

The Xanthoparmelia of Colorado: Diversity and Distributions

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The *Xanthoparmelia* of Colorado: Diversity and Distributions

Thesis directed by Associate Professor Erin A. Tripp

The genus *Xanthoparmelia* belongs to one of the largest and most species-rich foliose lichen families - Parmeliaceae. It occurs in generally arid regions around the world and is particularly abundant in southern Australia, South Africa, regions of northern South America, Mexico, and the southwestern U.S.A. (Elix 1986; Hale 1990). In the United States, *Xanthoparmelia* is extremely common in the state of Colorado and undoubtedly plays a significant ecological role. Since the late 18th century, scientists have described numerous species in this genus. Over the years it has become increasingly apparent that *Xanthoparmelia* is difficult to identify to a species level based on macro and micro morphology, leading to repeated descriptions of the same species, ambiguous keys, and other taxonomical challenges. It was not until chemistry started becoming a taxonomic tool that it became possible to better identify species with accuracy. While there are still some discrepancies that arise when using traditional methods of morphology-based identification with chemical information, it has become clear that the latter has proved to be an invaluable research tool to lichenology. However, achieving balance between merging traditional morphological keys and more chemical data has proved to be a delicate process. The following study emphasizes the use of Thin Layer Chromatography (TLC), protologue descriptions, distribution maps, and examination of type specimens to delimit *Xanthoparmelia* species in Colorado. Using the University of Colorado Herbarium (COLO) collection in addition to collections made by the author, a total of 18 species belonging to five different chemical groups are here recognized as occurring in Colorado. Two new synonyms are

here proposed: *X. angustiphylla* with *X. conspersa* and *X. arseneana* with *X. novomexicana*. In addition, two names have been excluded from the list of Colorado species: *X. taractica* and *X. hypopsila*. A dichotomous key followed by a treatment of these 18 species (including type citations, morphological descriptions, and chemical information) is included. This treatment is the first to focus solely on this abundant yet taxonomically challenging genus in Colorado. It will be useful to a variety of users ranging from seasoned lichenologists to amateur natural historians interested in Colorado lichen biota.

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CHAPTER I

INTRODUCTION

Lichens are elaborate symbioses of fungi, algae, cyanobacteria, and countless other microbes that biologists have yet to fully discover. While their complex existence creates many unique hurdles for researchers, this system offers invaluable insight into the evolution of symbioses including parasitisms and mutualisms. Lichens are also valuable in more economical ways such as pollution monitors (Hawksworth et al. 1976, Will-Wolf et al. 2015). While the anatomical makeup of lichens is primarily fungal, their frequent symbiosis with green algae (or, less commonly, other photosynthetic lineages) places most lichens between borders of botanical and mycological study. This has resulted in lichenology being somewhat unusual among both botanists and mycologists - not wholly embraced by either community. For example, we still do not know answers to basic questions about their life cycle or growth, or many details regarding reproduction. These unknowns have contributed to murky interpretations of species limits. As our technology to diagnose species has progressed over the decades, however, particularly with respect to the addition of chemical and molecular data, it has become clear that we must start using more quantitative methods when delimiting lichen species, as it is rarely a straightforward matter (Blanco et al. 2006, Del Prado et al. 2010, Leavitt et al. 2012).

The family Parmeliaceae is one of the largest foliose lichen families in the world, with over 1,200 currently recognized species (Thell et al. 2012). One of its most prominent genera, *Parmelia*, was described by Erik Acharius in 1803, and was meant to replace the name *Imbricaria* Ach. (1794). *Parmelia* was officially adopted by the IAPT (International Association

for Plant Taxonomy) in 1930 (Berry 1941). The name *Xanthoparmelia* was first introduced as a subgenus under *Parmelia* by Finnish lichenologist Edward Vainio to delimit the yellow-green group of parmelioid lichens (Vainio 1890). This green-yellow pigmentation is due to the presence of usnic acid - a metabolite that is present in the upper cortex of all *Xanthoparmelia* species. In later works, lichenologists added further definitions to delimit *Xanthoparmelia*, including species that are predominately saxicolous or terricolous, have simple rhizines, and lack cilia (Hale 1964; Hale 1973; Hale 1987). There are currently 800 species within this genus, making it one of the largest genera in the family (Leavitt et al. 2011a) as well as one of the largest genera globally in the world. *Xanthoparmelia* ecology encompasses a broad range of primarily arid regions around the globe, from low to mid elevation deserts, grasslands, and shrublands, but also ranging into the high alpine (Hale 1990).

Mason. E. Hale, who was historically the most prolific contributor to research in Parmeliaceae, is known for being one of the first lichenologists to fully use chemistry in a taxonomic system to delineate species. While it is still debatable how much impact chemistry has in differentiating species in *Xanthoparmelia* (Blanco et al. 2006; Leavitt et al. 2011a; Leavitt et al. 2011b; Leavitt et al. 2012), his works substantially transformed the state of research in the genus. His exhaustive efforts to monograph *Xanthoparmelia* by examining types located in herbaria all over the world built a solid foundation for subsequent decades of research on this important genus.

In the field, *Xanthoparmelia* can be particularly difficult to identify to species. When comparing literature, descriptions, and keys generated over the course of history of this genus, it is clear that many are relatively morphologically indistinct. They share the same upper cortex color, spore morphology, medulla and algal structure, and can be grouped into only three to four

different lobe types. In addition, many defining characteristics are based on qualitative and biased measurements, such as color. However, during evolution between these fungal and photosynthetic partners, many chemical and metabolic nuances have evolved to assist with survival, and these features are often useful in identifying lichen species (Sanders 2001). In fact, because in some groups (such as *Xanthoparmelia*) species share so numerous morphological and anatomical characteristics, other authors have found that sometimes the best way to differentiate the taxa is via the use of chemical "spot tests" and/or Thin Layer Chromatography (hereafter, TLC). The results from this present study support this method of discriminating species hypothesis, and will be described in greater detail later on. This raises a frequently asked and somewhat contentious question of how many lichens names are simply chemovariants of the same species (Poelt 1972, Culberson et al.1967; Culberson 1973). To help address this, researchers have moved from a molecular genetic approach (Leavitt et al. 2011; Leavitt et al. 2012) to take a molecular genomic approach (several authors, in prep. but no studies yet published), thus initiating the latest wave of innovations in lichen taxonomy.

