen. After the lichen dies it disappears from the substrate within a few months to a year as it disintegrates and decomposes (Wetmore, 1982).

Lichens are more sensitive to air pollution when they are wet and physiologically active and are least sensitive when dry (Nash, 1973, Marsh & Nash, 1979) and are more sensitive when growing on acid substrates.

Contrary to some published reports (Medlin, 1985) there is little evidence that most lichens are good indicators of acid precipitation. However, Sigal & Johnston (1986) have reported that one species of _Umbilicaria_ shows visible damage due to artificial acid rain. They also report that similar symptoms were found in collections from various localities in North America. Lechowicz (1987) reported that acid rain only slightly reduced growth of _Cladina stellaris_ but Hutchinson et al. (1986) reported that extremely acid precipitation killed or damaged some mosses and lichens. Scott & Hutchinson (1987) showed temporary reduction of photosynthesis in _Cladina stellaris_ and _C. rangiferina_ after artificial acid rain.

Lichens are able to accumulate chemical elements in excess of their metabolic needs depending on the levels in the substrate and the air and, since lichens are slow growing and long lived, they serve as good summarizers of the environmental conditions in which they are growing. Chemical analysis of the thallus of lichens growing in areas of high fallout of certain elements will show elevated levels in the thallus. Toxic substances (such as sulfur) are also accumulated and determination of the levels of these toxic elements can provide indications of the sub-lethal but elevated levels in the air.

The Great Gulf Wilderness Area is located just north of Mt. Washington in northern New Hampshire and the Presidential Dry River Wilderness Area is located just south of Mt. Washington. Only these two wilderness areas in the White Mts. National Forest were included in this study and Mt. Washington itself was outside of both wilderness areas. The elevations range from 1200 ft to over 5300 ft. The terrain is steep and rugged with granitic peaks and ridges. The forests at the lower elevations are mixed hardwoods with sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), yellow birch (*Betula allegheniensis*), white birch (*Betula papyrifera*) and some areas of hemlock (*Tsuga canadensis*) and white pine (*Pinus strobus*). At higher elevations there are balsam fir (*Abies balsam~~ifera~~ea*) and black spruce (*Picea mariana*) grading into krumholz at the highest elevations. On the highest peaks alpine vegetation occurs among the abundant rocks.

The White Mountains were one of the first areas of North America to be extensively studied by Edward Tuckerman and his co-workers in their lichenological studies over 150 years ago. These early lichenologists thoroughly collected around Mt. Washington and throughout the White Mts.for decades during the

19th century. Tuckerman published many reports on the lichens of the region (see literature cited). Until recent times this region was probably one of the best known areas of North America lichenologically. Since Tuckerman's time most North American lichenologists have collected around Mt. Washington at some time or another. Many ecologists have studied the alpine vegetation around Mt. Washington and some studies included lichens in their papers (Bliss, 1962, 1963, 1966, Bliss & Hadley, 1964, Hadley & Bliss, 1964). Many of the lichen collections of various collectors have been cited in monographs and revisions and these references are listed in the literature cited. A list of the 289 lichens reported in the literature is included in Appendix III. The names in Appendix III have been brought up to current nomenclatural practice according to Egan (1987) wherever possible but some of the smaller genera used by Egan are not recognized here.

METHODS

Field work was done during July, 1988 when 1005 collections were made at 21 localities. A complete list of collection localities is given in Appendix I and are indicated on Fig. 1. Localities for collecting were selected first to give a general coverage of the wilderness areas and be within practical walking distance from roads, second, to sample all vegetational types, and third, to be in localities that should be rich in lichens. Undisturbed as well as disturbed habitats were studied. At each locality voucher specimens of all species found were collected to record the total flora for each locality and to avoid missing different species that might appear similar in the field. At some localities additional material of selected species was collected for chemical analysis (see below). While collecting at each locality observations were made about the general health of the lichens.

Identifications were carried out at the University of Minnesota with the aid of comparison material in the herbarium and using thin layer chromatography for identification of the lichen substances where necessary. The original packet of each collection has been deposited in the University of Minnesota Herbarium. All specimens deposited at the University of Minnesota have been entered into the herbarium computerized data base maintained there. Lists of species found at each locality are available from this data base at any time on request.

LICHEN FLORA

The following list of lichens is based only on my collections. The species reported in the literature are given in Appendix III. Species found only once are indicated by "Rare". In the first columns the letters indicate the sensitivity to sulfur dioxide, if known, according to the categories proposed by Wetmore (1983): S=Sensitive, I=Intermediate, T=Tolerant. S-I is intermediate between Sensitive and Intermediate and I-T is intermediate between Intermediate and Tolerant. Species in the Sensitive category are absent when annual average levels of sulfur dioxide are above 50ug per cubic meter. The Intermediate category includes those species present between 50 and 100ug and those in the Tolerant category are present at over 100ug per cubic meter.

SPECIES LIST

Acarospora fuscata (Nyl.) Arn.
Acarospora sinopica (Wahlenb. in Ach.) Körb.
Arthothelium ruanum (Mass.) Zw.
1 additional unidentified species of Arthothelium
Aspicilia caesiocinerea (Nyl. ex Malbr.) Arn. Rare
Aspicilia cinerea (L.) Körb.
Bacidia chlorantha (Tuck.) Fink
Bacidia lugubris (Somm.) Zahlbr. Rare
Bacidia schweinitzii (Tuck.) Schneid. Rare
1 additional unidentified species of Bacidia
Baeomyces rufus (Huds.) Rebent.
Botrydina viridis (Ach.) Redh. & Kuyper
S Bryoria furcellata (Fr.) Brodo & Hawksw.
I Bryoria fuscescens (Gyeln.) Brodo & Hawksw.
Bryoria nadvornikiana (Gyeln.) Brodo & Hawksw.
Buellia arnoldii Serv.
Buellia disciformis (Fr.) Mudd
I Buellia stillingiana Steiner
Calicium trabinellum (Ach.) Ach.
S-I Caloplaca cerina (Ehrh. ex Hedw.) Th. Fr. Rare
I Caloplaca holocarpa (Hoffm.) Wade
S-I Cetraria ciliaris Ach.
Cetraria cucullata (Bellardi) Ach.
Cetraria delisei (Bory ex Schaer.) Nyl.
Cetraria halei W. & C. Culb.
Cetraria hepatizon (Ach.) Vain.
Cetraria islandica (L.) Ach.
Cetraria nivalis (L.) Ach.
Cetraria oakesiana Tuck.
I Cetraria orbata (Nyl.) Fink
I Cetraria pinastri (Scop.) Gray
I Cetraria sepincola (Ehrh.) Ach.
Cetrelia cetrarioides (Del. ex Duby) W. & C. Culb. Rare
Cetrelia olivetorum (Nyl.) W. & C. Culb.
Chaenotheca brunneola (Ach.) Müll. Arg.
Chaenotheca xyloxena Nadv. Rare
Chaenothecopsis debilis (Turn. & Borr. ex Sm.) Tibell
Cladina arbuscula (Wallr.) Hale & W. Culb.
Cladina mitis (Sandst.) Hustich
Cladina rangiferina (L.) Nyl.
Cladina stellaris (Opiz) Brodo
Cladina stygia (Fr.) Ahti
Cladonia amaurocraea (Flörke) Schaer.
Cladonia bacillaris Nyl.
Cladonia caespiticia (Pers.) Flörke

Cladonia cenotea (Ach.) Schaer. Rare
Cladonia chlorophaea (Flörke ex Somm.) Spreng.
Cladonia coccifera (L.) Willd.
I *Cladonia coniocraea* (Flörke) Spreng.
Cladonia cornuta (L.) Hoffm.
Cladonia crispata (Ach.) Flot.
I *Cladonia cristatella* Tuck.
Cladonia cyanipes (Somm.) Nyl.
Cladonia deformis (L.) Hoffm.
Cladonia digitata (L.) Hoffm.
S-I *Cladonia fimbriata* (L.) Fr. Rare
Cladonia floerkeana (Fr.) Flörke
Cladonia furcata (Huds.) Schrad.
Cladonia gracilis (L.) Willd.
Cladonia macilenta Hoffm. Rare
Cladonia maxima (Asah.) Ahti Rare
Cladonia merochlorophaea Asah.
Cladonia multiformis G. K. Merr. Rare
Cladonia phyllophora Ehrh. ex Hoffm. Rare
Cladonia pleurota (Flörke) Schaer.
Cladonia pseudorangiformis Asah.
Cladonia pyxidata (L.) Hoffm. Rare
Cladonia scabriuscula (Del.in Duby) Leight. Rare
Cladonia squamosa (Scop.) Hoffm.
Cladonia subsubulata Nyl. Rare
Cladonia sulphurina (Michx.) Fr.
Cladonia uncialis (L.) Web. ex Wigg.
Cladonia verticillata (Hoffm.) Schaer. Rare
Conotrema urceolatum (Ach.) Tuck.
Cornicularia aculeata (Schreb.) Ach.
Dimelaena oreina (Ach.) Norm. Rare
Diploschistes scruposus (Schreb.) Norm.
I *Evernia mesomorpha* Nyl.
I *Graphis scripta* (L.) Ach.
Haematomma cismonicum Beltr.
Haematomma elatinum (Ach.) Mass.
Haematomma lapponicum Räs.
I *Haematomma ochrophaeum* (Tuck.) Mass.
Hymenelia lacustris (With.) Poelt & Vezda Rare
Hypogymnia krogiae Ohls.
I *Hypogymnia physodes* (L.) Nyl.
I *Hypogymnia tubulosa* (Schaer.) Hav.
Icmadophila ericetorum (L.) Zahlbr.
I *Imshaugia aleurites* (Ach.) S. F. Meyer
Julella fallaciosa (Stizenb. ex Arn.) R. Harris
Lasallia papulosa (Ach.) Llano
Lecanora badia (Hoffm.) Ach.
Lecanora caesiorubella Ach. subsp. *caesiorubella*
I *Lecanora circumborealis* Brodo & Vitik.
Lecanora glabrata (Ach.) Malme
Lecanora hybocarpa (Tuck.) Brodo
Lecanora mutabilis Somm.
Lecanora piniperda Körb. Rare
Lecanora polytropa (Hoffm.) Rabenh.

I	*Lecanora pulicaris* (Pers.) Ach.
I	*Lecanora symmicta* (Ach.) Ach. Rare
	Lecanora thysanophora Harris ined.
	Lecanora wisconsinensis Magn.
I	*Lecidea albofuscescens* Nyl. Rare
	Lecidea albohyalina (Nyl.) Th. Fr.
	Lecidea diapensiae Th. Fr.
	Lecidea epixanthoidiza Nyl.
	Lecidea helvola (Körb. ex Hellb.) Oliv.
	Lecidea plana (Lahm in Körb.) Nyl.
	Lecidea tessellata Flörke Rare
	Lecidea tornoensis Nyl.
S	*Lecidea vernalis* (L.) Ach.
	2 additional unidentified species of *Lecidea*
	Lecidella euphorea (Flörke) Hert.
	Lecidella stigmatea (Ach.) Hert. & Leuck.
	Lecidoma demissum (Rutstr.) Schneid. & Hert.
	Lepraria finkii (B. de Lesd. in Hue) R. Harris
	Lepraria neglecta (Nyl.) Lett.
	Leptogium cyanescens (Rabenh.) Körb.
	Leptorhaphis epidermidis (Ach.) Th. Fr.
S	*Lobaria pulmonaria* (L.) Hoffm.
	Lobaria quercizans Michx.
I	*Lopadium pezizoideum* (Ach.) Körb.
	Micarea bauschiana (Körb.) V. Wirth & Vezda Rare
	Micarea lignaria (Ach.) Hedl.
	Micarea melaena (Nyl.) Hedl.
	Micarea peliocarpa (Anzi) Coppins & R. Sant.
	Micarea prasina Fr.
	Micarea turfosa (Mass.) Du Rietz Rare
	2 additional unidentified species of *Micarea*
I	*Mycoblastus sanguinarius* (L.) Norm.
	Mycocalicium subtile (Pers.) Szat.
	Nephroma parile (Ach.) Ach.
	Nephroma resupinatum (L.) Ach. Rare
S	*Ochrolechia androgyna* (Hoffm.) Arn.
	Ochrolechia arborea (Kreyer) Almb.
	Ochrolechia frigida (Sw.) Lynge
	Ochrolechia pallescens (L.) Mass.
	Ochrolechia pseudopallescens Brodo Rare
	Orphniospora moriopsis (Mass.) D. Hawksw.
	Parmelia aurulenta Tuck.
	Parmelia baltimorensis Gyeln.
	Parmelia centrifuga (L.) Ach.
	Parmelia cumberlandia (Gyeln.) Hale Rare
	Parmelia galbina Ach. Rare
	Parmelia halei Ahti
	Parmelia omphalodes (L.) Ach.
	Parmelia panniformis (Nyl.) Vain.
I	*Parmelia rudecta* Ach.
I	*Parmelia saxatilis* (L.) Ach.
I	*Parmelia septentrionalis* (Lynge) Ahti Rare
S	*Parmelia squarrosa* Hale
	Parmelia stygia (L.) Ach.

