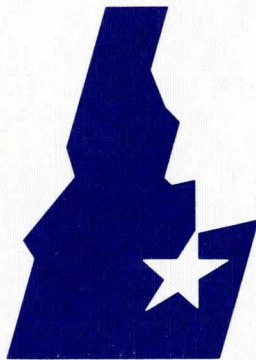


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# ***Lichens of the Idaho National Engineering Laboratory***



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***Idaho National Engineering Laboratory***

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*U.S. Department of Energy • Idaho Operations Office*

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# **LICHENS OF THE IDAHO NATIONAL ENGINEERING LABORATORY**

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## ABSTRACT

A study begun in 1984 to evaluate the feasibility of using lichens to monitor air pollution at the Idaho National Engineering Laboratory (INEL) has provided good baseline data on the lichen flora of the site. To date, 111 lichen taxa, including 25 genera and 110 species, have been identified. Six genera (*Agrestia*, *Heterodermia*, *Microthelia*, *Polyblastiopsis*, *Teloschistes*, and *Verrucaria*) and 49 species were previously unrecorded in Idaho. A key to the lichen species of the INEL and a general description of the genera are included as appendices to this report. Voucher specimens of lichens found at the INEL are being stored at the Radiological and Environmental Sciences Laboratory. As of May 1987, 43 species have been curated in the lichen herbarium there.

## ACKNOWLEDGMENTS

Dr. Larry L. St. Clair, Department of Botany and Range Science, Brigham Young University, made the BYU lichen herbarium available to us and also directly assisted in the identification of many of the crustose lichens. We thank him for his help and his encouragement. Dr. Sam Shushan of the University of Colorado and Dr. Roger Anderson of Denver University also examined some of our specimens and offered suggestions that helped in their identification. Dr. Roger Rosentreter, Bureau of Land Management, Boise, Dr. John Thomson, University of Wisconsin, and Dr. Cliff Wetmore, University of Minnesota, examined the report, especially the key, and offered helpful suggestions. Drs. O. D. Markham and T. D. Reynolds, U.S. Department of Energy, provided critical review of the report.

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# LICHENS OF THE IDAHO NATIONAL ENGINEERING LABORATORY

## INTRODUCTION

Because lichens are especially sensitive to air pollution and are also known to accumulate heavy metals over a period of years (Ferry et al. 1973; Hale 1983), a study was initiated in 1984 to evaluate the feasibility of using them as biomonitors at the Idaho National Engineering Laboratory (INEL). Knowledge of the species present is necessarily the first step in selecting the lichens best suited for monitoring purposes. This study, therefore, included (a) gathering comprehensive baseline data, involving species lists and distribution, to help future researchers assess the impact of ongoing activities at the INEL, and (b) preparing a key to the identification of all of the lichens present, and also brief descriptions of all the genera, as an aid to future researchers and other interested people in recognizing the species that are here.

Some species of lichens are much more sensitive to pollutants than others. Consequently, levels of air pollution can be estimated by careful observation of the number of species surviving in an area and mapping the distribution of the most sensitive ones, as was done by Brodo (1966) in the eastern United States and by Hawksworth (1973) and others in Europe. Such studies have never been conducted in the western United States. In fact, little published information on the species of lichens

that occur in the West exists. In 1984, essentially nothing was known about the sensitivity of western species to air pollution.

Schroeder et al. (1975) published a "catalog of the lichens of Idaho" based on an extensive survey of the literature. In it they listed a total of 287 species, primarily from northern Idaho, included in 62 genera. Based on this survey and their own experience, they concluded that the lichens of Idaho have been largely neglected, leaving vast areas of the state still lichenologically unexplored. Later, Hammon and Pearson (1976) published a list of lichens in the Ricks College Herbarium; included were 34 species and six genera not in Schroeder's catalog. Anderegg (1977) listed five additional species of *Cladonia*, bringing the total to 326 species and 68 genera recorded in Idaho. Present and future studies at the INEL may be expected to reveal additional species.

This report lists the species identified on the INEL up to 1986 and provides aids to identification. Due to the vast size of the INEL, this report should not be considered a definitive list of all lichens there. Nevertheless, because of the uniformity of substrate available over much of the Site, it is estimated that essentially all of the common species are listed, along with many of the less common and rare species.

## LICHEN MORPHOLOGY AND IDENTIFICATION

This section on morphology and identification is provided as a general overview for those unfamiliar with lichens. In addition, many of the terms used in the "Key to the Lichens of the INEL" (Appendix A) are defined here.

A lichen is a plant resulting from symbiosis between a fungus, usually an ascomycete, and an alga, either a cyanophyte (bluegreen alga) or, more commonly, a chlorophyte (green alga). Morphological and anatomical differences among species of lichens are determined primarily by the fungus. Therefore, international rules of lichen nomenclature dictate that the name of the lichen be the same as the name of the fungus.

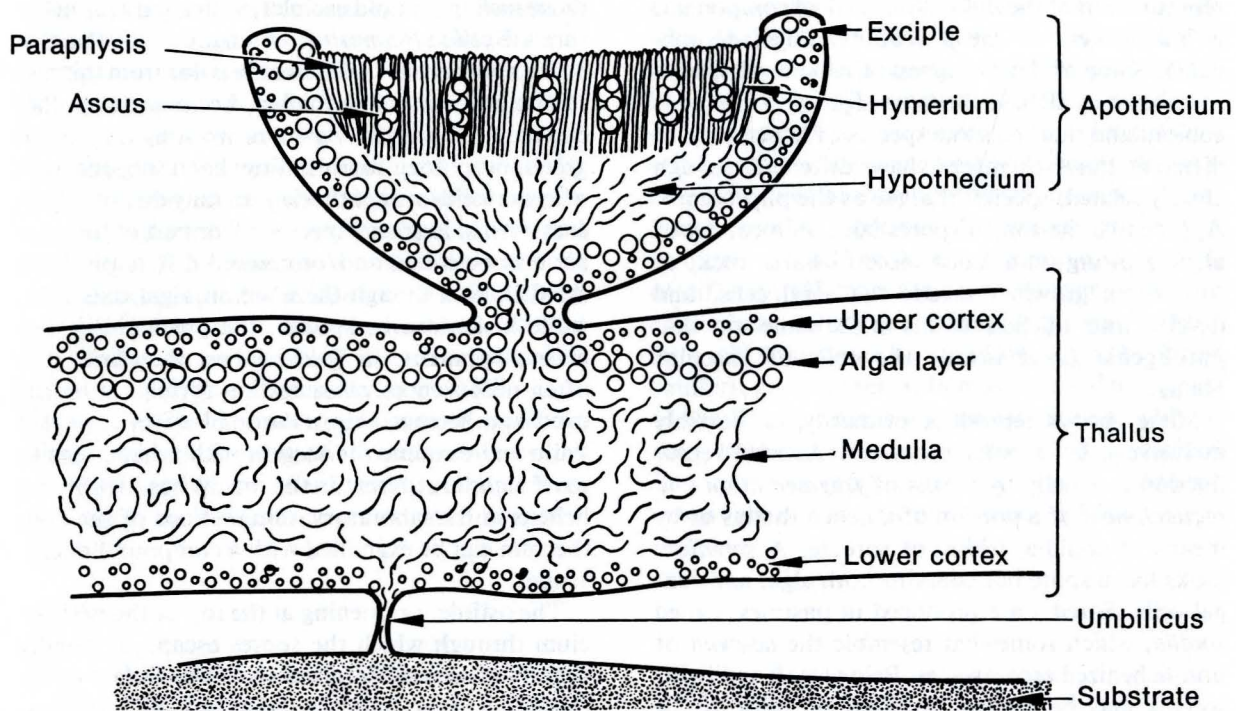
Lichens are complex, highly evolved plants. The plant body (*thallus*) of most lichens consists of three or four distinct layers of differentiated cells or tissues (Figure 1). The uppermost tissue, (*upper cortex*) is usually parenchymatous, several cell layers thick, and contains gelatinous substances which protect the inner tissues from desiccation and the bleaching effects of light. When moist, these substances become translucent and light readily penetrates the cortex; but when dry, the cortex is opaque. Beneath it is the thin algal layer (formerly called the "gonidial layer"), made up of both algal and fungal cells. Photosynthesis takes place in this tissue. The bulk of the thallus is a prosenchymatous, or stringy, tissue called the *medulla*. Most of the unique lichen substances, many of which are powerful chelating agents, are stored in the medulla. Many lichens also possess a *lower cortex* which is usually somewhat similar in structure to the upper cortex. Lichens may also have reproductive structures on the upper surface [either disk-like *apothecia* (Figure 1) or flask-shaped *perithecia*] and organs of anchorage (usually *rhizines*) on the lower surface.

The growth form of a lichen may be crustose, foliose, or fruticose. *Crustose lichens* consist of a thin layer of cells closely attached to soil, rock, bark, or other substrate; often they resemble splashes of paint on the desert rocks. Upper cortex, algal layer, and medulla are usually well developed in crustose lichens, but they lack a lower cortex, and the medulla typically grows down into the stone or wood to which they are attached. *Foliose lichens* resemble leaves in general appearance and also anatomy; all four tissues are well developed in most foliose species. *Fruticose lichens* resemble the leafless stems and branches of small vascular

plants. Some are erect, like miniature shrubs, growing on soil or on other plants; others are pendulous, like delicate vines hanging from the branches of trees, and occasionally reaching a length of a meter or more. The cortex completely surrounds the thallus; inside it is a ring of photosynthetic tissue, and the medulla occupies the center of the thallus.

Crustose lichens may be either areolate or squamulose. *Areolate lichens* usually have a "chinky" thallus which is typically broken up into small squares or polygons (called *areoles*) that are firmly attached to the substrate at all points by *hyphae*, or fungal filaments, growing out from the medulla. In some species, the thallus is *granular*: the areoles are reduced to small grains which may be widely spaced. Sometimes the margin of the thallus is lobed, or *effigurate*, and thus approaches foliose. In other species, the areolate nature extends all the way to the margin. Other crustose lichens are *endolithic*. These consist only of an apothecium with little or no thallus surrounding it, because most of the thallus is buried in the rock. Light reflecting on rock crystals penetrates into the substrate, where photosynthesis takes place. *Squamulose lichens* consist of multicellular scales, or *squamules*, each of which has an upper cortex, algal layer, and medulla plus a lower cortex along its raised margin. These appear intermediate between foliose and crustose. As in the areolate species, the medulla grows into the substrate.