The goal of the present work was to re-assess the nomenclature and taxonomy of *Xanthoparmelia* species found in Colorado. Because this genus is difficult to identify at the species level, and because it is so abundant in Colorado (Nash 2002, Leavitt et al. 2012) and the most speciose genus in the family (Thell et al. 2012), I was motivated to conduct work on it as opposed to other potential systems in need of taxonomic and / or nomenclatural work. I sought it as a suitable study system with the hope that results would be relatively high-impact among WNA lichen systematists. As I began this project, I knew there were approximately 250 collections at COLO that had never before been analyzed from a chemical perspective, which called into question the accuracy of the identifications of these specimens. I ultimately wanted to

simplify and streamline the identification process by building an identification system based on standardized quantitative and readily distinguishable characteristics. Prior to the present writing, existing *Xanthoparmelia* keys were not straightforward and often unreliable, especially those that relied heavily on morphology (i.e. Nash 2002, Brodo 2011, St. Clair 1999). I thus sought to build a key and accompanying species descriptions that focused on more quantitative and undisputable defining characteristics. To validate my species definitions, I relied on type concepts by sourcing all of the type specimens and accompanying protologues for species in this treatment. While my approach has yielded a system that does require access to TLC equipment and data, as a result it is grounded in a confident and strong nomenclature ,and one that I feel can now be interpreted and implemented with less confusion by future researchers and students. Using collections housed in the University of Colorado Herbarium (COLO), which is home to the largest collection of Colorado *Xanthoparmelia* in the world, in addition to my own collections from the field, I was able to build on progress of past researchers in making sense of the difficult diversity and species limits in the genus. The work described below will promote *Xanthoparmelia* taxonomy and make it less daunting and more accessible to a variety of individuals.

CHAPTER II

METHODS

Field, Herbarium, and Curatorial Work

My overall goal of this fieldwork was to build field collecting skills, learn, collect as much *Xanthoparmelia* diversity as possible, and contribute new material to the COLO Herbarium. I also wanted to experience the natural history of these organisms in the field - a step I feel is extremely important for a well-rounded museum employee in natural history collections management. To accomplish this, I collected *Xanthoparmelia* specimens from Boulder County between May-August 2013. Field sites ranged from cattle pastures to untouched montane areas. Elevations at my collection sites ranged from 5300-6300 ft. I collected both on and off trails, with the permits provided by City of Boulder Open Space and Mountain Parks. In total, I made 95 new field collections as part of this study. These have been deposited into the COLO Herbarium.

In addition to field materials, I surveyed all collections of Colorado *Xanthoparmelia* housed at COLO: approximately 275 specimens. Upon exhaustive examination of each specimen, I re-annotated many of these collections to a different species. All measurements provided in the taxonomic treatment are taken from the cited Colorado specimens only. The ranges were derived from measurements of 2-4 instances (i.e. 2 lobes, 3 ascospores, etc.) of each characteristic per individual collection. The minimum and maximum measurement found dictated the range.

Due to the nature of my study, one of my top priorities was to leave a clear and clean platform for future researchers while maintaining the integrity of the COLO collection. To do so, I conducted spot tests and TLC on my own *Xanthoparmelia* collections plus all collections of this genus housed in COLO. The decision was made to conduct spot tests on collections, even those tested by previous researchers, because I often found discrepancies in their results (this could be due to a number of reasons, including different definitions of color, or time allowed for tests to develop). While partial destruction of material was unavoidable, great care was taken to limit the amount of damage to any one specimen. I recorded all results for each specimen, leaving them accessible to anyone who opens a **packet in the** future.

Chemical Assays

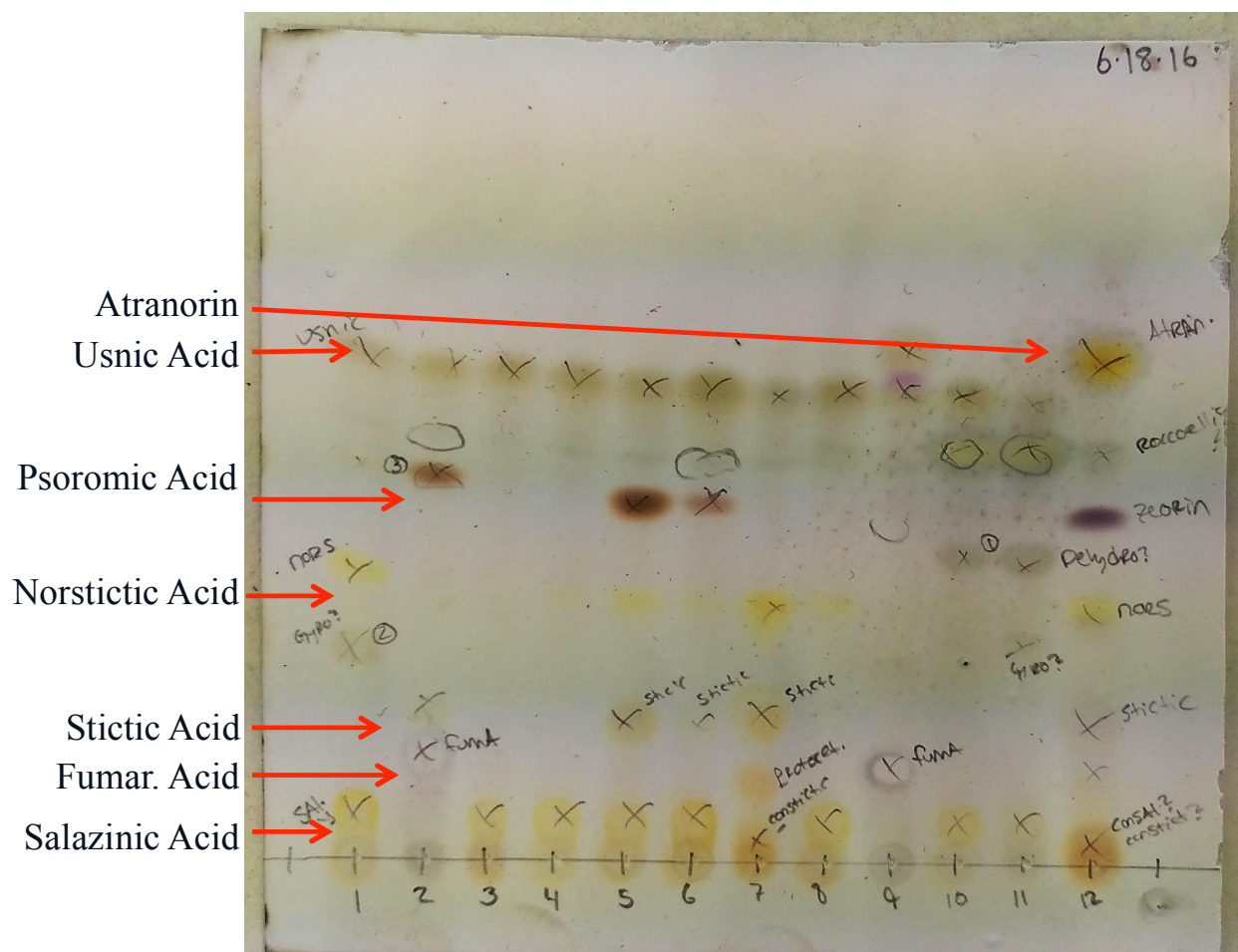
I utilized K (potassium hydroxide), C (sodium hypochlorite), KC (potassium hydroxide + sodium hypochlorite), and P (p-phenyldiamine) to aid in the identification process of all examined specimens following standard protocols described in Brodo et al. 2001. I incorporated any spot test information from prior testing of type specimens (this information provided as annotations on type material) to help me categorize all *Xanthoparmelia* specimens into species groups. To conduct spot tests, I focused in the medulla, as that is where differentiating chemistry resides in *Xanthoparmelia*. I made one to two cuts on the upper surface of the thallus, thus exposing the medulla. I spotted the appropriate chemicals on each cut, and allowed up to 30 seconds for the full development of color to occur. All spot tests were conducted only on material collected in Colorado.

