LICHENS AS INDICATORS OF ATMOSPHERIC QUALITY IN THE DOLLY SODS AND OTTER CREEK WILDERNESSES OF THE MONONGAHELA NATIONAL FOREST, WEST VIRGINIA

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SUMMARY

A lichen biomonitoring program was initiated in the Otter Creek and Dolly Sods Wildernesses, WV during the summer of 1987. The program had three objectives:

(1) to characterize the lichen floras of the two areas and note patterns characteristic of air pollution damage;

(2) to establish permanent study plots for photographic analysis of lichen community composition;

(3) to collect and analyze lichen material of a single lichen species (Flavoparmelia caperata) for concentrations of potential pollutant elements.

Lichen communities were sampled intensively during September, 1987, and collections were deposited in the Smithsonian Institution. Relatively high numbers of lichen species were found in both Otter Creek (48 spp.) and Dolly Sods (63 spp.), and many pollution-sensitive species (e.g., Usnea spp., Pseudevernia spp., Lobaria spp.) were among these, indicating that the lichen flora is not adversely affected by air pollution at the present time.

Specimens of Flavoparmelia caperata were sampled from June to September, 1987, within 121 1 km^2 sections (80 in Otter Creek and 41 in Dolly Sods) and analyzed for sulfur and 23 other elements to provide information about the present ambient air quality in the two wildernesses. Sulfur concentrations in F. caperata samples were found to be relatively low, with only 3 of 41 (7.3%) sites in Dolly Sods and 1 of 80 (1.2%) sites in Otter Creek having lichens with sulfur concentrations of 0.20% dry weight. When these results are compared with results of an identical study done in the Northern District

of Shenandoah National Park (SNP), VA, in which 26.5% of all sites had lichens with 0.20% or greater sulfur concentrations, one is led to conclude that the air quality in the Otter Creek and Dolly Sods Wildernesses is better than in SNP. Heavy metal concentrations in F. caperata were also quite low. Lead concentrations, for example, were almost all below 100 ug/g, and many were below 50 ug/g, generally lower than those found in lichens from SNP. Concentrations of other metals showed similar patterns. Taken together, these results suggest that the two wildernesses are not presently experiencing air pollution levels similar to SNP.

The only significant trend in the element data from the two study areas is that lichens from Dolly Sods have significantly higher concentrations of S, Pb and other metals than lichens from Otter Creek. This may be due to the generally higher elevations and more exposed site conditions in Dolly Sods. There was no apparent difference in lichen health or commmunity composition that would indicate that Dolly Sods is at greater risk from air pollution.

It is recommended that resurveys of the lichen communities of Otter Creek and Dolly Sods be done at 5-10 year intervals to document changes in the lichen flora and/or element status of F. caperata. Such information would be valuable in documenting potentially important pollution trends in the wildernesses and provide "early warning" of harmful air quality changes.

INTRODUCTION

Lichens have frequently been used as biomonitors of atmospheric pollution because of the sensitivity of some species to the toxic effects of air pollutants and the ability of other species to accumulate elements, including pollutants, from the ambient environment. Information gained from lichen biomonitoring programs can therefore provide early warning of catastrophic and irreversible effects of air pollution on biological systems. Results of long-term studies have also provided evidence for improved air quality resulting from changes in regional emissions patterns.

In the summer of 1987, a lichen biomonitoring program was initiated in the Dolly Sods and Otter Creek Wildernesses of the Monongahela National Forest. These two wildernesses were established by Public Law 93-622 on January 3, 1975 and are therefore designated Class I areas under the Clean Air Act Amendments of 1977. As such, they are to be closely monitored to prevent significant deterioration of air quality related values. Since no previous air quality related studies have been done in these wildernesses, a baseline analysis was done to provide information on the present air quality patterns in these sensitive areas. It is anticipated that results of this baseline study will also allow comparative studies to be done at various times in the future.

Some of the management questions to be addressed in this baseline survey are:

(1) What is the distribution and species richness of the lichen communities found, and how can that best be described?

(2) How does community distribution, species richness and relative species abundance, and the results of the elemental analysis,

compare with what is expected to be found in ecologically similar areas of the eastern United States?

(3) What evidence is there, if any, that the lichen communities of Dolly Sods and Otter Creek Wildernesses are under stress?

(4) If there is evidence of stress, what factors are, or could be, contributing to this stress? Is air pollution a contributing factor? If so, are specific air pollutants responsible?

(5) What evidence is there (if any) that air pollution is the cause of any observed deviation within the community structure from that which is expected in an unperturbed ecosystem?

In this report, we attempt to provide answers to these questions insofar as this is possible with one year's data. Specifically, we will discuss results of four tasks:

(1) A floristic lichen survey of the two study areas, listing all species observed in a sampling of the various habitats and including an assessment of sensitivity to air pollution.

(2) Establishment of permanent study plots for photographic analysis of lichen communities.

(3) Establishment of field quadrats systematically throughout the two areas, within which the presence or absence of lichen species known to be sensitive to air pollution is noted.

(4) Laboratory analysis of a single lichen species, Flavoparmelia caperata, collected throughout the two areas, for sulfur and metals concentrations. Other species (F. baltimorensis, Hypogymnia physodes, Tuckermannopsis oakesiana) were also collected when observed in the quadrats, and analyzed for sulfur and metals.

METHODS

Floristic Field Work

All field work was done in the summer of 1987 in the Dolly Sods and Otter Creek Wildernesses of the Monongahela National Forest. Dolly Sods is a 10,215 acre area of rugged, rocky terrain dominated by second-growth hardwoods with areas of shrubby heath barrens and patches of red spruce in the higher elevations. Much of the understory consists of dense Rhododendron thickets, and there are wetland bogs and beaver impoundments. Otter Creek is approximately 20,000 acres of 50- to 100-year-old hardwood forest with numerous Rhododendron thickets in the understory. It includes most of the drainage area of Otter Creek and Shavers Lick Run.

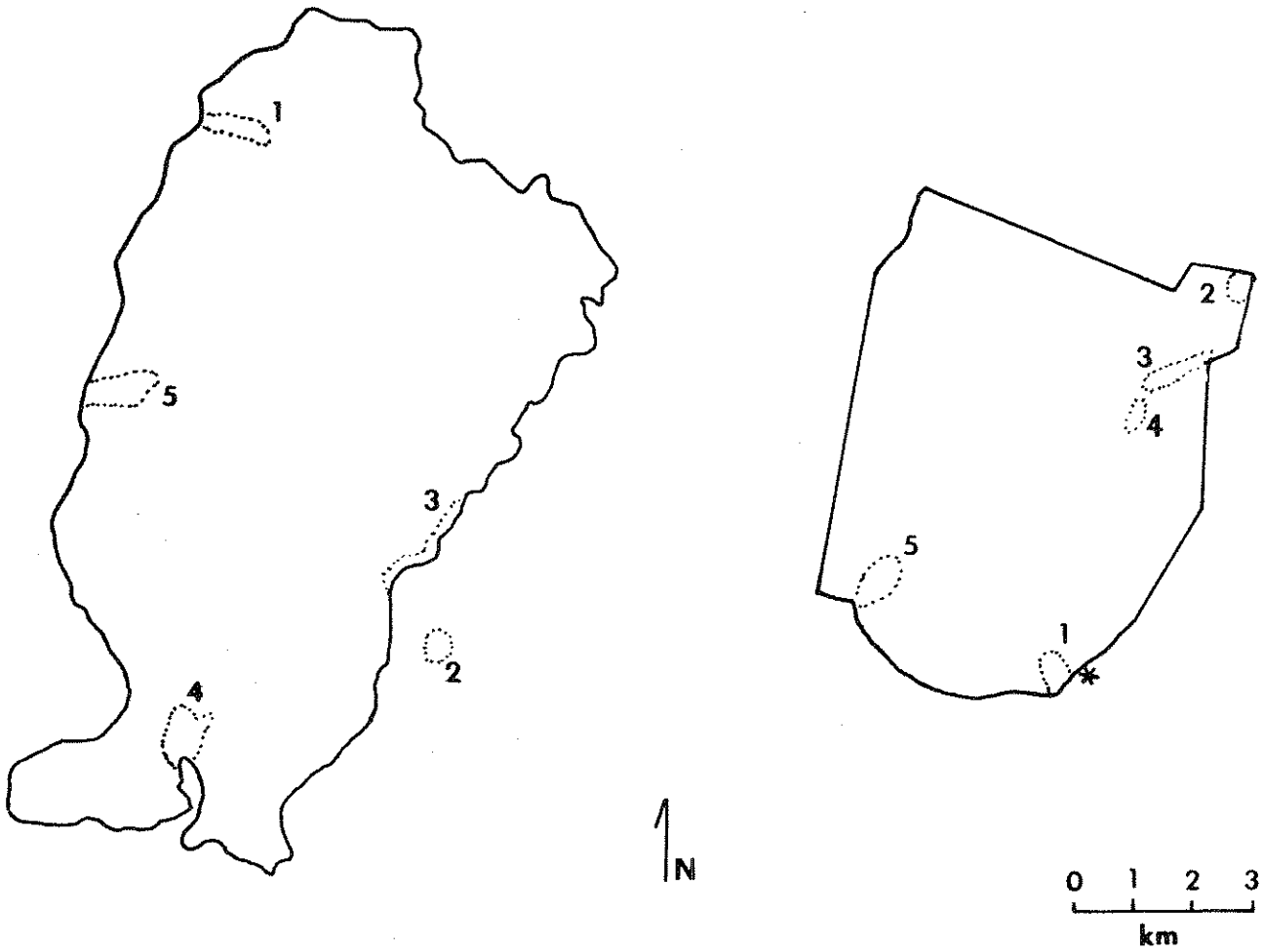
Field collections for the floristic analysis were made by Mason Hale in September, 1987. A total of ten locations, five each in Otter Creek and Dolly Sods (Fig. 1) were chosen for sampling. The precise locations of these sampling areas are as follows:

Otter Creek:

1. Big Springs Gap Trail (151), between trail head at Forest Road 701 and Otter Creek. Elev. 2066-2400 ft. This is part of a large area of mature eastern deciduous forest dominated by tulip poplar, ash, hickory, and sugar maple. Most of the lichens were collected at the base of large trees and on several felled trees. The relatively poor lichen flora is representative of mature, shady forests.
2. Mylius Trail (128) leading up Shavers Mountain from the trail head off Forest Road 228 from the Kuntzville Road (162), on the east flank of Shavers Mountain. Elev. about 2800 ft. This is a mature eastern deciduous forest along the foot of Shavers Mountain, dominated by sugar maple and beech. The lichens were especially well developed on old sugar maple trees. This site

FIGURE 1

Location of floristic survey sites in the Otter Creek (left) and Dolly Sods (right) Wildernesses, WV. Numbers refer to specific collecting sites described in the text. Photographic study quadrats were located in the southeastern corner of Dolly Sods and are marked with an asterisk (*). The precise location of these study quadrats is also given in the text.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was located outside the wilderness.

3. Shavers Mountain Trail between the crest junction with trail 128 (Mylius Trail) and going north to the virgin hemlock stand. Elev. 3200-3600 ft. The forest is dominated by red maple, red oak, yellow birch with an open understory and rock ledges along the eastern escarpment. The lichens are well developed on red oak and red maple trees scattered in the rocky areas. The rock ledges are shaded, but some colonies of Flavoparmelia baltimorensis were found.

4. Otter Creek from the trail head at the north end of Forest Road 303 to the junction with Yellow Creek Trail (135). Elev. 3000-3050 ft. This dense secondary forest is dominated by yellow birch with a nearly impenetrable understory of Rhododendron. It is very poor in lichens except for red maple trees in open sites along the stream near the parking area.

5. Moore Run Trail (138) between trail head at Forest Road 324 and junction with Turkey Run Trail (150). Elev. around 3320 ft. This swampy secondary forest is dominated by yellow birch with a dense Rhododendron understory. Lichens were collected along the open trail area on tree bases and stumps.

Dolly Sods:

1. Permanent plot #1 stop, on north side of Forest Road 19, 450 ft. west southwest of trail head marker for trail 517 (southwest of Dolly Sods Picnic Area). Elev. around 3900-4000 ft. This young secondary forest is dominated by red maple, yellow birch, red oak and beech and is typical of most of the forest on the southern end of the wilderness. Lichens are well developed on red maple and yellow birch.

2. 0.9 miles south of Red Creek Campground on the west side of Forest Road 75. Elev. 3900-3960 ft. This is an open swampy area dominated by spruce, red

maple, black birch, yellow birch with an understory of alder and mountain laurel. Lichens are extremely well developed on the trunks with several collections of Usnea spp.

3. Fisher Spring Run Trail (510) from trail head at Forest Road 75 to Wildlife Trail (560) junction. Elev. 3700-4000 ft. This young secondary forest is dominated by red maple and yellow birch with some black birch and beech. There is much exposed bedrock. Lichens are poorly developed.

4. Rohrbaugh Plains Trail (508) from junction with Fisher Spring Run Trail (510) to Forest Road 75. Elev. 3700-4000 ft. This secondary forest is dominated by sugar maple, red maple, yellow birch and ash. Outcrops of broken bedrock and ledges are common at the lower end of the trail. Lichens are well developed on the rock outcrops but poorly developed on the trees.

5. Red Creek Trail (514) between Laneville Wildlife Cabins and junction with Little Stonecoal Trail (552). Elev. 2600 ft. This is a mature deciduous forest along the river at the base of a hillside dominated by basswood, ash, tulip poplar with some hemlock and red maple. The lichen flora is well developed.

At each site, lichens were collected from all potential microhabitats, including felled trees, which provided a substrate for many species not otherwise seen. All lichens were packeted and returned to the Smithsonian Institution, where they were identified, labelled and placed in the lichen collection as voucher specimens. Species lists were developed by site and (where appropriate) by substrate. No attempt was made to produce a vegetation map for the two wildernesses. Rather, the objective was to intensively sample the lichen flora from as many different vegetation types as possible in each wilderness and to collect as many different lichen species as possible.

Species lists therefore reflect the commonly occuring lichens from the various habitats in each area and provide preliminary floristic evidence of possible pollution effects at the community level.

Two permanent photographic quadrats were established in the southeast corner of Dolly Sods (Fig. 1) and photographs were taken to provide a baseline for future resurveys of the lichen communities. These photographic quadrats were chosen in areas easy to relocate and least susceptible to canopy overgrowth so that any future changes would be most likely caused by air quality changes. The precise location of these permanent plots is as follows:

Permanent Plot #1: Located on the north side of Forest Road 19 (running E-W at this point), 150 ft west of the turn to the north, 465 ft WSW of the Trail 517 trail head. Quadrat rock selected from a small cluster of rocks at the top of the embankment just off the road and just before the forest edge (see photographs). Quadrat rock about 1 X 2 m with the 20 X 28 cm quadrat located horizontally on a nearly vertical face and marked with four drilled corner holes.

Permanent Plot #2: Located on the west side of Forest Road 19 (running nearly N-S at this point), about 560 ft. N of the Trail 517 trail head. A large horizontal slab about 2 m long and 1.5 m wide just at the edge of the road (see photographs). A 20 X 28 cm quadrat located at the north end (37 cm from the north edge of the rock) on a flat exposure with a 10% slope and marked by four drilled corner holes.

Establishment of Elemental Analysis Quadrats

During the period June to September, 1987, 169 elemental analysis quadrats 10 X 10 m in size were established in the two wildernesses. Of these, 121 were located within 1 km^2 sections located systematically in the two wildernesses, 80 in Otter Creek (Fig 2) and 41 in Dolly Sods (Fig. 3). The remaining 48 quadrats were replicates located at least 100 m from the original quadrat in every tenth section, four per section. Therefore, in each 1 km^2 section, there is at least one quadrat, and in every tenth section, there are five. The reason for including replicate quadrats in some of the 1 km^2 sections is to measure the within-section variability of pollutant element concentrations.

Each quadrat was marked with four aluminum tags bearing the section number, one in each corner. Section numbers are given in the site locations (Appendix 1) for the main sites and the elemental data (Appendix 3 & 4) for the replicate sites.

Within each quadrat, the presence/absence of certain indicator lichen species known to be sensitive to pollution was noted. Also, mature specimens of Flavoparmelia caperata were collected and returned to the laboratory for elemental analysis. In cases where sufficient quantities of other species (such as F. baltimorensis) were available, these were also collected for analysis.

Laboratory Analysis

Lichen material collected in each quadrat was cleaned of tree or rock debris, washed in distilled water, dried and ground in a Wiley mill. Samples were then sent to the Ohio Agricultural Research and Development Center (OARDC) in Wooster, Ohio for elemental analysis. Samples of

FIGURE 2

Location of the 1 km^2 sections in the Otter Creek Wilderness, WV. Exact locations are given in Appendix 1.