Foliose lichens may be either gelatinous or stratified. In *gelatinous lichens*, algal and fungal cells are not differentiated into distinct tissues but are mingled together throughout the thallus. The *phycobiont*, or algal component, is always a cyanophyte; consequently, the thallus is a characteristic bluish black color. When wet, the gelatinous materials which surround cyanophyte cells swell and give the entire thallus a gelatinous appearance. *Umbilicate lichens* are stratified into the four tissue layers. The entire thallus is attached to the substrate, which is nearly always rock, by a multicellular strand called an *umbilicus* (Figure 1). When moist, the thallus can usually be "popped" off the rock in one piece by prying gently with a knife blade at the single point of attachment. Most foliose lichens, however, are attached to the substrate by numerous simple or branched organs of anchorage called *rhizines*. Like the umbilicus, a rhizine is a complex organ, usually made up of



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Figure 1. Cross section through a typical umbilicate lichen.

prosenchymatous tissue, which grows out of the lower cortex and medulla. Hale (1979) refers to these rhizinate lichens, and also other foliose lichens which have neither rhizines nor umbilicus but are attached to the substrate by numerous minute hyphae extending from the lower cortex, as "stratified lichens."

Fruticose lichens may be either erect or pendulous, may be hollow in the center or possess a solid medulla, and may or may not have a dense, distinct central cord. They are the least common of the three groups in arid regions. Like foliose lichens, they are generally easy to identify. Some fruticose species have two kinds of thallus, a primary squamulose thallus and a secondary thallus, called a *podetium*. Podetia are erect and shrub-like. Fruticose thalli may be round in cross-section, or angular and more or less flabby.

Sexual reproduction in lichens is by means of meiospores produced in *sporocarps*, or fruit-like structures. These spore fruits are either flask-shaped perithecia or disk-like apothecia. Apothecia are the more common. Each sporocarp results from the union of two haploid nuclei. One nucleus is in an *ascogonium* (the egg-bearing structure), which is frequently provided with a long hair-like

extension called a *trichogyne*, through which the fertilizing nucleus (*spermatid*) migrates. *Karyogamy* (fusion of the nuclei) is delayed; consequently, most of the cells in the developing sporocarp are *dicaryotic* (have two haploid nuclei). The uppermost tier of dicaryotic cells forms the *hymenium* (Figure 1). Karyogamy takes place in the hymenial cells, followed by meiosis and (usually) one mitosis. Eight meiospores result; all are enclosed in an *ascus* (Figure 1) or sac formed from the wall of the diploid cell which underwent meiosis. These meiospores are called *ascospores*, and the fungi which produce ascospores are called *ascomycetes*.

Foliose and fruticose lichens are easily identified in most cases by gross morphological features; but to identify crustose lichens, it is often necessary to examine the spores. Ascospores may be simple, septate one or more times, *polarilocular* (2-celled with a thick wall between the cells and an isthmus connecting them), or *muriform* (divided transversely and longitudinally into many cells). The sporocarps, both apothecia and perithecia, are persistent and usually produce spores throughout the year. In many species, however, only spores produced between January and May are viable. Sexual

reproduction of the *mycobiont* (fungal component) is independent of the *phycobiont* (algal component). Some evidence suggests that several species of lichen may all have the same algal species as phycobiont and that the same species of lichen may, at different times or places, have different, though closely related, species of algae as the phycobiont. Apparently, the fungal spores land on a colony of algae growing on a moist piece of bark, rock, or soil, begin growing, invade the algal cells, and develop into a lichen thallus in the same way that pathogenic fungi invade the cells of vascular plants.

Some species reproduce primarily, or possibly exclusively, by asexual processes. Asexual reproduction is usually by means of *fragmentation* and *reattachment* of a portion of a lichen thallus or by means of conidia, isidia, or soredia. A *soredium* looks like a spore but contains both algal and fungal cells. Soredia are produced in pustules, called *soralia*, which somewhat resemble the *acervuli* of non-lichenized ascomycetes. Being small and light, soredia may be carried hundreds of miles by the wind. An *isidium* is a finger-like or cylindrical growth on the upper surface of the thallus; it consists of differentiated tissues and contains both algal and fungal cells.

*Conidia* are asexual spores produced by the mycobiont. They occur in flask-shaped structures called *pycnidia* which superficially resemble perithecia. Because of this, care must be taken when identifying lichens not to confuse the two. Perithecia produce ascospores which are always enclosed in asci interspersed within the perithecium among slender filaments called *paraphyses*. Pycnidia lack paraphyses, and their spores, the conidia, are never produced in asci or other sacs.

The nature of the ascocarps (the apothecia or perithecia), if present, and the presence or absence of soredia and isidia are important characteristics to note when studying lichen morphology and taxonomy. Because ascocarps are highly evolved, specialized, reproductive structures, they tend to vary the least of all the morphological and anatomical features of a species. A lichen may produce either apothecia or perithecia but never both. If apothecia are abundant on a lichen, there are generally no soredia or isidia present; if soredia are abundant, ascocarps are rare or lacking.

In some species, the algal layer extends up into the rim or *exciple* (Figure 1) of each apothecium. In others, the exciple is "proper," meaning that the apothecium contains no algal cells. Apothecia with proper exciples are called *lecidine* or *biatorine*, and

those having thalloid exciples, with algal cells in the rim, are called *lecanorine*. In most lichens, the disk of the apothecium is different in color from the vegetative body or lichen thallus. Lecanorine apothecia, therefore, tend to have a contrasting ring, often green in color, surrounding each apothecium whereas lecidine apothecia generally do not. However, even in lecidine species, all or part of the exciple may be raised and/or colored differently from the disk even though there are no algal cells in it, while in lecanorine species, the green rim is not always apparent. In field studies, therefore, it is often necessary to cut a section through a moistened apothecium with a razor blade or a pocket knife and examine the section with a hand lens to see if algae are present in the rim. When identifying lichens in the laboratory, thin sections of the apothecium can be examined with a compound microscope.

The ostiole, or opening at the top of the perithecium through which the spores escape, is usually slightly to noticeably raised above the surface of the thallus; at times, however, it may be level or sunken. An *involucrellum* may envelop the perithecium, or sometimes only the neck or upper portion of the neck and the ostiole. Involucrella are black, carbonized structures typical of many non-lichenized fungi as well as the closely related lichens. In some genera (e.g., *Microthelium*), the involucrellum is so massive that it is easily mistaken for an apothecium.

Four simple chemical tests are widely used in studying lichens: the K test, C test, KC test, and Pd test. Unique chemical substances, commonly but incorrectly referred to as "lichen acids" in the older literature, are found in the cortex and/or the medulla of most lichens. Many have a specific reaction with special chemical reagents. For example, the C test may be used to distinguish between *Lecanora melanophthalma* and *Lecanora novomexicana*. The upper cortex and algal layer are first scraped away. A small amount of C reagent, a pungent solution of bleaching liquid, is then applied to the exposed white medulla. *L. melanophthalma* is "C+ yellow," meaning that the medulla slowly changes in color from white to yellow; whereas *L. novomexicana* is "C-," meaning no color change takes place. The K and Pd tests are conducted in a similar manner. If a specimen tests K- and C-, the KC test may be made by applying first "K" and then "C" and watching for a change in color. Directions for preparing the K, C, and Pd reagents and for making the respective tests are presented in Hale (1979), pages 10 to 12.

Other simple tests often used by lichenologists to aid in the identification of species are the UV test, the starch-iodine test, and the limestone test. The UV test is made by exposing the lichen to ultraviolet light in a dark room and watching for fluorescence (Anderegg 1977). The starch-iodine test is made by placing a drop of Gram's iodine solution on the medulla or the inner tissues of the apothecium and watching for development of a blue, or occasionally a maroon, color. The limestone test is made by putting a few drops of dilute hydrochloric acid on the rock the lichen is growing on to see whether it is calcareous (HCl +) or non-calcareous (HCl -).

Lichen species are relatively constant as to the substrate on which they grow. Some *saxicolous* species grow only on calcareous rocks, while others grow only on acidic or non-calcareous rocks.

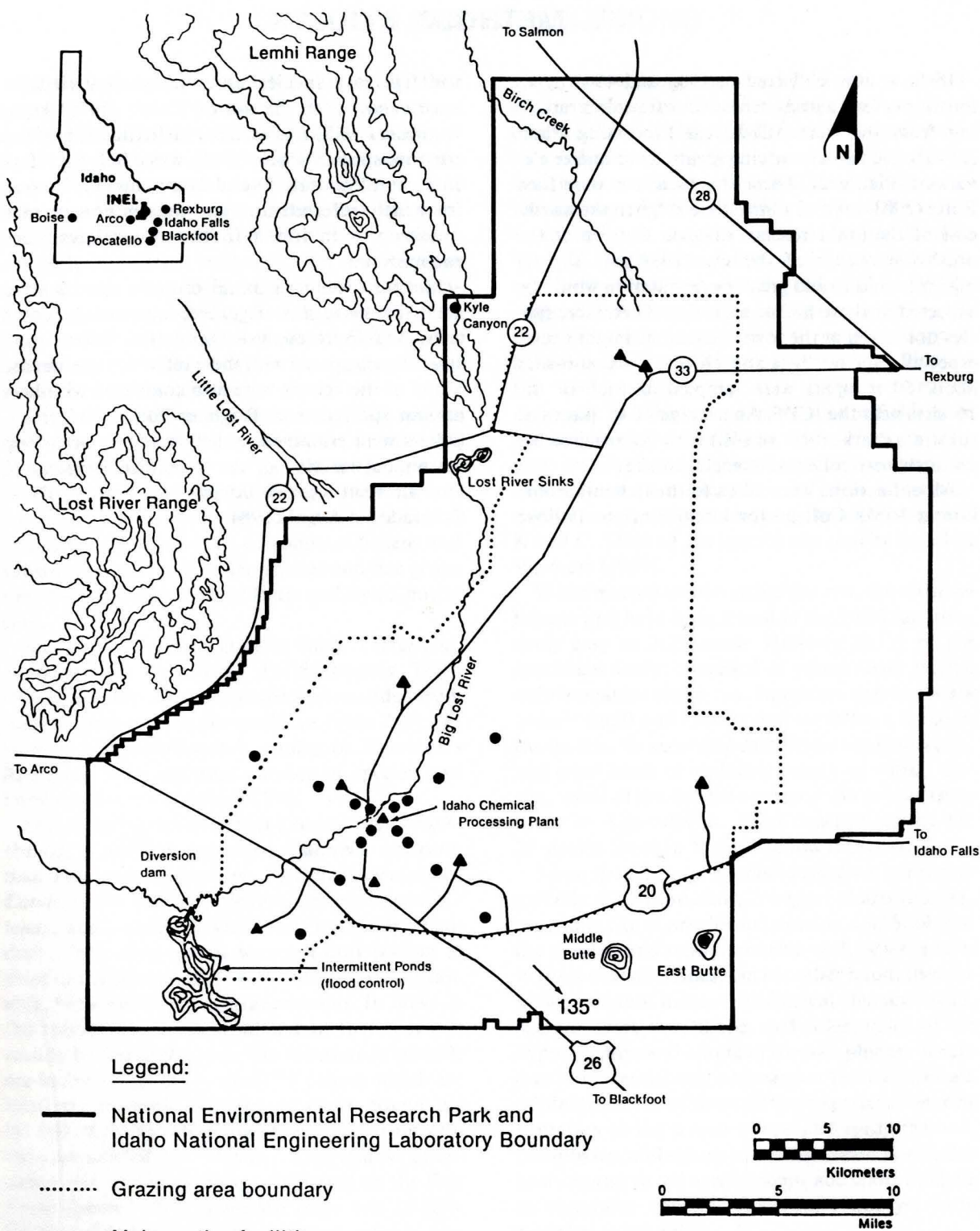
*Corticolous* species grow on bark, some only on what Du Rietz (1932) referred to as the "noble" trees (oak, maple, ash, etc.) and others on aspen, birch, poplars, and conifers. *Lignicolous* species grow directly on wood; *terricolous* species grow on soil, sometimes associated with terricolous mosses. However, most of these species will occasionally be found on other substrates. Saxicolous species may be found on wood or bark, for example, or on rock of different pH from the preferred type; while the corticolous lichens normally found on "noble" trees will sometimes be found on aspen, birch, or conifers, and vice versa. In most of the desert areas of the West, crustose species are especially abundant, both on rocks and on bark. Foliose lichens also occur on soil, bark, and rocks. Fruticose lichens are rare but are occasionally found.