Thin Layer Chromatography (TLC) is a straightforward and reliable method to measure lichen chemistry and thus facilitate identification (Elix 2014). It is by far the most readily

accessible and widely used technique among lichenologists to determine chemical makeup, and is less sensitive to chemical concentration issues associated with spot testing. All TLC tests I performed were on Colorado material. For all TLC runs, I placed an approximately 0.5 x 0.5 mm piece of thallus (cortex + medulla) into an individual ceramic well, avoiding reproductive structures that may contribute to chemical anomalies or variation. I soaked each sample in acetone for approximately 1 minute and then spotted the solute onto silica chromatography plates using a 10 μ l pipette until color ring depicting sufficient solute appeared on the plate. TLC was run using Solvent C (Culberson et al.1970) as well as other methods explained in Culberson (1972). At the conclusion of the run, plates were examined under a short wave UV light, where spot locations and colors visible under this light were marked using pencil. The plate was then run under water and warmed for fatty acid analysis. Finally, plates were "charred" to promote spot color development by treating them with 10% sulfuric acid followed by heat. Plates were scored approximately one hour after charring, to avoid any color fading and discoloration over time. Chemicals were identified following standardized R_F values provided in Elix (2014). The above standardized methodology allowed me to confidently compare data between plates.

Figure 1. TLC plate containing all major acids in Colorado *Xanthoparmelia*. Each lane represents a different thallus sample.

Note that usnic acid is an example of a major compound, while norstictic acid is an example of a trace compound.



Species Concepts

My approach for defining species of Colorado *Xanthoparmelia* relied first on protologue descriptions and type specimens and second on results of morphological characteristic measurements and chemical assays (TLC, spot tests) of Colorado *Xanthoparmelia* specimens. In cases where a protologue and/or type specimen yielded ambiguous or insufficient information with which to delimit species, TLC results were used as my final determining factor for identifications. In several instances below, I uncovered information from the protologues or

types that is in conflict with current usage, and have attempted to resolve these cases accordingly. My hope is that these actions make *Xanthoparmelia* species delimitations less ambiguous and confusing.

Map Generation

I used National Geographic TOPO! Version 3.4.2 (2003) software to generate latitude and longitude points for each Colorado specimen examined. These data were then exported into ArcGIS Version 10.2 software, where the maps below were generated.

CHAPTER III

RESULTS

After reviewing protologues, type specimen materials, chemical test results, and morphologies of all specimens included in this study, I here recognize a total of 18 *Xanthoparmelia* species occurring in the state of Colorado. Of these, four are asexual (*X. lavicola*, *X. mexicana*, *X. mougeotii*, *X. plittii*), four are vagrant (*X. chlorochroa*, *X. idahoensis*, *X. neochlorochroa*, *X. vagans*), and 10 are fertile (*X. coloradoensis*, *X. conspersa*, *X. cumberlandia*, *X. lineola*, *X. monticola*, *X. novomexicana*, *X. psoromifera*, *X. stenophylla*, *X. subdecipiens*, *X. wyomingica*). The term “vagrant” is here taken as both a mode of reproduction and a distinct growth-habit found in Colorado *Xanthoparmelia*. While vagrant lichens utilize fragmentation as a mode of reproduction (Rosentreter 1993), and are therefore technically asexual, the lack of conidia and isidia places them into their own subcategory in the present study. I have separated vagrant and asexual species here, as vagrancy is used to delimit species within this genus. Table 1 depicts the chemical and reproductive statuses of these taxa.

Table 2. Full list of recognized Colorado *Xanthoparmelia* species, their primary mode of reproduction, and their primary chemical constituents.

Taxon Name	Asexual	Sexual	Vagrant	Fumarprotocetraric Acid	Psoromic acid	Salazinic Acid	Stictic Acid	Atranorin
<i>X. chlorochroa</i>			x			x		
<i>X. coloradoensis</i>		x				x		
<i>X. conspersa</i>		x					x	
<i>X. cumberlandia</i>		x					x	
<i>X. idahoensis</i>			x			x		
<i>X. lavicola</i>	x				x			
<i>X. lineola</i>		x				x		
<i>X. mexicana</i>	x					x		
<i>X. monticola</i>		x		x				
<i>X. mougeotii</i>	x						x	
<i>X. neochlorochroa</i>			x	-	-	-	-	-
<i>X. novomexicana</i>		x		x				
<i>X. plittii</i>	x						x	
<i>X. psoromifera</i>		x			x			
<i>X. stenophylla</i>		x				x		
<i>X. subdecepiens</i>		x						x
<i>X. vagans</i>			x				x	
<i>X. wyomingica</i>		x				x		

I delimited five main chemical groups among the 18 taxa (Table 2). Chemical Group 1- salazinic acid group - contains seven species, Group 2 - stictic acid group, contains five, Group 3 - psoromic acid group, contains two species, Group 4 - fumarprotocetraric acid group - contains two species, and Group 5 – atranorin group, contains one species. All species were assigned to one and only one group except for *X. chlorochroa*, which was not included in any of these group as it is defined by a lack of salazinic acid. All taxa additionally contained usnic acid, which is characteristic of the genus, as well as minor and / or trace amounts of additional chemical constituents (e.g., norstictic acid, consalazinic acid). Group 1 was represented by the largest number of collections (219) and Group 4 the smallest number of collections (4).