S-I	*Parmelia subaurifera* Nyl.
I-T	*Parmelia sulcata* Tayl.
	1 additional unidentified species of *Parmelia*
I	*Parmeliopsis ambigua* (Wulf. in Jacq.) Nyl.
I	*Parmeliopsis hyperopta* (Ach.) Arn.
	Peltigera leucophlebia (Nyl.) Gyeln. Rare
	Peltigera polydactyla (Neck.) Hoffm.
	Peltigerá praetextata (Flörke ex Somm.) Zopf Rare
I	*Pertusaria amara* (Ach.) Nyl.
	Pertusaria consocians Dibb.
	Pertusaria leucostoma (Bernh.) Mass. Rare
	Pertusaria macounii (Lamb) Dibb. Rare
	Pertusaria ophthalmiza (Nyl.) Nyl.
	Pertusaria propinqua Müll. Arg.
	Pertusaria trachythallina Erichs. Rare
	Pertusaria velata (Turn.) Nyl.
	Pertusaria waghornei Hult. Rare
	2 additional unidentified species of *Pertusaria*
I	*Phaeophyscia orbicularis* (Neck.) Moberg Rare
	Phaeophyscia rubropulchra (Degel.) Moberg
I	*Physcia aipolia* (Ehrh. ex Humb.) Fürnr. Rare
	Placynthiella icmalea (Ach.) Coppins & James
	Placynthiella oligotropha (Laund.) Coppins & James
	Placynthiella uliginosa (Schrad.) Coppins & James
I	*Platismatia glauca* (L.) W. & C. Culb.
	Platismatia tuckermanii (Oakes) W. & C. Culb. Rare
	Porpidia crustulata (Ach.) Hert. & Knoph
	Porpidia macrocarpa (DC. in Lam. & DC.) Hert. & Schwab
	2 additional unidentified species of *Porpidia*
	Pseudevernia cladonia (Tuck.) Hale & W. Culb.
	Pseudevernia consocians (Vain.) Hale & W. Culb.
	Pycnothelia papillaria Duf.
	Pyrenula pseudobufonia (Rehm.) R. Harris
	Pyxine sorediata (Ach.) Mont.
	Ramalina intermedia (Del. ex Nyl.) Nyl. Rare
	Rhizocarpon badioatrum (Flörke ex Spreng.) Th. Fr. Rare
	Rhizocarpon cinereovirens (Müll. Arg.) Vain.
	Rhizocarpon eupetraeoides (Nyl.) Blomb. & Forss.
	Rhizocarpon geographicum (L.) DC.
	Rhizocarpon hochstetteri (Körb.) Vain.
	Rhizocarpon lecanorinum (Körb.) Anders
	Rhizocarpon obscuratum (Ach.) Mass. Rare
	Rhizocarpon oederi (Weber) Körb.
	Rhizoplaca chrysoleuca (Sm.) Zopf Rare
I	*Scoliciosporum chlorococcum* (Graewe ex Stenh.) Vezda
	Sphaerophorus fragilis (L.) Pers.
I	*Stenocybe major* Nyl. ex Körb.
	Stereocaulon dactylophyllum Flörke
	Stereocaulon glaucescens Tuck.
	Stereocaulon nanodes Tuck. Rare
	Stereocaulon saxatile Magn.
	Stereocaulon tomentosum Fr. Rare
	1 additional unidentified species of *Stereocaulon*
	Thamnolia subuliformis (Ehrh.) W. Culb.

Trapelia coarctata (Sm.) Choisy in Werner Rare
Trapelia involuta (Tayl.) Hert.
Trapeliopsis flexuosa (Fr.) Coppins & James Rare
Trapeliopsis gelatinosa Flörke) Coppins & James
Trapeliopsis granulosa (Hoffm.) Lumbsch.
Trapeliopsis viridescens (Schrad.) Coppins & James Rare
Umbilicaria deusta (L.) Baumg.
Umbilicaria hyperborea (Ach.) Hoffm.
Umbilicaria mammulata (Ach.) Tuck. Rare
Umbilicaria muehlenbergii (Ach.) Tuck.
Umbilicaria proboscidea (L.) Schrad.
Umbilicaria torrefacta (Lightf.) Schrad.
Umbilicaria vellea (L.) Ach.
S _Usnea filipendula_ Stirt. Rare
S-I _Usnea hirta_ (L.) Weber ex Wigg.

DISCUSSION OF FLORA

This list includes 214 species collected for this study. There are also an additional 12 unidentified species, some of which are undescribed. The most common species are _Cetraria islandica_, _Cladina rangiferina_, _Cladina stellaris_, _Cladonia amaurocraea_, _Hypogymnia physodes_, _Mycoblastus sanguinarius_, and _Ochrolechia frigida_.

Many alpine species occur at the higher elevations of the White Mts., such as _Thamnolia vermicularis_, _Cetraria nivalis_, and others. At lower elevations in the conifer forests the lichen flora is typical of the northern boreal forest that occurs across North America and includes _Hypogymnia physodes_, _Cladina stellaris_, _Calicium_ spp. and others. A few species that are restricted to eastern North America also occur in the White Mts., such as _Cladonia maxima_, _Hypogymnia krogiae_, and _Pseudevernia cladonia_. In the hardwood forests there are fewer species than in the conifer forests, probably due to the dense shade.

Some of the rare species are rare wherever they are found throughout their distributional range and might be found at other localities with further searching and others may require special substrates that are rare in the area.

Some localities that should have many species do not. An example is near the Halfway House locality on the Mt. Washington Road. This balsam fir forest should have had many more species of lichens. It is probably not due to the dead and dying conifers (possibly due to acid precipitation) because this opens up the forest and provides dead branches for good lichen growth. Whether this lack of species is natural or real is unknown. Periodic restudy of the same areas might provide some answers.

Most of the historical species were found during this study but there are a number of species that might be expected but were not found. Some of the more remote localities within the wilderness areas may have produced additional species. One cannot make valid comparisons between the collections for this study and the historical species list. The length of time the many lichenologists in the past collected in the area compared to the length of time available for this study is not comparable. Many of the old records give the locality as "White Mts." which covers much more than the present wilderness areas. Many species in the literature were found in Tuckerman's Ravine and on Mt. Washington, which are outside of the present study areas. For these reasons it is impossible to attribute all of the missing species to air pollution. However, the northeastern United States is known to have severe air pollution problems and many of the missing species may no longer occur in the area.

Another way of analyzing the lichen flora of an area is to study the distributions of the sensitive species within the National Forest to look for voids in the distributions that might be caused by air pollution. Showman (1975) has described and used this technique in assessing sulfur dioxide levels around a power plant in Ohio. Only the very common species have meaning with such a technique since the rare species may be absent due to other factors.

Many of the lichens in the area have known sensitivity to sulfur dioxide according to the list presented in Wetmore (1983). Species in the most sensitive category are usually absent when sulfur dioxide levels are above 50ug per cubic meter average annual concentrations. The species that occur in the study area in the most sensitive category are as follows.

Bryoria furcellata

Lecidea vernalis

Lobaria pulmonaria

Ochrolechia androgyna

Parmelia squarrosa

Usnea filipendula

The distributions of these species are mapped Fig. 2-7. Although these species are not found at all localities and many are not common, there is no indication that the voids in the distributions are due to poor air quality. Some of the localities where collections were made do not have suitable habitats or substrates for some of these species. This is especially true for Lobaria pulmonaria that requires moist habitats.

There were no cases where lichens sensitive to sulfur dioxide were observed to be damaged or killed. All species normally found fertile were also fertile in the wilderness areas. These observations indicate that there probably is no local air quality degradation due to sulfur dioxide that causes observable damage to the lichen flora in the wilderness areas but the regional air quality may have had an effect on the lichen flora.

ELEMENTAL ANALYSIS

An important method of assessing the effects of air quality is by examining the elemental content of the lichens (Nieboer et al, 1972, 1977, 1978; Erdman & Gough, 1977; Puckett & Finegan, 1980; Nash & Sommerfeld, 1981). Elevated but sublethal levels of sulfur or other elements might indicate incipient damaging conditions.

METHODS

Lichen samples of four species were collected in spunbound olefin bags at various localities in different parts of both wilderness areas for laboratory analysis. Species collected and the substrates were Cladina rangiferina on soil, Cladina stygia on soil, Hypogymnia physodes on conifer branches, Evernia mesomorpha on conifer branches. These species were selected because they are locally present in abundance and relatively easy to clean.

Five localities were selected for elemental analysis and are indicated on the map of collection localities and in the locality list (Appendix I). These localities are: Rocky Branch Trail at the pass over the ridge, Lows Bald Spot off Madison Gulf Trail, northeast of Mt. Crawford, Mt. Eisenhower, and Wamsutta Trail north of Mt. Washington. Ten to 20 grams of each species were collected at each locality.

Lichens were air dried and cleaned of all bark and detritis under a dissecting microscope but thalli were not washed. Three samples of each collection were submitted for analysis. Some replicates of each species were ground before being divided for analysis and are so marked in the tables. Analysis was done for sulfur and multi-element analysis by the Research Analytical Laboratory at the University of Minnesota. In the sulfur analysis a ground and pelleted 100-150 mg sample was prepared for total sulfur by dry combustion and measurement of evolved sulfur dioxide on a LECO Sulfur Determinator, model no. SC-132, by infra red absorption. Multi-element determination for Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, and B were determined simultaneously by Inductively Coupled Plasma (ICP) Atomic Emission Spectrometry. For the ICP one gram of dried plant material was dry ashed in a 20 ml high form silica crucible at 485 degrees Celsius for 10-12 hrs. Crucibles were covered during the ashing as a precaution against contamination. The dry ash was boiled in 2N HCl to improve the recovery of Fe, Al and Cr and followed by transfer of the supernatant to 7 ml plastic disposable tubes for direct determination by ICP.

RESULTS AND DISCUSSION

Table 1 gives the results of the analyses for all three replicates arranged by species. Table 2 gives the means and standard deviations for each set of replicates. Some of the reported values are below the lower detection limits of the instruments. If one reading was below the detection limit (indicated by * in the tables) 0.7 of the detection limit was used for that reading in the calculations. If two or more readings were below the detection limits (indiated by # in the tables) no calculations were done for that element on that species at that locality.

All of the elemental levels found in the lichens are within typical limits for similar lichens. All element levels are very similar to those found in the Boundary Waters Canoe Area in Minnesota (a known clean area). From these tables it can be seen that there is no consistent correlation between element levels and location in the area. Although one species may have somewhat higher levels of one replicate at one locality, the other species may have higher levels at another locality so there is no overall correlation between high element levels and any one locality.