## SITE DESCRIPTION

The 2,300-km<sup>2</sup> INEL is located on the upper Snake River Plain in eastern Idaho (Figure 2), covering portions of Butte, Bonneville, Bingham, Jefferson, and Clark counties. The topography is flat to gently rolling with frequent outcroppings of basalt typical of the Columbia Plateau. The Site is bordered on the north and west by the Lemhi, Lost River, and Bitterroot mountain ranges, and its average elevation is 1526 m. Although soils are relatively variable, ranging from very light sand to gravelly silt, often with outcroppings of black basalt, the vegetation is rather uniform, with bluebunch wheatgrass (*Agropyron spicatum*) and big sagebrush (*Artemisia tridentata*) being especially abundant over most of the area (McBride et al. 1978). Naturally occurring tree species are limited to junipers (*Juniperus* spp.) on the buttes and ridges and plains cottonwood (*Populus deltoides*) along the Big Lost River. Other grasses and shrubs which are abundant on the INEL include bunch bluegrasses (*Poa nevadensis* and *Poa sandbergii*),

needle-and-thread grass (*Stipa comata*), Indian ricegrass (*Oryzopsis hymenoides*), prairie junegrass (*Koeleria cristata*), bottlebrush squirreltail (*Sitanion hystrix*), Great Basin wildrye (*Leymus cinereus*), thickspike wheatgrass (*Agropyron dasystachyum*), cheatgrass (*Bromus tectorum*), bitterbrush (*Purshia tridentata*), rabbitbrushes (*Chrysothamnus nauseosus* and *C. viscidiflorus*), and shadscale (*Atriplex confertifolia*).

The INEL has a cool desert climate. Summers are mild and dry, with daily highs around 30°C and nightly lows around 10°C in July. Wind is common in the spring and summer, with relatively strong daytime wind from the southwest and weak nighttime wind from the northeast. Winters are long and severe, with nightly lows around -15°C and daily highs around 0°C during most of December and January. Extremes of -44°C and 39°C have been recorded. Average annual precipitation is 22 cm, with the greatest amounts in May and June (Yansky et al., 1966).



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Figure 2. Idaho National Engineering Laboratory, showing location of lichen collection sites.

## METHODS

Lichens were collected in 1984 and 1985 at 18 locations, four along each of four transects radiating from the Idaho Chemical Processing Plant (ICPP) and two at outlying locations at higher elevations (Figure 2). These two locations were East Butte (2003 m) and a limestone ridge to the northeast of the lower reaches of Kyle Canyon at the northwest corner of the site (1938 m). Slightly higher humidity and greater precipitation would be expected at these higher altitudes. Therefore, species not found at the lower elevations might occur, especially on north-facing cliffs. Three sub-sites about 50 m apart were sampled at each of the 16 sites near the ICPP. An average of 45 pieces of substrate (bark, rock, or soil) with lichens growing on them were collected at each sub-site.

All collections were taken to the lichen herbarium at Ricks College for identification. Foliose

and fruticose species were easily identified, in most cases, with the aid of Hale's (1979) keys. Wetmore (1969) was used for identification of the crustose species. Poelt (1969) was a helpful reference; and Fink (1935) and Thomson (1979) were frequently referred to when uncommon or rare species not included in the other keys were encountered.

Mature specimens of all crustose species were identified by means of general morphology, color tests, and spore analysis. Immature lichens were carefully compared with these reference specimens. Many of the lichens were also compared with herbarium specimens at Brigham Young University. Others were examined by lichenologists attending the annual meeting of the American Bryological and Lichenological Society at Fort Collins, Colorado, in August 1984.

## RESULTS AND CONCLUSIONS

In the area closest to the ICPP (Figure 2), there are very few outcroppings of lava, and consequently few umbilicate or large saxicolous lichens. Rocks up to 4 or 5 cm in diameter are common, and many have small crustose lichens on them. Soil lichens are abundant. Surrounding this flat area, and extending from the ICPP for 30 km or more, is a slightly undulating landscape with outcroppings of basalt that often form ridges 3 or 4 m in elevation above the surrounding land. In this rocky habitat, saxicolous lichens abound. Corticolous lichens are relatively abundant on sagebrush and other shrubs in both areas.

A total of 111 taxa, representing 110 species (including one with two taxonomic forms) and 25 genera, was found at the 18 sampling sites (Table 1). These are listed alphabetically in Table 2 with notes on their abundance. Figures 3 through 5 show examples of common lichens and substrates on the INEL. Ten species and one genus were found only at the East Butte and Kyle Canyon sites.

Six of the 25 genera listed in Table 1 (*Agrestia*, *Heterodermia*, *Microthelia*, *Polyblastiopsis*, *Teloschistes*, and *Verrucaria*) were the first recorded from Idaho. Forty-nine of the species in Table 2 are not listed in either Schroeder's catalog or Hammon's list; these bring the total number of species now known to occur in Idaho to 370.

Our sampling revealed that *Lecanora melanophthalma*, *Xanthoria polycarpa*, *Parmelia exasperatula*, *Fulgensia desertorum*, *Xanthoria candelaria*, *Candelariella rosulans*, *Collema coccophorum*, *C. tenax*, and *Lecidea luridella* were especially abundant. These nine species were not only present at most of the sites where suitable substrate was available, but were present in large amounts. In Table 2, the species which are so abundant that they can readily be found wherever the substrate is suitable are indicated by the symbol "A"; those which are relatively common but not as easily found are labeled "C"; and those which are rare or uncommon are labeled "U." No record of relative abundance was kept of the lichens collected on the East Butte (labeled "B") or on the ridge next to Kyle Canyon (labeled "K"). Also, lichen species first identified when curating the original collections (labeled "R") are all rare species.

Identification of seven of the 111 taxa is more or less uncertain. The notation "tent," enclosed in brackets, following the names of three species indi-

cates that our identification should only be considered tentative for the time being. Each of four others is labeled "sp.," followed by a species epithet, in brackets, of a species to which it keys (in the keys being used), but with sufficient discrepancy that positive identification was not possible.

Appendix A is a key to the 111 taxa listed in Table 2. Because the foliose and fruticose lichens are readily identified with the aid of Hale (1979), Appendix A only makes reference to the page number in Hale where keys to these two groups of lichens begin. Thus, a key to the crustose species of the INEL makes up the greater part of Appendix A. The key can be used in the field, since spore characteristics and anatomical features have been avoided, and a microscope is therefore not essential to identification. All that is usually needed is a good hand lens and the color reagents, K and C. Most of the species can also be keyed in Wetmore (1969).

When mature ascocarps are present, the crustose lichens that have been found at the INEL are relatively easy to distinguish. However, many of the specimens found consisted of young thalli having only immature ascocarps. Immature apothecia are usually small and cuplike and are often sunken in the thallus. To accommodate immature specimens, and other kinds of variation occurring within species, some of the lichens are keyed out two or three times in Appendix A. Brief descriptions of the 25 genera listed in Table 1 follow in Appendix B.

Some species, e.g., *Lecanora calcarea*, are highly variable as to gross morphological characteristics, especially size of areoles and apothecia and color of the areoles, and tend to overlap with other species in these characteristics. On the other hand, they are highly constant in most anatomical characteristics, such as spore size, shape, and color; color of the hypothecium; and nature of the paraphyses. Whenever it is essential that a researcher be 100% certain of identification of these difficult species, it may be necessary to use a microscope and study the asci, paraphyses, and spores in careful detail. It will also be necessary to use a microscope and spore analysis to recognize species which have not yet been recorded at the INEL.

Voucher specimens of lichens found at the INEL are being stored at the Radiological and Environmental Sciences Laboratory. As of May 1987, 43 species have been curated in the lichen herbarium there.