Table 3. Number of collections for each species housed at COLO divided by chemical group

Group 1: Salazinic Acid Group

	# of collections at COLO
<i>X. chlorochroa</i>	43
<i>X. coloradoensis</i>	72
<i>X. idahoensis</i>	10
<i>X. lineola</i>	29
<i>X. mexicana</i>	34
<i>X. stenophylla</i>	7
<i>X. wyomingica</i>	24
<i>Total</i>	219

Group 2: Stictic Acid Group

	# of collections at COLO
<i>X. conspersa</i>	5

<i>X. cumberlandia</i>	15
<i>X. mougeotii</i>	2
<i>X. plittii</i>	13
<i>X. vagans</i>	12
<i>Total</i>	41

Group 3: Psoromic Acid Group

	# of collections at COLO
<i>X. lavicola</i>	3
<i>X. psoromifera</i>	2
<i>Total</i>	5

Group 4: Fumarprotocetraric Acid Group

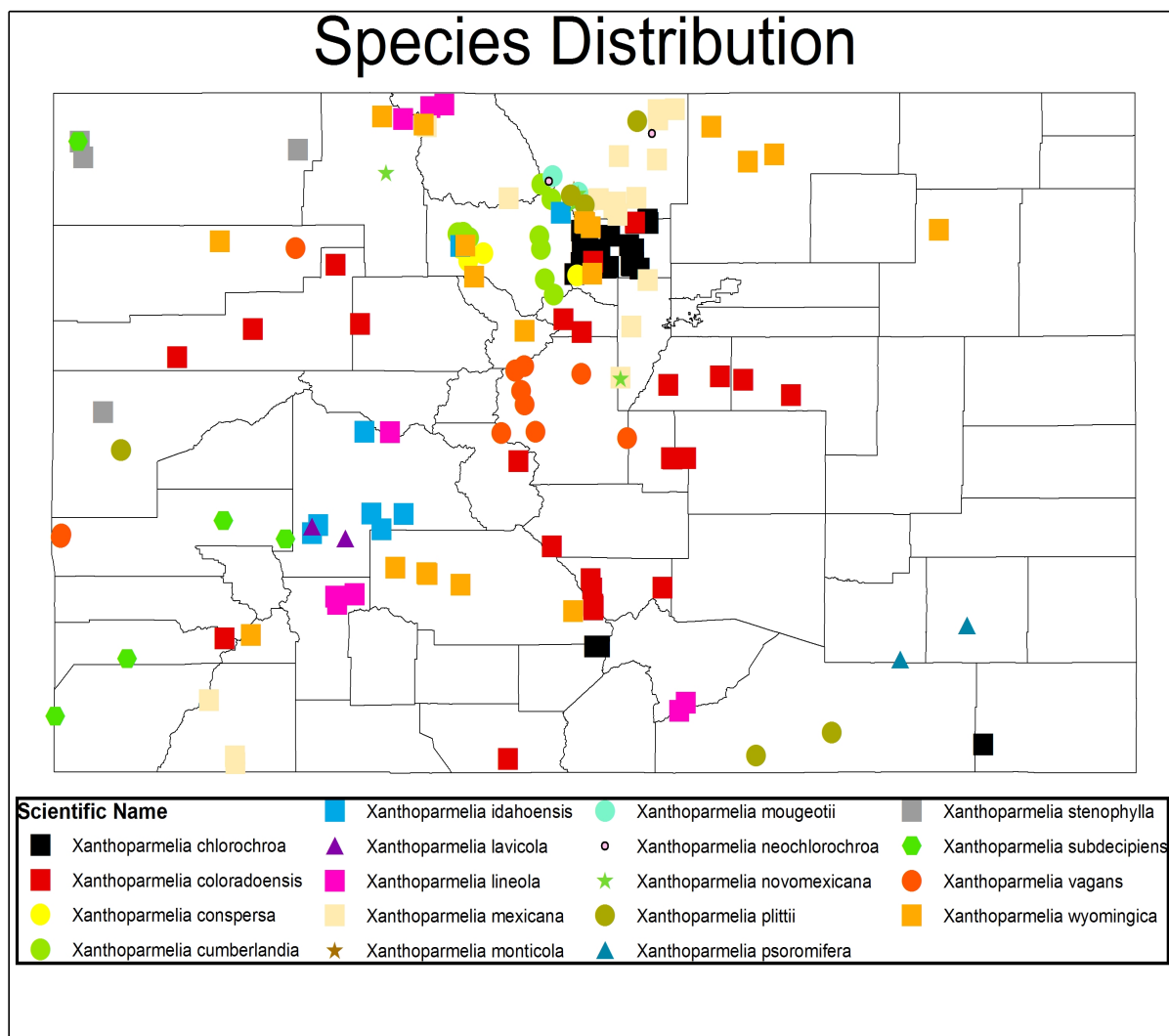
	# of collections at COLO
<i>X. monticola</i>	1
<i>X. novomexicana</i>	3
<i>Total</i>	4