The sulfur levels in lichens tested range from 430 to 1250 ppm for all samples and these values are near background levels as cited by Solberg (1967) Erdman & Gough (1977), Nieboer et al (1977) and Puckett & Finegan (1980) for other

Table 1. Analysis of White Mt. Lichens
- Values in ppm of thallus dry weight

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Cladina rangiferina	498	1507	494	257	109	102	21.7	197.7	13.3	1.6	0.6	2.0	1.0	0.3	#	460	Rky Br. Ridge
Cladina rangiferina	440	1315	421	226	96	89	27.7	179.0	12.2	1.6	0.5	3.7	0.9	0.3	#	450	Rky Br. Ridge
Cladina rangiferina	460	1364	479	244	103	99	26.9	149.2	12.9	1.6	0.6	2.6	0.8	0.2	#	430	Rky Br. Ridge
Cladina rangiferina	368	1464	347	209	128	139	25.8	24.3	19.6	2.0	0.6	10.5	0.9	0.3	0.2	530	Lows Bald Spot @
Cladina rangiferina	353	1458	339	203	129	135	26.7	24.1	20.6	2.0	0.6	8.7	1.1	0.2	0.1	560	Lows Bald Spot @
Cladina rangiferina	344	1468	341	207	128	135	24.3	24.3	18.9	2.0	0.6	8.0	1.1	0.4	0.2	590	Lows Bald Spot @
Cladina rangiferina	259	1014	245	159	197	216	29.2	59.6	16.5	1.9	0.6	10.5	1.0	0.5	0.1	510	NE Mt. Crawford
Cladina rangiferina	270	1060	258	170	165	175	27.1	52.3	17.6	1.8	0.5	8.9	0.6	0.3	0.2	440	NE Mt. Crawford
Cladina rangiferina	267	1003	249	159	165	171	32.9	96.4	15.7	1.7	0.5	7.8	1.0	0.3	0.2	450	NE Mt. Crawford
Cladina rangiferina	658	1963	445	240	149	195	23.0	86.9	29.3	2.0	0.7	6.7	1.0	0.4	0.3	590	Mt. Eisenhower
Cladina rangiferina	752	2105	459	252	145	181	18.4	92.2	30.5	2.2	0.6	5.8	1.1	0.4	0.2	600	Mt. Eisenhower
Cladina rangiferina	708	1917	466	242	142	184	16.9	96.6	32.1	2.1	0.6	5.3	1.0	0.5	0.2	640	Mt. Eisenhower
Cladina stygia	419	1656	354	199	114	118	19.9	56.5	18.8	1.9	0.5	5.7	1.0	0.1	0.2	540	Wamsutta Tr.
Cladina stygia	423	1640	363	192	130	133	21.1	51.1	19.6	1.8	0.5	7.7	0.7	0.3	0.3	630	Wamsutta Tr.
Cladina stygia	468	1779	340	207	112	115	23.3	54.2	18.3	1.7	0.6	8.2	0.8	*0.1	0.2	570	Wamsutta Tr.
Hypogymnia physodes	868	3300	6842	498	289	322	23.5	309.5	107.6	4.3	0.7	49.2	2.4	0.9	0.9	890	Rky Br. Ridge
Hypogymnia physodes	688	2544	9866	447	373	444	22.8	270.8	107.5	4.8	1.0	61.2	2.2	0.9	1.3	960	Rky Br. Ridge
Hypogymnia physodes	708	2896	5318	459	377	430	30.1	241.7	98.3	4.8	1.0	66.9	2.3	1.1	1.1	1030	Rky Br. Ridge
Hypogymnia physodes	791	2950	5981	507	327	393	34.3	170.3	97.7	4.2	1.2	51.9	3.2	0.8	0.6	1000	Lows Bald Spot @
Hypogymnia physodes	740	2863	5325	507	315	392	26.1	145.9	92.0	4.3	1.0	50.6	2.8	0.9	0.7	1030	Lows Bald Spot @
Hypogymnia physodes	752	2856	4851	522	302	367	30.9	181.1	89.8	4.2	1.1	47.0	3.2	0.9	0.6	1110	Lows Bald Spot @
Hypogymnia physodes	563	2383	6894	417	328	464	33.1	361.6	99.9	4.8	1.4	61.5	2.7	1.1	0.6	1070	NE Mt. Crawford
Hypogymnia physodes	545	2260	9556	392	313	428	29.5	263.2	101.1	5.1	1.2	64.5	2.6	0.9	0.9	1110	NE Mt. Crawford
Hypogymnia physodes	595	2551	7651	423	312	417	29.3	320.2	108.6	5.1	1.4	64.2	3.5	1.0	0.7	1105	NE Mt. Crawford
Hypogymnia physodes	721	2621	5598	534	414	486	35.0	164.6	97.5	5.8	1.4	64.3	3.2	1.1	1.0	1000	Mt. Eisenhower
Hypogymnia physodes	986	3078	7474	621	398	477	35.0	252.0	95.0	6.2	1.4	61.0	3.6	1.0	1.0	1040	Mt. Eisenhower
Hypogymnia physodes	798	2921	8762	558	408	468	34.8	208.3	98.6	6.7	1.7	61.8	3.2	1.2	1.5	1080	Mt. Eisenhower
Hypogymnia physodes	643	2472	21905	603	226	267	18.1	409.1	97.7	3.5	1.1	42.6	2.3	0.8	1.7	840	Wamsutta Tr.
Hypogymnia physodes	658	2499	19032	664	263	289	17.8	380.1	105.5	3.4	1.1	38.1	2.4	1.0	1.4	980	Wamsutta Tr.
Hypogymnia physodes	728	2732	14871	587	284	319	19.7	306.0	93.3	3.9	1.4	47.0	1.5	0.9	1.2	930	Wamsutta Tr.
Evernia mesomorpha	424	1782	220	192	220	251	33.9	29.8	37.2	2.7	1.1	25.3	1.1	0.7	0.3	1130	NE Mt. Crawford
Evernia mesomorpha	390	1700	197	178	195	211	33.0	22.5	32.6	2.4	1.1	21.4	1.3	0.5	0.3	1000	NE Mt. Crawford
Evernia mesomorpha	418	1749	213	180	185	199	33.1	28.7	32.8	2.5	1.0	21.8	0.5	0.5	0.4	1250	NE Mt. Crawford

* = one value at or below detection limit; included as 0.7 of detection limit
# = two or more values at or below detection limit; not included in calculations
@ = ground before dividing into replicates

Table 2. Summary of White Mt. Lichens
Values in ppm of thallus dry weight

Cladina rangiferina

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	466	1395	465	243	103	97	25.4	175.3	12.8	1.6	0.6	2.7	0.9	0.3	#	447	Rky Br. Ridge
Std. dev.	29	99	38	15	7	7	3.3	24.4	0.6	<.1	<.1	0.9	0.1	0.1	#	15	Rky Br. Ridge
Mean	355	1463	342	206	128	136	25.6	24.2	19.7	2.0	0.6	9.1	1.0	0.3	0.2	560	Lows Bald Spot @
Std. dev.	12	5	4	3	<.1	3	1.2	0.1	0.8	<.1	<.1	1.3	0.1	0.1	0.1	30	Lows Bald Spot @
Mean	266	1026	251	163	176	187	29.7	69.4	16.6	1.8	0.5	9.1	0.9	0.4	0.2	467	NE Mt. Crawford
Std. dev.	6	30	7	6	19	25	2.9	23.7	0.9	0.1	<.1	1.3	0.2	0.1	<.1	38	NE Mt. Crawford
Mean	706	1995	457	245	145	187	19.4	91.9	30.6	2.1	0.6	5.9	1.0	0.5	0.2	610	Mt. Eisenhower
Std. dev.	47	98	11	6	4	7	3.2	4.9	1.4	0.1	<.1	0.7	0.1	0.1	<.1	26	Mt. Eisenhower

Cladina stygia

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	437	1692	352	199	119	122	21.4	53.9	18.9	1.8	0.5	7.2	0.8	*0.2	0.2	580	Wamsutta Tr.
Std. dev.	27	76	12	7	10	10	1.7	2.7	0.7	0.1	0.1	1.3	0.2	0.1	<.1	46	Wamsutta Tr.

Evernia mesomorpha

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	410	1744	210	183	200	220	33.3	27.0	34.2	2.6	1.1	22.8	1.0	0.6	0.4	1127	NE Mt. Crawford
Std. dev.	18	41	12	7	18	27	0.5	3.9	2.6	0.2	<.1	2.2	0.4	0.1	<.1	125	NE Mt. Crawford

Hypogymnia physodes

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	755	2913	7342	468	346	399	25.5	274.0	104.4	4.6	0.9	59.1	2.3	0.9	1.1	960	Rky Br. Ridge
Std. dev.	99	378	2315	27	50	67	4.0	34.0	5.3	0.3	0.2	9.0	0.1	0.1	0.2	70	Rky Br. Ridge
Mean	761	2890	5386	512	315	384	30.4	165.8	93.2	4.3	1.1	49.8	3.1	0.9	0.7	1047	Lows Bald Spot @
Std. dev.	27	53	567	8	13	15	4.1	18.0	4.1	<.1	0.1	2.5	0.2	<.1	0.1	57	Lows Bald Spot @
Mean	568	2398	8034	410	318	436	30.6	315.0	103.2	5.0	1.3	63.4	2.9	1.0	0.7	1095	NE Mt. Crawford
Std. dev.	25	146	1372	16	9	25	2.2	49.4	4.7	0.2	0.1	1.7	0.5	0.1	0.1	22	NE Mt. Crawford
Mean	835	2873	7278	571	407	477	34.9	208.3	97.1	6.2	1.5	62.3	3.3	1.1	1.2	1040	Mt. Eisenhower
Std. dev.	136	232	1591	45	8	9	0.1	43.7	1.8	0.4	0.1	1.7	0.2	0.1	0.3	40	Mt. Eisenhower
Mean	676	2568	18603	618	258	291	18.5	365.0	98.8	3.6	1.2	42.6	2.1	0.9	1.4	917	Wamsutta Tr.
Std. dev.	45	143	3537	41	30	26	1.0	53.2	6.2	0.2	0.2	4.5	0.5	0.1	0.2	71	Wamsutta Tr.

* = one value at or below detection limit; included as 0.7 of detection limit
\# = two or more values at or below detection limit; not included in calculations
@ = ground before dividing into replicates

species of lichens. These levels are very close to those reported in the same species in the Boundary Waters Canoe Area (Wetmore, 1987). Levels may be as low as 200-300 in the arctic (Tomassini et al, 1976) while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. Different species may accumulate different amounts of elements and this is evident when comparing sulfur levels of different species. Cladina rangiferina and Cladina stygia have lower levels than Hypogymnia physodes and Evernia mesomorpha. Even when taking these differences into account there is no clear trend in accumulated levels of sulfur.

These tables indicate that there are no air pollution problems in the wilderness areas that can be detected with these methods.

CONCLUSIONS

The lichen flora is quite diverse and includes most of the species previously reported from the White Mts. There is no impoverishment of the lichen flora in any part of the the study areas. However, some of the species reported from the area that were not found may have been lost because of the regional degradation of the air quality. The elemental analyses shows no elevated levels of sulfur or other common pollutant elements so there is probably no local source causing damage to the lichen flora. There are several species present in the most sensitive category to sulfur dioxide and some of these are rare. This rarity seems to be due more to ecological and climatic conditions than pollution since these species are quite healthy when present. The maps of the distributions of the more sensitive species do not show any significant voids that are not due to normal ecological conditions. There is no evidence of damaged or dead lichens in any area where healthy ones are not also present. The elemental analyses do not show abnormal accumulations of polluting elements at any locality.

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APPENDIX I

Collection Localities

Collection numbers are those of Clifford Wetmore. All collections are listed in ascending order by collection number and date of collection.

Coos County

61580-61649 Great Gulf Wilderness Area. NE slope of Mt. Clay. In alpine area with rock tallus, heath meadow and some areas of krumholz with balsam fir, spruce and birch, elev. 6050 ft. 7 July 1988.

61650-61719 Great Gulf Wilderness Area. Madison Gulf Trail at stream crossing about 1 mile from road. Along stream with balsam fir, black spruce and birch, elev. 1550 ft. 8 July 1988.

61720-61777 Great Gulf Wilderness Area. Lows Bald Spot off Madison Gulf Trail near Mt. Washington Auto Road. Rocky knob with small balsam fir and black spruce, elev. 2875 ft. 8 July 1988. CHEMICAL ANALYSIS.

61778-61849 Great Gulf Wilderness Area. Around Great Gulf Trail and W. Peabody River. Along ridge and river with black spruce, some balsam fir and rocks, elev. 2300 ft. 9 July 1988.

61850-61891 Great Gulf Wilderness Area. Near W. Peabody River and Great Gulf Trail at NE corner of wilderness area. Back from stream with sugar maple, yellow birch, balsam fir and some black spruce, elev. 1725 ft. 9 July 1988.