**Table 1. The genera<sup>a</sup> and number of species of lichens found at the Idaho National Engineering Laboratory (1984-1986 surveys)**

| Foliose and Frutiose Lichens |                   | Crustose Lichens       |                   |
|------------------------------|-------------------|------------------------|-------------------|
| Genus                        | Number of Species | Genus                  | Number of Species |
| <i>Agrestia</i>              | 1                 | <i>Acarospora</i>      | 7                 |
| <i>Anaptychia</i>            | 1                 | <i>Buellia</i>         | 1                 |
| <i>Candelaria</i>            | 1                 | <i>Caloplaca</i>       | 9                 |
| <i>Collema</i>               | 5                 | <i>Candelariella</i>   | 6                 |
| <i>Dermatocarpon</i>         | 3                 | <i>Diploschistes</i>   | 1                 |
| <i>Heterodermia</i>          | 1                 | <i>Fulgensia</i>       | 2                 |
| <i>Letharia</i>              | 1                 | <i>Lecanora</i>        | 27                |
| <i>Parmelia</i>              | 9                 | <i>Lecidea</i>         | 18                |
| <i>Physcia</i>               | 4                 | <i>Microthelia</i>     | 1                 |
| <i>Teloschistes</i>          | 1                 | <i>Polyblastiopsis</i> | 1                 |
| <i>Umbilicaria</i>           | 3                 | <i>Rhizocarpon</i>     | 1                 |
| <i>Xanthoria</i>             | 4                 | <i>Staurothele</i>     | 2                 |
|                              |                   | <i>Verrucaria</i>      | 1                 |
| Total                        | 34                | Total                  | 77                |

a. See Appendix B for a brief description of each genus.

**Table 2. Species list and abundance of lichens from 18 locations at the Idaho National Engineering Laboratory**

| Species                                                         | Percent of Sites<br>at Which Found <sup>a</sup> |
|-----------------------------------------------------------------|-------------------------------------------------|
| <i>Acarospora americana</i> Magn.                               | 19 U                                            |
| <i>A. badiofusca</i> (Nyl.) Th. Fr.                             | 31 U                                            |
| * <i>A. chlorophana</i> (Wahlenb. ex Ach.) Mass.                | B                                               |
| <i>A. fuscata</i> (Schröd.) Arn.                                | 44 C                                            |
| * <i>A. schleicheri</i> (Ach.) Mass.                            | B                                               |
| <i>A. smaragdula</i> (Wahlenb. ex Ach.) Mass. <sup>b</sup>      | 31 C                                            |
| <i>A. strigata</i> (Nyl.) Jatta                                 | 50 A                                            |
| <i>Agrestia hispida</i> (Mereschk.) Hale & W. Culb.             | 6 U                                             |
| <i>Anaptychia palmatula</i> (Michx.) Vain.                      | 12 U                                            |
| * <i>Buellia punctata</i> (Hoffm.) Mass.                        | R                                               |
| <i>Caloplaca cerina</i> (Ehrh.) Th. Fr.                         | 12 U                                            |
| <i>C. citrina</i> (Hoffm.) Th. Fr.                              | 6 U                                             |
| <i>C. epithallina</i> Lynge                                     | 31 C                                            |
| <i>C. fraudans</i> (Th. Fr.) Olive.                             | 19 U                                            |
| <i>C. geophila</i> (Ras) Ras [tent] <sup>c</sup>                | 31 C                                            |
| <i>C. lamprocheila</i> (D.C. in Lam. & D.C.) Flag. <sup>b</sup> | 12 U                                            |
| <i>C. pyracea</i> (Ach.) Th. Fr. <sup>b</sup>                   | 38 C                                            |
| <i>C. saxicola</i> (Hoffm.) Nordin                              | 25 A                                            |
| <i>C. trachyphylla</i> (Tuck.) Zahlbr.                          | 38 A                                            |
| <i>Candelaria concolor</i> Mass.                                | 19 A                                            |
| <i>Candelariella aurella</i> (Hoffm.) Zahlbr.                   | 94 C                                            |
| <i>C. deflexa</i> (Nyl.) Zahlbr.                                | 94 C                                            |
| <i>C. dispersa</i> (Ras.) Hak. [tent]                           | 31 U                                            |
| <i>C. rosulans</i> (Mull. Arg.) Zahlbr.                         | 62 A                                            |
| <i>C. vitellina</i> (Ehrh. Mull.) Arg.                          | 44 A                                            |
| <i>C. xanthostigma</i> (Ach.) Lett.                             | 12 U                                            |
| <i>Collema coccophorum</i> Tuck.                                | 75 A                                            |
| <i>C. conglomeratum</i> Hoffm.                                  | 31 C                                            |
| <i>C. polycarpon</i> Hoffm.                                     | 19 C                                            |
| <i>C. tenax</i> (Sw.) Ach.                                      | 81 A                                            |
| <i>C. texanum</i> Tuck.                                         | 6 U                                             |
| <i>Dermatocarpon hepaticum</i> (Ach.) Th. Fr.                   | 12 U                                            |
| <i>D. lachneum</i> (Ach.) A. L. Sm.                             | 50 A                                            |
| <i>D. miniatum</i> (L.) Mann                                    | 25 C                                            |
| <i>Diploschistes scruposus</i> (Schreb.) Norm.                  | 6 U                                             |
| <i>Fulgensia desertorum</i> (Tomin) Poelt                       | 100 A                                           |
| <i>F. fulgens</i> (Sw.) Elenk.                                  | 19 C                                            |
| * <i>Heterodermia albicans</i> (Pers.) Swinsc. & Krog           | R                                               |

Table 2. (continued)

| Species                                                                 | Percent of Sites<br>at Which Found <sup>a</sup> |
|-------------------------------------------------------------------------|-------------------------------------------------|
| <i>Lecanora alphoplaca</i> (Wahlenb. ex Ach.) Ach.                      | 31 C                                            |
| <i>L. atra</i> (Huds.) Ach.                                             | 6 U                                             |
| * <i>L. badia</i> (Hoffm.) Ach.                                         | R                                               |
| <i>L. caesiocinerea</i> Nyl.                                            | 31 C                                            |
| <i>L. calcarea</i> (L.) Somm.                                           | 38 A                                            |
| <i>L. cenisia</i> Ach.                                                  | 6 U                                             |
| <i>L. christoi</i> W. A. Weber                                          | 31 C                                            |
| * <i>L. chrysoleuca</i> (Sm.) Ach.                                      | B                                               |
| <i>L. cinerea</i> (L.) Somm.                                            | 19 C                                            |
| <i>L. crenulata</i> (Dicks.) Nyl.                                       | 25 C                                            |
| <i>L. desertorum</i> Kremp.                                             | 6 U                                             |
| <i>L. dispersa</i> (Pers.) Somm.                                        | 12 U                                            |
| <i>L. garovaglii</i> (Korb.) Zahlbr.                                    | 19 C                                            |
| <i>L. hageni</i> (Ach.) Ach.                                            | 50 C                                            |
| <i>L. melanophthalma</i> (Ram.) Ram.                                    | 44 A                                            |
| <i>L. muralis</i> (Schreb.) Rabenh.                                     | 19 C                                            |
| * <i>L. nigromarginata</i> Magn.                                        | B                                               |
| <i>L. novomexicana</i> (B. de Lesd.) B. de Lesd. non Magn. <sup>b</sup> | 12 U                                            |
| <i>L. peltata</i> (Ram.) Steud.                                         | 31 C                                            |
| <i>L. piniperda</i> f. <i>nigrescens</i> Korb.                          | 56 A                                            |
| <i>L. piniperda</i> f. <i>piniperda</i> Korb.                           | 38 C                                            |
| * <i>L. polytropa</i> (Ehrh.) Rabenh.                                   | K                                               |
| <i>L. rupicola</i> (L.) Zahlbr.                                         | 19 A                                            |
| <i>L. varia</i> (Ehrh.) Ach.                                            | 62 C                                            |
| <i>L. sp.</i> [" <i>albescens</i> "]                                    | 62 U                                            |
| <i>L. sp.</i> [" <i>beringii</i> "]                                     | 19 U                                            |
| <i>L. sp.</i> [" <i>mastrucata</i> "]                                   | 6 U                                             |
| <i>Lecidea aenea</i> (Duf.) Nyl.                                        | 31 U                                            |
| <i>L. atrobrunnea</i> (Ram.) Schaer.                                    | 44 C                                            |
| <i>L. crustulata</i> (Ach.) Spreng.                                     | 6 U                                             |
| <i>L. decipiens</i> (Hedw.) Ach.                                        | 56 A                                            |
| <i>L. globifera</i> Ach.                                                | 19 U                                            |
| <i>L. lithophila</i> (Ach.) Ach.                                        | 50 C                                            |
| <i>L. luridella</i> Tuck.                                               | 81 A                                            |
| <i>L. lyngei</i> Degel.                                                 | 50 C                                            |
| <i>L. macrocarpa</i> (DC.) Steud.                                       | 25 U                                            |
| <i>L. novomexicana</i> (B. de Lesd.) W. Web.                            | 31 C                                            |
| <i>L. rivulosa</i> Ach.                                                 | 6 C                                             |
| <i>L. rufonigra</i> (Tuck.) Nyl.                                        | 44 C                                            |
| <i>L. russellii</i> Tuck.                                               | 38 C                                            |
| <i>L. scalaris</i> (Ach.) Ach.                                          | 12 U                                            |
| <i>L. stigmathea</i> Ach.                                               | 62 A                                            |
| <i>L. tessellata</i> (Sm.) Flk.                                         | 56 A                                            |
| <i>L. turgidula</i> Fr.                                                 | 75 C                                            |
| <i>L. sp.</i> [" <i>berengeriana</i> "]                                 | 19 U                                            |
| <i>Letharia vulpina</i> (L.) Hue                                        | 12 U                                            |
| <i>Microthelia aterrima</i> (Anzi) Zahlbr.                              | 12 U                                            |