Group 5: Atranorin Group

	# of collections at COLO
<i>X. subdecepiens</i>	5
<i>Total</i>	5

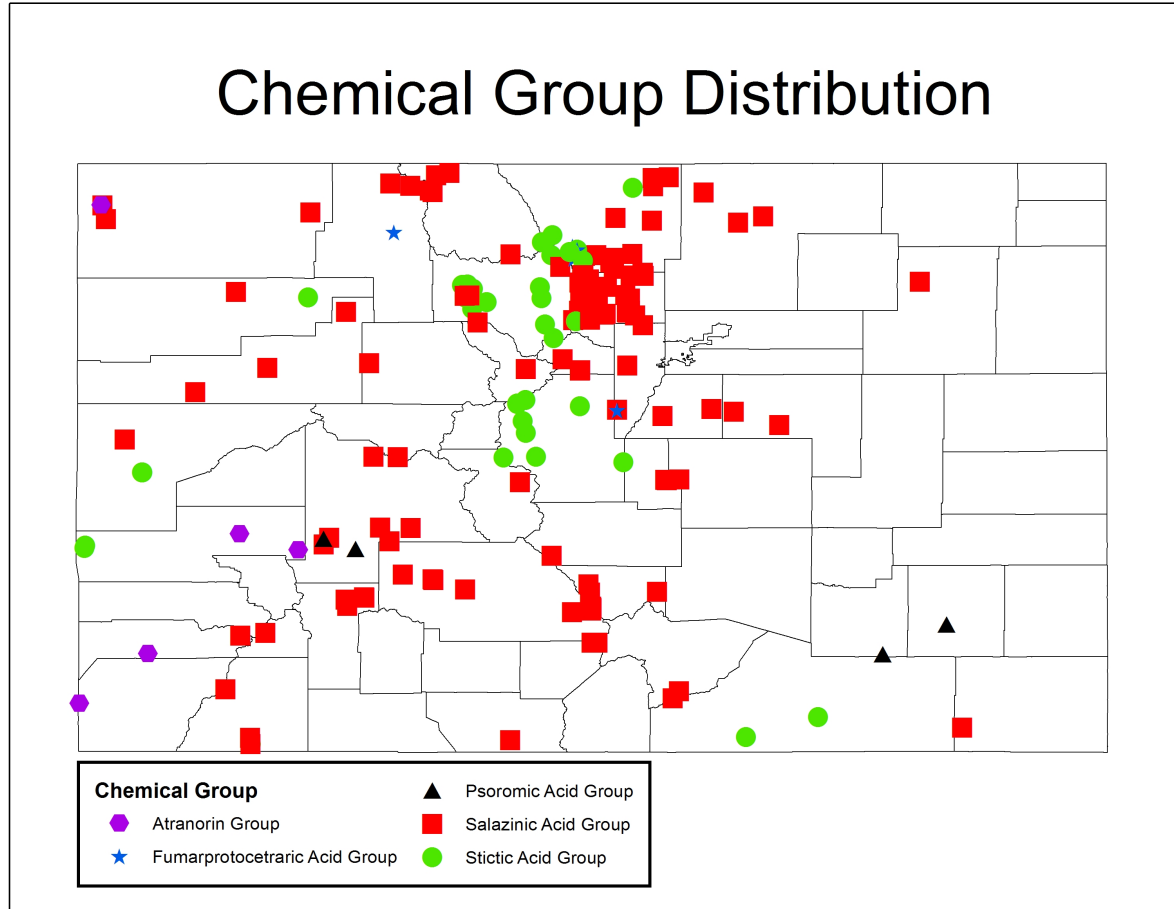
The below map depicts distributions of all 18 species found in Colorado. The shapes coincide with chemical groups, while colors differentiate species. *Xanthoparmelia coloradoensis* appears to have the overall widest distribution range and frequency.

Map 1. Distribution of *Xanthoparmelia* species found in Colorado.



Map 2 depicts chemical distributions within Colorado. As stated above, the Salazinic Acid group appears to be by far the most widespread and frequent. The atranorin group only occurs on the western slope, while all other groups appear to occur across the state.

Map 2. Distribution of chemical groups found in Colorado.



After review of 300+ Colorado specimens, two new synonymies are proposed as part of this treatment - *Xanthoparmelia arseneana* was synonymized with *X. novomexicana* and *X. angustiphylla* was synonymized with *X. conspersa*. These decisions were made based on the similarities as deduced from protologue descriptions, type locations, chemistry and morphology. Priority was assigned using the earliest published name (Chapter II, Section 3, Article 11.2 under the IAPT Melbourne Code). *Xanthoparmelia arseneana* was first collected in the same city a few years after *X. novomexicana*, and share identical morphological descriptions. *Xanthoparmelia angustiphylla* was considered the fertile morph of *X. conspersa*; however, as *X. conspersa* seems to also be fertile, these names are here considered synonyms. A more full discussion on these synonyms are provided in the taxonomic treatment.

Xanthoparmelia taractica and *X. hypopsila* are two names here rejected from this treatment but represent names previously included in some North American flora (Nash 2002, St. Clair 1999). In both of these cases, upon exhaustive review of literature, it is unlikely that these species occur in the USA (Hale 1990). The protologue description and type specimen of *X. taractica* do suggest a high affinity to *X. coloradoensis* (a prominent western US species), and therefore caused me to investigate the possibility of a synonymy between the two epithets. Upon further investigation, I found *X. taractica* was originally collected in Argentina. In addition, that two of the most experienced scientists on this genus consider it to only dwell in Argentina and up into Mexico and Australasia (Elix et al. 1986; Hale 1990; Nash 1974). While *X. taractica* doesn't seem to be listed in any recent treatments for this region of the country, this name is still used in many North American Herbaria (CNALH 2016). A similar situation occurred in the case of *X. hypopsila*. Hale (1988) regarded *X. hypopsila* to be a South American and South African species, and the North American species a separate name- *X. angustiphylla*. While this nomenclature seemed to carry over into to most North American keys, some herbaria are still considering *X. hypopsila* to be found in North America (CNALH 2016). Further investigation that includes broad molecular sampling will most likely be needed to further assess the relationship of these species.

Other major revisions to species concepts such as that of *Xanthoparmelia conspersa* where additionally made, as described in detail in the taxonomic treatment.

CHAPTER IV

DISCUSSION

Upon exhaustive examination of 300+ *Xanthoparmelia* specimens collected in Colorado, it is concluded that TLC data represent the most efficient means of most accurate species identification in the state. Based on morphological delimitations that I present in the treatment, it seems one can only narrow identifications down to reproductive group (i.e., asexual, sexual, or vagrant). Spot test results, while useful as confirmation of TLC, do not vary enough to facilitate confident identifications. K test results are useful in confirming stictic acid (K+ yellow) and salazinic acid (K+ red) acids but can be variable across a single thallus. All other spots are the same amongst all the species found in Colorado (P+ orange, C-, and KC-), making them not very helpful at a diagnostic level. Thus, to confidently identify Colorado *Xanthoparmelia*, TLC is required.

After collecting TLC data from all the COLO and newly collected specimens, it appears there are five main chemical groups that occur in Colorado. The chemical groups as a whole do not appear to be restricted to any specific habitat or elevation (however there are some species within the chemical groups that are) (see Map 2). Group 1 (salazinic) and Group 2 (stictic) acid were the largest, containing seven and five species respectively; they were also the most commonly occurring, as assessed by numbers of collections. Both of these groups seem to thrive throughout the entire state, which agrees with their high COLO collection numbers. Groups 3 (psoromic) and 4 (fumarprotocetraric) each contained two species, and are by far the most rare in terms of numbers of species and collections found in the state. However, it appears that they

have a broad range of distribution, occurring on both sides of the state. Group 5 (atranorin) appears to only occur on the western slope, and only contains one species – *X. subdecepiens*. While the COLO lichen collection is quite ample when compared to others in this region, these maps make it clear that more collection is needed (particularly in the eastern plains) to paint a more well-rounded picture of the lichen biota distribution within Colorado.