61892-61946 Presidential Dry River Wilderness Area. Knob half mile NE of Mt. Crawford along Davis Path. Rocky hilltop with black spruce and some balsam fir, elev. 2950 ft. 10 July 1988. CHEMICAL ANALYSIS.

61947-61979 Presidential Dry River Wilderness Area. One mile SW of Mt. Crawford along Davis Path. At edge of ridge with balsam fir, birch and black spruce, elev. 2600 ft. 10 July 1988.

61980-62015 Presidential Dry River Wilderness Area. Rocky Branch Trail at junction with Rocky Branch River E of Mt Davis. Along stream in balsam fir, white birch and mountain ash, elev. 2900 ft. 12 July 1988.

62016-62052 Presidential Dry River Wilderness Area. North of Rocky Branch Trail at pass over ridge, E. of Mt. Davis.

On rocky ridge just below peak with balsam fir, elev. 3450 ft. 12 July 1988. CHEMICAL ANALYSIS.

62053- 62082 Presidential Dry River Wilderness Area. Stairs Col Trail along Lower Stairs Brook NE of Stairs Mt. In valley along stream with yellow birch, beech and sugar maple, elev. 2100 ft. 13 July 1988.

Carroll County

62083- 62136 Presidential Dry River Wilderness Area. Along Rocky Branch River and trail NE of Maple Mt. At bend in river with birch, maple beech, balsam fir and some hemlock, elev. 1800 ft. 13 July 1988.

Coos County

62137- 62180 Presidential Dry River Wilderness Area. Along Dry River 1.5 miles from highway 302 at bridge. In river bottom with red maple, yellow birch and few beech and spruce, elev. 1700 ft. 14 July 1988.

62181- 62243 Great Gulf Wilderness Area. Wamsutta Trail north of Mt. Washington auto road. Around rocky knob 0.75 miles N of road with stunted balsam fir and black spruce and rocks, elev. 4350 ft. 15 July 1988. CHEMICAL ANALYSIS.

62244- 62285 Great Gulf Wilderness Area. Wamsutta Trail just below Mt. Washington auto road. In alpine meadow with rocks, heath and stunted balsam fir, elev. 5000 ft. 15 July 1988.

62286- 62327 Great Gulf Wilderness Area. Below Halfway House site on Mt. Washington auto road. On steep slope with balsam fir and yellow birch, elev. 3600 ft. 16 July 1988.

62328- 62378 Presidential Dry River Wilderness Area. Mt. Monroe on SW side in patches of balsam fir krumholz and openings, elev. 5000 ft. 17 July 1988.

62379- 62428 Presidential Dry River Wilderness Area. On east side of Mt. Monroe in sedge and heath meadow in alpine area, elev. 5000 ft. 17 July 1988.

62429- 62462 Presidential Dry River Wilderness Area. South side of Mt. Eisenhower (Mt. Pleasant of Tuckerman). In dwarf balsam fir along trail on hillside, elev. 4400 ft. 18 July 1988. CHEMICAL ANALYSIS.

62463- 62504 Presidential Dry River Wilderness Area. Mt. Franklin. Near top on south side in alpine meadow with rocks, elev. 4900 ft. 18 July 1988.

62505 White Mts. Nat. Forest. On concrete at Lakes of the

Clouds Hut near Mt. Monroe, elev. 5000 ft. 18 July 1988.

62506-62541 Presidential Dry River Wilderness Area. Upper end of Oakes Gulf near Camel Trail. In alpine meadow of sedge and heath and rocks, elev. 5350 ft. 19 July 1988.

62542-62584 Presidential Dry River Wilderness Area. Two miles up Dry River and above Clinton Trail junction. Along stream with yellow birch, red maple, balsam fir and some black spruce, elev. 2200 ft. 21 July 1988.

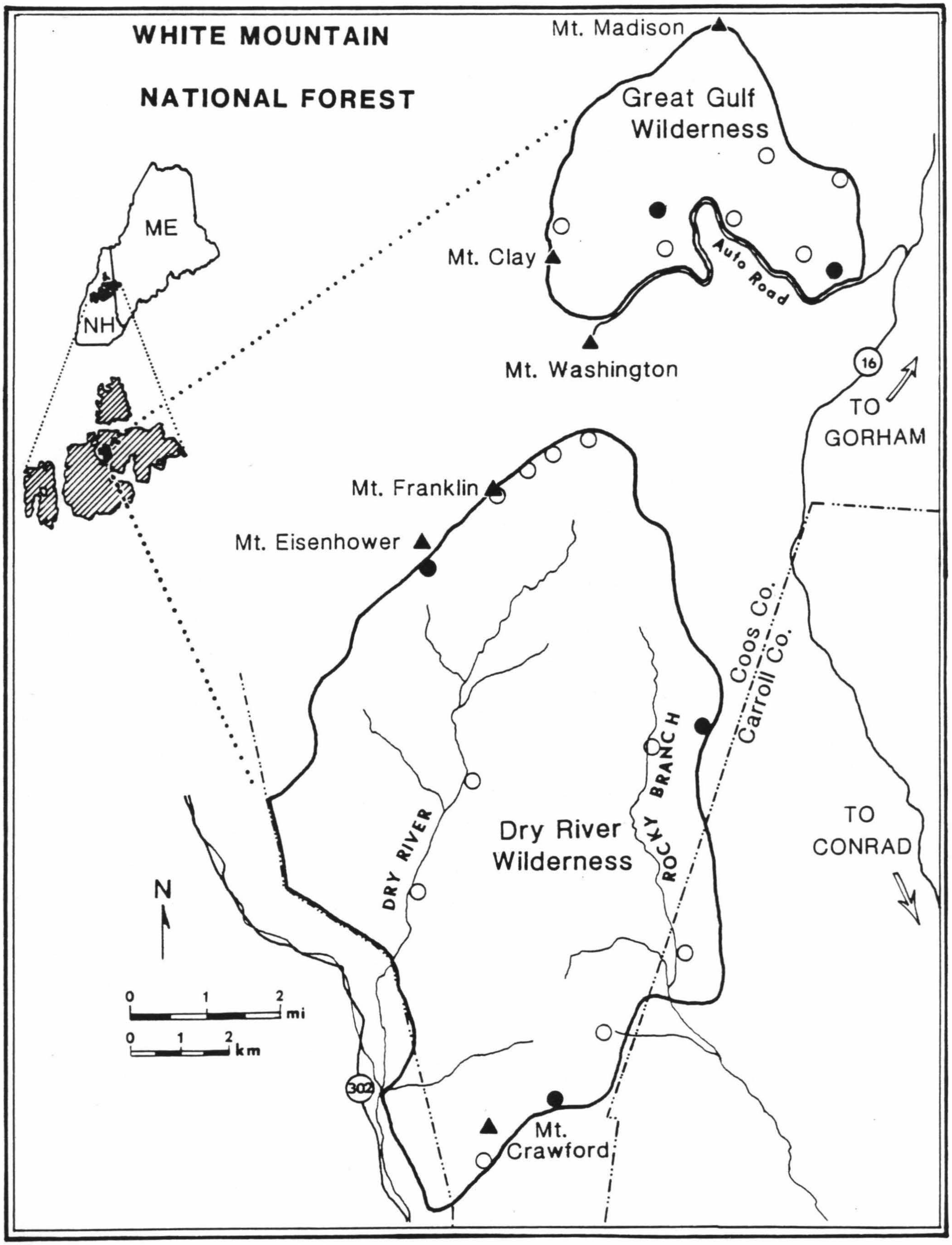

Fig. 1. Open circles are collection localities, solid circles are elemental analysis localities.

APPENDIX II

Species Sensitive to Sulfur Dioxide

Based on the list of lichens with known sulfur dioxide sensitivity compiled from the literature, the following species in the White Mt. wilderness areas are within the Sensitive category as listed by Wetmore, 1983. Sensitive species (S) are those present only under 50ug sulfur dioxide per cubic meter (average annual). The intermediate category includes species present between 50ug and 100ug. The S-I group falls between the Sensitive and Intermediate categories. Open circles on the maps are localities where the species was not found and solid circles are where it was found.

Note: Refer to text for interpretation of these maps and precautions concerning absence in parts of the park.

Fig. 2 Bryoria furcellata
Fig. 3 Lecidea vernalis
Fig. 4 Lobaria pulmonaria
Fig. 5 Ochrolechia androgyna
Fig. 6 Parmelia squarrosa
Fig. 7 Usnea filipendula

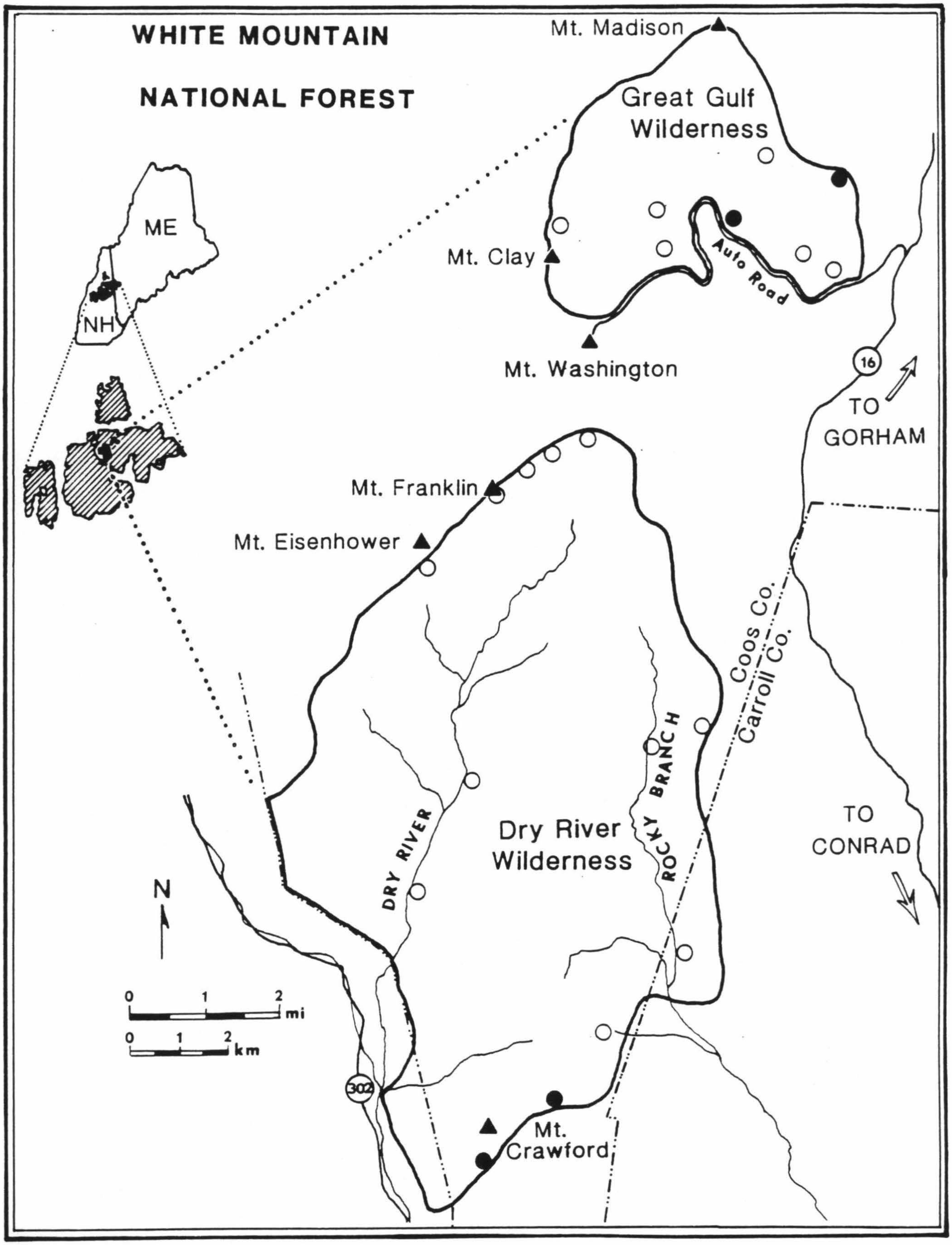

Fig. 2. Open circles are collection localities, solid circles are localities where Bryoria furcellata was found.