Table 2. (continued)

| Species                                                          | Percent of Sites<br>at Which Found <sup>a</sup> |
|------------------------------------------------------------------|-------------------------------------------------|
| <i>Parmelia elegantula</i> (Zahlbr.) Szat.                       | 56 C                                            |
| <i>P. exasperatula</i> Nyl.                                      | 44 A                                            |
| * <i>P. loxodes</i> Nyl.                                         | B                                               |
| <i>P. mexicana</i> Gyeln.                                        | 6 C                                             |
| * <i>P. plittii</i> Gyeln.                                       | K                                               |
| <i>P. saxatilis</i> (L.) Ach.                                    | 6 C                                             |
| <i>P. subaurifera</i> Nyl.                                       | 19 U                                            |
| <i>P. subolivacea</i> Nyl.                                       | 31 C                                            |
| <i>P. substygia</i> Ras.                                         | 12 U                                            |
| <i>Physcia adscendens</i> (Th.Fr.) Olive.                        | 12 C                                            |
| <i>Ph. aipolia</i> (Ehrh.) Hampe                                 | 6 U                                             |
| <i>Ph. millegrana</i> Degel.                                     | 12 C                                            |
| <i>Ph. tenella</i> D. C. em Britt.                               | 6 U                                             |
| <i>Polyblastiopsis lactea</i> (Mass.) Zahlbr.                    | 56 C                                            |
| <i>Rhizocarpon disporum</i> (Naeg. ex Hepp) Mull. Arg.           | 25 C                                            |
| <i>Staurothele catalepta</i> (Ach.) Blomb. & Forss. <sup>b</sup> | 12 U                                            |
| <i>S. clopima</i> (Wahlenb. ex Ach.) Th.Fr. <sup>b</sup>         | 50 C                                            |
| <i>Teloschistes chrysophthalmus</i> (L.) Th. Fr.                 | 25 U                                            |
| * <i>Umbilicaria hyperborea</i> (Ach.) Hoffm.                    | B                                               |
| * <i>U. krascheninnikovii</i> (Sw.) Zahlbr.                      | B                                               |
| * <i>U. virginis</i> Schaer.                                     | B                                               |
| * <i>Verrucaria virens</i> Nyl.                                  | R                                               |
| <i>Xanthoria candelaria</i> (L.) Th.Fr.                          | 94 A                                            |
| <i>X. elegans</i> (Link) Th.Fr.                                  | 19 C                                            |
| <i>X. fallax</i> (Hepp) Arn.                                     | 31 C                                            |
| <i>X. polycarpa</i> (Ehrh.) Olive.                               | 88 A                                            |

a. The abundance of each taxon is indicated by a letter following the percent of sites at which the taxon was found: A = abundant, C = relatively common, U = uncommon or rare. An asterisk (\*) preceding the name of a taxon indicates it was found either on East Butte (B), on the ridge northeast of Kyle Canyon (K), or in previously collected material that was re-examined in the process of curating (R).

b. Professor Wetmore has pointed out that what has been called *Acarospora smaragdula* in this report may be a variant of *A. americana*. He also suggests that *Caloplaca lamprocheila* may be synonymous with *C. arenaria*, *C. pyracea* synonymous with *C. holocarpa*, *Lecanora novomexicana* synonymous with *L. nipponica*, and the *Staurothele catalepta* - *S. clopima* complex synonymous with *S. fuscocuprea*.

c. Identification of the species marked "tent" or "sp." is uncertain, as indicated in the text.



a. *Parmelia exasperatula* Nyl. on juniper.



b. *Xanthoria polycarpa* (Ehrh.) Oliv. and *X. candelaria* (L.) Th.Fr. on sagebrush.

Figure 3. Examples of common corticolous lichen species on the INEL.



a. *Collema coccophorum* Tuck.

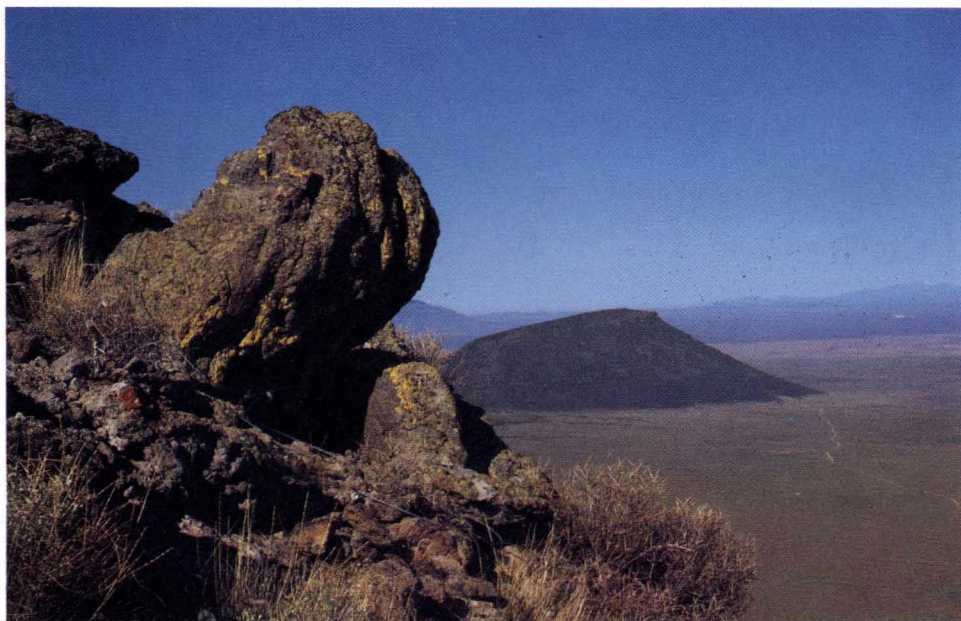


b. *Lecidea luridella* Tuck.

Figure 4. Examples of common terricolous lichen species on the INEL.



a. Orange *Caloplaca* and *Candelariella* species on basaltic outcropping.



b. Chartreuse *Acarospora chlorophana* (Wahlenb. ex Ach.) Mass. and *A. schleicheri* (Ach.) Mass. on East Butte.

Figure 5. Examples of common saxicolous lichen species on the INEL.

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**APPENDIX A**  
**KEY TO THE LICHENS OF THE INEL**

## APPENDIX A

### KEY TO THE LICHENS OF THE INEL

Refer to the "Lichen Morphology and Identification" section and to the glossary in Hale (1979) for descriptions of terms and to the frontispiece in Hale (1979) for colors.

1. Growth form fruticose or stemlike with a cortex surrounding the entire thallus which is attached at one end to the substrate ..... Go to "How to Know the Lichens" (Hale 1979), p. 168
1. Growth form foliose or leaflike with distinct upper and lower surfaces, lower cortex usually present; thallus attached to the substrate by a single umbilicus, by several root-like rhizines, or by numerous minute hyphae extending from the lower cortex into the substrate ..... 2
1. Growth form crustose (areolate or squamulose), lacking a distinct lower surface or lower cortex but with an upper cortex, algal layer, and medulla usually present ..... 12
  2. Lichen gelatinous in appearance when wetted; phycobiont a cyanophyte; color of thallus lead gray to bluish black; little or no differentiation of tissues or strata apparent  
..... Go to "How to Know the Lichens" (Hale 1979), page 147
  2. Lichen not gelatinous in appearance when wetted; phycobiont generally a green alga; color of thallus yellow green, brown, bright green, yellow, or orange; distinct differentiation of tissues in the thallus ..... 3
3. Thallus attached to the substrate at a single point by an umbilicus ..... 4
3. Thallus attached to the substrate at numerous points, either by rhizines or by hyphae growing out of the lower cortex ..... 7

#### 4. UMBILICATE LICHENS

4. Upper cortex yellowish green to gray; apothecia lecanorine, flat to slightly concave when mature ..... 5
4. Upper cortex brown to black; apothecia, if present, lecideine, usually slightly convex, otherwise perithecia present ..... Go to "How to Know the Lichens" (Hale 1979), p. 159
5. Disk of apothecium dark green to nearly black; lower cortex usually smoky gray to black with tan margins, upper cortex yellowish green; flavor bitter ..... *Lecanora melanophthalma*
5. Disk of apothecium tan to brown or reddish; lower cortex usually tan with dark brown or black margin; flavor pleasant ..... 6
6. Thallus mineral gray; apothecial disks reddish brown to salmon colored ... *Lecanora chrysoleuca*
6. Thallus yellowish green; apothecial disks tan to brown; lower surface usually with reticulate white cracks ..... *Lecanora peltata*

## 7. "STRATIFIED" FOLIOSE LICHENS

7. Apothecia lecanorine and rhizines absent; plant body usually <4 cm in diameter and attached to the substrate by numerous hyphae; center of thallus often areolate ..... 8
7. Apothecia lecideine or if lecanorine, rhizines present; plant body often >4 cm in diameter, attached to substrate by simple or branched rhizines; thallus not areolate  
..... Go to "How to Know the Lichens" (Hale 1979), p. 29
8. Thallus lobes tightly appressed, brownish gray, cortex K + deep red ..... *Lecanora alphoplaca*
8. Thallus lobes free to appressed, yellowish green, cortex K + yellow or K - ..... 9
9. With marginal lobes that are flat or convex but not distinctly inflated; apothecia with white to light green rims ..... 10
9. With marginal lobes that are distinctly inflated; rims of apothecia not white or light green ..... 11
10. Apothecial disks black with light green rims; thallus often >4 cm in diameter, areolate to the margin, if margins are effigurate, the lobes are convex ..... *Lecanora novomexicana*
10. Apothecial disks tan to brown with white rims; thallus effigurate with flat to slightly concave lobes ..... *Lecanora muralis*
11. Medulla thick and dense, easily sectioned; thallus lobes not plicate; apothecia convex, ochre brown, the color contrasting with the thallus color ..... *Lecanora christoi*
11. Medulla thin and cottony, not easily sectioned; lobes plicate; apothecia concave, greenish brown ..... *Lecanora garovaglii*

## 12.

12. Pseudocyphellae (white dots on upper surface) present (do not confuse with pruinosity on cortex) ..... *Lecanora desertorum*
12. Pseudocyphellae not present, but cortex may be pruinose ..... 13
13. Growth form squamulose, the thallus consisting of scale-like squamules usually overlapping each other; growing on soil or on rock, usually in cracks where soil has accumulated, or occasionally on wood, especially burned wood ..... 14  
See also Hale (1979), p. 230
13. Growth form areolate, the thallus either granular or consisting of square or angular areoles, or lacking; growing on rock or bark, less commonly on soil or other substrate ..... 20

## 14. SQUAMULOSE LICHENS

14. On wood, especially on burned wood; cortex C + red; apothecia plane; margins of squamules sorediate ..... *Lecidea scalaris*
14. On soil or rocks; cortex C - ; apothecia convex to globose; squamules not sorediate ..... 15