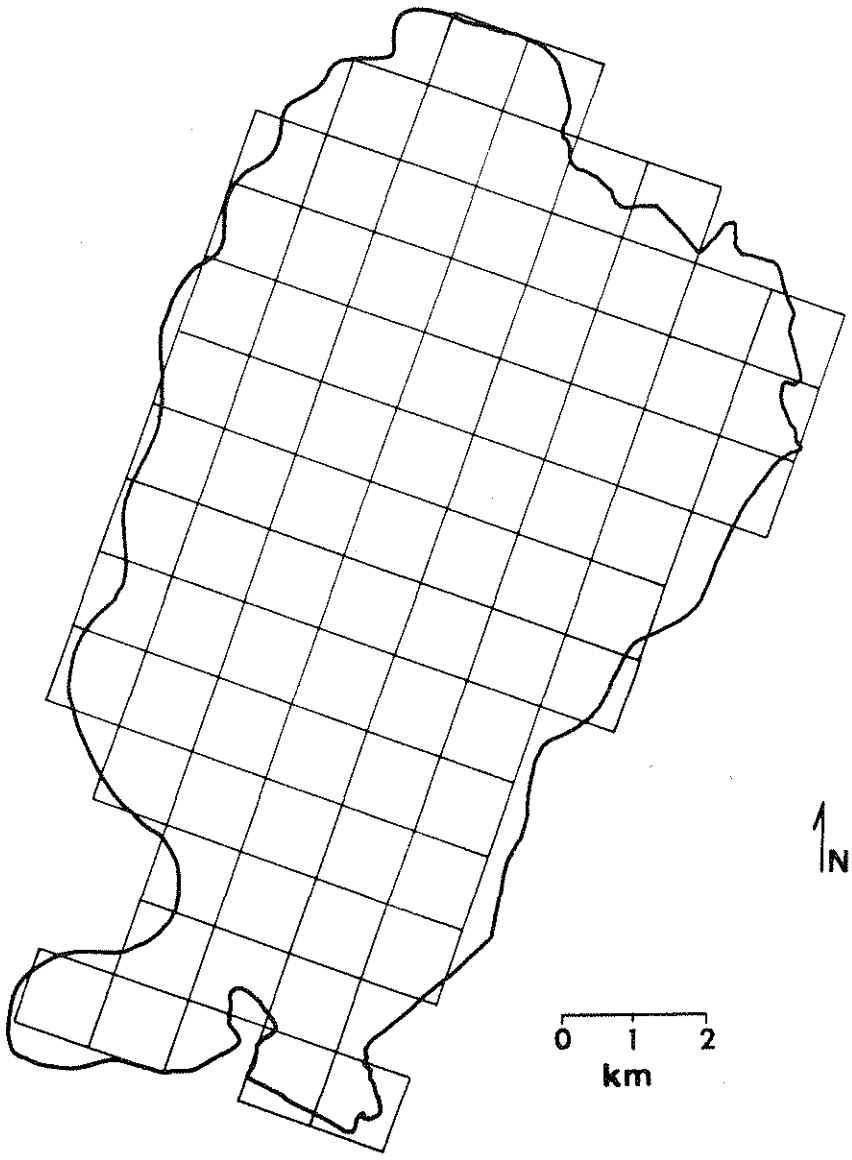
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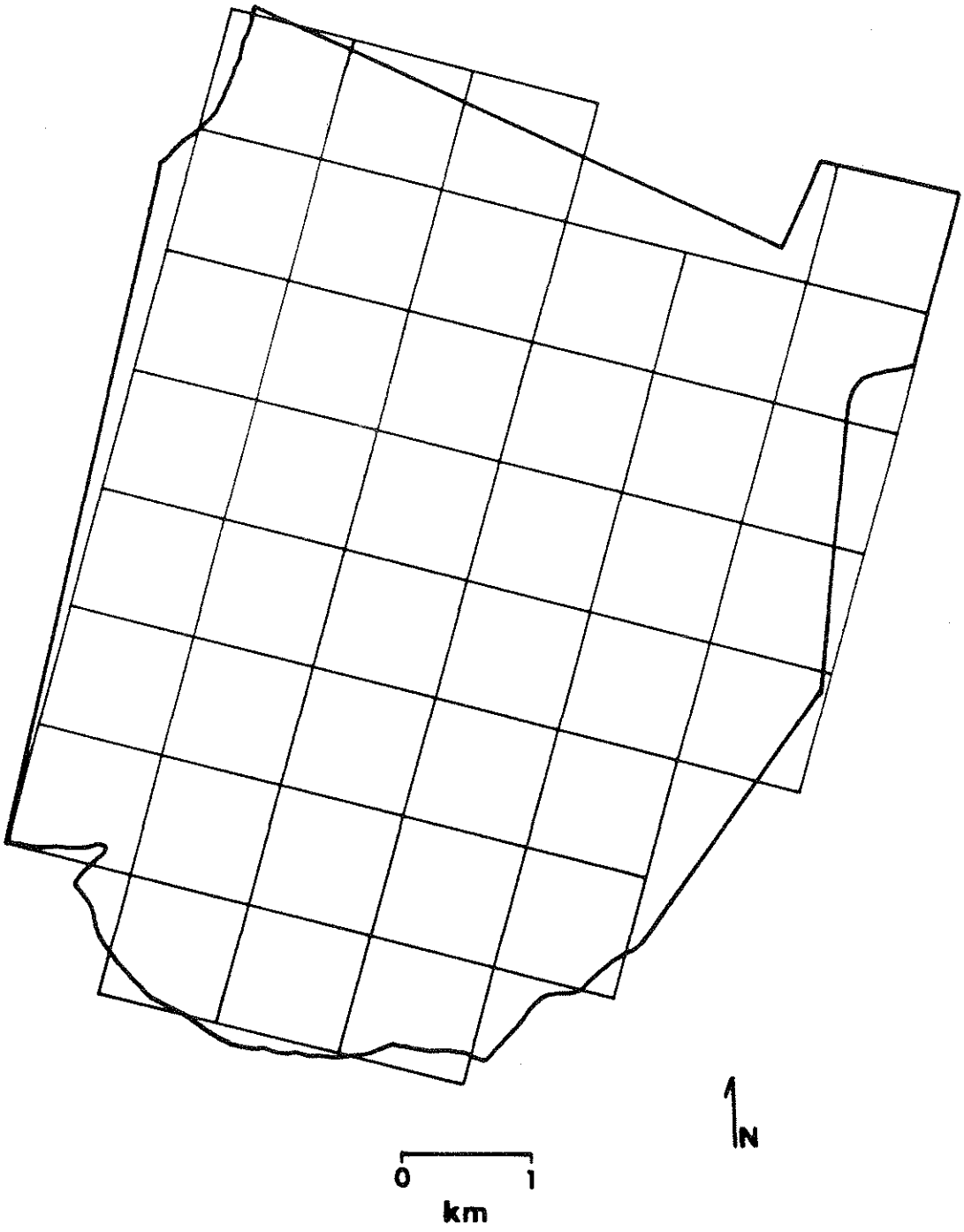
FIGURE 3

Location of the 1 km^2 sections in the Dolly Sods, Wilderness, WV. Exact locations are given in Appendix 1.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reference material (citrus leaf reference) from the National Bureau of Standards were also sent to insure reliability of results. All lichen samples were analyzed at OARDC for total concentrations of 23 elements (P, K, Ca, Mg, Na, Fe, Mn, Cu, Zn, B, Ni, Cr, Pb, Cd, Al, Mo, Sr, Ba, V, Ti, Be, Sn, Co) using an Inductively Coupled Plasma Spectrograph. Total sulfur was also determined for each sample using a Leco sulfur analyzer, in which sulfur of the sample is oxidized in a stream of oxygen at very high temperature.

RESULTS

Floristic Analysis

Forty-eight lichen species were collected in Otter Creek and 63 species were collected in Dolly Sods (species lists are given in Appendix 2). The ten commonest species for each site (Table 1) were similar, suggesting the lichen floras of the two wildernesses are not distinct but rather part of a larger homogeneous flora characteristic of the northern Allegheny Mountains. Lichens known to be especially sensitive or insensitive to pollution were found in both wildernesses (Table 2), with a generally greater diversity of both types found in Dolly Sods.

The permanent photographic plots contained several lichen species (photographs attached) whose presence and size may be used for future comparative studies. Plot #1 contains two large colonies of the common *Xanthoparmelia conspersa*; a black crustose lichen, *Aspicilia cinerea* covers about 10% of the rock with inconspicuous colonies of the endolithic lichen *Sarcogyne similis* in crevices. The rest of the background is bare rock.

Table 1. The ten commonest lichen species from each wilderness, as determined from the frequency of reportings in field notes.

Otter Creek	Freq. of Reports	Dolly Sods	Freq. of Reports
Cladonia spp.	20	Cladonia spp.	16
Flavoparmelia caperata	14	Punctelia rudecta	12
Punctelia rudecta	12	Parmelia squarrosa	9
Punctelia subrudecta	10	Flavoparmelia caperata	8
Tuckermannopsis oakesiana	10	Tuckermannopsis oakesiana	8
Parmelia sulcata	9	Graphis scripta	8
Hypogymnia physodes	7	Lepraria sp.	8
Lepraria spp.	7	Hypogymnia physodes	6
Graphis scripta	6	Usnea sp.	5
Parmelia squarrosa	4	Parmelia sulcata	4

Table 2. Pollution sensitive and insensitive lichen species collected in the floristic survey of Otter Creek and Dolly Sods Wildernesses, WV.

	Otter Creek	Dolly Sods
Pollution-sensitive	Heterodermia speciosa	Heterodermia speciosa
	Lobaria quercizans	Peltigera canina
	Pseudevernia consocians	Pseudevernia consocians
	Tuckermannopsis oakesiana	Tuckermannopsis oakesiana
	Usnea sp.	T. ciliaris
		Usnea sp.
Pollution-insensitive	Cladonia coniocraea	Cladonia coniocraea
	Graphis scripta	Graphis scripta
	Lepraria sp.	Lepraria sp.
	Lepraria zonata	Lepraria zonata
	Parmelia sulcata	Parmelia sulcata
	Porpidia albocaerulescens	Porpidia albocaerulescens
	Punctelia rudecta	Puctelia rudecta
	P. subrudecta	P. subrudecta
		Sarcogyne similis

Plot #2 contains one large and several smaller colonies of X. conspersa. The background is a mixture of several crustose or granular lichens, including Aspicilia cinerea and Candelariella vitellina.

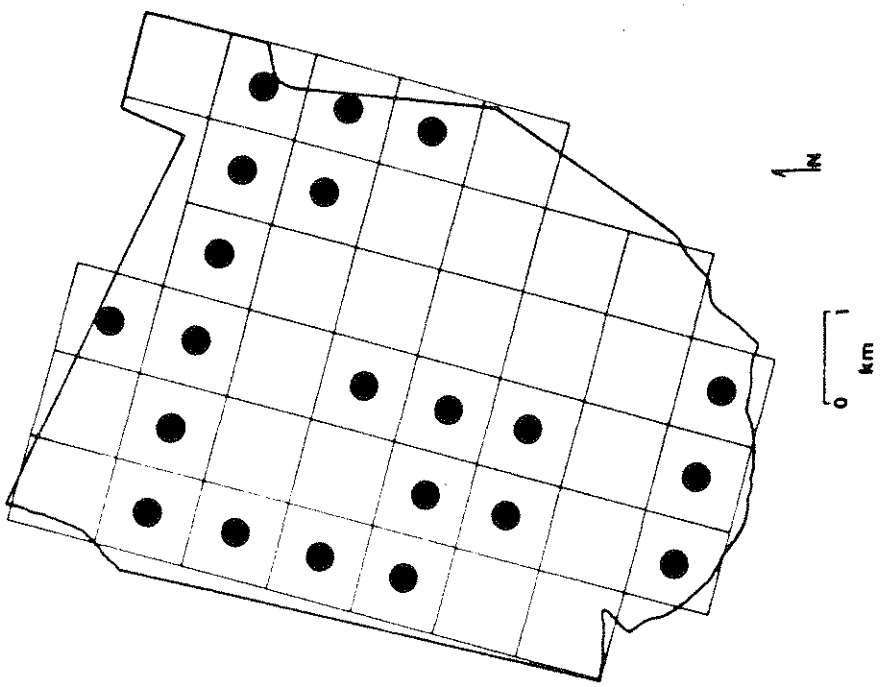
Elemental Analysis Quadrats: Indicator Lichen Species

Each of the elemental analysis quadrats was chosen in habitats where at least one lichen species, Flavoparmelia caperata, was available for collection. Other species were sometimes present, but F. caperata was clearly the dominant species throughout the study areas. The only other indicator species that was observed frequently enough in the quadrats to be used for future surveys was Tuckermannopsis oakesiana, a fairly common tree- and rock-inhabiting foliose species. It was observed more frequently in Otter Creek than in Dolly Sods (Fig. 4).

Other lichen species observed in the quadrats included Flavoparmelia baltimorensis, which has similar ecological requirements as F. caperata except it usually is found on rocks, and Pseudevernia consocians, a fairly uncommon alpine species. Flavoparmelia baltimorensis was observed in eight sites, three in Otter Creek and five in Dolly Sods; it was collected for elemental analysis (see Table 5) except for site 120, where it was too small in volume. Pseudevernia consocians was found in Otter Creek only (sites 41 and 69). Hypogymnia physodes, a common lichen on conifers, was found in sites 44 and 45 in Otter Creek, which were dominated by red spruce. Ground-dwelling Cladina spp. were also observed frequently throughout the study areas. No other species were observed in the quadrats. As the floristics results demonstrate, however, this does not mean the lichen flora is depauperate. A much greater lichen species diversity is present on fallen trees, indicating that conditions are frequently too dark in the quadrats for many species used as pollution indicators (e.g., Usnea spp.).

FIGURE 4

Location of 1 km^2 sections in Otter Creek (left) and Dolly Sods (right) in which Tuckermannopsis oakesiana was observed within 10 X 10 m quadrats.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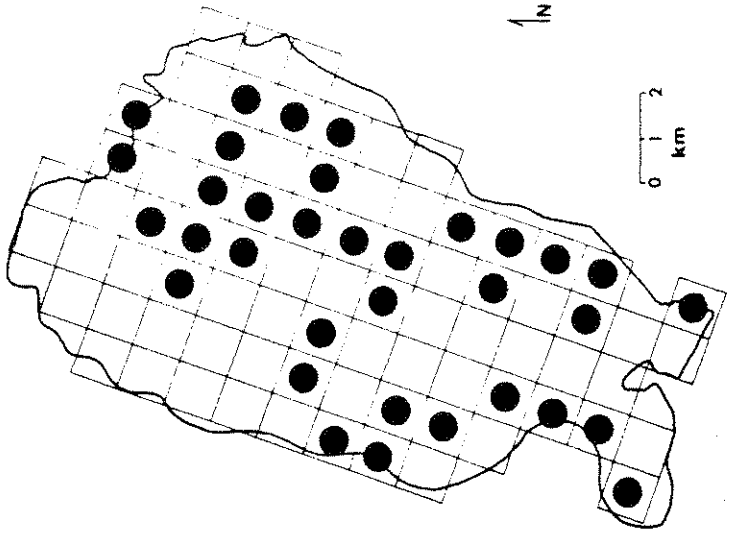
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Elemental Analysis Quadrats: Elemental Analysis of Test Lichens

Analysis of Flavoparmelia caperata specimens from each quadrat suggested that the Otter Creek and Dolly Sods Wildernesses are relatively unaffected by sulfur or other elements indicative of air pollution (all element data are provided in Appendix 3 & 4). Most element concentrations were either so variable that they showed no particular distribution pattern in the study areas or were found at concentrations below detection limits of the ICP instrument (Table 3); these included elements commonly considered pollutants (V, Cr, Co, Ni, Cd). Nine elements were found in significantly higher concentrations in lichens collected from Dolly Sods than from Otter Creek (Table 3). Some of these (S, Pb, Cu, Zn, Fe, Al) represent possible air pollutants. None of the concentrations represent unusually high values, however (Table 4). One element, Ca, was found in concentrations significantly higher in Otter Creek specimens; however, calcium is not generally considered to be associated with air pollutants.

The spatial distribution of lichens containing the highest concentrations of sulfur (Fig. 5) and lead (Fig. 6) indicate only that Dolly Sods has a greater number of "hot spots" than Otter Creek. There is no apparent distribution pattern suggesting a single pollution source is responsible for elevated concentrations of these elements. Plots of other heavy metal concentration patterns show a similar lack of pattern; furthermore, there is no correspondence between the spatial distributions of any single pollutant element concentration and that of any other element, suggesting that the causes of elevated concentrations of these elements are not the same.

All of the elements exhibited considerable variability in concentration from site to site. An analysis of variance of the element concentrations

Table 3. Summary of elements measured in Flavoparmelia caperata specimens collected from the Otter Creek and Dolly Sods Wildernesses, WV. Elements are arranged according to distribution pattern (if any) exhibited in the study areas.

Elements for which no significant distribution pattern was detected:

Ba	P	B
V	Cr	
Ti	Sr	

Elements for which concentrations were below limits of instrument detection:

Be	Ni
Sn	Cd
Co	Mo (some samples)

Elements for which concentrations were significantly higher in specimens from Dolly Sods than from Otter Creek:

K	Pb	Zn	Na
Mg	S	Fe	
Mn	Cu	Al	

Elements for which concentrations were significantly higher in specimens from Otter Creek than from Dolly Sods:

Ca

Table 4. Range and mean values of 18 elements in Flavoparmelia caperata specimens collected from Otter Creek and Dolly Sods Wildernesses, WV. Elements found at concentrations below detection limits are not included.

Element[1]	Range (site number)	Mean Element Conc. ± S.E. Otter Cr. (N=112)	Dolly Sods (N=57)	signif.[2] level
Nonpollutants				
P	330.1 (67) - 1996 (46)	786.65 ± 27.39	854.39 ± 48.71	ns
K	1277 (72) - 5458 (58)	2588.28 ± 68.18	2926.16 ± 97.10	0.001
Ca	1301 (29) - 93448 (3)	17652 ± 1446	12947 ± 1526	0.05
Mg	137.3 (50) - 648.8 (10)	268.61 ± 9.77	336.95 ± 15.66	0.001
Na	7.85 (40) - 148.7 (10)	28.42 ± 1.59	50.06 ± 4.19	0.001
Mn	19.84 (99) - 920 (95)	159.56 ± 10.42	223.16 ± 21.45	0.001
B	3.769 (24) - 48.26 (103)	9.73 ± 0.54	9.81 ± 0.79	ns
Sr	2.924 (102) - 69.32 (17)	14.14 ± 0.95	12.18 ± 1.26	ns
Ba	8.25 (10) - 337.6 (113)	64.60 ± 5.86	67.70 ± 8.04	ns
Ti	4.59 (77) - 98.94 (90)	22.79 ± 1.12	23.47 ± 1.90	ns
Potential Pollutants				
Pb	13.06 (3) - 103.2 (75)	33.67 ± 1.45	40.92 ± 2.24	0.01
Cr	0.967 (42) - 6.392 (120)	2.87 ± 0.110	2.90 ± 0.130	ns
Cu	4.057 (3) - 27.94 (120)	8.46 ± 0.22	9.74 ± 0.130	0.01
Zn	16.07 (40) - 227.5 (105)	41.14 ± 2.28	64.24 ± 4.99	0.001
Fe	101.0 (77) - 1586 (120)	400.50 ± 15.80	471.7 ± 37.13	0.05
Al	239.3 (110) - 2927 (120)	668.77 ± 24.94	954.59 ± 71.32	0.001
V	3.631 (87) - 1008 (38)	145.08 ± 13.67	99.79 ± 17.87	ns
S[3]	0.078 (42,47) - 0.200 (61,89, 104,116)	0.124 ± 0.002	0.147 ± 0.003	0.001

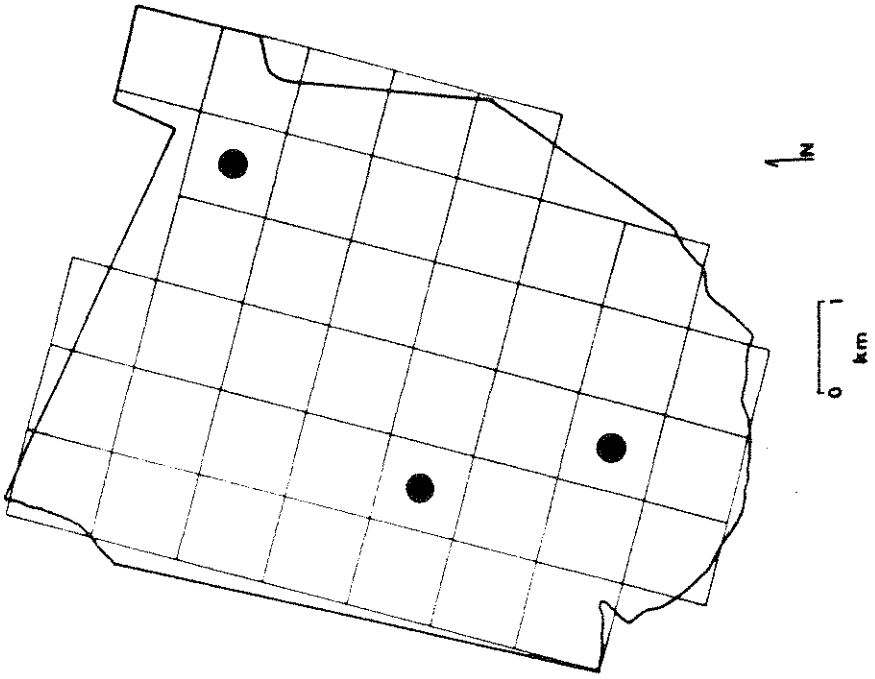
[1] All element concentrations except S are reported in ug/g.