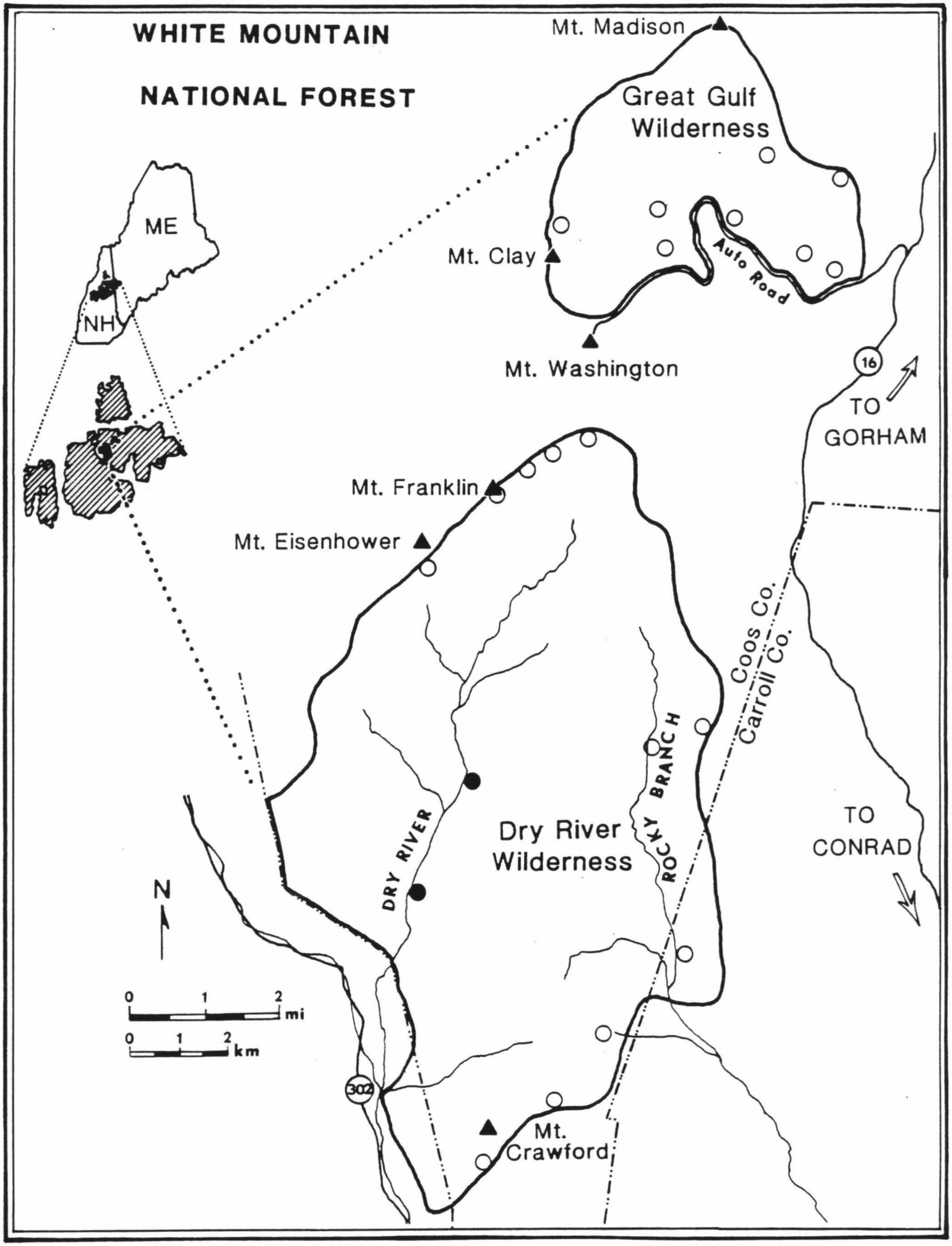

Fig. 3. Open circles are collection localities, solid circles are localities where Lecidea vernalis was found.

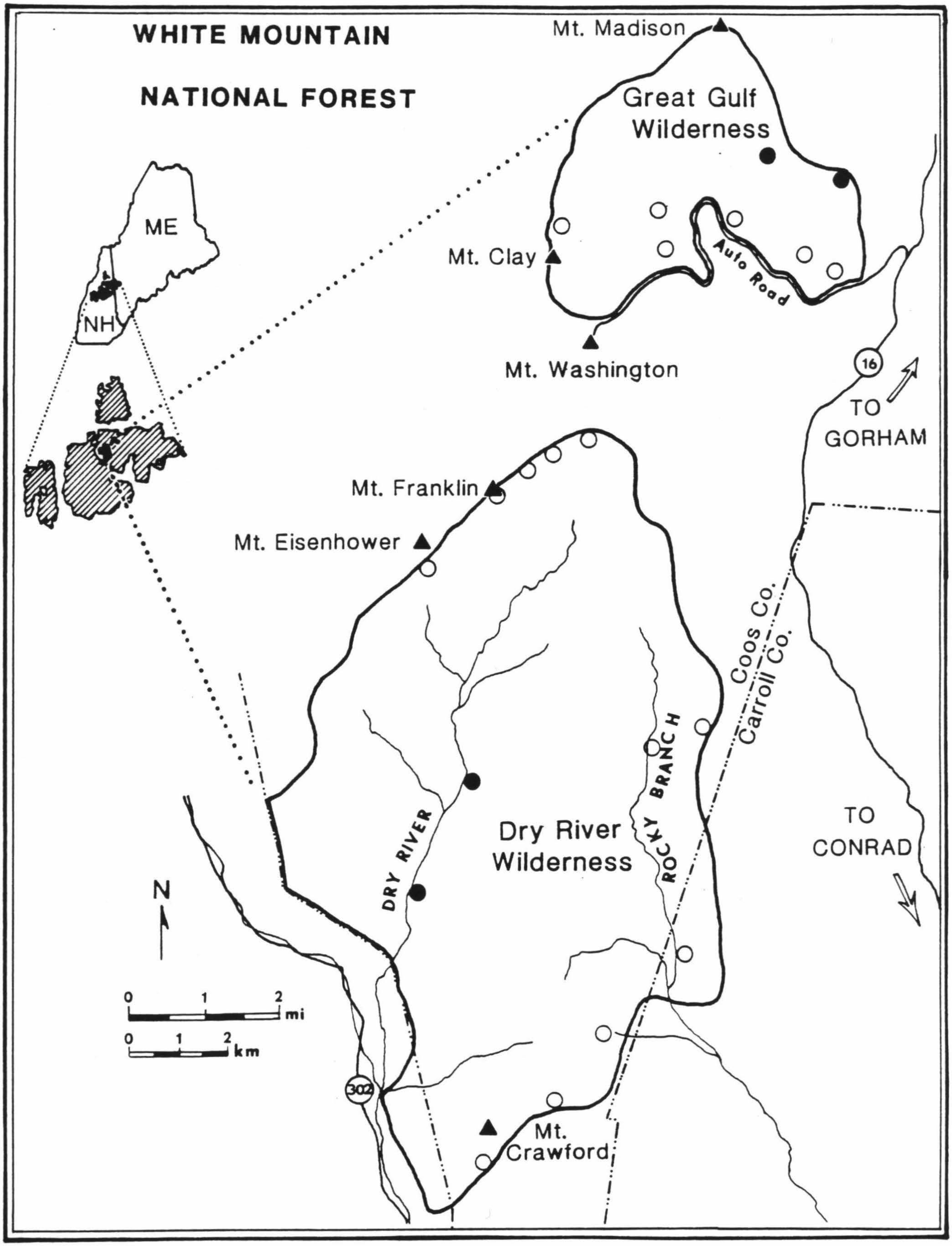

Fig. 4. Open circles are collection localities, solid circles are localities where Lobaria pulmonaria was found.

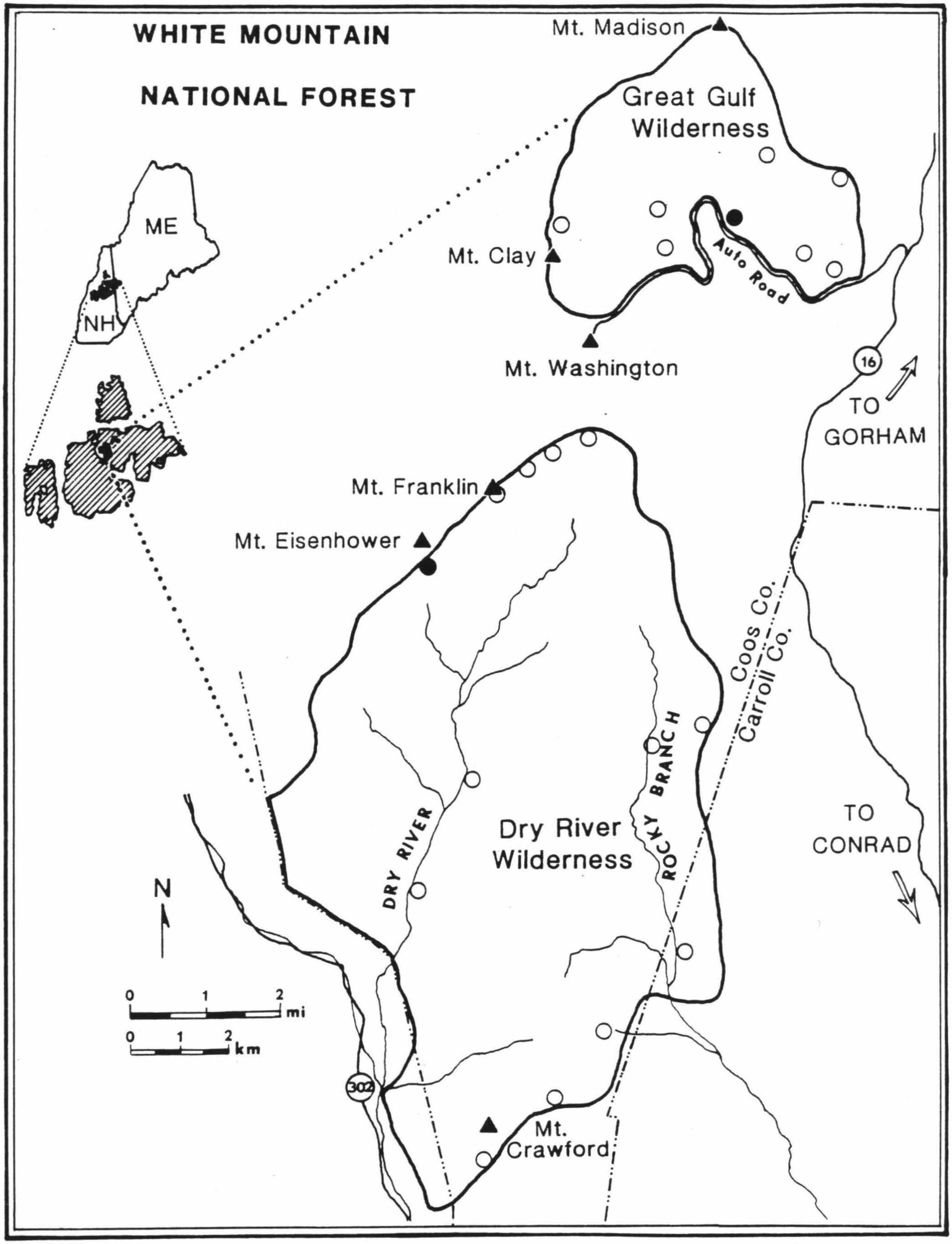

Fig. 5. Open circles are collection localities, solid circles are localities where <u>Ochrolechia</u> <u>androgyna</u> was found.