15. Squamules having upturned white margins or undersurface of squamules white and squamules ascending, thus giving the appearance of having white margins; perithecia never present ..... 16
15. Squamules not having upturned white margins, generally appressed or, if ascending, not exposing a white undersurface or else with perithecia present ..... 18
16. Thallus red to pink, often very pruinose and thus appearing white; common on calcareous clay soils; apothecia brown, smooth, globose, mostly or entirely on margins of the squamules, often becoming quite large ..... *Lecidea decipiens*
16. Thallus brown, not pruinose; on rocks or thin soil, usually non-calcareous; apothecia black, flat to convex, laminal, never marginal, relatively small ..... 17
17. The squamules ascending, thallus almost fruticose in appearance; lower cortex white, upper cortex gray to gray brown; substrate HCl – ..... *Lecidea novomexicana*
17. The squamules appressed, not appearing fruticose; lower cortex white, upper cortex brown; substrate usually HCl + ..... *Lecidea russellii*
18. Margin of thallus bluish black, flat or slightly upturned; thallus chestnut brown to olive brown; apothecia numerous, small, brown ..... *Lecidea rufonigra*
18. Margin of thallus not bluish, squamules appressed to convex; thallus chestnut red to brown; apothecia brown to black ..... 19
19. Pruina abundant, white on chestnut red squamules; margins adnate to very convex; apothecia brown, laminal, flat, often cracked and/or angular ..... *Lecidea luridella*
19. Pruina sparse or lacking, squamules greenish gray to reddish brown; apothecia dark brown to black, smooth, strongly convex ..... *Lecidea globifera*
19. Pruina lacking, squamules olive green to liver brown, convex; apothecia never present but perithecia present ..... 45

## 20. AREOLATE AND GRANULAR CRUSTOSE LICHENS

20. Lichens bright lemon yellow to orange ..... 21
20. Lichens gray, brown, black, white, yellowish green, or chartreuse, not bright lemon yellow to orange ..... 36
21. Growing on soil ..... 22
21. Growing on rock, bark, wood, or on other lichens ..... 25
22. Cortex K + purple ..... 23
22. Cortex K – ..... *Candelariella rosulans*
23. Areoles consisting of apothecia with very little or no surrounding thallus; thallus, if present, yellow; apothecia yellow orange to rusty red; spores polarilocular (having two cells separated by an isthmus) ..... *Caloplaca geophila*

23. Areoles consisting of abundant yellow to yellow orange thallus with apothecia present on some of the areoles; apothecia yellow to yellow orange; spores not polarilocular ..... 24
24. Substrate usually HCl – ; thallus yellow, granular non-effigurate; spores two-celled (but not polarilocular) ..... *Fulgensia desertorum*
24. Substrate HCl + ; thallus yellow to yellow orange, areolate to squamulose at margins; spores one-celled ..... *Fulgensia fulgens*
25. Apothecia or thallus or both K + purple, usually orange ..... 26
25. Apothecia and thallus both K – , yellow ..... 32
26. Growth form effigurate, thallus orange and abundant ..... 27
26. Growth form areolate, thallus yellow to orange and relatively abundant ..... 29
26. Growth form endolithic to areolate, thallus gray and scanty or lacking ..... 30
27. Thallus appressed but free from substrate; lower cortex present; lobes finely dissected, 0.3 to 0.6 mm broad, wider at apex; thallus deep red orange ..... *Xanthoria elegans*
27. Thallus attached to the substrate; lower cortex absent; lobes less finely dissected, typically 1.0 to 1.5 mm broad, often areolate to the margin; if finely dissected, yellow orange ..... 28
28. Lobes plane, often areolate; thallus red orange ..... *Caloplaca saxicola*
28. Lobes inflated or verrucose; thallus yellow orange ..... *Caloplaca trachyphylla*
29. Areoles lemon yellow, verrucose, dissolving into granular soredia; apothecia usually lacking; growing on calcareous rock ..... *Caloplaca citrina*
29. Areoles buff, thallus relatively scanty, non-sorediate; apothecia rusty red; growing on stone or bark ..... *Caloplaca fraudans*
29. Areoles deep red, flat, thallus abundant, bordering on foliose, growing on rock, usually HCl – ..... *Caloplaca saxicola*
30. Growing on other lichens, usually on HCl – species of *Acarospora*, *Candelariella*, or *Lecanora*; apothecial disks scarlet red to carmine, plane ..... *Caloplaca epithallina*
30. Growing on rock, bark, wood, or bone; apothecial disks yellowish orange to dark red brown, usually convex ..... 31
31. Apothecial disks bright orange, margin same color as disks; apothecia very small and numerous; thallus very scant or absent; common on poplar or cottonwood bark, but also occurring on rock and wood ..... *Caloplaca pyracea*
31. Apothecial disks dark yellowish orange with a persisting gray margin; thallus gray; on bark or rock ..... *Caloplaca cerina*
31. Apothecial disks and margin dark red brown; thallus absent; on HCl – rocks or on bone ..... *Caloplaca lamprocheila*

32. Thallus granular, sorediate, often reduced to a mass of granular soredia; growing on bark or wood; apothecia rare ..... *Candelariella xanthostigma*
32. Thallus squamulose or with elongated, ascending areoles that are almost fruticose, with black pycnidia or isidia; apothecia rare ..... *Candelariella dispersa*
32. Thallus areolate to granular, neither sorediate nor isidiate; apothecia abundant ..... 33
33. Habitat corticolous (growing on bark); thallus scant or lacking; apothecia scattered; disks plane, yellow, with greenish yellow rims ..... *Candelariella deflexa*
33. Habitat saxicolous, lignicolous, or terricolous; apothecia scattered to abundant with convex to concave yellow to greenish yellow disks, yellow rims ..... 34
34. Areoles scattered, relatively large; apothecia with greenish yellow concave disks and bright yellow rims; growing on moss, detritus, or HCl+ rock ..... *Candelariella aurella*
34. Areoles close, small to granular, sometimes slightly effigurate; apothecia with bright yellow disks and rims, plane to slightly convex or slightly concave; usually on HCl- rock, soil, wood, or bark ..... 35
35. UV+; apothecia bright yellow, plane to slightly convex; asci with 8 spores; growing on rock (HCl+ or HCl-) or soil ..... *Candelariella rosulans*
35. UV-; apothecia bright yellow, plane to slightly concave; asci with 12 or more spores; growing on HCl- rock, bone, or wood ..... *Candelariella vitellina*
36. Growing on rock or on soil ..... 37
36. Growing on bark or on wood ..... 75
37. Lichens bright sea foam green or chartreuse, usually growing on vertical cliffs; not scruffy; apothecia sunken ..... 38
37. Lichens dark brown to black, often scruffy appearing, growing on various substrates but generally not on cliffs; apothecia if present, either sunken or adnate, or perithecia may be present, typically discernable as black dots on the surface of the cortex, usually in the center of a slightly raised "pimple" ..... 39
37. Lichens gray, chestnut brown, yellowish green, or other color, but not chartreuse, black, or dark brown, and generally not scruffy; usually not on cliffs; apothecia, if present, sunken, adnate, or raised; perithecia usually lacking (but pycnidia may be present as black, unraised dots on the surface of the cortex) ..... 43
38. Margin of thallus effigurate; found primarily on cliffs at high elevations or in forest habitats ..... *Acarospora chlorophana*
38. Margin of thallus areolate to granulose; found primarily on cliffs in desert or semidesert habitats ..... *Acarospora schleicheri*

### 39. SAXICOLOUS BLACK AND DARK BROWN CRUSTOSE LICHENS

39. Apothecia present, immersed or raised ..... 40

39. Apothecia lacking, but perithecia present ..... 41
40. Thallus dark brown, areoles convex; apothecia raised, brown with dark brown to black rim; spores fusiform (long and narrow), 8 per ascus ..... *Lecanora badia*
40. Thallus black, areoles flat; apothecia immersed in both immature and mature specimens; spores small, globose, more than 100 per ascus ..... *Acarospora smaragdula*
41. Areoles globose, black, and very small (0.1 to 0.4 mm), when young, becoming convex with wrinkled surface (0.5 to 1.5 mm in diameter) and dark brown; perithecia immersed; spores nonseptate ..... *Verrucaria virens*
41. Areoles warty, black, becoming gray, with raised black perithecia which superficially resemble lecideine apothecia (cut with razor blade or knife and examine with hand lens); spores 1-3 septate ..... *Microthelia aterrima*
41. Areoles flat, angular, dark brown to black, with immersed perithecia; spores muriform ..... 42
42. Hymenial algal cells elongated; ostioles slightly raised; vigorous lichens often surrounded by a black prothallus ..... *Staurothele catalepta*
42. Hymenial algal cells round; ostioles slightly sunken; less vigorous; black prothallus never present ..... *Staurothele clopima*
43. Thallus deep tan to liver brown or chestnut red ..... 44
43. Thallus grayish brown to white, yellow green, or lacking ..... 51

#### 44. BROWN AREOLATE TO SQUAMULOSE LICHENS

44. Growing on soil, sometimes a very thin layer of soil in cracks in rocks; areoles large, scattered, more or less squamulose or subfoliose, rhizines present; reproduction by means of perithecia ..... 45
44. Growing directly on rock; areoles usually neither squamulose nor scattered, rhizines lacking; reproduction by means of apothecia ..... 46
45. Hymenium I+ blue; lobes olive green, overlapping; spores large (9 x 16  $\mu\text{m}$  average size) ..... *Dermatocarpon lachneum*
45. Hymenium I+ red; lobes liver brown, not overlapping; spores small (7 x 13  $\mu\text{m}$  average size) ..... *Dermatocarpon hepaticum*
46. Apothecia distinctly immersed ..... 47
46. Apothecia sessile or slightly immersed to distinctly raised ..... 48
47. Inner cortex (in thin sections) K+ fleeting red; areoles sometimes scattered; apothecial disks reddish to dark brown ..... *Acarospora fuscata*
47. Inner cortex K-; areoles close; apothecial disks dark brown to black ..... *Acarospora americana*

48. Cortex K+ yellow, UV+; areoles pale brown, young areoles almost white; apothecia raised, red brown; growing on HCl+ rock ..... *Lecidea lyngei*
48. Cortex K-, UV-; areoles darker brown; apothecia slightly immersed to raised; growing on HCl- rock ..... 49
49. Areoles fleshy, sub-squamulose; apothecia rounded ..... 50
49. Areoles dry, hard, often cracked; apothecia angular ..... *Lecidea aenea*
50. Apothecia brown with prominent black rim, sessile to slightly immersed, large (1-2 mm); areoles brown, no noticeable prothallus present ..... *Acarospora badiofusca*
50. Apothecia brown with no contrasting rim, distinctly raised, small (mostly <0.5 mm); areoles brown, no prothallus present ..... *Lecidea rivulosa*
50. Apothecia black with no contrasting rim, distinctly raised, small (0.5-1 mm); areoles dark brown with black prothallus ..... *Lecidea atrobrunnea*