[2] Significance level indicates alpha level at which significant difference in the two means is detectable.

[3] Sulfur concentrations reported in percent.

FIGURE 5

Location of 1 km^2 sections in Otter Creek (left) and Dolly Sods (right) in which sulfur concentrations in Flavoparmelia caperata samples were 0.20% dry wt.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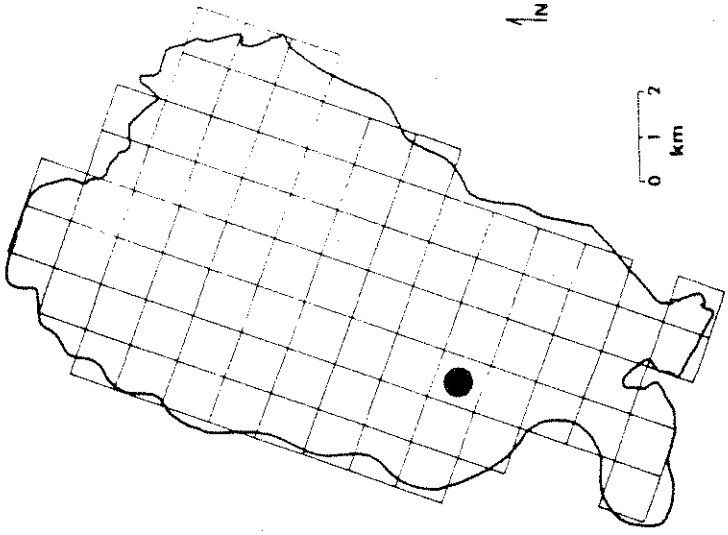
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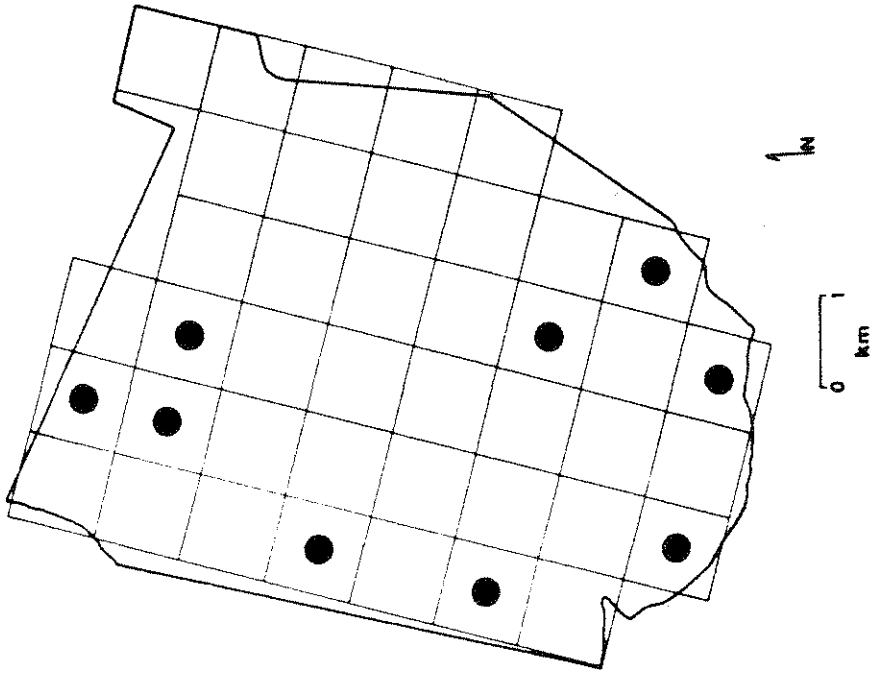
FIGURE 6

Location of 1 km^2 sections in Otter Creek (left) and Dolly Sods (right) in which lead concentrations in Flavoparmelia caperata samples exceeded 50 ug/g dry wt.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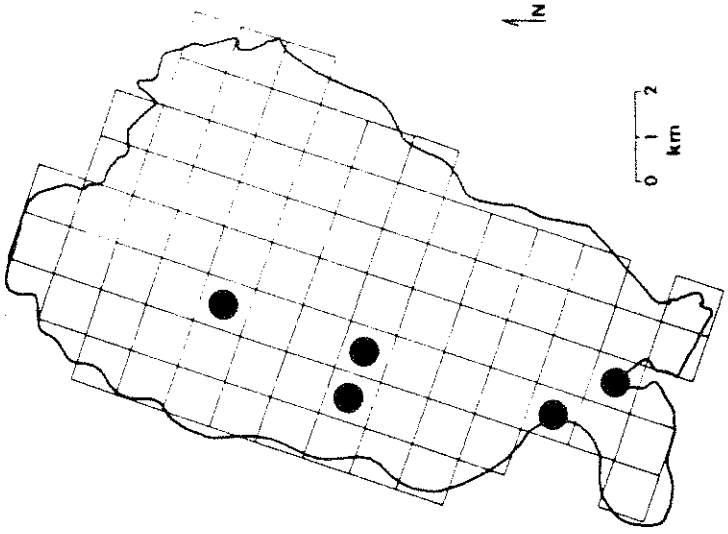
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obtained from the 12 replicated sites (Table 5) shows that seven of eighteen elements surveyed were found at concentrations so variable that no significant difference between any of the replicated means could be detected. Of the remaining elements, most were found at significantly elevated concentrations in only one of the 12 sites. It is interesting that site 120 on the southern border of the Dolly Sods study area had significantly elevated concentrations of seven elements; in the case of Fe and Al concentrations, the differences in mean concentration from the other sites are marked.

No correlation was found between element concentration in F. caperata and the elevation of the quadrat from which the lichens were collected (obtained from topographic maps), although quadrat elevations tended not to vary much in either of the study areas. Also, the generally high variance in most element concentrations would tend to mask such a correlation, even if one existed.

In eleven sections, sufficient lichen material of a species other than Flavoparmelia caperata was available for elemental analysis. A comparison of the element concentrations of F. caperata with the other species collected from the same section generally indicated a wide variation between species for most elements. For example, a comparison of S and Pb concentrations observed for F. caperata and three other species collected in the study areas (Table 6) indicated that concentrations, though similar in most cases, were not identical and, in some cases, were very different from one species to another.

Table 5. Analysis of variance of 18 elements measured in Flavoparmelia caperata specimens obtained from 12 sites for which five replicate samples were taken in the Otter Creek and Dolly Sods study areas. All elements except S are reported in ug/g; sulfur is reported in percent. Only the F value and the significance level, which indicates the alpha value at which a significant difference in the means is detectable, are given. All of the values in parentheses are standard errors.

Site	Pb	Cr	B	Cu	Zn	Fe	Sr	Al	Ba
Otter Creek									
10	28.46 (3.47)	3.19 (0.67)	9.78 (1.73)	10.68 (1.93)	42.71 (8.80)	478.3 (88.55)	26.08 (8.44)	865.58 (162.28)	67.06 (28.68)
20	23.75 (2.89)	2.20 (0.29)	8.13 (0.76)	7.92 (0.82)	55.38 (16.1)	392.4 (45.43)	11.77 (1.96)	516.74 (77.2)	47.23 (5.23)
30	43.90 (9.94)	2.81 (0.23)	7.92 (0.72)	8.15 (0.66)	37.99 (4.31)	419.0 (97.32)	7.29 (0.94)	677.20 (114.4)	41.47 (9.08)
40	39.67 (11.74)	2.35 (0.29)	7.94 (0.85)	7.44 (.054)	24.18 (3.49)	431.58 (47.73)	7.39 (1.43)	507.44 (61.16)	39.13 (12.12)
50	30.92 (7.89)	2.47 (0.28)	8.30 (0.36)	7.98 (0.45)	37.49 (2.63)	354.04 (39.49)	6.85 (1.04)	503.42 (69.92)	52.81 (12.28)
60	31.59 (4.61)	3.42 (0.45)	21.05 (4.44)	11.23 (1.91)	48.26 (6.11)	473.30 (74.69)	9.24 (2.09)	731.56 (60.67)	38.16 (6.53)
70	52.28 (6.72)	2.96 (0.59)	8.38 (1.07)	7.88 (0.54)	32.28 (2.60)	307.68 (51.23)	13.49 (1.92)	609.40 (50.41)	51.74 (10.23)
80	37.02 (6.44)	2.85 (0.57)	8.88 (1.26)	8.25 (0.83)	35.48 (3.97)	330.26 (21.12)	11.43 (2.24)	763.34 (148.8)	68.84 (11.88)
Dolly Sods									
90	48.99 (9.76)	3.01 (0.14)	7.48 (0.61)	10.05 (0.99)	43.34 (7.42)	312.28 (74.78)	10.63 (2.03)	844.24 (64.26)	73.63 (19.78)

Table 5. (cont.)

Site	Pb	Cr	B	Cu	Zn	Fe	Sr	Al	Ba
100	27.08 (3.91)	2.15 (0.14)	10.16 (1.52)	6.23 (0.33)	95.90 (15.27)	310.56 (24.98)	11.24 (1.92)	510.44 (53.11)	31.01 (13.18)
110	25.64 (4.40)	2.38 (0.28)	8.98 (0.94)	7.37 (0.43)	45.66 (8.12)	417.24 (28.64)	19.75 (6.19)	508.10 (71.77)	49.25 (12.84)
120	41.90 (7.95)	4.68 (0.76)	8.51 (1.45)	15.46 (2.56)	54.69 (3.73)	1115.66 (232.6)	8.22 (2.09)	2186.00 (406.5)	64.22 (42.28)
$F_{11,48}$	1.73	2.48	4.89	4.17	4.88	6.23	2.71	10.06	0.56
Signif. level	ns	0.05	0.001	0.001	0.001	0.001	0.001	0.001	ns

Site	V	Ti	P	K	Ca	Mg	Na	Mn	S
Otter Creek									
10	154.45 (75.51)	25.53 (3.03)	811.9 (81.7)	2768.8 (300.6)	31298 (5355)	469.2 (56.9)	61.09 (23.0)	66.64 (12.33)	0.114 (0.01)
20	204.24 (94.39)	20.34 (3.42)	792.9 (91.7)	3144.5 (407.2)	26119 (6287)	337.5 (19.33)	26.25 (5.78)	122.42 (32.31)	0.131 (0.006)
30	124.96 (33.71)	31.78 (5.28)	616.1 (49.8)	2357.0 (220.0)	10007 (3501)	207.2 (22.11)	26.94 (4.99)	162.19 (29.37)	0.126 (0.009)
40	157.28 (60.43)	25.14 (3.76)	601.2 (52.9)	2015.4 (180.8)	8451 (3160)	192.6 (14.05)	18.60 (6.30)	103.94 (23.72)	0.117 (0.003)
50	176.54 (70.71)	19.09 (5.33)	776.1 (57.7)	2364.6 (169.6)	12070 (10069)	163.14 (15.08)	25.39 (3.86)	162.70 (16.31)	0.118 (0.007)
60	141.75 (40.97)	25.31 (5.33)	923.3 (119.3)	2655.4 (187.4)	23847 (6891)	249.28 (12.16)	34.18 (7.66)	184.86 (24.44)	0.135 (0.009)

Table 5. (cont.)

Site	V	Ti	P	K	Ca	Mg	Na	Mn	S
70	153.31 (53.62)	16.05 (4.19)	524.3 (147.8)	2145.8 (374.3)	17577 (6891)	214.08 (12.64)	22.80 (3.88)	138.10 (10.91)	0.105 (0.003)
80	81.93 (30.88)	15.77 (2.59)	945.8 (184.6)	2394.8 (177.2)	9327 (2272)	242.56 (21.45)	31.48 (3.44)	128.18 (17.44)	0.136 (0.012)
Dolly Sods									
90	145.60 (33.24)	34.42 (16.35)	793.2 (145.1)	2660.6 (326.1)	11746 (3098)	230.82 (72.34)	21.44 (3.09)	180.04 (28.95)	0.144 (0.005)
100	188.6 (74.74)	14.45 (0.64)	1252.2 (222.4)	3874.2 (329/4)	19404 (5285)	404.38 (50.76)	52.70 (19.51)	462.84 (76.92)	0.131 (0.007)
110	140.84 (45.03)	17.64 (2.03)	1095.1 (146.7)	3399.0 (405.9)	23294 (7767)	378.36 (80.65)	28.55 (5.87)	205.33 (60.98)	0.139 (0.005)
120	365.65 (102.2)	38.27 (7.51)	812.62 (86.11)	3333.6 (256.7)	9279 (4419)	392.08 (52.24)	46.90 (3.41)	139.27 (34.52)	0.139 (0.009)
$F_{11,48}$	1.17	1.58	2.64	3.78	1.96	5.42	1.85	7.58	2.24
Signif. level	ns	ns	0.01	0.001	ns	0.001	ns	0.001	0.05

Table 6. Comparison of lead and sulfur concentrations observed in *Flavoparmelia caperata* and other lichen species collected from the same site in the Otter Creek and Dolly Sods, WV Wildernesses.

Site	Element	Flavoparmelia caperata	Flavoparmelia baltimorensis	Hypogymnia physodes	Tuckermannopsis oakesiana
19	S	0.161	0.126		
	Pb	21.38	37.02		
27	S	0.137	0.145,0.126[1]		
	Pb	25.80	50.95,52.29		
44	S	0.138		0.135	
	Pb	45.51		52.20	
45	S	0.118		0.154	
	Pb	37.23		36.31	
58	S	0.115	0.122		
	Pb	40.82	38.96		
83	S	0.14	0.112		
	Pb	40.10	37.82		
86	S	0.12			0.100
	Pb	52.14			51.84
87	S	0.14			0.117,0.104
	Pb	66.33			61.26,44.38
91	S	0.17	0.113,0.082		
	Pb	49.27	52.92,31.05		

Table 6. (cont.)

Site	Element	Flavoparmelia caperata	Flavoparmelia baltimorensis	Hypogymnia physodes	Tuckermannopsis oakesiana
111	S	0.14	0.156		
	Pb	49.55	86.79		
119	S	0.16	0.143,0.133		
	Pb	51.19	68.05,66.63		

[1] When two numbers are given, split samples were sent for analysis.

DISCUSSION

The lichen communities of the Otter Creek and Dolly Sods Wildernesses are quite diverse and include species not seen in polluted areas (e.g., Lobaria spp., Pseudevernia consocians, Usnea spp.). This suggests that the lichens of the two study areas are not adversely affected by atmospheric pollution at the present time. The fact that more species were collected from Dolly Sods than from Otter Creek is probably due to the greater heterogeneity of available habitats in Dolly Sods. Many of the Dolly Sods species not seen in Otter Creek, for example, are found in more or less open habitats not frequently found in Otter Creek (e.g., Cladina rangiferina, Cladonia spp., Melanelia subaurifera, Phaeophyscia pusilloides, Physcia spp., Tuckermannopsis ciliaris). In our opinion, air pollution is not responsible for this result.

The lichen species richness values obtained from Otter Creek (48 species) and Dolly Sods (63 species) also reflect, in our opinion, values that would be obtained from other ecologically similar areas unaffected by air pollution. Inasmuch as pollution-sensitive species were also found in the floristic surveys, we are led to conclude that lichen community composition in Otter Creek and Dolly Sods is unaffected by pollution at the present time.

Despite the high lichen species diversity observed during collecting trips to both wildernesses, indicator species were seldom found in the elemental analysis quadrats. However, this probably has little to do with air pollution. Collections for floristic analysis were made primarily from the tops of felled trees, where a much larger number of species could be obtained. The microhabitat of tree bases in the quadrats was generally too dark to permit growth of any but the most ubiquitous species, such as Flavoparmelia caperata and Tuckermannopsis oakesiana, which apparently have

relatively broad ecological requirements. Therefore, indicator species other than these two (e.g., Usnea species) were not observed.

The fact that Tuckermannopsis oakesiana was observed more frequently in Otter Creek than in Dolly Sods is probably also a reflection more of the availability of suitable microhabitats than of pollution effects. This species was found even more frequently in the Northern District of Shenandoah National Park (Lawrey, 1987), which is apparently subjected to greater pollution stress than Otter Creek or Dolly Sods, so care must be taken in interpreting distribution data for this species. Furthermore, it is generally impossible to evaluate the possible effect of pollution on particular lichen distribution patterns from a single survey. If future surveys of mature forested sites show changes in lichen distributions, these will most likely be due to air quality changes and not changes in microhabitat.

The elemental data obtained from Flavoparmelia caperata collections in the quadrats indicate a much better air quality for Otter Creek and Dolly Sods than for the Northern District of Shenandoah National Park (SNP) (Lawrey, 1987), where a very similar study was done. As an example, consider the sulfur results. Only 3 of 41 (7.3%) sites in Dolly Sods and 1 of 80 (1.2%) sites in Otter Creek had lichens with sulfur concentrations of 0.20%. In SNP, 49 of 185 1 km^2 sites (26.5%) had lichens (also F. caperata) with sulfur concentrations of 0.20% or more, and many were almost 0.30%. Although it is not known what levels of atmospheric sulfur are required to produce these high concentrations in lichens, concentrations of 0.20% and higher have been measured in various lichens collected in, or transplanted to, polluted areas (Table 7). We believe, therefore, that this justifies the use of 0.20% sulfur in F. caperata as the indicator concentration for potential sulfur "hot spots".

Table 7. Selected total sulfur concentrations reported from lichens sampled from various environments.