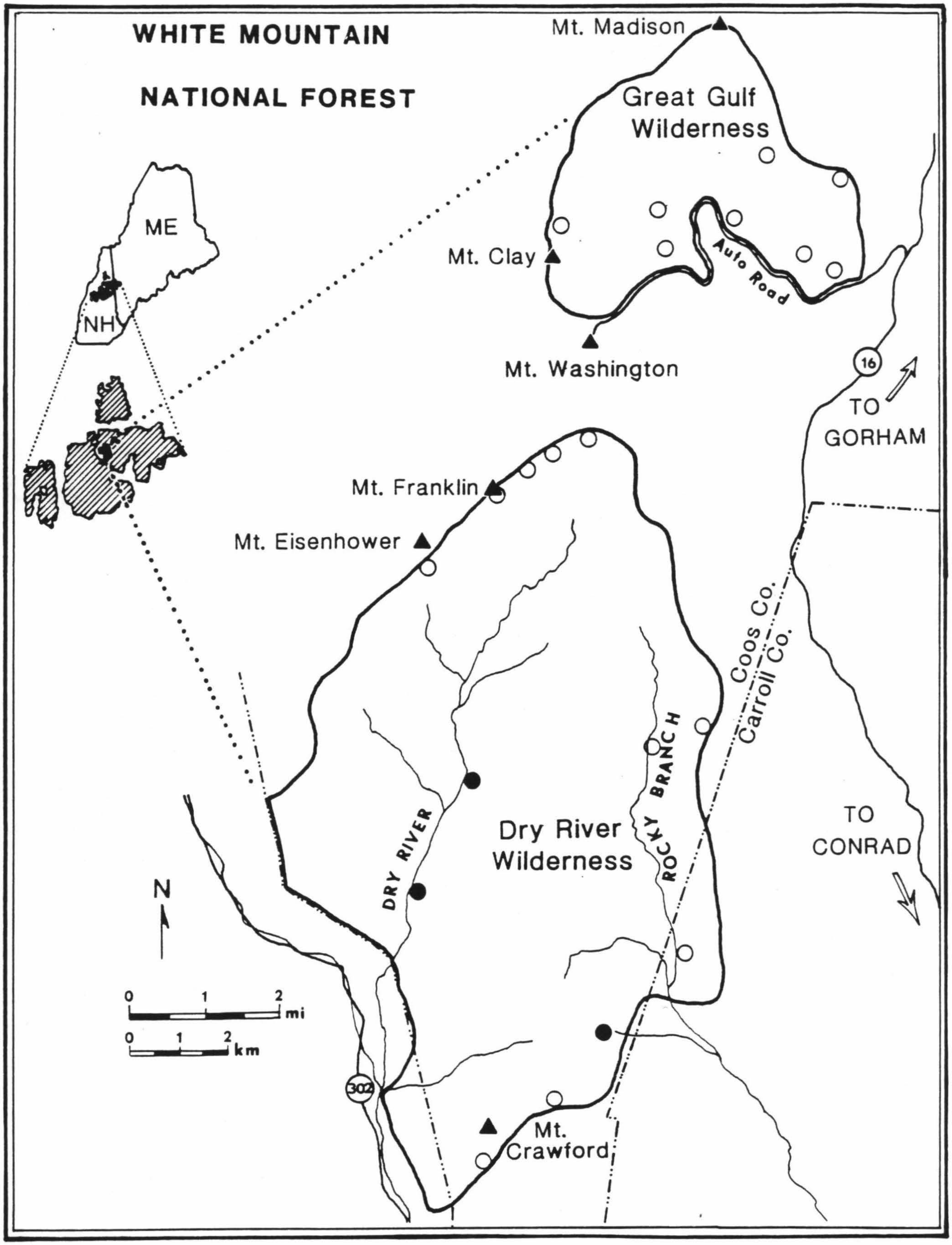

Fig. 6. Open circles are collection localities, solid circles are localities where Parmelia squarrosa was found.

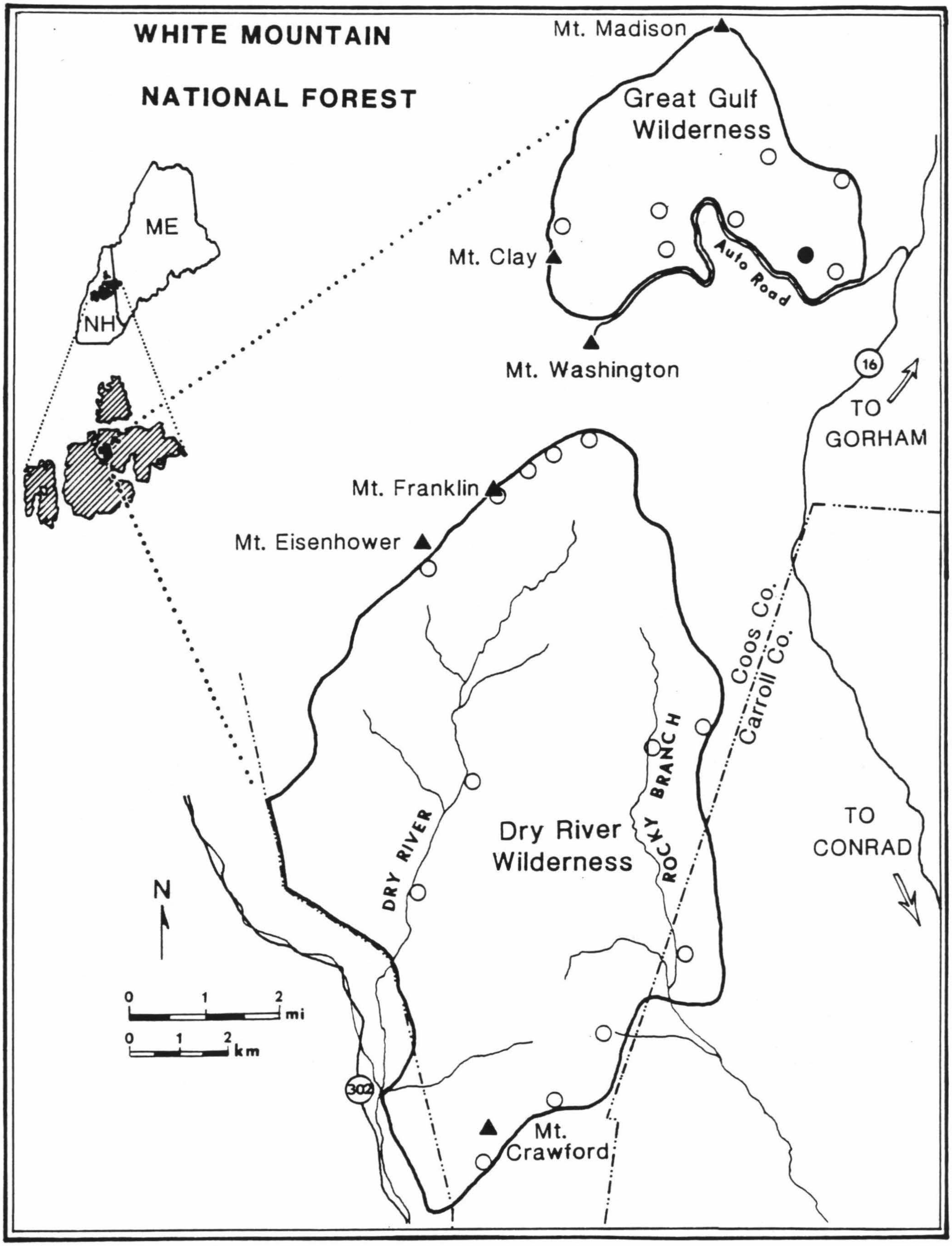

Fig. 7. Open circles are collection localities, solid circles are localities where Usnea filipendula was found.

APPENDIX III

Lichens reported in the literature from the White Mts.

Names have been brought up to date with present nomenclature whenever possible. In some cases the old names were missapplied and without studying the original collections it is not possible to determine what the present name should be. In this case the old name is enclosed in brackets.

[Acarospora cervina Tuckerman, 1847, Flint, 1874 Misident.]
Acarospora sinopica (Wahlenb. in Ach.) Körb. Tuckerman, 1882
Alectoria fallacina Mot. Brodo & Hawksworth, 1977
[Alectoria ochroleuca (Hoffm.) Mass. Flint, 1874 Misident.]
Alectoria sarmentosa (Ach.) Ach. Tuckerman, 1845, Brodo & Hawksworth, 1977
Amygdalaria panaeola (Ach.) Hertel & Brodo Tuckerman, 1847, 1888, Flint, 1874
Anaptychia palmulata (Michx.) Vain. Tuckerman, 1845, Kurokawa, 1962, Hale, 1956
Anzia colpodes (Ach.) Stizenb. Hale, 1955b
Arthonia cinereopruinosa Schaer. Tuckerman, 1872, Flint, 1874
Arthonia diffusa Nyl. Tuckerman, 1872, Flint, 1874
[Arthonia luridoalba Nyl. Flint, 1874 Misident.]
Arthonia patellulata Nyl. Tuckerman, 1872, Flint, 1874
Arthonia spadicea Leight. Tuckerman, 1872, Flint, 1874
Aspicilia cinerea (L.) Körb. Tuckerman, 1840
Aspicilia gibbosa (Ach.) Körb. Tuckerman, 1882
Bacidia bagleittoana (Mass. & De Not. in Mass.) Jatta Tuckerman, 1840, 1872, 1888
Bacidia chlorantha (Tuck.) Fink Tuckerman, 1872, 1888, Flint, 1874
Bacidia inundata (Fr.) Körb. Tuckerman, 1888
[Bacidia sabuletorum (Schreb.) Lett. Flint, 1874 Misident.]
Bacidia sphaeroides (Dicks.) Zahlbr. Tuckerman, 1888
Baeomyces placophyllus Ach. Tuckerman, 1845, 1847, 1888, Flint, 1874, Thomson, 1967
Baeomyces roseus Pers. Tuckerman, 1847, Flint, 1874, Thomson, 1967
Baeomyces rufus (Huds.) Rebent. Tuckerman, 1839, 1847, 1888, Flint, 1874, Thomson, 1967
Botrydina viridis (Ach.) Redh. & Kuyper Tuckerman, 1847, 1872, Flint, 1874
Bryoria bicolor (Ehrh.) Brodo & Hawksw. Tuckerman, 1840, 1847, 1882, Brodo & Hawksworth, 1977
Bryoria chalybeiformis (L.) Brodo & Hawksw. Tuckerman, 1839, 1882
Bryoria furcellata (Fr.) Brodo & Hawksw. Brodo & Hawksworth,

1977

Bryoria fuscescens (Gyeln.) Brodo & Hawksw. Brodo & Hawksworth, 1977

Bryoria nadvornikiana (Gyeln.) Brodo & Hawksw. Brodo & Hawksworth, 1977, Lang et al., 1980

Bryoria tenuis (Dahl) Brodo & Hawksw. Brodo & Hawksworth, 1977

Bryoria trichodes (Michx.) Brodo & Hawksw. Brodo & Hawksworth, 1977

Buellia coracina (Hoffm.) Körb. Tuckerman, 1888, Flint, 1874

Buellia schaereri De Not. Tuckerman, 1872, 1888, Flint, 1874

Buellia wahlenbergii (Ach.) Sheard Tuckerman, 1872, 1888, Flint, 1874

Calicium abietinum Pers. Tuckerman, 1872, Flint, 1874

[Calicium adspersum Pers. Flint, 1874 Misident.]

Calicium salicinum Pers. Tuckerman, 1845, 1872, Flint, 1874

Caloplaca flavovirescens (Wulf.) Dalla Torre & Sarnth. Tuckerman, 1847, 1888, Flint, 1874

Caloplaca saxicola (Hoffm.) Nordin Tuckerman, 1845

Catillaria globulosa (Flörke) Th. Fr. Tuckerman, 1872, 1888, Flint, 1874

Catillaria griffithii (Sm.) Malme Tuckerman, 1872, Flint, 1874

Cetraria arenaria Kärnef. Kärnefelt, 1979

Cetraria ciliaris Ach. Tuckerman, 1841, Hale, 1963, Lang et al., 1980

Cetraria commixta (Nyl.) Th. Fr. Tuckerman, 1840, 1847, 1882, Flint, 1874

Cetraria cucullata (Bellardi) Ach. Tuckerman, 1839, 1840, 1847, 1882, Flint, 1874, Bliss, 1962, 1963

Cetraria delisei (Bory ex Schaer.) Nyl. Kärnefelt, 1979, Bliss, 1963

Cetraria ericetorum Opiz Tuckerman, 1840

Cetraria islandica (L.) Ach. Tuckerman, 1839, 1840, 1882, Bliss, 1962, 1963, 1966, Hadley & Bliss, 1964, Bliss & Hadley, 1964,

Cetraria islandica subsp. crispiformis (Räs.) Kärnef. Kärnefelt, 1979

Cetraria laevigata Rass. Kärnefelt, 1979

Cetraria nivalis (L.) Ach. Tuckerman, 1839, 1845, 1847, 1882, Flint, 1874, Bliss, 1962, 1963, Bliss & Hadley, 1964

Cetraria oakesiana Tuck. Tuckerman, 1841, Hale, 1956, Lang et al., 1980

Cetraria pinastri (Scop.) Gray Tuckerman, 1839, 1840, Lang et al., 1980

Cetraria sepincola (Ehrh.) Ach. Tuckerman, 1847, 1882, Flint, 1874, Lang et al., 1980

Cetrelia cetrarioides (Del. ex Duby) W. & C. Culb. Berry, 1941, Culberson, 1958, Culberson, 1962

Cetrelia chicitae (W. Culb.) W. & C. Culb. Culberson, 1965, Culberson & Culberson, 1968

Cetrelia olivetorum (Nyl.) W. & C. Culb. Culberson, 1962, Culberson & Culberson, 1968

[Chaenotheca ferruginea (Turn. ex Sm.) Mig. Flint, 1874 Misident.]