While the above data give occurrence statistics from the perspective of TLC, molecular data is becoming a different way to look at such questions. Lichenologists that have begun using genetic or genomic approaches in their research programs are finding (as is the case with much newfound molecular data) that our previous notions of species delimitations may or may not be supported by molecular information (Del Prado et al. 2010; Leavitt et al. 2011a).

Xanthoparmelia in particular is an exceptional example of how molecular data can help to facilitate species delimitations in problematic genera in which species concepts have otherwise been based only on chemistry and morphology. In Leavitt et al. (2011), results indicated that traditionally circumscribed species were not supported by molecular data. Their study included six species that occur in Colorado, and found that they belong to three polymorphic population clusters. Further studies by this research group (Leavitt et al. 2012) confirmed that chemical and morphological characteristics overestimate the number of species compared to species delimitation on a molecular level. Further work on this genus will clearly benefit from an integrated molecular and morphological approach, and revisiting the identifications of voucher specimens used in previous molecular studies will be especially necessary.

Although the use of molecular techniques is undoubtedly a very exciting and promising next step in all taxonomy, one must also consider how accessible and applicable these data and techniques are available to researchers, amateurs, or other users of taxonomy. Such individuals

do not necessarily have access to molecular techniques, thus a cheap and easy way to ID species remains of high priority, especially for diverse and ecologically abundant lichens such as *Xanthoparmelia*. Based on this study, I am confident that the use of chemistry (TLC) and morphology is still the best first step in identifying these Coloradan species, especially considering the goal to make science accessible to as many people in our community as possible. As we are better able to gain a more comprehensive picture of the molecular aspects of biological systems, we will determine how to successfully incorporate those data into our existing ways of thinking, our scientific philosophies, and our everyday practices. Until then, we must do our best with what information is available to us.

CHAPTER V
KEY TO SPECIES

The following species treatments are based on examination of type specimen digital loans, study of protologues, study of previously accessioned COLO material, and study of material collected by the author. All material in specimens cited references a unique identifier, which refers to barcodes affixed to COLO material. The spot test and TLC data listed in the below treatment of species are taken from my observations of Colorado material. All results agree with those listed in protologues and type material, unless otherwise discussed. The key is based heavily on TLC data, which, as discussed above, appears to be the least-disputable method of species identification in *Xanthoparmelia*.

Key to the Species of *Xanthoparmelia* in Colorado

- | | |
|--------------------------------------|---------------------|
| 1. Contains soredia or isidia..... | 3 |
| 2. Is not sorediate or isidiate..... | 6 |
| 3a. Contains soredia..... | <i>X. mougeotii</i> |
| 3b. Contains isidia..... | 4 |
| 4a. K+ red..... | <i>X. mexicana</i> |
| 4b. K+ yellow or orange..... | 5 |
| 5a. Contains psoromic acid..... | <i>X. lavicola</i> |
| 5b. Contains stictic acid..... | <i>X. plittii</i> |

- 6a. Thallus free-growing, usually forming rosettes.....7
- 6b. Thallus loosely to tightly adnate growing on rocks, pebbles, or bark.....10
- 7a. Contains stictic acid..... *X. vagans*
- 7b. Does not contain stictic acid.....8
- 8a. Does not contain salazinic acid..... *X. neochlorochroa*
- 8b. Contains salazinic aid.....9
- 9a. Has maculate upper surface..... *X. idahoensis*
- 9b. Has emaculate upper surface..... *X. chlorochroa*
- 10a. Contains salazinic acid.....11
- 10b. Does not contain salazinic acid.....14
- 11a. Thallus loosely adnate (possibly growing on pebbles or moss), narrow lobes (0.5-2 mm wide).....12
- 11b. Thallus more tightly adnate to substrate.....13
- 12a. Lobes separate to subimbricate, growing on pebbles, moss or dirt, lobes convolute 3000m+ elevation..... *X. wyomingica*
- 12b. Lobes more broad and flat, tightly imbricate towards center of thallus forming a mat, adnate to loosely adnate growing on rock *X. stenophylla*
- 13a. Thallus tightly adnate to rock, lobes flat..... *X. lineola*
- 13b. Thallus less adnate to rock, with lobes often lifting off substrate, almost foliose in places..... *X. coloradoensis*

- 14a. Contains stictic acid..... 15
- 14b. Does not contain stictic acid.....16
-
- 15a. Underside black..... *X. conspersa*
- 15b. Underside pale..... *X. cumberlandia*
-
- 16a. Contains atranorin and protoconstipatic acids (both major to trace).....
 *X. subdecepiens*
- 16b. Contains fumarprotocetraric acid..... 17
-
- 17a. Thallus adnate to tightly adnate to rock..... *X. novomexicana*
17. Thallus loosely adntate to rock..... *X. monticola*

CHAPTER VI
TAXANOMIC TREATMENT

Xanthoparmelia chlorochroa (Tuck.) Hale, Phytologia 28: 486. 1974. ≡ *Parmelia chlorochroa* Tuck., Proc. Amer. Acad. Arts 4: 383. 1860. TYPE: U.S.A., North Dakota, Missouri River, 1859-1860, *F.V. Hayden s.n.* (lectotype: FH- image! [designated by Berry, Ann. Mo. Bot. Gard. 2: 70. 1941.] ; isoelectotypes: H [H9503765]-image!, MSC [MSC0122044]- image!, US [00068756]- image!). Additional syntypes: On sand, Inscription Rock, *Bigelow s.n.*, Black Water of the Platte, *H. Engelmann s.n.*

Morphological and Chemical Description:

Thallus foliose; vagrant. **Lobes** irregular; dichotomously branched and deeply divided, 3-8 mm wide; separate to subimbricate and strongly convolute; margins entire to crenate. **Upper surface** yellow-green, smooth, cracking and darkening towards older portions of thallus. **Medulla** white, with continuous algal layer. **Lower surface** dark brown to black, shiny; rhizines black. **Soredia & isidia** absent in Colorado material. **Apothecia & ascospores** absent in Colorado material. **Pycnidia** infrequent to occasional, black, sunken below upper cortex. **Figure 2.**

Secondary Metabolites- Salazinic acid (major), usnic acid (major); norstictic acid (minor).

Spot Tests- Medulla, K+ red, C-, KC+ yellow, P+ orange.