Species and Location	S, % dry wt.	Source
Cladina mitis		
Sudbury, Ontario	0.10	Tomassini, 1976
Cladina stellaris		
Sudbury, Ontario	0.09	Tomassini, 1976
Rural northern Finland	0.07	Kauppi, 1976
Transplant, urban center, Oulu, Finland	0.21	"
Transplant, fertilizer factory	0.29	"
Flavoparmelia caperata		
Northern district, Shenandoah Nat. Park	0.085-0.29	Lawrey, 1987
Otter Cr. and Dolly Sods, WV	0.078-0.20	Present study
Hypogymnia physodes		
Western Finland, near industrial complex	0.19	Laaksovirta & Olkkonen, 1977
Transplant to chlor-alkali plant, Norway	0.30	Steinnes & Krog,1977
Transplant to aluminum smelter, Poland	0.14	Swieboda & Kalemba, 1978
Norway	0.14	Solberg, 1967
Xanthoparmelia chlorochroa		
Powder River Basin, Wyoming and Montana	0.07	Erdman & Gough, 1977
Xanthoparmelia conspersa		
Sendai City, Japan	0.16	Saeki et al., 1977
Xanthoparmelia cumberlandia		
Flat Tops, Colorado	0.11-0.16	Hale, 1982

Table 7. (cont.)

Species and Location	S, % dry wt.	Source
Umbilicaria deusta		
Sudbury, Ontario	0.25	Nieboer et al., 1977
Usnea sp.		
Flat Tops, Colorado	0.13-0.15	Hale, 1982
Various arctic lichens	0.005-0.02	Nieboer et al., 1977

Lead and other metal concentrations in Dolly Sods and Otter Creek lichens are also low when compared with concentrations found in lichens from polluted environments. For example, lead concentrations above 100 ug/g are frequently observed in lichens near roads and urban areas (Table 8). In SNP, Lawrey (1984, 1985) has observed Pb concentrations over 600 ug/g near Skyline Drive, and over 100 ug/g in lichens from 19 of 64 (29.7%) sites at least 100 m from paved roads. This compares with only one site (75, near a road terminus north of Alpena Gap) in the present study with lichen Pb concentrations above 100 ug/g, and only 5 of 80 (6.25%) sites in Otter Creek and 9 of 41 (21.9%) sites in Dolly Sods with concentrations above 50 ug/g. If there is a trend at all in the Pb results, it is that Dolly Sods lichens have greater concentrations of Pb than Otter Creek lichens. However, the actual concentrations of Pb are relatively low.

Other elements indicative of air pollution were either found at concentrations too low for accurate analysis (Cd, Be, Sn, Co, Ni) or showed no pattern at all (V, Cr), although some potential pollutant metals (Cu, Zn, Fe, Al) were, like Pb, found at significantly higher concentrations in Dolly Sods than in Otter Creek. However, concentrations of these elements were generally lower than those obtained from lichens collected in SNP. Taken together, this information suggests that Otter Creek and Dolly Sods are not presently experiencing air pollution at levels similar to SNP.

The only significant trend in the element data from the two study areas is the elevated concentrations of S, Pb and other metals in lichens from Dolly Sods when compared with lichens from Otter Creek. This might be caused by generally higher elevations and more exposed site conditions in Dolly Sods, although high elevations are quite common in Otter Creek

Table 8. Selected lead concentrations reported in the literature for lichen species sampled in areas variously affected by automobile-generated atmospheric lead fallout.

Species and Location	Pb (ug/g)	Source
Caloplaca aurantia		
Rural area, Israel	49	Garty et al., 1977
Urban area, Israel	150	"
Cladina arbuscula		
23 sites in Finland and northern Norway	3.4-30	Pakarinen et al., 1978
Cladina mitis		
23 sites in Finland and northern Norway	3.4-11.8	"
Cladonia furcata		
Urban and suburban areas near Scunthorpe, Lincolnshire, U.K.	79-180	Seaward, 1973
Cladonia stellaris		
Unpolluted areas in Finland	20	Kauranen & Miettinen, 1974
Unpolluted areas in Sweden	8-17	Persson et al., 1974
Cornicularia aculeata		
Urban and suburban areas near Scunthorpe, Lincolnshire, U.K.	134	Seaward, 1973
Flavoparmelia baltimorensis		
Plummers Island, MD	1893	Lawrey & Hale, 1981
Bear Island, MD	273	"
Shenandoah Nat. Park, within 5 m of paved roads	91-702	Lawrey, 1985
Shenandoah Nat. Park, away from roads	58-134	"

Table 8. (cont.)

Species and Location	Pb, ug/g	Source
Flavoparmelia caperata		
Otter Cr. and Dolly Sods, WV	13-103	Present study
Hypogymnia physodes		
Unpolluted area in North Yorkshire, U.K.	15	Seaward, 1974
100 m from road, southern Finland	40-100	Laaksovirta et al., 1976
20 m from road, southern Finland	120-270	"
Lecanora muralis		
Near Buchanty, Scotland	102	Seaward, 1974
Near Forfar, Scotland	132	"
Near Leeds, Yorkshire, U.K.	375-440	"
Outer suburbs, Leeds	500-1090	"
Inner suburbs, Leeds	285-3124	"
Peltigera rufescens		
Urban and suburban areas near Scunthorpe, Lincolnshire, U.K.	46-454	Seaward, 1973
Xanthoparmelia conspersa		
Sendai City, Japan	50-200	Saeki et al., 1975
Plummers Island, MD	1647	Lawrey, 1980
Bear Island, MD	95	"

as well. In SNP, Lawrey (1987) found a significant positive correlation between percent sulfur in Flavoparmelia caperata and the elevations of the collecting site, suggesting that elevated sites were intercepting more pollution than lower elevation sites. This result was interpreted as a consequence of long-range dispersal of anthropogenic pollution. In the present study, no such correlation was found, but this may have been due to the relatively low concentrations of sulfur found in lichens from the two wildernesses.

Another possible explanation for increased background levels of S, Pb and metals in Dolly Sods may be local pollution sources. Although this study was not designed specifically to measure the effects of local pollution sources, the absence of noticeable pollution "hot spots" in the element data, combined with floristic information that suggests little or no pollution-caused damage to the lichen communities in either wilderness, suggests that local pollution effects are relatively unimportant. However, future studies should probably be done to rule out effects of specific local point sources of pollution.

CONCLUSIONS

A number of tentative conclusions can be made based on the results of this study:

(1) The lichen flora of the two wildernesses is not presently affected by air pollution, as indicated by a relatively high species richness in each wilderness. Also, many pollution-sensitive species were found in good condition throughout the two wildernesses.

(2) The lichen communities are not different in structure or composition from lichen communities expected from ecologically similar areas unaffected by pollution. There is no floristic evidence that the lichen communities are under stress.

(3) Few indicator lichen species were found frequently enough in the elemental analysis quadrats to provide much reliable information about air quality. One rather ubiquitous species, Tuckermannopsis oakesiana, was observed more frequently in Otter Creek than in Dolly Sods, although this could have been caused by differences in the availability of microhabitats.

(4) Elemental data from Flavoparmelia caperata collected in the quadrats indicated that Otter Creek and Dolly Sods are not under stress from air pollution. The air quality in the two wildernesses is better than that in the Northern District of Shenandoah National Park (SNP), as indicated by lichen concentrations of S, Pb and other metals, which are generally lower in the two wildernesses than in SNP or other areas where similar data have been collected.

(5) Lichens from Dolly Sods have significantly higher concentrations of S, Pb and some other metals than lichens from Otter Creek, which may be a consequence of the elevated and exposed site conditions generally found at Dolly Sods. However, there was no apparent difference in the lichen

community structure or health of the lichens in the two wildernesses, which suggests that Dolly Sods is not at greater risk from air pollution.

(6) There is no indication in the elemental results that a specific air pollutant is especially important in the two wildernesses. All element data were indicative of good air quality conditions in the wildernesses.

RECOMMENDATIONS

Based on the results of this study, the following recommendations can be made:

(1) Follow-up floristic analysis should be done in 5-10 years to document any changes in lichen species diversity.

(2) Elemental analysis quadrats should be resampled in 5 years to collect F. caperata for element, especially S, analysis. Element data collected at that time can then be compared with the baseline data presented in this report.

(3) Permanent photographic study plots should be visited at 5-year intervals to document changes in lichen growth rates and community composition with time.

(4) Studies should be designed to investigate the possible effects of specific local point sources of pollution around the two wildernesses.

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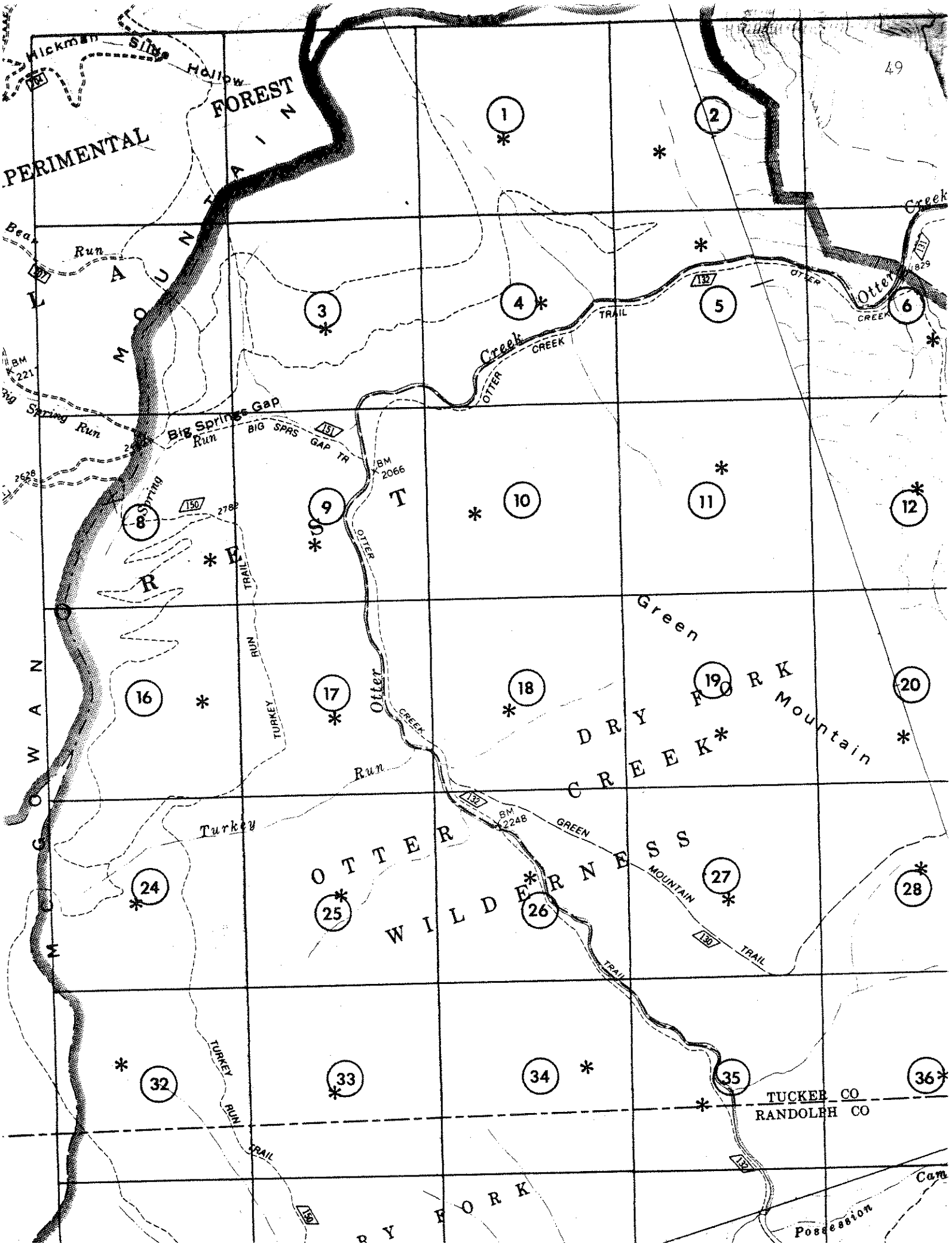
APPENDIX 1

Locations of elemental analysis quadrats in the Otter Creek (sites 1-80) and Dolly Sods (sites 81-121) study areas. Stars and asterisks mark the quadrat locations within each 1 km^2 section. Base maps are USGS 7.5 minute series maps (Otter Creek: Bowden, Harman, Parsons, Mozark Mtn., WV; Dolly Sods: Blackwater Falls, Blackbird Knob, Laneville, Hopeville, WV).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Big Springs Gap
Run
BIG SPRS GAP TR
BM 2066
BM 2221
Spring
Run
TRAIL
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CREEK
Green Mountain
DRY FORK
CREEK
Otter
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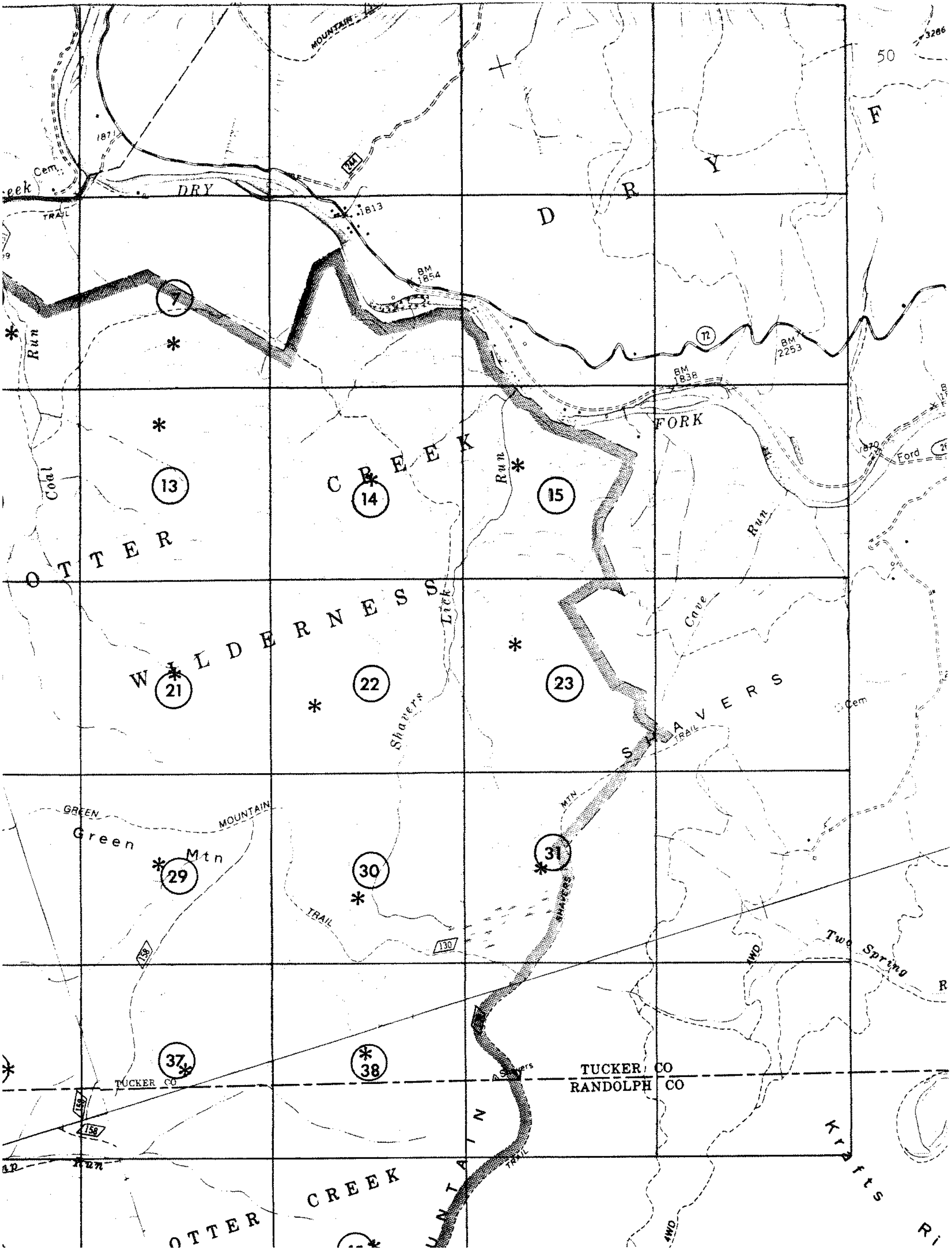
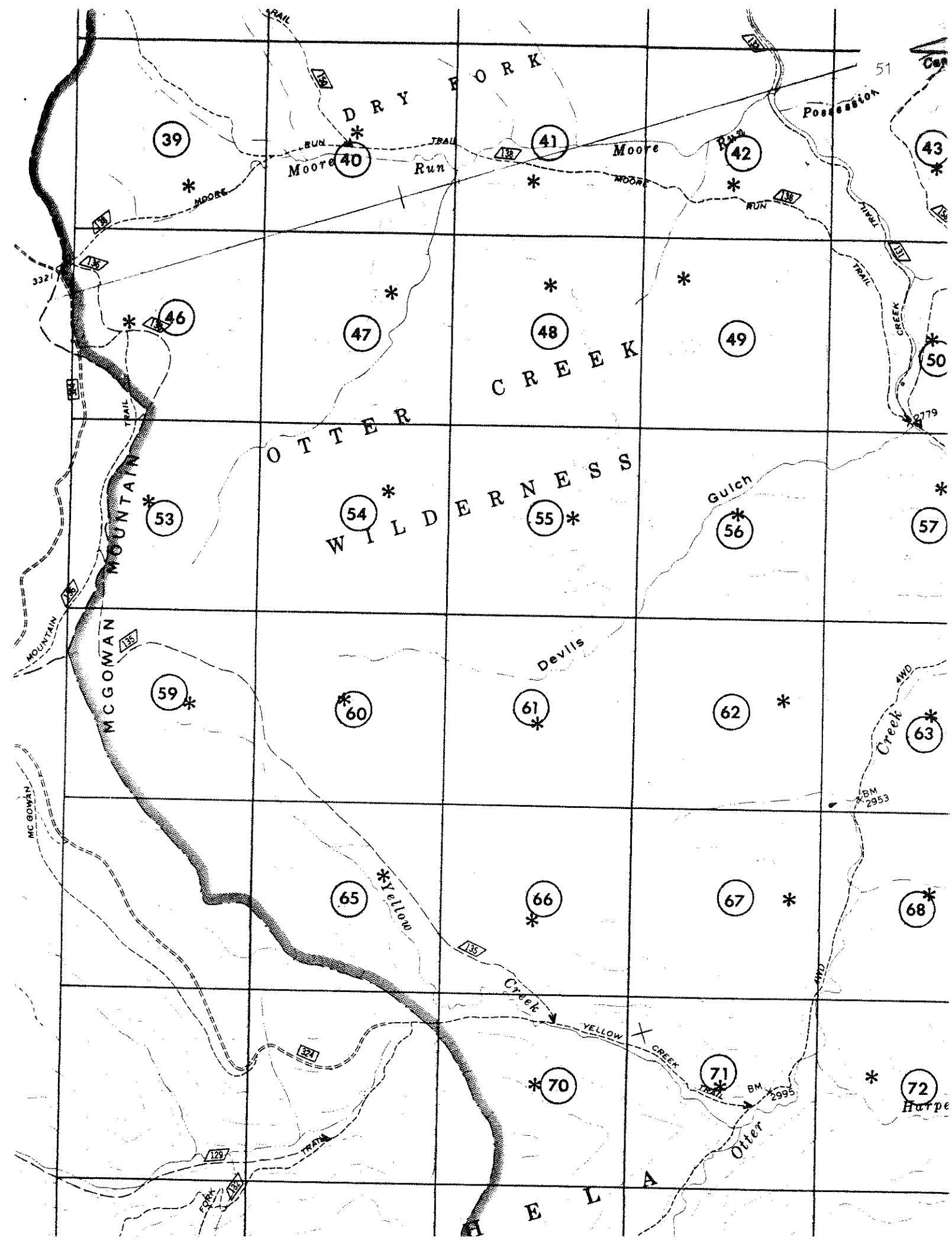