## 51. WHITE OR GRAY TO YELLOW GREEN AREOLATE LICHENS

51. Thallus very scanty, areoles consisting mostly or entirely of apothecia ..... 52
51. Thallus more or less abundant, with or without apothecia or apothecia-like sporocarps on the areoles ..... 53
52. Disks of apothecia orange-red to black with white rim; thallus, if present, gray, K+ yellowish, margins very crenulate with one or more fissures across the apothecial surface; on rock ..... *Lecanora crenulata*
52. Disks tan to brown; thallus, if present, K- with entire margins and no fissures across the apothecia; on rock ..... *Lecanora dispersa*
52. Disks white; thallus white, smooth, K+ yellow; on soil or on terricolous mosses ... *Lecanora* sp. ["*beringii*"]
53. With white to irridescent violet, usually somewhat scattered, areoles with sunken, crater-like apothecia; thallus strongly fluorescent in ultraviolet light ..... *Acarospora strigata*
53. With gray to yellowish green, usually close areoles; sporocarps if present, immersed, sessile, or raised; ..... 54
54. Thallus yellow green, scanty to very abundant, areolate to almost foliose, margins often effigurate ..... 55
54. Thallus mineral gray to white, grayish green or dirty gray, but not yellow green, scanty to abundant, areolate to granular ..... 57
55. Areoles greenish yellow, sometimes almost lemon yellow; thallus scanty to relatively abundant; apothecia yellow to flesh colored ..... *Lecanora polytropa*
55. Areoles yellowish green; thallus very abundant, often > 10 cm in diameter; apothecia black or brown ..... 56

56. Margin of thallus flat, black, effigurate; apothecial disks brown ..... *Lecanora nigromarginata*
56. Margin of thallus convex, yellow green, or sometimes black; apothecial disks black; thallus often areolate to the margin, but occasionally effigurate ..... *Lecanora novomexicana*
57. Thallus very light gray to white, K – ..... 58
57. Thallus light brown or tan to dirty gray; if white, K + ..... 59
58. Areoles scattered, very convex to globose with concave apothecia at top of areole; apothecial disks black, pruinose; spores large (avg. 20 x 25  $\mu$ m), 2-6 per ascus; usually growing on HCl + rock ..... *Lecanora calcarea*
58. Areoles granular becoming continuous, smooth, and flat; mature apothecia raised, very black, not at all pruinose; spores smaller, 8 per ascus; hymenium distinctly purple; growing on HCl – rock ..... *Lecanora atra*
58. Areoles continuous, rimose, flat; apothecia slightly concave with dark brown, pruinose, disks ..... *Lecanora* sp. [“albescens”]
59. Cortex K + yellow or red; thallus abundant, effigurate or noneffigurate, areolate to subfoliose .... 60
59. Cortex K – ; thallus noneffigurate, areolate to granular ..... 66
60. K + red; apothecia, if present, immersed; medulla K + red ..... *Lecanora cinerea*
60. K + yellow turning red; apothecia raised or lacking; if apothecia lacking, soredia present, K + red ..... 61
60. K + yellow; apothecia usually abundant, raised or immersed; if apothecia lacking, medulla K – ..... 62
61. Soredia present and abundant; thallus areolate, the areoles often becoming a mass of granular soredia; apothecia rare or lacking ..... *Lecanora* sp. [“mastrucata”]
61. Soredia lacking; thallus areolate to subfoliose with convex effigurate margins; apothecia abundant ..... *Lecanora alphoplaca*
62. Apothecia immersed in the thallus, either permanently so or because of immaturity, or apothecia not present ..... 63
62. Apothecia sessile or raised above the thallus ..... 65
63. Pycnidia (black, unraised dots on surface of the cortex) common; apothecia rare, but if present, the exciple is thalloid (rim of apothecium contains algae and is same color as the thallus); cortex K + very pale yellow ..... *Lecanora caesiocinerea*
63. Pycnidia absent; apothecia common, exciple proper (rim without algae, same color as disk); cortex K + distinct yellow ..... 64
64. Areoles small (0.5-1 mm), flat to slightly convex, angular, continuous, distinctly UV + , C – ; apothecia large, black, raised when mature, disks flat, somewhat pruinose; spores simple, clear ..... *Lecidea tessellata*

64. Areoles relatively small (0.5-1.5 mm), flat, wart-like, continuous and crowded, greenish gray to ashy white, C + red, UV slightly + ; apothecia relatively small, immersed to adnate, deeply concave, black or grayish pruinose; spores muriform, 4-8 per ascus ..... *Diploschistes scruposus*
64. Areoles large (1-2 mm), flat to convex, rounded, continuous to scattered, C – , UV – ; apothecia brown to black, immersed when mature; disks flat to convex, never pruinose ... *Lecidea stigmatea*
65. With very small areoles and small, black lecanorine apothecia with white rims and large clumps of clear oxalate crystals usually in the margins ..... *Lecanora cenisia*
65. With relatively small (0.5-1 mm) areoles and prominent lecideine apothecia ..... *Lecidea tessellata*
66. Pycnidia common, apothecia rare, immersed in thallus; thallus rimose areolate to margin ..... *Lecanora caesiocinerea*
66. Pycnidia lacking, apothecia common, immersed, sessile, or raised; thallus areolate to granular ..... 67
66. Pycnidia lacking but perithecia present, resembling raised, black, lecideine apothecia until sectioned; thallus areolate to granular ..... *Microthelia atterima*
67. Apothecia immersed to adnate ..... 68
67. Apothecia distinctly raised above the thallus ..... 71
68. Growing on moss or soil, occasionally with or on other lichens; areoles greenish gray, C + yellow, dispersed, globose; apothecia concave ..... *Lecidea* sp. [“*berengeriana*”]
68. Growing on rock; areoles distinctly gray, C – , continuous, convex to flat; apothecia flat to slightly concave ..... 69
69. Thallus distinctly UV + ; immature apothecia immersed, brownish; mature apothecia adnate, black ..... *Lecidea lithophila*
69. Thallus UV – ; apothecia black, even when immature, or dark brown and pruinose, raised when mature ..... 70
70. Areoles very convex, essentially globose, lead gray, almost blue with large, flat, black apothecia, adnate when immature; areoles resemble miniature cobblestones ..... *Rhizocarpon disporum*
70. Areoles flat, rimose, light gray; apothecia dark brown, pruinose, slightly convex ..... *Lecanora* sp. [“*albescens*”]
71. With lecanorine apothecia, the exciple containing algal cells, same color as thallus; thallus dirty gray ..... 72
71. With lecideine apothecia, the exciple without algal cells, usually similar in color to the disks; thallus greenish gray to brown ..... 73
72. Disks C + orange; thallus well developed, often covering many square centimeters of rock surface; apothecia abundant, greenish gray, concave; substrate mostly HCl – ..... *Lecanora rupicola*

72. Disks C – ; thallus scanty; apothecia dark brown, pruinose, slightly convex; substrate mostly HCl+ ..... *Lecanora* sp. [“*albescens*”]
73. The thallus well developed with closely packed, very convex to globose (“cobblestone-like”), lead gray to almost blue areoles on a black hypothallus ..... *Rhizocarpon disporum*
73. The thallus scanty to relatively well developed with ashy gray to brown, flat to slightly convex areoles ..... 74
74. Apothecia red brown; thallus dirty gray to brown; apothecial sections K + red .... *Lecidea lyngei*
74. Apothecia olivaceous to dark brown; thallus greenish gray to ashy; apothecial sections K – ; apothecia relatively small (0.5-1.5 mm) ..... *Lecidea crustulata*
74. Apothecia blackish brown to distinctly black; thallus gray to greenish gray; apothecial sections K – ; apothecia relatively large (0.4-2.5 mm) ..... *Lecidea macrocarpa*

## 75. CORTICOLOUS CRUSTOSE LICHENS

75. Having abundant black or bluish black thallus with or without apothecia ..... 76
75. Having scanty, gray thallus or thallus lacking; apothecia abundant ..... 77
76. Thallus becoming gelatinous blue when wet; apothecia usually present assembled into a mound or cone-shaped conglomeration; on various trees and shrubs ..... *Collema conglomeratum*
76. Thallus not becoming gelatinous when wet; perithecia with large ostioles at the apex of a slightly raised neck usually present; common on sagebrush ..... *Polyblastiopsis lactea*
77. Apothecia lecanorine, black, tan, or gray; thallus scant but usually present ..... 78
77. Apothecia lecideine, black, thallus scant or lacking ..... 81
78. Disk of apothecia black or gray, rim gray; thallus gray but scant ..... 79
78. Disk of apothecia tan, rim white or yellow green; thallus yellow green or lacking ..... 80
79. Ascocarps black with gray rims ..... *Lecanora piniperda* f. *nigrescens*
79. Ascocarps gray ..... *Lecanora piniperda* f. *piniperda*
80. Rim of apothecia white; thallus, if present, gray, pruinose ..... *Lecanora hageni*
80. Rim of apothecia yellow green; thallus yellow green, often slightly pruinose ..... *Lecanora varia*
81. Apothecial disk concave; spores non-septate, hyaline ..... *Lecidea turgidula*
81. Apothecial disk flat to convex; spores 1-septate, brown ..... *Buellia punctata*

## **APPENDIX B**

### **DESCRIPTIONS OF GENERA**

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### DESCRIPTIONS OF GENERA

The family to which each genus belongs and the number of species known from North America north of Mexico is indicated in parentheses following each genus name. Two species not included in Hale (1979) are described. Classification follows Henssen and Jahns (1974). The number of species in each genus is taken primarily from Hale and Culberson (1970).

Some of the large genera are frequently divided into smaller genera by some taxonomists. When the traditional genus forms a neat continuum without distinctive characteristics separating the segregated groups, many taxonomists, for example Aino Henssen, object to such segregating as unnecessary splitting. Since Hale is a "splitter," the segregate genera that will be encountered in material from the INEL have been indicated in the following list as an aid in the use of Hale's "How to Know the Lichens."

**Acarospora** (Acarosporaceae, 93) Typical crustose lichens of the deserts and mountains, characterized by sunken, crater-like apothecia, small, unicellular, colorless spores, and more or less spherical asci containing large numbers of spores (often >100). Most species are liver brown to gray in color, but two very common Idaho species are bright yellow green or chartreuse; some species that colonize slag dumps are reddish.