Chaenotheca phaeocephala (Turn.) Th. Fr. Tuckerman, 1872

Cladina mitis (Sandst.) Hustich Bliss, 1962, 1963
Cladina rangiferina (L.) Nyl. Bliss, 1962, 1963, 1966, Bliss & Hadley, 1964, Hadley & Bliss, 1964
Cladina stellaris (Opiz) Brodo Bliss, 1962, 1963
Cladonia amaurocraea (Flörke) Schaer. Tuckerman, 1847, 1882, Flint, 1874, Bliss, 1963
Cladonia bellidiflora (Ach.) Schaer. Tuckerman, 1847, 1882, Flint, 1874
Cladonia boryi Tuck. Tuckerman, 1841, 1847, 1882, Flint, 1874
Cladonia caespiticia (Pers.) Flörke Tuckerman, 1845
Cladonia cenotea (Ach.) Schaer. Tuckerman, 1847, 1882, Flint, 1874
Cladonia cervicornis (Ach.) Flot. Tuckerman, 1882
Cladonia cornuta (L.) Hoffm. Tuckerman, 1882
Cladonia cristatella Tuck. Tuckerman, 1858, 1862, 1882
Cladonia cyanipes (Somm.) Nyl. Tuckerman, 1847, Flint, 1874
Cladonia decorticata (Flörke) Spreng. Tuckerman, 1847, 1882, Flint, 1874
Cladonia digitata (L.) Hoffm. Tuckerman, 1840
Cladonia fimbriata (L.) Fr. Tuckerman, 1845, 1882, Flint, 1874
Cladonia floerkeana (Fr.) Flörke Bliss, 1963
Cladonia furcata (Huds.) Schrad. Tuckerman, 1839, 1882
Cladonia gracilis (L.) Willd. Tuckerman, 1839, 1840, 1845, Flint, 1874, Bliss, 1962, 1963
Cladonia gracilis subsp. *nigripes* (Nyl.) Ahti Tuckerman, 1840
Cladonia macilenta Hoffm. Tuckerman, 1841, 1882
Cladonia maxima (Asah.) Ahti Ahti, 1980
Cladonia parasitica (Hoffm.) Hoffm. Tuckerman, 1845
Cladonia pseudorangiformis Asah. Ahti, 1962
[*Cladonia pyxidata* (L.) Hoffm. Flint, 1874 Misident.]
Cladonia squamosa (Scop.) Hoffm. Tuckerman, 1840, Lang et al., 1980
Cladonia uncialis (L.) Web. ex Wigg. Bliss, 1963, Hadley & Bliss, 1964
Cladonia verticillata (Hoffm.) Schaer. Tuckerman, 1882
Cornicularia aculeata (Schreb.) Ach. Tuckerman, 1840, 1847, 1882, Flint, 1874, Bliss, 1963
Dendriscocaulon intricatulum (Nyl.) Hanssen Tuckerman, 1872, 1882, Flint, 1874
Dirinaria frostii (Tuck.) Hale & W. Culb. Thomson, 1963
Eopyrenula leucoplaca (Wallr.) R. Harris Tuckerman, 1872, Flint, 1874
Ephebe lanata (L.) Vain. Tuckerman, 1845, 1847
Evernia mesomorpha Nyl. Tuckerman, 1847, Lang et al., 1976, Lang et al., 1980
[*Evernia purpuracea* Flint, 1874 Unknown name]
Fuscidea cyathoides (Ach.) V. Wirth & Vezda Tuckerman, 1845, Flint, 1874
Fuscidea mollis (Wahlenb.) V. Wirth & Vezda Tuckerman, 1872
Haematomma lapponicum Räs. Tuckerman, 1839, 1840, 1847, 1882, Flint, 1874, Culberson, 1963
Haematomma ochrophaeum (Tuck.) Mass. Flint, 1874
Heterodermia hypoleuca (Muhl.) Trevis. Tuckerman, 1845
Hydrothyria venosa J. Russell Tuckerman, 1872, Flint, 1874

Hypogymnia krogiae Ohls. Tuckerman, 1840, Berry, 1941, Lang et al., 1980
Hypogymnia physodes (L.) Nyl. Berry, 1941, Lang et al., 1980
Hypogymnia tubulosa (Schaer.) Hav. Lang et al., 1980
Hypogymnia vittata (Ach.) Gas. Tuckerman, 1882, Lang et al., 1980
Icmadophila ericetorum (L.) Zahlbr. Flint, 1874
Ionaspis odora (Ach.) Th. Fr. in B. Stein Tuckerman, 1882
Imshaugia aleurites (Ach.) S. F. Meyer Tuckerman, 1845, 1872, Flint, 1874, Lang et al., 1980
Julella lactea (Mass.) Zahlbr. Tuckerman, 1872, Flint, 1874
Lasallia papulosa (Ach.) Llano Tuckerman, 1839, Flint, 1874, Llano, 1950
Lasallia pensylvanica (Hoffm.) Llano Tuckerman, 1839, Llano, 1950
Lasallia pustulata (L.) Merat Tuckerman, 1845, 1882
Lecanactis chloroconia Tuck. Tuckerman, 1864
Lecania cyrtella (Ach.) Th. Fr. Tuckerman, 1872, Flint, 1874
Lecanora allophana Nyl. Brodo, 1984
Lecanora argentata (Ach.) Malme Brodo, 1984
Lecanora argopholis (Ach.) Ach. Tuckerman, 1882
Lecanora atriseda (Fr.) Nyl. Tuckerman, 1882
Lecanora badia (Hoffm.) Ach. Tuckerman, 1882, Flint, 1874
Lecanora caesiorubella Ach. subsp. caesiorubella Imshaug & Brodo, 1966
Lecanora caesiorubella subsp. prolifera (Fink) R. Harris Imshaug & Brodo, 1966
Lecanora cinereofusca Magn. Brodo, 1984
Lecanora circumborealis Brodo & Vitik. Brodo, 1984
[Lecanora discreta Flint, 1874 Misident.]
Lecanora glabrata (Ach.) Malme Brodo, 1984
Lecanora granatina Somm. Tuckerman, 1872, 1882, Flint, 1874
Lecanora hybocarpa (Tuck.) Brodo Brodo, 1984
Lecanora intricata (Ach.) Ach. Tuckerman, 1882
Lecanora polytropa (Hoffm.) Rabenh. Tuckerman, 1841, 1882
Lecanora straminea Wahlenb. ex Ach. Tuckerman, 1845
Lecidea aglaea Somm. Tuckerman, 1872, 1888, Flint, 1874
Lecidea auriculata Th. Fr. Tuckerman, 1888
Lecidea caesioatra Schaer. Tuckerman, 1847, 1872, 1888, Flint, 1874
Lecidea carnulenta (Tuck.) Fink Tuckerman, 1877, 1888
[Lecidea confluens (Web.) Ach. Flint, 1874 Misident.]
[Lecidea contigua b hydrophila Tuckerman, 1888 Name unknown]
Lecidea diapensiae Th. Fr. Tuckerman, 1872, 1888, Flint, 1874
Lecidea elabens Fr. Tuckerman, 1847, Flint, 1874
Lecidea fuscoatra (L.) Ach. Tuckerman, 1888
Lecidea fuscocinerea Nyl. Tuckerman, 1888
Lecidea lapicida (Ach.) Ach. Tuckerman, 1872, 1888, Flint, 1874
Lecidea lugubris Somm. Tuckerman, 1872, 1888, Flint, 1874
Lecidea peliaspis (Tuck.) Zahlbr. Tuckerman, 1888
Lecidea pycnocarpa (Körb.) Ohl. Tuckerman, 1888
Lecidea tenebrosa Flot. Tuckerman, 1872, 1888, Flint, 1874
Lecidea tornoensis Nyl. Tuckerman, 1888

Lecidoma demissum (Rustr.) G. Schneid. & Hert. Tuckerman, 1847, 1872, 1888, Flint, 1874
Lepraria membranacea (Dicks.) Vain. Tuckerman, 1845, Lang et al., 1980
Lepraria neglecta (Nyl.) Lett. Tuckerman, 1888
Leprocaulon microscopicum (Vill.) Gams ex D. Hawksw. Tuckerman, 1847, Flint, 1874
Leptogium burgessii (L.) Mont. Tuckerman, 1872, 1882
Leptogium cyanescens (Rabenh.) Kőrb. Sierk, 1964
Leptogium saturninum (Dicks.) Nyl. Sierk, 1964
Leptogium tenuissimum (Dicks.) Kőrb. Sierk, 1964
[Leptogium tremelloides Tuckerman, 1840 Misident.]
[Letharia vulpina (L.) Hue Flint, 1874 Misident.]
Lobaria linita (Ach.) Rabenh. Tuckerman, 1882, Flint, 1874
Lobaria pulmonaria (L.) Hoffm. Tuckerman, 1839, 1840, 1847, Flint, 1874, Jordan, 1973
Lobaria quercizans Michx. Tuckerman, 1845, Jordan, 1973
Lopadium pezizoideum (Ach.) Kőrb. Tuckerman, 1888, Flint, 1874, Lang et al., 1980
Megalospora tuberculosa (Fee) Sipman Tuckerman, 1872, 1888, Flint, 1874
Menegazzia terebrata (Hoffm.) Mass. Tuckerman, 1840, 1882, Hale, 1955b
Micarea melaena (Nyl.) Hedl. Tuckerman, 1888
Microcalicium arenarium (Hampe ex Mass.) Tibell Tuckerman, 1872, Flint, 1874
Microcalicium disseminatum (Ach.) Vain. Tuckerman, 1872, Flint, 1874
Mycoblastus sanguinarius (L.) Norm. Lang et al., 1980
Mycocalicium subtile (Pers.) Szat. Tuckerman, 1845
Nephroma arcticum (L.) Torss. Tuckerman, 1839, 1847, 1882, Flint, 1874, Wetmore, 1960
Nephroma bellum (Spreng.) Tuck. Wetmore, 1960
Nephroma helveticum Ach. Wetmore, 1960
Nephroma parile (Ach.) Ach. Tuckerman, 1840, 1847, Flint, 1874, Wetmore, 1960
Nephroma resupinatum (L.) Ach. Tuckerman, 1839, Wetmore, 1960
Opegrapha atra Pers. Tuckerman, 1845
Opegrapha microcycla Tuck. Tuckerman, 1858
Pannaria conoplea (Ach.) Bory Tuckerman, 1845, 1847
Pannaria pezizoides (Web.) Trev. Tuckerman, 1882
[Pannaria rubiginosa (Ach.) Bory Flint, 1874 Misident.]
Parmelia alpicola Th. Fr. Tuckerman, 1882
Parmelia aurulenta Tuck. Tuckerman, 1882, Berry, 1941, Hale, 1958
Parmelia caperata (L.) Ach. Berry, 1941
Parmelia centrifuga (L.) Ach. Tuckerman, 1845, 1882, Flint, 1874, Berry, 1941
Parmelia cetrata Ach. Berry, 1941
Parmelia coniocarpa Laurer Berry, 1941
Parmelia conspersa (Ach.) Ach. Berry, 1941, Hale, 1955a, 1964, Bliss, 1963
Parmelia exasperata De Not. Esslinger, 1977
Parmelia galbina Ach. Berry, 1941, Culberson, 1961, Hale, 1976