OTTER CREEK WILDERNESS
DRY FORK
SHAVERS MOUNTAIN
OTTER CREEK
Krafts Ri
Coal Run
Run
Shavers Lick Run
Cave Run
Two Spring R
Green Mountain
Green Mtn
Cem.
Cem
Ford
BM 1854
BM 1838
BM 2253
1813
1871
1870
3266
TRAIL
MOUNTAIN
MTN
SHAVERS
4WD
72
130
158
TUCKER CO
RANDOLPH CO
7
13
14
15
21
22
23
29
30
31
37
38


DRY FORK
OTTER CREEK
WILDERNESS
MOUNTAIN
MCGOWAN
Moore Run
Devils Gulch
Yellow Creek
Possession
TRAIL
MOORE RUN
YELLOW CREEK
4WD
BM 2953
BM 2995
39
40
41
42
43
46
47
48
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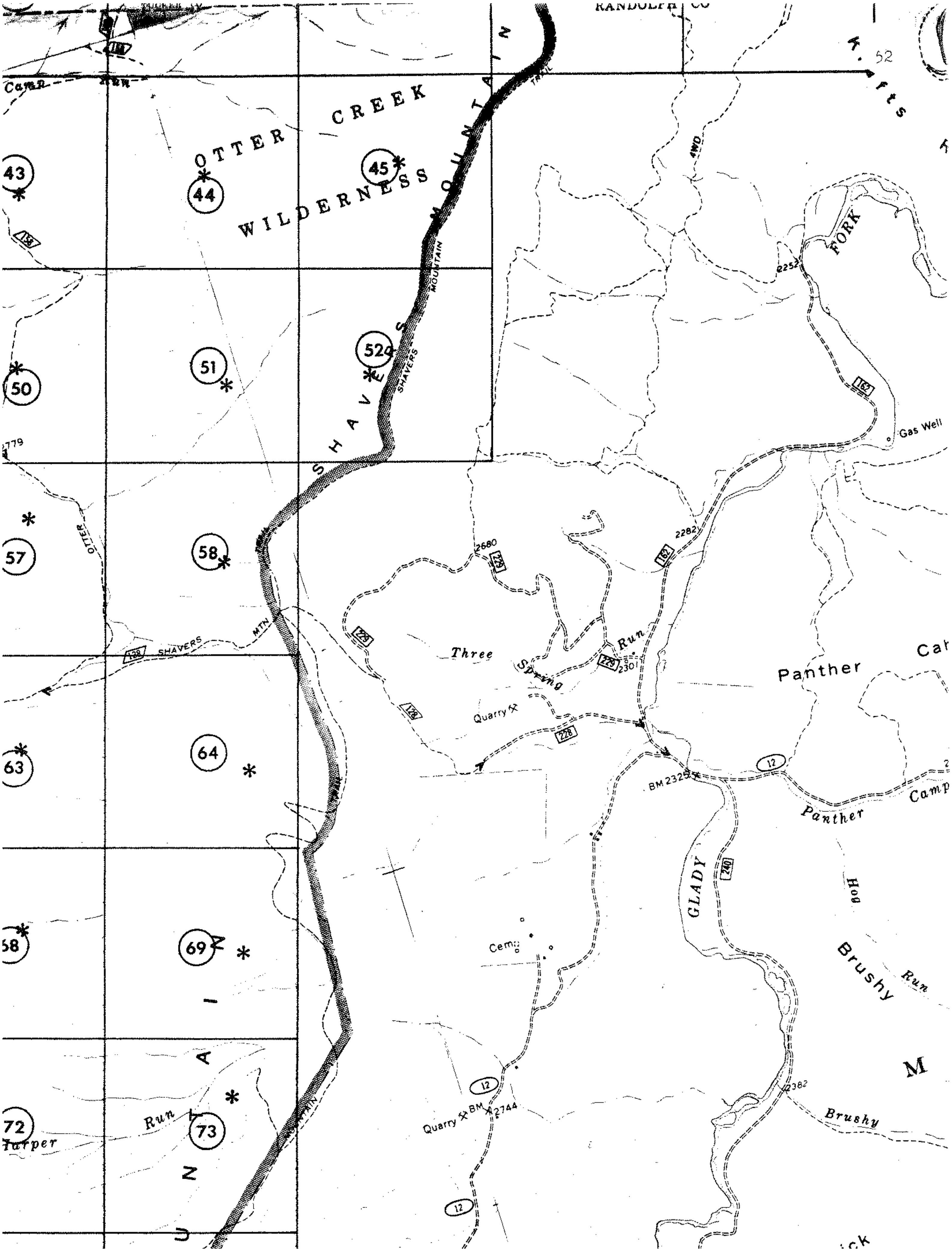
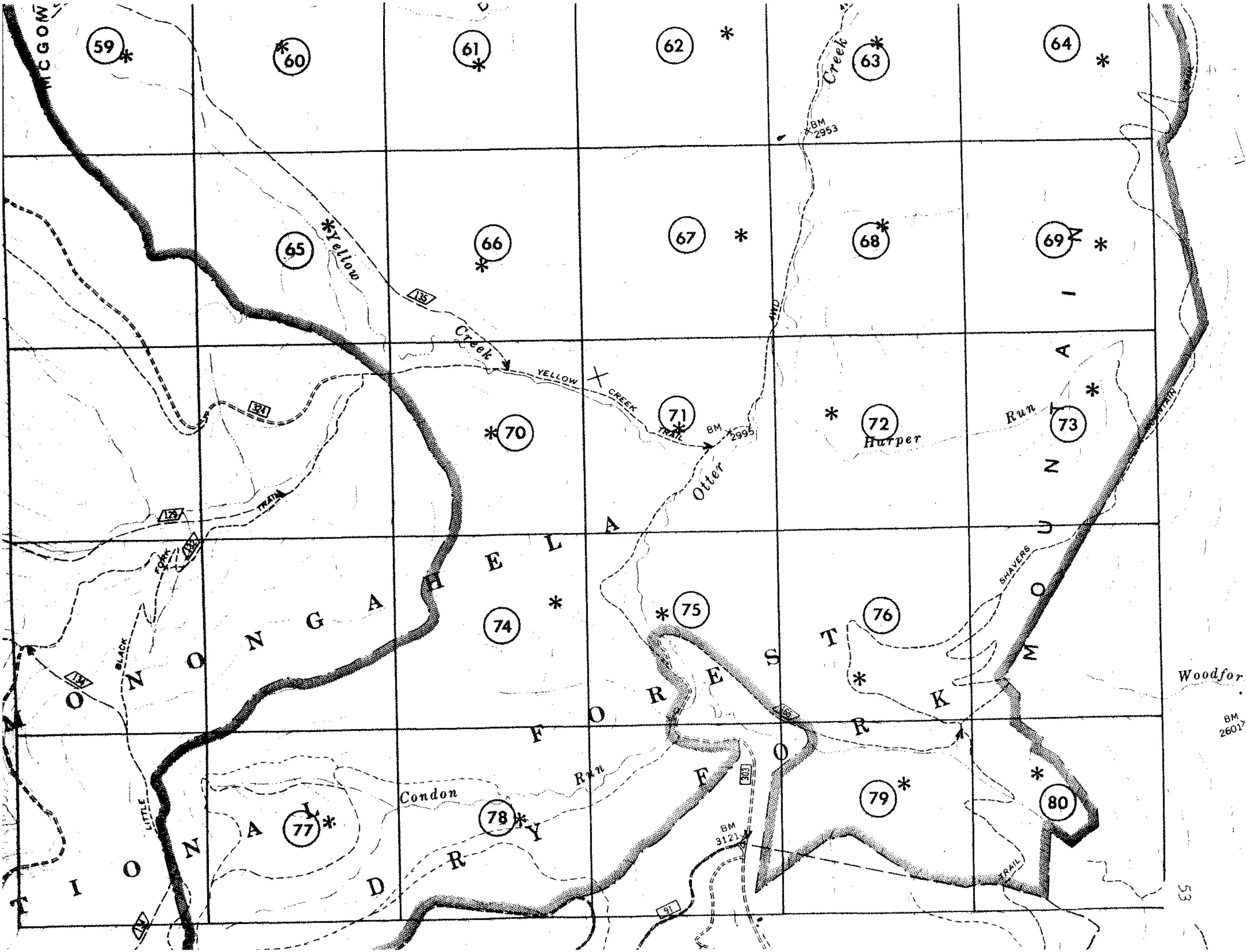


RANDOLPH CO
Camp Run
OTTER CREEK WILDERNESS
SHAVERS MOUNTAIN
SHAVERS MOUNTAIN TRAIL
43
44
45
50
51
52
57
58
63
64
68
69
72
73
4WD
FORK
2252
162
Gas Well
2779
OTTER
SHAVERS MTN
128
2680
225
2282
229
Three Spring Run
2301
Panther
Quarry
228
12
BM 2325
Panther Camp
GLADY
240
Hog
Brushy Run
Cem
M
2382
Brushy
Quarry BM 2744
Run


59
60
61
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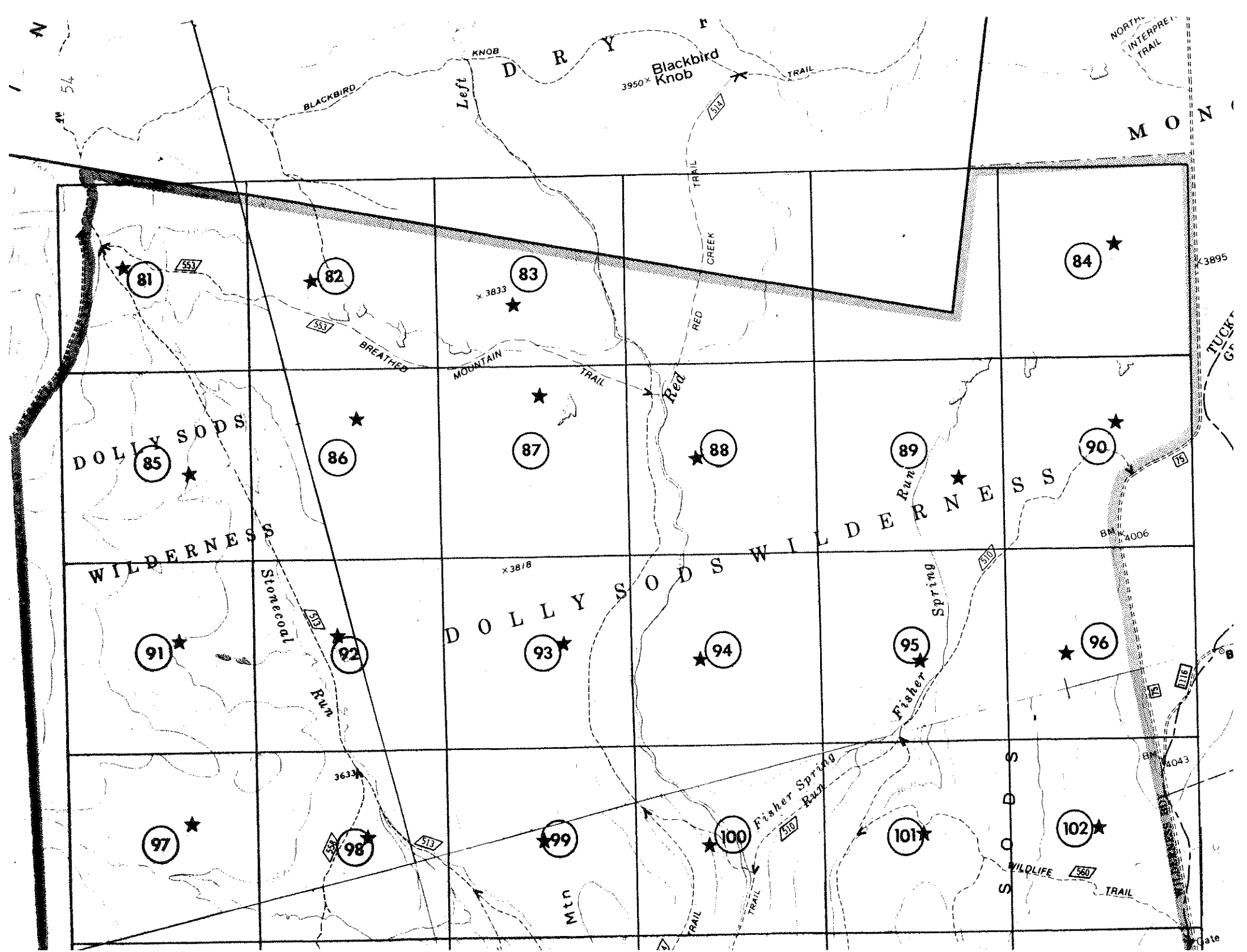
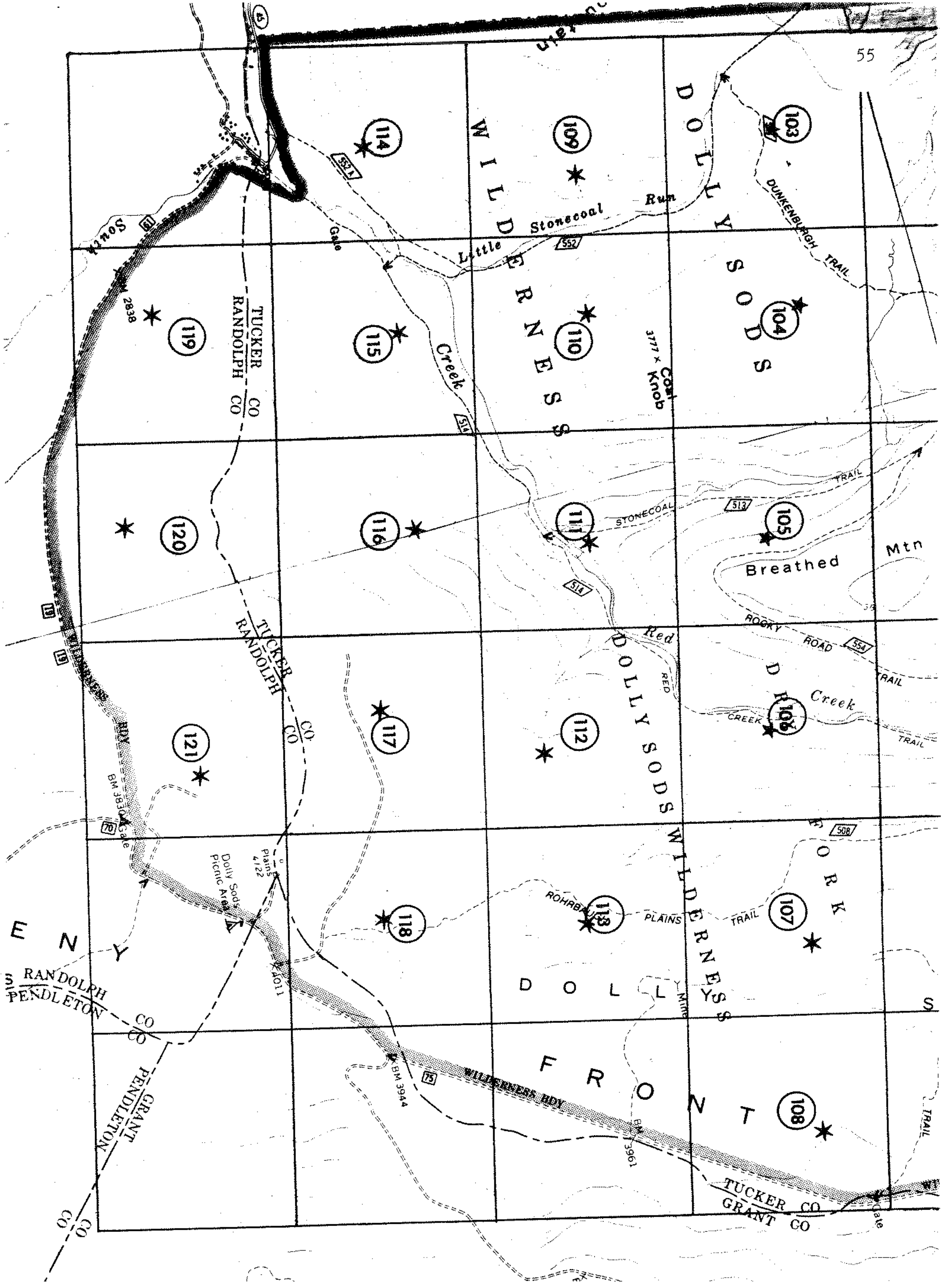
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
Yellow Creek
Creek
YELLOW CREEK TRAIL
BM 2953
BM 2995
BM 3121
BM 2601
Otter
Harper Run
Condon Run
SHAVERS
BLACK FORK
LITTLE
Woodfor
MONONGAHELA NATIONAL FOREST
SHAVERS MOUNTAIN
FORK RIDGE
ALLEGHENY
135
324
129
303
91
134
MCGOW


Blackbird Knob
3950
BLACKBIRD KNOB TRAIL
Left
DRY
514
MON
NORTH INTERPRET TRAIL
81
553
82
83
x 3833
84
x 3895
RED CREEK TRAIL
BREATHED MOUNTAIN TRAIL
Red
DOLLY SODS WILDERNESS
85
86
87
88
89
90
75
Run
BM x 4006
Stonecoal Run
513
x 3818
DOLLY SODS WILDERNESS
Spring
510
91
92
93
94
95
96
Fisher
116
3633
Fisher Spring Run
97
98
99
100
101
102
BM 4043
WILDLIFE TRAIL
560
Mtn
TRAIL
Gate


DOLLY SODS WILDERNESS
DOLLY SODS
DOLLY SODS WILDERNESS
DOLLY FRONT
Little Stonecoal Run
Creek
Coal Knob
3777
DUNKENBURGH TRAIL
STONECOAL TRAIL
Breathed Mtn
Red Creek
RED CREEK TRAIL
ROCKY ROAD TRAIL
ROHRBAUGH PLAINS TRAIL
FORK
South
TUCKER CO
RANDOLPH CO
RANDOLPH CO
PENDLETON CO
GRANT
PENDLETON
TUCKER CO
GRANT CO
WILDERNESS BDY
Dolly Sods Picnic Area
Plains 4122
Gate
BM 2838
BM 3830
BM 3944
BM 3961
4011
552
552A
514
513
554
508
19
70
75
45
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APPENDIX 2

Lichen species lists for Otter Creek and Dolly Sods Wildernesses, WV. For each area, species are listed twice: (1) according to their presence at each of five sampling locations and (2) according to their substrate type. In all lists, sensitive (S) and insensitive (I) species are indicated.