**Agrestia** (Lecanoraceae, 1) Brittle, gray fruticose lichens of arid and semi-arid, cold areas; widespread in the great plains and Great Basin. Spores small, colorless, eight per ascus; apothecia rare. *A. hispida* is now believed by some lichenologists to be an environmentally induced variant of *Lecanora desertorum*.

**Anaptychia** (Physciaceae, 3) White or gray foliose lichens of forested areas characterized by K - cortex, lecanorine apothecia, brown 2-celled spores with thin walls, and well-developed rhizines. Difficult to distinguish from *Physcia* and *Heterodermia*.

**Buellia** (Physciaceae, 60) Crustose lichens characterized by lecideine apothecia, nondescript gray to brown color with the thallus usually growing on a black prothallus, and septate, brown spores, widespread from the arctic and antarctic regions to the

tropics. The *Buellias* favor dusty habitats. Not all *Buellias* are lichenized; some are saprophytes and others are parasitic on other lichens. The genus characteristics overlap with those of *Rinodina*; the two genera are artificially separated by the presence of lecanorine apothecia in the latter.

**Caloplaca** (Teloschistaceae, 96) Orange, yellow, or sometimes gray crustose lichens characterized by the presence of parietin in the cortex and/or apothecia (K + purple) and by polarilocular spores (2-celled with a thick wall between the cells and an isthmus connecting them). This genus intergrades with *Xanthoria*, and a good case could be made for combining the two genera or even for including both in the genus *Teloschistes*. *Caloplaca* is probably the most xeric of the three genera, and several species are very common and widespread on desert rocks and cliffs throughout the West. Our most abundant species, *Caloplaca trachyphylla*, is also known as *Xanthoria elegans* var. *trachyphylla*. Some species have lecanorine apothecia, while others have lecideine apothecia.

**Candelaria** (Candelariaceae, 2) A small genus of small, foliose lichens which are very common on trees. They are closely related to the *Lecanoras*. Thallus and/or apothecia contain a bright yellow pigment; there are eight or more colorless, single celled spores in each ascus.

**Candelariella** (Candelariaceae, 15) Yellow crustose lichens usually found on rocks but also occurring on bark and on soil. The thallus may be granular or areolate, but not foliose; this is the only characteristic separating it from *Candelaria*.

**Collema** (Collemataceae, 35) Gelatinous lichens of the temperate zone and mountainous areas of the tropics, usually foliose. Lack soredia but often have isidia. Phycobiont is always a species of *Nostoc*. Spores unicellular to muriform.

*Collema texanum* will key out in Hale (1979) to *C. coccophorum* but differs in flat rather than swollen lobe tips and squamulose rather than globose isidia. Isidia are almost always present in *C. texanum*, but are rare in *C. coccophorum*.

Degelius (1954) includes both species under *C. coccophorum*.

**Dermatocarpon** (Verrucariaceae, 25) Squamulose or umbilicate lichens of Arctic and temperate zones. Perithecia are often sunken in the thallus; they do not have an involucrellum. There are one to eight brown or colorless spores per ascus. Pycnidia are often present. Species of *Dermatocarpon* are easily confused with sterile *Umbilicarias*; however, perithecia are usually abundant. Like *Umbilicaria*, they may have either veins or rhizines—or both—on the undersurface of the thallus.

*Dermatocarpon hepaticum* and *D. lachneum* are often combined in a single species, *D. lachneum* (Hale 1979). *D. hepaticum* differs in having a brown rather than an olive green thallus, in not having imbricated lobes, and in having an I+ red hymenium instead of I+ blue. The spores are also smaller with little or no overlap in spore size.

**Diploschistes** (Thelotre mataceae, 6) Gray, saxicolous, crustose lichens having a poorly developed upper cortex which consists only of tangled hyphae, and well developed algal layer and medulla. There are two to eight brown, ellipsoid, multicellular or muriform spores per ascus borne in lecideine apothecia.

**Fulgensia** (Teloschistaceae, 3) Yellow crustose lichens common on clay and silt soils of desert areas, characterized by presence of parietin in the cortex and apothecia (K+ purple). They are closely related to *Caloplaca*, but have unicellular or simple 2-celled spores, not polarilocular spores. The thallus is granular to areolate and resembles *Candelariella* in color, but is easily distinguished by the K+ purple reaction of the thallus and apothecia.

**Heterodermia** (Physciaceae, 13) Foliose, largely tropical and sub-tropical genus, formerly included in *Anaptychia* but differing from the latter in some chemical characteristics (e.g., K+ yellow cortex), spore structure, and distribution, the *Anaptychias* being adapted to temperate and colder climates. Spores are smooth, brown, 2-celled, often with a very thick septum.

**Lecanora** (Lecanoraceae, 168) Typical crustose lichens of cold, dry habitats; however, many species are foliose or umbilicate and at least one, *L. esculenta*, the manna of the Old Testament, is fruticose. Foliose species resemble small *Parmelias* but lack rhizines. This is a

very large genus with over 1100 species. The apothecia are usually surrounded by a light colored rim containing algal cells. Usnic acid gives a yellowish green color to the cortex of many species and may be responsible for the antibiotic characteristics many *Lecanoras* (and other lichens) possess. The spores are small, colorless, and unicellular. Segregate genera include *Aspicilia*, *Rhizoplaca*, and others.

**Lecidea** (Lecideaceae, 244) Typical crustose and squamulose lichens of cold, dry climates, probably closely related to the *Lecanoras*. In number of species, this is believed to be the largest genus of plants, over 2000 species having been described. The spores are small, colorless, and unicellular. Apothecia are usually dark brown or black and often are surrounded by a very dark, slightly raised rim which does not contain algal cells. A commonly cited segregate genus is *Psora*.

**Letharia** (Parmeliaceae, 2) Bushy, fruticose lichens which are very common in the West on trees at or near timberline. The chartreuse color is caused by vulpinic acid. Because of the angular, flabby thallus, the genus was formerly included in *Evernia*. The apothecia are lecanorine, and each ascus contains eight unicellular, colorless spores.

**Microthelia** (Arthopyreniaceae, 9) Crustose facultative lichens, usually found on bark but some species occur on rock. The younger parts of the plant generally have no algal layer and the mycobiont can apparently survive without the phycobiont under natural conditions. The paraphyses extend to the mouth of the perithecia, which are rather open so that they almost resemble very immature apothecia.

**Parmelia** (Parmeliaceae, 141) Large, shield-like foliose lichens of world-wide distribution common on bark and occurring also on rock and on soil. Apothecia are lecanorine and develop from an ascogonium characterized by a long trichogyne. There are over 600 species worldwide, most abundant in forested areas of the north temperate zone. Hale and others have split the genus into several segregate genera, but most lichenologists are reluctant to accept the splitting partly because it depends primarily on the presence or absence of particular lichen pigments. Segregate genera in Hale (1979) include *Neofuscelia*, *Parmelina*, *Pseudoparmelia*, and *Xanthoparmelia*.

**Physcia** (Physciaceae, 42) Rather small, mineral gray, shield-like foliose lichens of worldwide distribution especially common on bark and on rock of temperate forests. Very similar in appearance to *Parmelia* except for size and color. Rhizines attach the thallus to the substrate. Apothecia are lecanorine and the asci usually have eight brown, 2-celled spores with thin walls. Several genera of non-lichenized fungi are included in the Physciaceae. *Physconia* is a common segregate genus.

**Polyblastiopsis** (Arthopyreniaceae, 9) Corticolous lichens with carbonized perithecia and colorless, muriform or septate spores; thallus is partly or entirely immersed in the substratum, such that the only visible part of the lichen is the perithecium.

**Rhizocarpon** (Lecideaceae, 49) Usually gray, areolate thallus with flat, angular lecideine apothecia on the corners of the areoles. Areoles develop on a black prothallus; sometimes the apothecia develop directly upon the prothallus. A widespread cosmopolitan species very common in Idaho is *R. geographicum* which has bright yellow green or chartreuse areoles making it superficially resemble some of the *Acarosporas*, from which it can easily be distinguished by the position and form of the apothecia. Spores are light to dark brown, septate to muriform.

**Staurothele** (Verucariaceae, 14) Saxicolous, crustose lichens common on both calcareous and acid rocks. The perithecia are very small and are usually at the top of a slightly raised area. The spores are brown and muriform. The two species found at the INEL differ primarily in the shape of some of the algal cells, especially those in the hymenium; in addition, *S. catalepta* tends to be more vigorous than *S. clopima* and the opening of the perithecium, the ostiole, tends to be slightly raised rather than slightly sunken. These differences suggest that the same mycobiont may be parasitizing two species of algae. Many lichenologists include both types in *S. clopima*.

**Teloschistes** (Teloschistaceae, 5) Orange, yellow, or gray corticolous, fruticose lichens of temperate and arctic forests, characterized by presence of parietin in the cortex and apothecia (K + purple) and by polarilocular spores. Closely related to *Xanthoria*, *Caloplaca*, and *Fulgensia*, this is ecologically the most hydric of the four genera.

**Umbilicaria** (Umbilicariaceae, 17) Brown or gray, saxicolous, disk-shaped lichens which are attached to rock by a centrally located cord or umbilicus. Rhizines are present in many species but are not used to attach the thallus to the substrate. Furrows radiating from the depressed center of the thallus give it the appearance of a navel.

**Verrucaria** (Verrucaria, 51) Crustose, mostly saxicolous lichens bearing spores in perithecia. Many species are aquatic, some growing submerged; others grow in dry habitats where they produce varnish-like to areolate thalli. Some species are endolithic, growing in either calcareous or non-calcareous rocks. Marine cliffs are often covered with species of this genus down to water level. Spores are hyaline and non-septate, usually quite small.

**Xanthoria** (Teloschistaceae, 8) Orange or yellow-orange foliose lichens common on bark and sometimes on rock, characterized by parietin in the cortex (K + purple), by polarilocular spores, and usually by rhizines on the lower cortex. It differs from *Caloplaca* in being foliose rather than crustose and in having rhizines. However, species of *Caloplaca* and *Xanthoria* form a continuum that suggests the two genera could logically be combined as one. For example, *Xanthoria elegans*, one of our most common species, has either short, sparse rhizines, or none at all, and is listed as *Caloplaca elegans* in many books and articles. Another common species at the INEL, *Caloplaca trachyphylla*, is also known as *Xanthoria elegans* var. *trachyphylla*.