Ecology and Distribution: *Xanthoparmelia chlorochroa* is relatively common in the southern Rocky Mountains across an elevation range of ~5000-10000 ft., particularly the northern part of Colorado (see Map 1) (Consortium of North American Lichen Herbaria 2016, hereafter

“CNALH”). It is a vagrant species commonly found on soil. Common names include Tumbleweed Shield Lichen and Ground Lichen. The Navajo use it to create dyes for rugs, and it has also been known to poison livestock and elk (Brodo 2001, Daily 2008).

Notes: There has been quite a bit of confusion delimitating the vagrant *Xanthoparmelia* species around the world. Lack of apothecia, presence of salazinic acid, and occurrence only in the Americas distinguish *X. chlorochroa* from other vagrant species found around the world (Hale 1990; Rosentreter 1993). *Xanthoparmelia chlorochroa* is most frequently confused with *X. vagans* (see Figures 2 and 18), with which it shares morphology but can be differentiated by presence of stictic acid rather than salazinic acid (Hale 1990 and here confirmed).

TLC conducted on the isoelectotype at US (researcher unknown) also confirms the presence of salazinic and usnic acids; however, at some unspecified but presumably later date (i.e., because of relative positional placements of TLC annotations on the packet), a different researcher (also unknown) added “stictic acid +” to the label, which I here presume to be an error. TLC conducted on all Coloradan material housed at COLO recovers only salazinic and usnic acids as major compounds (norstictic also commonly present in trace amounts).

Additional Specimens Examined:

Alamosa: 5 miles south of headquarters, Great Sand Dunes National Monument, 10 June 1954, *S. Shushan s.n.* [COLO-L-0047587]. **Boulder:** Rabbit Mountain, east of Lyons, 04 October 1997, *W.A. Weber s.n.* [COLO-L-0047569]; Base of Steamboat Mountain, 2 miles northwest of Lyons, 12 March 1959, *W.A. Weber s.n.* [COLO-L-0047575]. **Conejos:** 5 miles West of Antonito. Along roadside, 18 July 1952, *W. A. Weber s.n.* [COLO-L-0047563]. **Custer:** 8 miles W of Westcliffe, Alvarado Picnic Grounds, 13 June 1952, *T.P. Maslin s.n.* [COLO-L-0047557]. **Douglas:** Castlewood Canyon State Park, on the Arkansas Divide, 5 mi. S of Franktown, vicinity of Bridge Canyon Overlook, 39.33028 -104.73778, 28 September 2002, *W. A. Weber s.n.* [COLO-L-0047539]. **Elbert:** 14 miles east of Elbert, 13 May 1951, *W.A. Weber 5991* [COLO-L-0047545]; Ca. 7 miles northwest of Elbert, 03 July 1956, *R.P. Higgins s.n.* [COLO-L-0047551]. **Grand:** Approximately 4 miles southeast of Kremmling, 01 February 1972, *D. W. Reichert 262* [COLO-L-0047496]; Table Mountain, Shadow Mountain National Recreation Area, 30 July 1957, *J. Douglass s.n.* [COLO-L-0047521]; Between Parshall and Kremmling, 11 May 1952, *W.A.*

Weber 7323 [COLO-L-0047527]; SE of road and 1.4 road miles east of Granby, 25 July 1957, *J. Douglass s.n.* [COLO-L-0047533]; BLM, approx. 2.2 air miles NE of Kremmling. S of Wolford Mountain in the vicinity of Cow Gulch, 40.09117 -106.37737, 30 August 2014, *B. Elliot 16352* [COLO-L-0050857]. **Gunnison:** 0.25 mi. S of US Highway 50, on Colorado Highway 114, 01 June 1955, *J. Douglass s.n.* [COLO-L-0047484]; 4 miles SW of Gunnison, 16 July 1953, *W.A. Weber s.n.* [COLO-L-0047508]; Gunnison Co., 4 miles S.W. of Gunnison. Along roadside, 16 July 1953, *W.A. Weber s.n.* [COLO-L-0047514]; Along Gunnison River Canyon, 2-5 miles west of Sapinero, 29 May 1952, *W.A. Weber s.n.* [COLO-L-0047520]; Gunnison Co., 8.5 miles south of Gunnison, 14 August 1952, *M.L. Mattoon s.n.* [COLO-L-0048363]. **Hinsdale:** Mesa Seco, near Slumgullion Pass, 24 July 1964, *W.A. Weber s.n.* [COLO-L-0047472]; Above Slumgullion Pass, 16 August 1951, *G. Alexander s.n.* [COLO-L-0047490]. **Jackson:** 4.7 miles SE of Pearl, road to Big Creek Lake, 09 July 1956, *M.M. Douglass s.n.* [COLO-L-0047478]. **La Plata:** Just north of Bondad at junction of Florida and Animas Rivers, 12 June 1955, *S. Shushan s.n.*, [COLO-L-0047460]. **Larimer:** 12 miles NW of Wellington, 19 April 1952, *W.A. Weber s.n.* [COLO-L-0047454]. **Moffat:** Douglas Mountain, triangulation point above the Copper Mine, 29 July 1960, *M. MacLeod 147* [COLO-L-0047466]; Northern end of Dinosaur Nat. Monument, at entrance of Green River into the Canyon of Lodore, ca. 1 mi. S of Browns Park, 29 July 1962, *S. Flowers s.n.* [COLO-L-0047519]. **Montrose:** Above Cimarron Creek, 5 miles south of Cimarron, 08 August 1954, *S. Shushan s.n.* [COLO-L-0047483]. **Park:** 4 miles south of Fairplay, 06 June 1952, *W.A. Weber s.n.* [COLO-L-0047471]; Near north end of Antero Reservoir, 29 May 1955, *J. Douglass s.n.* [COLO-L-0047489]; Nordamerika, south of Fairplay, 06 July 1952, *S. Shushan s.n.* [COLO-L-0047507]; 3 miles west of Florissant, just over Teller-Park county line, 12 April 1954, *S. Shushan s.n.* [COLO-L-0047513]; Hoosier Pass campground, 04 July 1954, *S. Shushan s.n.* [COLO-L-0047477]. **Rio Blanco:** Valley of Strawberry Creek. 7 miles n.w. of Meeker, 10 May 1952, *W.A. Weber 7380* [COLO-L-0047501]. **Saguache:** Mineral King Trail off Brook Trout Road, Grats Parcel of Baca Grande Subdivision near Crestone, west base of Sangre de Cristo range; Great Sand Dunes National Park, 27 January 2001, *J. Erdman 44* [COLO-L-0047453]; 0.6 mile from Old Agency Ranger Station on Los Pinos Pass Road, 01 June 1955, *J. Douglass s.n.* [COLO-L-0047459]; Cochetopa Park, just south of summit of Cochetopa Pass, 10 August 1955, *W. A. Weber s.n.* [COLO-L-0047465]; 3 miles northwest of Cochetopa Pass on Colorado Highway 114, 01 June 1955, *J. Douglass s.n.* [COLO-L-0047495]. **Weld:** 7 miles north of Nunn on Highway 85, 08 April 1955, *J. Douglass s.n.* [COLO-L-0047506]; 20 km ENE of Ault along Rte. 12, Pawnee National Grassland, 40.60000 -104.55000, 09 August 1984, *T. H. Nash III 25761* [COLO-L-0047512]; Pawnee National Grassland, 20 miles east of Ault, 18 February 1994, *J. K. Nelson 1670* [COLO-L-0047518].