Species list for Otter Creek Wilderness and occurrence by site.

1=Big Springs Gap Trail; 2=Mylius Trail; 3=Shavers Mtn. Trail; 4=Otter Creek-Yellow Creek; 5=Moore Run.

	1	2	3	4	5
Bacidia schweinitzii	X	-	X	-	X
Calicium sp.	-	-	-	-	X
Cetrelia chicitae	-	-	X	-	-
Cetrelia olivetorum	X	X	-	-	-
Cladonia bacillaris	-	-	X	-	-
Cladonia caespiticia	X	-	X	-	X
Cladonia coniocraea (I)	X	-	X	-	-
Cladonia furcata	-	X	-	-	-
Cladonia grayi	-	-	X	-	-
Cladonia squamosa	-	-	X	-	-
Cladonia sp.	X	-	X	X	X
Collema subfurvum	X	-	-	-	-
Conotrema urceolatum	-	-	X	-	-
Flavoparmelia baltimorensis	-	-	X	-	-
Flavoparmelia caperata	-	X	X	X	X
Flavopunctelia flaventior	X	X	-	-	-
Graphis scripta (I)	X	X	X	X	X
Heterodermia speciosa (S)	-	-	X	-	-
Hypocenomyce scalaris	-	-	-	-	X
Hypogymnia physodes	X	X	X	X	-
Lecanora varia	-	-	X	-	-

	1	2	3	4	5
Lepraria sp. (I)	X	-	X	X	X
Lepraria zonata (I)	-	-	X	-	-
Lobaria quercizans (S)	X	-	X	-	-
Menegazzia terebrata	-	X	X	X	X
Myelochroa aurulenta	X	X	-	-	-
Myelochroa galbina	X	-	-	-	-
Parmelia squarrosa	X	X	X	X	-
Parmelia sulcata (I)	X	-	-	X	X
Parmelinopsis minarum	X	-	X	-	-
Parmelinopsis spumosa	X	X	-	X	-
Parmotrema arnoldii	-	-	X	-	-
Parmotrema stuppeum	-	-	X	X	-
Pertusaria sp.	-	-	X	-	-
Phaeophyscia rubropulchra	X	X	-	-	-
Platismatia tuckermanii	-	X	-	-	-
Porpidia albocoerulescens (I)	X	-	X	X	-
Pseudevernia consocians (S)	-	-	X	X	-
Punctelia appalachensis	X	-	X	-	-
Punctelia rudecta (I)	X	X	X	X	X
Punctelia subrudecta (I)	-	-	X	X	-
Pyxine sorediata	X	X	-	-	-
Trypethelium virens	X	X	X	-	-
Tuckermannopsis oakesiana (S)	X	-	X	X	X
Umbilicaria mammulata	-	-	X	-	-
Usnea sp. (S)	X	X	X	-	-
Xanthoparmelia conspersa	X	-	X	-	-
Xanthoparmelia cumberlandia	-	-	X	-	-

Species list for Otter Creek Wilderness and occurrence by substrate. Rock, ash, bch=beech, blb=black birch, hky=hickory, rma=red maple, rok=red oak, sma=sugar maple, yeb=yellow birch.

	rock	ash	bch	blb	hky	rma	rok	sma	yeb
Bacidia schweinitzii	-	X	-	-	-	-	-	X	-
Calicium sp.	-	-	-	-	-	-	-	-	X
Cetrelia chicitae	X	-	-	-	-	-	-	-	-
Cetrelia olivetorum	-	-	-	-	-	-	-	X	-
Cladonia bacillaris	-	-	-	X	-	-	-	-	-
Cladonia caespiticia	-	-	-	X	-	-	-	-	X
Cladonia coniocraea (I)	X	-	-	-	-	-	-	-	-
Cladonia furcata	X	-	-	-	-	-	-	-	-
Cladonia grayi	X	-	-	-	-	-	X	-	-
Cladonia squamosa	X	-	-	-	-	-	-	-	-
Cladonia sp.	X	X	-	X	-	X	X	-	X
Collema subfurvum	-	X	-	-	-	-	-	-	-
Conotrema urceolatum	-	-	-	-	-	-	-	X	-
Flavoparmelia baltimorensis	X	-	-	-	-	-	-	-	-
Flavoparmelia caperata	-	-	-	X	-	X	X	X	X
Flavopunctelia flaventior	-	X	-	-	-	-	-	X	-
Graphis scripta (I)	-	-	-	-	-	X	-	X	X
Heterodermia speciosa (S)	-	X	-	-	-	-	-	-	-
Hypocenomyce scalaris	-	-	-	-	-	-	-	-	X
Hypogymnia physodes	X	-	-	-	-	-	-	X	X
Lecanora varia	X	-	-	-	-	-	-	-	-

	rock	ash	bch	blb	hky	rma	rok	sma	yeb
Lepraria sp. (I)	-	X	-	X	-	-	-	-	X
Lepraria zonata (I)	X	-	-	-	-	-	-	-	-
Lobaria quercizans (S)	-	X	-	-	-	X	-	-	-
Menegazzia terebrata	-	-	-	X	-	-	-	X	X
Myelochroa aurulenta	-	X	-	-	X	-	-	X	-
Myelochroa galbina	-	X	-	-	-	-	-	-	-
Parmelia squarrosa	-	-	-	X	X	X	-	-	X
Parmelia sulcata (I)	-	X	-	-	-	X	-	-	X
Parmelinopsis minarum	-	X	-	-	-	-	-	-	-
Parmelinopsis spumosa	-	-	-	-	-	-	-	X	X
Parmotrema arnoldii	-	-	-	-	-	-	X	-	-
Parmotrema stuppeum	-	-	-	X	-	-	X	-	-
Pertusaria sp.	-	-	-	-	-	-	X	-	-
Phaeophyscia rubropulchra	-	X	-	-	X	-	-	-	-
Platismatia tuckermanii	-	-	-	-	-	-	X	-	-
Porpidia albocoerulescens (I)	X	-	-	-	-	-	-	-	-
Pseudevernia consocians (S)	-	-	-	-	-	X	-	-	-
Punctelia appalachensis	-	X	-	-	X	-	-	-	-
Punctelia rudecta (I)	X	X	-	X	X	X	X	X	X
Punctelia subrudecta (I)	-	-	-	-	-	X	X	-	X
Pyxine sorediata	-	X	-	-	X	-	-	-	-
Trypethelium virens	-	-	X	-	-	-	-	-	-
Tuckermannopsis oakesiana (S)	X	-	-	X	-	X	X	-	X
Umbilicaria mammulata	X	-	-	-	-	-	-	-	-
Usnea sp. (S)	-	-	-	-	-	-	X	-	-
Xanthoparmelia conspersa	X	-	-	-	-	-	-	-	-
Xanthoparmelia cumberlandia	X	-	-	-	-	-	-	-	-

Species list for Dolly Sods Wilderness and occurrence by site.

1=Photographic Quadrat stop; 2=1 mi S Red Creek Campgd; 3=Fisher Spring Run Trail; 4=Rohrbaugh Plains Trail; 5=Red Creek Trail near Laneville.

	1	2	3	4	5
Anaptychia palmatula	-	-	-	-	X
Bacidia schweinitzii	-	-	-	-	X
Cetrelia chicitae	-	-	-	-	X
Cetrelia olivetorum	-	X	-	-	X
Cladina rangiferina	-	-	-	X	-
Cladonia chlorophaea	X	X	X	-	-
Cladonia coniocraea (I)	X	-	X	-	X
Cladonia deformis	X	-	-	-	-
Cladonia furcata	X	-	X	X	X
Cladonia gracilis	-	-	-	X	-
Cladonia grayi	X	-	-	-	-
Cladonia macilenta	-	X	X	-	-
Cladonia squamosa	-	-	X	X	-
Cladonia sp.	X	X	X	X	X
Conotrema urceolata	-	-	-	X	-
Dermatocarpon miniatum	-	-	-	X	-
Dimelaena oreina	X	-	-	-	-
Flavoparmelia baltimorensis	-	-	X	X	-
Flavoparmelia caperata	X	X	X	X	X
Flavopunctelia flaventior	-	X	-	-	X

	1	2	3	4	5
Graphis scripta (I)	X	-	X	X	X
Heterodermia speciosa (S)	-	-	-	-	X
Hypogymnia krogii	-	X	-	-	-
Hypogymnia physodes	-	X	X	-	-
Lecanora subfusca	-	X	X	-	-
Lecidea sp.	-	X	-	-	-
Lepraria sp.(I)	-	X	X	X	X
Lepraria zonata (I)	X	-	X	-	-
Melanelia subaurifera	-	-	X	-	-
Myelochroa aurulenta	-	-	-	-	X
Myelochroa galbina	-	-	-	X	-
Ochrolechia sp.	-	X	-	X	-
Parmelia squarrosa	-	X	-	X	X
Parmelia sulcata (I)	X	X	X	X	X
Parmelinopsis spumosa	X	-	-	-	-
Parmeliopsis aleurites	-	X	-	-	-
Parmeliopsis ambigua	-	X	-	-	-
Parmeliopsis hyperopta	-	-	-	X	-
Parmotrema stuppeum	-	-	-	-	X
Peltigera canina (S)	-	-	-	-	X
Pertusaria sp.	-	X	-	-	-
Phaeophyscia pusilloides	-	-	-	-	X
Phaeophyscia rubropulchra	X	-	X	-	-
Physcia aipolia	-	-	-	-	X
Physcia phaea	-	-	-	-	X

	1	2	3	4	5
Physcia stellaris	-	-	X	-	X
Platismatia tuckermanii	-	X	-	-	X
Porpidia albocoerulescens (I)	X	-	X	-	X
Pseudevernia consocians (S)	-	X	-	-	-
Punctelia appalachensis	-	-	-	-	X
Punctelia rudecta (I)	X	X	-	X	X
Punctelia subrudecta (I)	X	X	X	X	X
Pyxine sorediata	-	X	-	X	X
Sarcogyne similis (I)	-	-	X	-	-
Tuckermannopsis ciliaris (S)	-	X	-	-	-
Tuckermannopsis oakesiana (S)	X	X	X	X	X
Umbilicaria mammulata	X	-	-	X	-
Umbilicaria muhlenbergii	X	-	X	-	-
Umbilicaria papulosa	X	-	X	X	-
Usnea sp. (S)	-	X	-	-	-
Xanthoparmelia conspersa	X	-	-	X	-
Xanthoparmelia cumberlandia	X	-	-	-	X
Xanthoparmelia plittii	X	-	X	X	-

Species list for Dolly Sods Wilderness and occurrence by substrate. Rock, as=ash, bb=black birch, la=mountain laurel, po=aspen, rm=red maple, ro=red oak, sp=spruce, sm=sugar maple, yb=yellow birch.

	rk	as	bb	bc	la	po	rm	ro	sp	sm	yb
Anaptychia palmatula	-	X	-	-	-	-	-	-	-	-	-
Bacidia schweinitzii	-	X	-	-	-	-	-	-	-	-	-
Cetrelia chicitae	X	-	-	-	-	-	-	-	-	-	-
Cetrelia olivetorum	-	-	-	-	-	-	X	X	-	-	-
Cladina rangiferina	X	-	-	-	-	-	-	-	-	-	-
Cladonia chlorophaea	-	-	X	-	-	-	-	-	-	-	X
Cladonia coniocraea (I)	X	-	-	-	-	-	-	-	-	-	X
Cladonia deformis	X	-	-	-	-	-	-	-	-	-	-
Cladonia furcata	X	-	-	-	-	-	-	-	-	-	-
Cladonia gracilis	X	-	-	-	-	-	-	-	-	-	-
Cladonia grayi	-	-	-	-	-	-	X	-	-	-	-
Cladonia macilenta	-	-	-	-	-	-	-	-	-	-	X
Cladonia squamosa	X	-	-	-	-	-	-	-	-	-	-
Cladonia sp.	X-	-	-	-	X	-	X	-	-	X	X
Conotrema urceolata	-	-	-	-	-	-	-	-	-	X	-
Dermatocarpon miniatum	X	-	-	-	-	-	-	-	-	-	-
Dimelaena oreina	X	-	-	-	-	-	-	-	-	-	-
Flavoparmelia baltimorensis	X	-	-	-	-	-	-	-	-	-	-
Flavoparmelia caperata	-	X	X	X	-	-	X	X	-	X	X
Flavopunctelia flaventior	-	X	-	-	-	-	X	-	X	X	X

	rk	as	bb	bc	la	po	rm	ro	sp	sm	yb
Graphis scripta (I)	-	X	-	-	-	-	-	-	-	X	X
Heterodermia speciosa (S)	-	X	-	-	-	-	-	-	-	-	-
Hypogymnia krogii	-	-	-	-	-	-	-	-	-	-	X
Hypogymnia physodes	-	-	X	-	X	X	X	-	X	-	X
Lecanora subfusca	-	-	X	-	-	-	X	-	-	-	-
Lecidea sp.	-	-	X	-	-	-	-	-	-	-	-
Lepraria sp.(I)	X	X	-	-	-	-	-	-	-	-	X
Lepraria zonata (I)	X	-	-	-	-	-	-	-	-	-	-
Melanelia subaurifera	-	-	X	-	-	-	-	-	-	-	-
Myelochroa aurulenta	-	-	-	-	-	-	-	-	-	X	-
Myelochroa galbina	-	-	-	-	-	-	-	-	-	-	X
Ochrolechia sp.	-	-	-	-	-	-	X	-	-	-	-
Parmelia squarrosa	-	-	-	X	-	-	X	-	-	-	-
Parmelia sulcata (I)	-	-	X	-	-	X	X	-	-	-	X
Parmelinopsis spumosa	-	-	X	-	-	-	-	-	-	-	-
Parmeliopsis aleurites	-	-	-	-	X	-	-	-	-	-	-
Parmeliopsis ambigua	-	-	-	-	X	-	-	-	-	-	-
Parmeliopsis hyperopta	X	-	-	-	-	-	-	-	-	-	-
Parmotrema stuppeum	-	X	-	-	-	-	-	-	-	-	-
Peltigera canina (S)	X	-	-	-	-	-	-	-	-	-	-
Pertusaria sp.	-	-	-	-	-	-	-	-	-	-	X
Phaeophyscia pusilloides	X	-	-	-	-	-	-	-	-	-	-
Phaeophyscia rubropulchra	-	-	X	-	-	-	X	-	-	-	X
Physcia aipolia	-	X	-	-	-	-	-	-	-	-	-
Physcia phaea	X	-	-	-	-	-	-	-	-	-	-
Physcia stellaris	-	-	X	-	-	-	-	-	-	-	-

	rk	as	bb	bc	la	po	rm	ro	sp	sm	yb
Platismatia tuckermanii	-	-	X	-	-	-	-	-	-	-	X
Porpidia albocoerulescens (I)	X	-	-	-	-	-	-	-	-	-	-
Pseudevernia consocians (S)	-	-	-	-	-	-	-	-	X	-	-
Punctelia appalachensis	-	X	-	-	-	-	-	-	-	-	-
Punctelia rudecta (I)	X	X	-	X	-	-	X	-	-	X	X
Punctelia subrudecta (I)	-	X	X	-	X	X	-	-	-	X	X
Pyxine sorediata	-	X	-	-	-	-	X	-	-	-	-
Sarcogyne similis (I)	X	-	-	-	-	-	-	-	-	-	-
Tuckermannopsis ciliaris (S)	-	-	X	-	-	-	-	-	-	-	-
Tuckermannopsis oakesiana (S)	X	-	X	X	-	-	X	-	X	-	X
Umbilicaria mammulata	X	-	-	-	-	-	-	-	-	-	-
Umbilicaria muhlenbergii	X	-	-	-	-	-	-	-	-	-	-
Umbilicaria papulosa	X	-	-	-	-	-	-	-	-	-	-
Usnea sp. (S)	-	-	X	-	-	-	-	-	-	-	-
Xanthoparmelia conspersa	X	-	-	-	-	-	-	-	-	-	-
Xanthoparmelia cumberlandia	X	-	-	-	-	-	-	-	-	-	-
Xanthoparmelia plittii	X	-	-	-	-	-	-	-	-	-	-

APPENDIX 3

Concentration of trace elements (in ug/g dry wt.) in Flavoparmelia caperata samples collected from each elemental analysis quadrat in the Otter Creek and Dolly Sods Wildernesses. Site numbers in parenthesis are replicates.

Appendix 3. Concentration of trace elements (in ug/g dry wt.) in Flavoparmelia caperata samples collected from each elemental analysis quadrat in the Otter Creek and Dolly Sods, WV Wildernesses. Site numbers in parenthesis are replicates.

Site	P	K	Ca	Mg	Na	Mn	B	Mo	Ba	Ti
1	692.5	2016	19336	386.2	14.60	341.3	8.721	1.867	312.7	28.10
2	1390	4667	24396	311.1	14.39	198.7	5.702	1.186	88.87	24.48
3	691.3	1786	93448	278.4	35.78	194.3	8.457	1.230	526.6	20.10
4	682.3	2317	69821	435.2	36.35	46.61	5.073	< 0.667	134.3	19.66
5	1708	4061	19519	400.4	36.50	293.9	9.157	3.840	86.30	15.27
6	699.3	3323	18798	343.5	35.09	83.66	10.87	1.649	99.39	22.49
7	908.1	2934	21818	259.2	21.92	91.69	10.12	1.114	75.47	24.30
8	679.1	2565	3261	400.7	29.72	92.47	9.415	1.413	45.06	22.67
9	799.4	3190	27067	592.3	31.73	76.80	7.312	0.925	34.84	23.94
10	609.9	1972	38994	525.9	50.85	46.86	12.24	4.562	27.92	24.51
(166)	617.2	2285	47033	317.9	148.7	31.92	4.775	< 0.667	8.246	21.79
(167)	906.7	2827	29449	648.8	34.40	68.43	14.87	1.265	162.6	37.42
(168)	974.4	3687	16604	388.3	55.88	98.22	8.478	0.999	101.9	22.89
(169)	951.2	3073	24408	465.3	15.65	87.78	8.571	1.509	34.64	21.87
11	717.3	3038	28026	281.3	16.49	55.02	9.908	< 0.667	60.09	21.04
12	595.9	2854	32604	260.5	13.11	57.41	7.551	0.840	71.62	16.55
13	794.3	2650	23108	241.4	38.63	92.80	23.82	1.579	80.71	27.13
14	786.6	2516	25434	244.4	13.51	102.4	9.983	1.096	97.46	20.35
15	707.9	2200	17965	292.0	85.71	123.3	32.20	1.902	117.0	35.57
16	592.1	2952	13783	263.6	42.32	124.3	7.844	3.428	53.77	23.50
17	720.8	3067	34365	337.1	19.19	76.60	4.500	1.260	183.3	11.24
18	1285	3528	7981	444.4	41.60	72.53	4.871	0.794	18.43	13.67

Appendix 3. (cont.)