Parmelia glabratula (Lamy) Nyl. Esslinger, 1977
Parmelia halei Ahti Ahti, 1966, Esslinger, 1977
[Parmelia halseyana Tuck. Tuckerman, 1841 Name unknown]
Parmelia incurva (Pers.) Fr. Tuckerman, 1845, 1847, 1882, Flint, 1874, Berry, 1941
Parmelia livida Tayl. Culberson, 1961
Parmelia olivacea (L.) Ach. Berry, 1941
Parmelia omphalodes (L.) Ach. Tuckerman, 1882
Parmelia panniformis (Nyl.) Vain. Esslinger, 1977
Parmelia pulla Ach. Tuckerman, 1872, Flint, 1874
Parmelia revoluta Flörke Lang et al., 1980
Parmelia rudecta Ach. Berry, 1941, Culberson & Culberson, 1956
Parmelia saxatilis (L.) Ach. Tuckerman, 1882, Berry, 1941, Lang et al., 1976, Lang et al., 1980
Parmelia septentrionalis (Lynge) Ahti Ahti, 1966, Esslinger, 1977
Parmelia somloensis Gyeln. Hale, 1955a
Parmelia sorediata (Ach.) Th. Fr. Flint, 1874, Esslinger, 1977
Parmelia sphaerospora Nyl. Tuckerman, 1847, Flint, 1874
Parmelia stygia (L.) Ach. Tuckerman, 1839, 1847, 1882, Flint, 1874, Berry, 1941, Esslinger, 1977
Parmelia subargentifera Nyl. Esslinger, 1977
Parmelia sulcata Tayl. Berry, 1941, Lang et al., 1980
Parmeliopsis ambigua (Wulf. in Jacq.) Nyl. Tuckerman, 1845, 1847, 1872, 1882, Flint, 1874, Lang et al., 1980
Parmeliopsis hyperopta (Ach.) Arn. Lang et al., 1980
Peltigera aphthosa (L.) Willd. Thomson, 1950
Peltigera canina (L.) Willd. Tuckerman, 1872, 1882, Flint, 1874, Thomson, 1950
Peltigera collina (Ach.) Schrad. Tuckerman, 1882
Peltigera didactyla (With.) Laundon Tuckerman, , 1872, 1882
Peltigera evansiana Gyeln. Thomson, 1950
Peltigera horizontalis (Huds.) Baumg. Thomson, 1950
Peltigera malacea (Ach.) Funck Tuckerman, 1845, 1882, Flint, 1874, Thomson, 1950
Peltigera membranacea (Ach.) Nyl. Thomson, 1950
Peltigera polydactyla (Neck.) Hoffm. Tuckerman, 1841, Thomson, 1950
Peltigera rufescens (Weis.) Humb. Thomson, 1950
Peltigera scabrosa Th. Fr. Tuckerman, 1882
Peltigera venosa (L.) Hoffm. Thomson, 1950
Pertusaria amara (Ach.) Nyl. Dibben, 1980
Pertusaria dactylina (Ach.) Nyl. Tuckerman, 1882, Dibben, 1980
Pertusaria globularis (Ach.) Tuck. Dibben, 1980
Pertusaria glomerata (Ach.) Schaer. Tuckerman, 1872, 1882, Flint, 1874
Pertusaria leucostoma (Bernh.) Mass. Dibben, 1980
Pertusaria macounii (Lamb) Dibb. Dibben, 1980
Pertusaria neoscotica Lamb Dibben, 1980
Pertusaria oculata (Dicks.) Th. Fr. Tuckerman, 1845, 1847, Flint, 1874
Pertusaria trachythallina Erichs. Dibben, 1980
Pertusaria velata (Turn.) Nyl. Dibben, 1980
Pertusaria waghornei Hult. Dibben, 1980

Phaeocalicium curtisii (Tuck.) Tibell Tuckerman, 1872, Flint, 1874
Phaeocalicium praecedens (Nyl.) A. Schmidt Tuckerman, 1888
Phaeophyscia chloantha (Ach.) Moberg Esslinger, 1978
Phaeophyscia ciliata (Hoffm.) Moberg Thomson, 1963, Esslinger, 1978, Flint, 1874
Phaeophyscia orbicularis (Neck.) Moberg Thomson, 1963
Phaeophyscia rubropulchra (Degel.) Moberg Thomson, 1963, Esslinger, 1977b
Phylliscum demangeonii (Moug. & Mont. in Mont.) Nyl. Tuckerman, 1872, 1882, Flint, 1874
Physcia aipolia (Ehrh. ex Humb.) Fürnr. Thomson, 1963
Physcia dubia (Hoffm.) Lett. Thomson, 1963
Physcia stellaris (L.) Nyl. Thomson, 1963
Physcia tenella (Scop.) DC. in Lam. & DC. Thomson, 1963
Physconia detersa (Nyl.) Poelt Thomson, 1963
Physconia muscigena (Ach.) Poelt Thomson, 1963
Pilophorus cereolus (Ach.) Th. Fr. in Hellb. Tuckerman, 1847, 1858, 1882, Flint, 1874
Placopsis gelida (L.) Linds. Tuckerman, 1882
Placynthiella uliginosa (Schrad.) Coppins & James Tuckerman, 1872, Flint, 1874
Placynthium flabellosum (Tuck.) Zahlbr. Tuckerman, 1882, Henssen, 1963
Platismatia glauca (L.) W. & C. Culb. Tuckerman, 1882, Culberson & Culberson, 1968, Lang et al., 1976, Lang et al., 1980
Platismatia tuckermanii (Oakes) W. & C. Culb. Culberson & Culberson, 1968, Lang et al., 1980
Polychidium muscicola (Sw.) Gray Tuckerman, 1872, 1882, Flint, 1874
Porina lectissima (Fr.) Zahlbr. Tuckerman, 1872, Flint, 1874
Porpidia flavocaerulescens (Hornem.) Hert. & Schwab Tuckerman, 1888
Porpidia macrocarpa (DC. in Lam. & DC.) Hert. & Schwab Tuckerman, 1888
Porpidia speirea (Ach.) Kremp. Tuckerman, 1888
Pseudevernia cladonia (Tuck.) Hale & W. Culb. Tuckerman, 1882, Hale, 1955b, Lang et al., 1976, Lang et al., 1980
Pseudevernia consocians (Vain.) Hale & W. Culb. Tuckerman, 1840, Berry, 1941, Hale, 1955b, Lang et al., 1980
Pseudocyphellaria crocata (L.) Vain. Tuckerman, 1840
[Psora decipiens (Hedwig) Hoffm. Flint, 1874 Misident.]
Psoroma hypnorum (Vahl) Gray Tuckerman, 1847, 1882, Flint, 1874
Pycnothelia papillaria Duf. Tuckerman, 1840, 1847, 1882, Flint, 1874
Pyxine sorediata (Ach.) Mont. Tuckerman, 1845, Imshaug, 1957
[Ramalina calicaris (L.) Fr. Flint, 1874 Misident.]
Ramalina farinacea (L.) Ach. Tuckerman, 1841
Ramalina geniculata Hook. f. & Tayl. Tuckerman, 1882
Ramalina intermedia (Del. ex Nyl.) Nyl. Bowler & Rundel, 1974
Ramalina tenuis (Tuck.) G. K. Merr. Tuckerman, 1872
Rhizocarpon alpicola (Anzi) Rabenh. Tuckerman, 1872, 1888,

Flint, 1874
Rhizocarpon badioatrum (Flörke ex Spreng.) Th. Fr. Tuckerman, 1888
Rhizocarpon geographicum (L.) DC. Tuckerman, 1840, Flint, 1874
Rhizocarpon obscuratum (Ach.) Mass. Tuckerman, 1839
Rhizocarpon oederi (Weber) Körb. Tuckerman, 1841, 1888
Rinodina ascociscana Tuck. Tuckerman, 1858, 1872, 1882, Flint, 1874
Rinodina milliaria Tuck. Tuckerman, 1872, 1888, Flint, 1874
Rinodina turfacea (Wahlenb.) Körb. Tuckerman, 1872, 1882, Flint, 1874
Sarea difformis (Fr.) Fr. Tuckerman, 1888
Schismatomma pericleum (Ach.) Branth & Rostr. Tuckerman, 1888
Scoliciosporum chlorococcum (Graewe ex Stenh.) Vezda Lang et al., 1980
Sphaerophorus fragilis (L.) Pers. Tuckerman, 1839, 1840, 1847, 1872, Flint, 1874
Sphaerophorus globosus (Huds.) Vain. Tuckerman, 1839, 1847, 1872, Flint, 1874
Sporastatia testudinea (Ach.) Mass. Tuckerman, 1847, 1872, 1888, Flint, 1874
[Staurothele fissa (Tayl.) Zw. Flint, 1874 Misident.]
Staurothele fuscocuprea (Nyl.) Zsch. Tuckerman, 1872
Stereocaulon condensatum Hoffm. Tuckerman, 1845, 1847, Flint, 1874
Stereocaulon dactylophyllum Flörke Tuckerman, 1845, 1847, Flint, 1874
Stereocaulon glaucescens Tuck. Tuckerman, 1840
Stereocaulon nanodes Tuck. Tuckerman, 1859, 1872, 1882, Flint, 1874
Stereocaulon paschale (L.) Hoffm. Tuckerman, 1840, 1845, 1847, Flint, 1874, Bliss, 1962, 1963
Stereocaulon tomentosum Fr. Tuckerman, 1847, Flint, 1874
Stereocaulon vesuvianum Pers. Tuckerman, 1845, Flint, 1874
Strigula stigmatella (Ach.) R. Harris Tuckerman, 1872, Flint, 1874
Thamnolia subuliformis (Ehrh.) W. Culb. Tuckerman, 1839, 1840
Thamnolia vermicularis (Sw.) Ach. ex Schaer. Tuckerman, 1882, Bliss, 1963
[Toninia caeruleonigricans (Lightf.) Th. Fr. Flint, 1874 Misident.]
Trapeliopsis flexuosa (Fr.) Coppins & James Tuckerman, 1888, Flint, 1874
Trapeliopsis gelatinosa Flörke) Coppins & James Tuckerman, 1888
Trapeliopsis viridescens (Schrad.) Coppins & James Tuckerman, 1872, 1888, Flint, 1874
Trypethelium virens Tuck. ex Michen. in Darl. Tuckerman, 1872, Flint, 1874
Umbilicaria arctica (Ach.) Nyl. Tuckerman, 1839
Umbilicaria cylindrica (L.) Del. ex Duby Llano, 1950
Umbilicaria deusta (L.) Baumg. Tuckerman, 1839, 1840, 1882, Llano, 1950
Umbilicaria hirsuta (Sw. ex Westr.) Hoffm. Tuckerman, 1840,

Flint, 1874

Umbilicaria hyperborea (Ach.) Hoffm. Tuckerman, 1840, 1847, 1882, Flint, 1874, Llano, 1950

Umbilicaria mammulata (Ach.) Tuck. Llano, 1950

Umbilicaria muehlenbergii (Ach.) Tuck. Tuckerman, 1840, 1847, 1882, Flint, 1874, Llano, 1950

Umbilicaria polyphylla (L.) Baumg. Tuckerman, 1840, 1847, 1882, Flint, 1874

Umbilicaria proboscidea (L.) Schrad. Tuckerman, 1839, 1840, 1847, 1882, Flint, 1874, Llano, 1950

Umbilicaria torrefacta (Lightf.) Schrad. Tuckerman, 1839, 1840, 1847, 1882, Flint, 1874, Llano, 1950,

Umbilicaria vellea (L.) Ach. Tuckerman, 1839, 1841, 1882, Llano, 1950

Usnea cavernosa Tuck. Tuckerman, 1882

Usnea longissima Ach. Tuckerman, 1845

Usnea trichodea Ach. Tuckerman, 1882

Verrucaria margacea (Wahlenb. in Ach.) Wahlenb. Tuckerman, 1872, Flint, 1874

Xylographa abietina (Pers.) Zahlbr. Tuckerman, 1872, 1888, Flint, 1874