Site	P	K	Ca	Mg	Na	Mn	B	Mo	Ba	Ti
19	528.5	2516	6931	213.6	22.70	148.3	11.26	1.457	37.10	25.15
20	475.8	1804	2973	203.2	42.06	95.61	6.270	1.269	60.96	27.16
(170)	899.8	2944	31126	231.9	38.54	205.4	10.34	< 0.667	51.22	25.32
(171)	827.6	3395	41009	201.5	18.69	144.2	7.316	< 0.667	35.05	11.37
(172)	962.3	3251	26519	243.2	16.67	158.8	7.154	1.631	34.98	25.20
(173)	698.8	4330	28966	307.8	15.32	138.1	9.453	1.719	53.95	12.67
21	739.8	2729	2529	190.1	12.53	86.98	9.272	0.951	47.48	26.93
22	726.5	2541	25646	178.3	29.03	155.9	7.147	<0.667	58.95	17.99
23	666.2	2793	22198	327.7	12.26	93.03	10.98	0.750	135.7	26.66
24	546.0	2245	16951	208.3	22.28	55.46	3.769	8.279	19.28	31.92
25	774.3	3039	5830	246.2	22.73	195.5	7.104	1.649	63.93	25.47
26	1086	3669	3162	479.4	42.19	230.6	0.558	1.525	91.65	59.39
27	738.0	2746	26968	180.8	11.54	178.8	7.663	1.692	27.69	32.61
28	632.3	2156	15816	171.9	15.56	121.6	7.214	1.701	69.78	15.25
29	792.6	2557	1301	206.6	12.68	75.15	8.524	1.509	30.59	18.87
30	788.9	3059	9148	290.2	19.94	246.4	8.806	1.300	54.96	47.36
(174)	486.2	1700	2866	192.4	20.24	102.9	5.173	1.424	34.86	40.90
(175)	637.5	2298	10771	179.1	28.76	199.4	9.334	1.422	69.76	20.52
(176)	570.6	2222	22754	163.9	45.74	172.9	7.973	0.986	22.02	27.93
(177)	597.2	2506	4494	210.6	20.00	90.27	8.326	2.172	25.78	22.22
31	708.9	2433	6229	179.7	12.23	180.2	7.472	1.509	31.26	13.45
32	455.4	1984	14425	233.4	36.62	46.25	5.874	1.230	25.03	24.49
33	484.4	2228	13236	229.1	27.38	46.77	4.760	< 0.667	25.28	19.00

Appendix 3. (cont.)

Site	P	K	Ca	Mg	Na	Mn	B	Mo	Ba	Ti
34	544.6	1932	8137	326.4	17.75	39.01	7.512	1.204	157.2	19.94
35	593.5	2149	9761	316.5	22.19	41.92	5.810	1.143	164.7	22.52
36	635.8	2255	43187	173.6	32.69	159.9	8.255	1.492	76.69	20.78
37	697.1	2006	21779	171.0	28.28	200.5	6.407	< 0.667	67.43	10.79
38	723.3	2173	6205	195.7	29.84	142.0	7.788	6.250	98.92	21.71
39	506.9	1621	2471	174.7	17.27	72.58	8.035	1.352	94.40	53.90
40	600.1	1948	2854	179.8	42.50	75.77	9.767	1.858	18.06	33.66
(150)	716.2	2206	11788	245.1	7.850	190.7	10.21	1.169	38.23	19.56
(151)	607.1	2284	6926	195.4	18.38	72.12	6.019	2.502	39.34	33.81
(152)	407.8	1338	1745	163.4	8.54	62.61	6.766	1.579	16.41	23.64
(153)	674.6	3201	18942	180.3	15.75	118.6	6.918	1.525	83.60	15.01
41	826.0	3503	32881	213.0	33.89	137.6	8.974	1.396	10.20	24.72
42	780.6	2938	31452	149.6	9.042	163.2	6.391	< 0.667	41.90	7.437
43	607.2	2595	50441	142.8	17.82	21.01	5.925	< 0.667	47.03	11.82
44	1580	4129	2479	338.9	32.30	157.0	7.778	1.867	14.20	61.50
45	1212	3047	2666	297.3	33.63	171.8	23.57	2.593	20.89	12.34
46	1996	4514	6631	604.3	21.95	282.6	10.92	< 0.667	25.64	59.50
47	642.9	2820	24565	247.9	23.44	152.4	7.232	1.242	45.89	27.82
48	451.5	1783	10834	154.8	21.80	162.5	4.485	3.059	43.12	7.894
49	626.9	2100	19867	149.4	10.97	138.2	7.348	< 0.667	38.82	44.83
50	932.2	2954	10984	222.2	25.58	121.0	7.398	1.012	24.01	20.03
(154)	744.4	2128	3582	148.6	24.93	207.7	8.107	1.771	40.91	32.30
(155)	581.8	2406	5186	156.4	36.68	132.2	9.494	1.649	35.65	25.47
(156)	834.6	2383	21875	151.2	12.46	187.8	8.712	< 0.667	88.12	11.27

Appendix 3. (cont.)

Site	P	K	Ca	Mg	Na	Mn	B	Mo	Ba	Ti
(157)	787.7	1952	18723	137.3	27.31	164.8	7.818	2.960	75.38	6.391
51	1154	3019	13095	233.9	31.38	524.7	11.73	2.911	58.40	18.71
52	1156	2665	19131	256.1	32.06	152.8	9.615	3.351	55.43	29.39
53	1124	3340	10783	442.6	15.65	160.0	6.521	1.317	27.66	25.95
54	943.0	2868	14282	310.1	35.48	166.6	6.200	1.260	69.23	6.600
55	481.8	2488	17343	235.7	25.46	115.2	7.742	1.397	68.52	25.65
56	814.6	2366	27375	145.3	33.74	198.9	10.31	1.378	146.1	15.96
57	874.7	3239	13890	322.0	26.18	111.4	11.63	3.963	67.88	7.111
58	1439	5458	11433	376.7	38.91	427.5	36.09	0.744	36.09	11.37
59	599.7	2355	3080	202.2	50.09	85.44	8.492	1.954	18.05	37.63
60	965.3	2505	9432	277.7	28.11	191.3	26.39	0.709	26.39	15.95
(178)	1310	3163	62946	240.5	34.01	243.2	10.91	< 0.667	30.21	28.44
(179)	982.9	2337	8030	268.4	37.43	232.0	21.39	1.640	44.51	44.88
(180)	605.7	2236	20398	208.0	11.99	140.5	12.02	1.317	61.00	18.01
(181)	752.5	3036	18439	251.8	59.37	118.3	34.56	1.771	28.71	19.37
61	788.5	3877	2956	410.2	39.74	135.3	15.38	2.504	10.12	41.94
62	795.3	2575	4192	319.0	38.71	204.4	9.575	3.657	104.9	14.53
63	482.0	2045	6669	172.2	40.82	58.35	17.51	1.343	19.10	23.10
64	1102	2697	27777	307.9	27.68	407.8	10.22	3.424	43.20	12.65
65	728.2	2133	42291	172.4	25.25	121.8	9.079	0.995	33.35	20.74
66	864.0	2557	3871	325.1	29.36	126.9	10.89	1.788	44.62	43.67
67	330.1	1515	29039	222.6	25.09	251.6	9.904	3.131	95.97	12.23
68	931.1	2076	31621	420.6	14.44	24.68	7.834	1.187	77.38	28.65
69	805.0	2724	5134	284.6	24.12	163.7	7.197	2.365	34.54	47.68

Appendix 3. (cont.)

Site	P	K	Ca	Mg	Na	Mn	B	Mo	Ba	Ti
70	521.9	1530	11490	194.9	33.63	151.7	10.23	5.039	76.60	27.51
(158)	801.7	3360	18063	257.7	24.40	109.0	4.955	1.059	54.10	4.795
(159)	447.0	1373	5211	192.7	16.21	125.7	9.747	1.159	70.43	11.64
(160)	507.7	1823	9267	197.3	12.08	131.7	10.21	1.169	34.60	23.90
(161)	843.0	2643	43856	227.8	27.77	172.4	6.762	4.268	22.97	12.38
71	1206	2704	12508	402.3	21.83	258.4	11.37	3.119	50.00	11.12
72	500.2	1277	24927	290.3	30.55	409.5	8.453	3.510	73.69	33.04
73	1015	2749	4567	398.3	34.88	186.1	7.223	2.336	34.01	9.702
74	893.3	2109	7067	258.0	28.54	387.5	7.611	2.654	53.34	6.543
75	594.8	1841	8371	195.6	30.92	130.8	6.458	3.082	30.06	12.33
76	460.3	1758	3476	180.7	22.79	162.1	8.407	1.004	19.32	17.99
77	436.2	1485	3108	354.3	22.94	770.4	5.097	1.068	42.57	4.590
78	1081	2867	13249	267.1	24.02	509.3	23.27	1.003	72.98	10.85
79	472.5	1951	6945	274.5	14.22	119.0	6.818	1.159	69.22	15.06
80	1310	2632	10740	255.7	26.21	172.3	7.502	3.559	55.99	23.61
(162)	375.5	1787	15446	233.8	29.03	123.2	4.850	1.050	111.9	7.915
(163)	1015	2537	2494	200.1	29.39	79.60	11.86	3.522	64.75	17.78
(164)	1338	2788	6068	318.3	45.07	103.7	11.12	< 0.667	40.79	13.05
(165)	690.5	2230	11887	204.9	27.74	162.1	9.110	3.645	70.39	16.51
81	698.9	2581	27328	179.3	34.84	160.6	6.097	< 0.667	194.4	22.95
82	690.6	1893	4402	256.4	37.57	264.3	6.759	0.827	62.23	11.35
83	675.2	1879	2773	245.9	26.88	143.3	8.369	< 0.667	44.05	22.42
84	854.7	2579	6500	244.3	36.46	181.9	6.669	1.106	107.4	24.11
85	661.3	2804	3020	359.5	45.63	201.1	10.70	1.696	53.14	28.35

Appendix 3. (cont.)

Site	P	K	Ca	Mg	Na	Mn	B	Mo	Ba	Ti
86	549.0	2272	2782	240.1	34.71	225.9	7.890	1.528	57.59	42.37
87	809.8	3126	12371	220.4	35.95	169.4	7.075	<0.667	17.96	16.78
88	638.0	2801	7269	363.9	106.8	169.7	12.01	0.802	58.98	8.720
89	1429	3772	11730	387.5	101.9	199.2	12.16	1.350	31.62	17.17
90	548.5	1946	14404	171.4	32.98	154.2	9.305	1.494	114.4	10.96
(131)	498.7	1809	1689	199.9	15.56	114.5	6.651	1.876	18.41	25.65
(132)	737.8	3158	15717	277.2	16.68	157.4	5.699	0.895	79.81	13.59
(133)	873.8	3014	7883	466.2	20.52	188.1	7.878	1.013	38.75	22.98
(134)	1307	3378	19035	289.0	21.50	286.0	7.916	1.492	116.8	98.94
91	809.9	2295	8883	323.9	40.41	145.4	6.670	1.511	96.32	47.86
92	911.5	3001	1873	578.8	40.65	216.9	5.856	1.063	45.67	17.07
93	653.9	2617	16284	406.4	41.19	336.2	11.10	1.207	133.7	28.54
94	524.3	2384	8473	282.3	34.01	120.5	8.113	<0.667	54.86	11.30
95	872.9	2373	31883	240.7	56.73	920.0	11.52	0.810	110.5	18.20
96	1626	4073	8172	463.6	40.85	249.7	9.049	<0.667	48.53	16.89
97	1036	2559	10262	323.1	139.2	344.1	11.02	1.477	201.3	20.38
98	715.5	1971	4070	216.1	36.28	110.8	11.92	1.173	52.55	18.34
99	445.0	1722	44417	215.9	24.89	19.84	5.737	0.920	73.22	16.35
100	1088	3028	38860	320.5	110.6	362.9	14.07	1.207	82.82	15.44
(135)	1932	4859	16363	494.3	11.75	498.9	6.650	1.841	12.09	12.01
(136)	1598	4229	17025	552.3	36.56	512.1	11.52	1.282	17.29	15.08
(137)	888.5	3971	6605	290.8	87.52	240.9	12.07	0.895	15.88	14.31
(138)	754.5	3284	18168	364.0	18.08	699.4	6.510	1.823	26.95	15.45
101	1395	3973	6985	573.8	47.98	151.7	14.44	2.810	86.33	31.38

Appendix 3. (cont.)

Site	P	K	Ca	Mg	Na	Mn	B	Mo	Ba	Ti
102	770.9	2564	696.1	335.8	35.53	106.8	6.259	1.283	24.28	25.83
103	760.2	2570	7952	393.6	129.5	475.7	48.26	0.760	40.74	20.35
104	883.9	2977	5460	420.2	201.9	206.3	12.10	0.861	43.76	12.90
105	1237	3267	29267	613.0	33.96	199.3	11.15	< 0.667	39.03	25.24
106	502.7	2284	27804	293.4	102.3	482.5	12.66	0.743	67.03	19.17
107	942.1	2384	2269	282.2	41.37	84.10	6.480	0.701	17.46	15.34
108	1210	3410	5256	320.8	40.78	148.8	9.578	1.291	41.02	34.22
109	636.7	2246	2221	216.5	66.05	155.2	6.925	1.004	15.35	21.66
110	876.3	2253	36432	230.5	25.72	412.6	11.30	0.709	49.00	16.72
(139)	650.2	2730	2414	242.4	20.96	129.2	10.63	1.333	18.85	15.15
(140)	1356	3549	21307	287.3	22.20	153.7	7.380	1.050	26.29	18.43
(141)	1163	4482	44693	490.9	51.88	265.2	9.317	0.852	90.41	25.79
(142)	1430	3981	11625	640.7	22.08	65.96	6.296	1.433	61.71	14.13
111	615.5	2919	5775	228.2	110.5	95.29	18.83	< 0.667	39.69	8.613
112	598.0	3119	3327	301.2	42.79	176.7	5.697	6.431	39.21	19.87
113	999.1	2162	21099	277.8	23.42	114.9	9.114	< 0.667	337.6	19.46
114	949.6	3121	2210	352.4	37.06	110.6	6.714	0.903	25.32	19.18
115	895.9	2728	32733	365.5	27.99	49.10	5.243	0.869	65.94	26.01
116	1201	3721	14820	455.0	111.0	141.2	10.98	1.266	176.9	17.06
117	575.7	2293	3809	243.4	32.41	194.8	6.919	0.709	45.72	23.89
118	539.1	1907	2587	109.9	36.70	93.78	8.219	1.713	71.26	27.36
119	997.8	3361	17931	265.1	90.80	258.6	17.32	< 0.667	68.56	20.62
120	764.6	2780	26087	208.1	36.18	271.9	7.868	1.055	233.0	14.08
(143)	1019	4132	1191	525.4	45.35	98.09	6.197	2.766	17.62	50.31

Appendix 3. (cont.)

Site	P	K	Ca	Mg	Na	Mn	B	Mo	Ba	Ti
(144)	988.0	3725	9616	430.6	52.05	124.0	6.278	2.200	26.74	41.31
(145)	553.6	2910	3848	371.6	56.09	74.56	14.02	1.835	14.41	29.63
(146)	737.9	3121	5657	424.7	44.84	127.8	8.731	2.678	29.33	56.07
121	763.3	2744	14679	262.1	47.90	358.6	7.355	1.131	77.98	36.34

The following are sites in which more than one species was collected. The data presented are for the additional species. (Key: Fb = Flavoparmelia baltimorensis, Co = Cetraria oakesiana, Hp = Hypogymnia physodes). Some are split samples.

19 Fb	768.6	3510	1444	325.0	47.83	65.35	7.409	1.333	8.868	27.41
27 Fb	768.4	3161	1958	374.5	27.35	112.8	6.982	2.792	17.41	36.14
	721.8	3167	2121	354.4	36.97	107.0	6.249	1.205	19.53	43.50
44 Hp	408.4	1381	882.7	186.8	32.35	87.54	5.328	3.779	7.755	20.40
45 Hp	648.1	2587	2030	394.7	49.66	157.1	4.468	3.388	11.20	9.558
58 Fb	698.7	2713	1231	274.1	26.78	119.0	7.347	1.998	13.30	46.23
83 Fb	603.8	2391	1979	336.6	48.35	93.71	5.991	2.704	13.01	46.98
86 Co	697.4	3224	4122	402.0	66.43	264.0	9.687	3.779	25.48	30.59
87 Co	791.3	3153	3087	473.7	76.63	207.7	6.501	3.013	14.90	94.60
	605.2	3703	5397	394.6	92.64	223.7	4.976	2.036	10.35	51.39
91 Fb	590.4	1982	1025	237.1	30.98	64.72	6.212	3.791	11.22	20.49
	551.3	2075	970.0	186.3	26.32	50.32	5.541	3.559	6.056	10.91
111 Fb	703.2	2361	1237	310.7	23.72	69.31	6.641	2.041	13.78	43.65
119 Fb	654.8	2128	3686	419.4	26.18	839.4	5.830	2.268	59.31	39.55
	625.8	2461	5912	364.9	33.08	471.3	6.072	2.242	32.81	24.95

APPENDIX 4

Concentration of sulfur (in percent dry wt.) and other potential pollution trace elements (in ug/g dry wt.) in Flavoparmelia caperata samples collected from each elemental analysis quadrat in the Otter Creek and Dolly Sods wilderness. Site numbers in parenthesis are replicates. The following elements were found at concentrations below limits of detection: Cd, Ni, Be, Sn, Co.

Appendix 4. Concentration of sulfur (in percent dry wt.) and other potential pollution trace elements[1] (in ug/g dry wt.) in Flavoparmelia caperata samples collected from each elemental analysis quadrat in the Otter Creek and Dolly Sods wildernesses. Site numbers in parenthesis are replicates.

Site	S	Pb	Cr	Cu	Zn	Fe	Sr	Al	V
1	0.186	46.85	2.991	7.032	43.78	551.6	32.42	859.4	272.6
2	0.137	27.02	2.612	10.56	42.01	442.0	10.96	712.9	312.7
3	0.093	13.06	1.872	4.057	45.07	256.6	45.58	426.7	35.20
4	0.131	27.67	1.984	5.705	25.86	405.5	35.69	850.8	88.68
5	0.151	22.16	3.771	7.243	73.60	380.1	13.08	528.6	131.9
6	0.125	40.25	2.772	8.539	26.62	479.1	28.54	841.8	26.17
7	0.148	16.45	3.035	8.111	28.56	463.2	33.60	878.5	182.5
8	0.141	22.60	2.786	10.01	27.31	553.1	10.07	912.3	40.94
9	0.122	41.56	2.974	17.42	36.53	453.1	13.79	1066	59.99
10	0.110	40.44	5.467	14.74	35.58	526.3	16.60	1388	444.9
(166)	0.078	19.27	1.824	6.385	25.66	221.1	8.343	528.2	20.03
(167)	0.141	24.80	3.824	7.041	76.73	762.8	52.87	970.3	136.5
(168)	0.123	28.72	2.010	9.524	38.84	392.6	38.62	512.1	115.1
(169)	0.117	29.09	2.850	15.72	36.76	488.7	13.98	929.3	55.74
11	0.144	18.41	1.461	9.295	23.33	452.4	25.47	572.8	31.10
12	0.120	23.20	1.369	6.433	20.53	319.9	28.94	457.7	293.9
13	0.139	18.80	2.438	7.118	28.79	371.8	33.35	788.4	217.0
14	0.148	20.50	1.845	7.333	26.62	408.0	39.43	828.7	96.29
15	0.144	31.53	4.815	9.735	30.25	751.4	38.18	1151	370.2
16	0.114	34.75	2.829	7.578	25.70	383.3	15.09	707.0	155.4

Appendix 4. (cont.)

Site	S	Pb	Cr	Cu	Zn	Fe	Sr	Al	V
17	0.110	29.36	1.733	6.952	29.06	337.9	69.32	503.8	346.2
18	0.112	13.85	1.773	7.005	38.58	348.2	13.87	465.3	140.0
19	0.161	21.38	3.689	9.040	34.34	427.8	6.111	844.0	202.9
20	0.137	29.84	2.694	9.149	20.68	459.6	6.666	736.4	229.4
(170)	0.124	29.59	2.643	8.457	69.62	444.5	12.65	592.5	122.2
(171)	0.113	20.63	1.087	8.098	35.95	295.1	11.71	323.1	19.20
(172)	0.151	24.23	2.386	9.154	39.34	491.6	9.386	572.2	93.51
(173)	0.131	14.76	2.215	4.743	111.3	271.0	18.43	359.0	556.9
21	0.120	18.32	2.391	8.976	17.02	434.5	6.666	544.4	97.84
22	0.117	21.96	1.651	9.930	46.50	309.9	15.99	568.4	43.05
23	0.134	42.82	2.379	7.991	30.79	488.1	34.39	729.2	196.6
24	0.119	28.87	1.733	5.608	19.36	297.2	12.05	412.6	12.28
25	0.129	34.28	2.450	6.883	49.96	446.5	13.14	669.7	383.4
26	0.154	51.59	5.862	9.398	45.60	1018	10.90	1912	124.5
27	0.137	25.80	3.070	7.221	39.30	512.4	12.14	677.8	73.07
28	0.109	24.10	2.148	6.863	20.92	241.0	8.887	436.7	111.2
29	0.133	22.99	2.703	7.786	22.06	281.9	5.242	486.0	57.09
30	0.152	65.97	3.401	9.484	37.59	688.4	8.498	919.9	117.4
(174)	0.140	65.87	3.027	9.213	33.90	102.9	6.151	984.8	50.65
(175)	0.104	21.75	1.986	6.461	54.27	349.1	10.31	441.6	67.46
(176)	0.107	21.22	2.793	6.615	35.67	425.9	6.438	556.4	240.1
(177)	0.129	44.71	2.836	8.958	28.56	528.7	5.042	483.3	149.2
31	0.138	25.88	2.355	7.560	40.03	290.5	5.595	539.3	47.37
32	0.106	30.68	2.057	8.586	27.55	392.4	10.33	565.2	45.34

Appendix 4. (cont.)

Site	S	Pb	Cr	Cu	Zn	Fe	Sr	Al	V
33	0.089	28.32	1.842	10.21	25.55	339.6	10.22	590.1	165.1
34	0.119	23.53	2.524	10.17	33.70	408.3	20.42	590.7	74.42
35	0.117	32.39	2.341	9.906	36.80	421.8	23.35	575.4	85.50
36	0.084	20.81	2.267	5.859	62.42	350.3	14.62	454.8	160.4
37	0.084	30.66	1.107	9.998	34.98	237.2	14.43	380.2	51.93
38	0.113	40.07	4.891	7.030	34.32	386.6	7.370	714.6	1008
39	0.137	43.40	3.560	6.803	31.55	660.2	6.866	781.6	230.1
40	0.108	25.44	3.270	9.013	21.46	506.4	5.640	587.7	37.02
(150)	0.112	23.61	2.074	6.229	16.07	324.6	8.786	424.7	323.9
(151)	0.130	84.82	2.757	8.142	35.66	562.2	6.863	709.8	88.42
(152)	0.116	23.61	2.074	6.229	19.43	439.9	3.652	424.7	282.7
(153)	0.120	40.85	1.565	7.608	28.43	324.8	12.05	390.3	54.87
41	0.109	31.77	2.305	6.280	28.60	381.8	8.030	565.1	98.73
42	0.078	13.33	0.967	6.416	28.74	192.2	9.517	258.8	12.80
43	0.079	25.58	1.232	5.994	31.89	279.8	17.75	488.5	107.1
44	0.138	45.51	3.339	8.534	30.00	807.5	5.071	953.8	39.76
45	0.118	37.23	5.921	8.364	57.06	220.3	4.435	738.7	5.957
46	0.174	32.16	3.055	7.421	46.97	629.2	13.83	854.2	104.7
47	0.149	50.29	3.317	8.397	35.78	522.0	12.95	1070	135.9
48	0.097	51.26	1.687	10.04	29.19	178.9	8.856	736.0	106.6
49	0.099	18.76	1.838	7.461	46.49	334.1	9.642	465.6	50.68
50	0.144	61.33	2.822	7.092	30.08	354.4	6.192	716.1	48.13
(154)	0.118	25.48	2.699	9.295	37.56	472.8	5.019	562.7	406.5

Appendix 4. (cont.)

Site	S	Pb	Cr	Cu	Zn	Fe	Sr	Al	V
(155)	0.124	29.42	2.784	6.863	46.46	396.7	4.531	503.4	276.4
(156)	0.103	16.75	1.344	8.496	35.68	306.0	9.960	445.1	61.77
(157)	0.100	21.60	2.720	8.199	37.67	240.3	8.572	289.8	90.00
51	0.187	34.46	5.115	11.50	48.08	343.1	7.638	646.6	16.88
52	0.129	44.47	4.734	10.29	93.16	471.1	11.88	668.8	54.10
53	0.169	43.29	3.882	7.483	29.98	539.6	12.95	1023	91.92
54	0.112	64.95	2.002	8.995	116.2	204.8	13.67	743.3	124.5
55	0.105	32.84	2.160	13.73	105.2	419.7	13.24	522.3	137.5
56	0.104	13.51	1.486	7.233	49.41	191.9	18.63	295.5	239.3
57	0.109	31.79	2.842	5.001	164.8	214.7	13.23	258.9	202.5
58	0.115	40.82	3.729	9.277	119.3	378.1	7.815	646.4	25.94
59	0.114	24.39	2.919	10.93	30.42	608.8	5.963	759.9	118.6
60	0.144	47.85	4.200	15.01	50.42	264.4	6.666	699.7	4.959
(178)	0.107	24.25	2.405	5.608	32.33	424.9	17.57	681.6	119.3
(179)	0.157	22.27	4.668	12.41	36.20	712.1	6.679	935.9	255.3
(180)	0.122	28.67	2.450	8.021	63.39	547.4	7.395	568.2	149.9
(181)	0.146	34.89	3.374	15.11	58.94	417.7	7.868	772.4	179.3
61	0.200	44.78	5.482	11.37	79.72	801.8	4.447	1718	367.6
62	0.133	27.38	4.322	8.658	57.75	211.9	16.04	659.4	31.24
63	0.101	19.12	2.329	5.465	18.96	421.2	8.610	558.1	206.4
64	0.136	35.46	4.074	9.055	49.24	316.7	17.32	729.7	83.87
65	0.088	25.59	3.079	13.04	37.66	377.3	13.68	610.8	577.4
66	0.155	42.32	3.891	9.420	110.6	697.8	6.539	803.2	124.9
67	0.084	35.93	4.354	6.812	19.19	179.6	13.71	598.7	14.16

Appendix 4. (cont.)

Site	S	Pb	Cr	Cu	Zn	Fe	Sr	Al	V
68	0.085	17.51	1.672	5.400	21.57	305.9	46.16	398.2	192.5
69	0.134	43.69	3.307	8.839	56.69	797.4	6.813	885.7	372.4
70	0.102	40.35	4.525	8.205	22.78	430.2	14.20	720.7	107.5
(158)	0.100	33.63	0.947	8.349	35.60	174.7	13.74	599.6	146.8
(159)	0.115	60.77	3.693	9.117	37.85	260.2	10.69	688.6	108.2
(160)	0.107	56.42	2.891	7.852	31.41	425.7	8.786	607.8	357.9
(161)	0.103	70.27	2.758	5.863	33.78	247.6	20.04	430.3	46.17
71	0.129	42.07	4.930	6.699	30.30	292.6	21.57	400.6	19.18
72	0.125	48.48	4.870	10.50	20.10	462.9	30.95	808.9	29.23
73	0.154	40.36	3.261	10.03	32.65	197.7	13.22	594.6	28.86
74	0.116	40.18	3.470	9.793	30.85	174.7	6.204	683.4	46.58
75	0.153	103.2	3.226	9.444	33.93	178.9	7.851	764.6	40.11
76	0.124	14.45	2.479	7.971	20.98	293.5	5.057	565.8	40.74
77	0.078	28.54	1.667	6.875	29.74	101.0	9.895	482.3	91.64
78	0.104	35.28	1.955	7.094	47.99	301.5	10.01	448.5	125.3
79	0.130	23.86	2.208	8.107	24.82	250.1	9.098	696.2	240.7
80	0.131	21.34	3.729	6.727	41.78	385.6	11.58	590.5	32.94
(162)	0.094	58.03	1.715	6.306	22.47	344.9	19.46	1357	126.5
(163)	0.160	25.84	3.861	7.894	45.43	282.9	5.780	626.1	15.94
(164)	0.132	40.30	1.206	9.690	32.76	358.6	9.452	646.5	54.46
(165)	0.163	39.59	3.753	10.63	34.97	279.3	10.87	596.6	179.8
81	0.11	38.64	1.633	7.922	37.08	394.6	14.20	508.4	9.837
82	0.14	90.39	2.684	13.88	44.50	237.6	12.37	837.2	41.27
83	0.14	40.10	3.034	11.30	37.33	403.3	7.397	930.6	36.08

Appendix 4. (cont.)

Site	S	Pb	Cr	Cu	Zn	Fe	Sr	Al	V
84	0.15	39.09	3.125	7.377	42.35	414.2	13.04	1014	16.15
85	0.15	47.97	4.073	8.838	73.13	441.7	4.757	1225	106.5
86	0.12	52.14	4.809	8.520	72.31	835.5	6.293	1106	10.40
87	0.14	66.33	1.989	8.417	41.94	347.8	4.551	573.0	3.631
88	0.13	49.17	2.653	8.624	88.64	194.8	7.438	859.1	63.19
89	0.20	34.65	2.598	10.45	46.24	460.0	8.545	1116	15.83
90	0.16	32.92	3.009	8.978	42.27	254.9	11.82	741.3	63.31
(131)	0.150	40.69	3.141	7.642	24.46	401.2	3.854	687.2	150.4
(132)	0.137	40.73	2.516	13.20	42.37	157.4	15.83	842.6	139.2
(133)	0.141	87.35	3.355	11.45	69.99	188.1	8.803	1056	264.2
(134)	0.131	43.56	3.015	8.978	37.63	559.8	12.83	894.1	110.9
91	0.17	49.27	4.061	22.27	51.61	863.4	10.11	1494	88.98
92	0.16	33.24	2.319	11.04	135.6	386.5	6.450	1222	69.38
93	0.16	38.27	2.965	9.496	31.64	441.7	23.12	1476	26.08
94	0.15	31.86	1.956	9.796	72.83	208.8	7.027	625.2	20.90
95	0.15	22.12	1.898	8.087	31.91	362.7	6.450	583.9	33.74
96	0.17	35.10	3.429	8.087	96.60	398.4	6.797	1058	31.66
97	0.17	77.94	3.420	10.75	38.38	486.9	35.94	931.0	19.45
98	0.13	28.35	2.691	8.275	26.76	348.7	8.013	625.4	0.13
99	0.18	14.99	2.402	6.101	29.63	324.4	15.65	642.7	11.64
100	0.11	19.65	2.514	6.065	119.9	362.9	17.55	686.6	127.2
(135)	0.118	22.00	1.953	5.138	91.13	233.9	9.754	438.8	158.0
(136)	0.134	25.26	1.791	6.335	110.8	340.5	12.21	571.7	93.93
(137)	0.15	26.57	2.451	6.328	38.47	269.3	5.693	390.3	81.23

Appendix 4. (cont.)

Site	S	Pb	Cr	Cu	Zn	Fe	Sr	Al	V
(138)	0.143	41.94	2.024	7.232	119.2	346.3	10.99	464.8	482.8
101	0.18	35.14	2.904	13.10	53.34	642.0	10.88	941.3	5.890
102	0.17	32.78	3.919	8.689	80.44	476.8	2.924	953.4	22.66
103	0.17	37.64	3.141	9.649	144.0	475.7	10.03	1025	15.41
104	0.20	41.79	2.879	8.944	109.7	303.2	7.986	1205	45.67
105	0.15	41.98	2.955	6.506	227.5	497.5	27.48	937.5	19.14
106	0.14	45.79	1.984	8.649	50.48	433.0	33.04	736.9	170.7
107	0.09	15.44	1.922	7.017	20.15	298.2	3.171	407.6	5.797
108	0.17	49.89	3.401	11.29	46.98	643.5	5.529	1091	29.18
109	0.15	61.95	3.148	11.61	84.79	408.0	4.654	907.1	48.71
110	0.15	35.75	2.435	7.857	48.06	390.8	15.82	525.6	20.51
(139)	0.136	36.76	2.529	8.692	25.00	343.9	5.651	639.0	249.4
(140)	0.121	18.86	1.735	6.583	74.08	394.9	11.57	513.1	76.17
(141)	0.14	20.79	3.355	7.395	44.30	512.8	41.28	239.3	118.9
(142)	0.146	16.04	1.867	6.314	36.88	443.8	24.46	623.5	239.2
111	0.14	49.55	1.685	8.763	97.87	200.6	10.98	552.4	125.0
112	0.14	59.32	2.296	8.753	87.20	364.9	4.028	1118	12.14
113	0.15	18.88	2.358	9.900	105.2	473.1	18.21	672.9	22.39
114	0.18	41.01	3.383	11.45	71.26	432.5	4.386	894.9	49.71
115	0.09	29.18	2.128	6.057	28.74	449.3	48.73	534.9	9.528
116	0.20	29.91	2.370	11.67	39.98	442.1	21.96	1533	9.267
117	0.12	46.45	2.944	7.495	100.5	471.1	4.624	925.5	10.81
118	0.15	52.68	2.607	9.938	25.25	501.2	6.262	643.7	79.24
119	0.16	51.19	2.686	9.572	37.41	390.6	11.31	715.2	10.95

Appendix 4. (cont.)

Site	S	Pb	Cr	Cu	Zn	Fe	Sr	Al	V
120	0.17	14.87	1.982	9.062	46.90	332.8	16.19	604.0	7.360
(143)	0.139	36.37	5.676	16.54	60.47	1586	4.871	2927	528.2
(144)	0.113	62.71	4.247	22.94	59.82	1247	8.493	2555	415.6
(145)	0.125	47.24	5.104	18.28	61.88	878.5	5.111	2370	295.4
(146)	0.150	48.32	6.392	10.47	44.38	1534	6.456	2474	581.7
121	0.16	69.40	3.980	9.988	54.43	655.0	11.14	1023	13.42

The following are sites in which more than one species was collected. The data presented are for the additional species. (Key: Fb = Flavoparmelia baltimorensis, Co = Cetraria oakesiana, Hp = Hypogymnia physodes). Some are split samples.

19 Fb	0.126	37.02	3.571	14.81	47.77	495.0	2.707	1260	131.3
27 Fb	0.145	50.95	4.234	9.960	69.14	890.7	3.000	1211	127.6
	0.126	52.29	4.674	9.387	69.21	827.7	3.708	1441	81.00
44 Hp	0.135	52.20	3.558	9.250	31.62	364.2	1.800	556.7	68.22
45 Hp	0.154	36.31	4.598	10.05	58.08	187.4	3.036	690.3	26.57
58 Fb	0.122	38.96	3.967	48.69	72.35	770.8	3.673	1343	166.1
83 Fb	0.112	37.82	4.315	6.744	29.15	1129	3.404	1535	372.5
86 Co	0.100	51.84	6.899	9.054	63.79	1047	6.343	1695	361.6
87 Co	0.117	61.26	7.459	9.002	48.17	2299	5.132	2663	187.2
	0.104	44.38	3.996	8.538	48.19	1175	5.170	1169	283.7
91 Fb	0.113	52.92	5.422	8.915	35.28	397.3	2.345	1236	351.6
	0.082	31.05	3.634	6.723	31.51	243.3	1.536	525.0	114.7

Appendix 4. (cont.)

Site	S	Pb	Cr	Cu	Zn	Fe	Sr	Al	V
111 Fb	0.156	86.79	5.053	9.501	44.46	1217	4.004	1908	39.91
119 Fb	0.143	68.05	4.784	10.28	85.21	954.9	5.934	1865	81.01
	0.133	66.63	3.334	10.12	80.22	764.2	5.300	1456	421.3

[1] The following elements were found at concentrations below limits of detection: Cd < 2.00 ug/g, Ni < 4.00 ug/g, Be < 0.004 ug/g, Sn < 3.33 ug/g, Co < 0.333 ug/g.