Figure 2. *Xanthoparmelia chlorochroa*, one of the four vagrant *Xanthoparmelia* species found in Colorado. *Xanthoparmelia chlorochroa* frequently has dichotomous branching and lacks apothecia, and is probably the most common vagrant lichen found in the state.



Xanthoparmelia coloradoensis (Gyel.) Hale, Mycotaxon 33: 402. 1988. \equiv *Parmelia ioannis-simae* var. *coloradoensis* Gyel., Repert. Spec. Nov. Regni Veg. 31: 287. 1931. TYPE: U.S.A., Colorado, Caribou (“Cariberu”), 10,200 ft. elevation, 18 February 1916, *I.W. Clokey 14* (lectotype: US [00344632]-image!; isolectotype: BP- image! [designated by Hale in Smithsonian Contr. Bot. 74: 87. 1990]).

Morphological and Chemical Description:

Thallus lobulate to foliose; adnate to loosely adnate; saxicolous. **Lobes** sublinear; moderately divided, 1-9 mm wide; minimally to moderately imbricate; margins browning towards tips; apices usually crenate. **Upper surface** yellow-green, smooth, cracking and darkening towards older portions of thallus. **Medulla** white, with continuous algal layer. **Lower surface** pale brown; rhizines brown, frequent. **Soredia & isidia** absent in Colorado material. **Apothecia** frequent, sessile, disks light to dark brown, margins subconvex. **Ascospores** ellipsoid, non-septate, colorless; 6-7x 4-5 μ m. **Pycnidia** frequent, black, sunken below upper cortex. **Figure 3**

Secondary Metabolites- Salazinic acid (major), usnic acid (major); consalazinic (minor), norstictic acid (minor).

Spot Tests- Medulla K+ yellow to red, C-, KC-, P+ orange.

Ecology and Distribution: *Xanthoparmelia coloradoensis* is primarily found within the southern Rocky Mountains but also occurs in mountainous areas of Arizona, New Mexico, Southern Baja California, and California coastal sage communities (CNALH 2016). The species grows in an extremely broad diversity of habitats in Colorado (see Map 1) ranging from sagebrush plains to coniferous forests. It is commonly known as the Colorado Rock-Shield Lichen.

Notes: *Xanthoparmelia coloradoensis* falls into the largest chemical group in Colorado with *X. lineola*, *X. chlorochroa*, and *X. wyomingica* (see Map 2). All contain salazinic, consalazinic,

norstictic, and usnic acids. The variation between the three pertains to the lobes- *X. lineola* (Figure 8) is saxicolous and tightly adnate with narrow lobes while *X. wyomingica* (Figure 19) is extremely loosely adnate with convoluted lobes. *X. coloradoensis* falls in the middle of these two, having broader lobes than those of *X. lineola* but being moderately to loosely adnate to its substrate (Hale 1990).

Spot tests conducted by V. Gyelnik on the isolectotype indicated a KC+ red test(as annotated on type material). Upon testing the Colorado material, all KC tests were negative.

Additional Specimens Examined:

Baca: Vicinity of Dodge Ranch, southwest of Utleyville, 4500 ft, 04 September 1955, *S. Shushan s.n.* [COLO-L-0047975]. **Boulder:** West side of Steamboat Mt., 3 mi. n.w. of Lyons, ca. 5600 ft, 07 February 1954, *W.A. Weber s.n.* [COLO-L-0048103]; First Flatiron just above mouth of Gregory Canyon 1800 m.s.m., 06 July 1976, *W.A. Weber s.n.* [COLO-L-00448011]; Rocky Mountain National Park, Longs Peak Valley, 2774m, 14 September 1932, *W. Kiener 80* [COLO-L-0047763]; Lytle Formation, Dakota Group, ca. 4 mi N of Boulder, T1N, R71W, SEC1, 6100 ft., 01 August 1959, *R.A. Anderson s.n.* [COLO-L-0048077]; Northwest slope of Green Mountain, southwest of Boulder, 2286m, 02 February 1952, *S. Shushan s.n.* [COLO-L-0047731]; Rocky Mountain National Park, Longs Peak Valley, 2774m, 10 August 1935, *W. Kiener 3042* [COLO-L-0047769]; White Rocks, 8 mi NE of Boulder on north side of Boulder Creek, 30 November 1975, *W.A. Weber s.n.* [COLO-L-0048060]; Colorado Front Range west of Boulder, junction of Peak-to-Peak Highway and Gold Hill road, 13 June 1998, 2743m, *W.A. Weber s.n.* [COLO-L-0047586]; White Rocks Nature Preserve, 40.05335 -105.15531, 22 July 2014, 569m, *E.A. Tripp 4840* [COLO-L-0050574]; White Rocks Nature Preserve, 40.05352 -105.15909, 06 August 2014, 1580m, *E.A. Tripp 4855* [COLO-L-0050587]; One mile NE of Gold Hill along Lefthand Creek, 04 June 1967, 2256m, *C.M. Wetmore 16082* [COLO-L-0047780]. **Chaffee:** 5 miles east of Buena Vista, 8500 ft, 06 June 1952, *S. Shushan s.n.* [COLO-L-0048017]. **Custer:** 8 miles west of Westcliffe, 8000 ft, 13 June 1952, *T.P. Maslin s.n.* [COLO-L-0048096]. **Dolores:** 10.2 road miles northeast of Rico Lizard Head Pass, 9800 ft, 16 June 1954, *J. Douglass s.n.* [COLO-L-0048040]. **Douglas:** Jackson Gulch, 7800 ft, 28 June 1952, *S. Shushan s.n.* [COLO-L-0048053]. **Eagle:** Benches of Eagle River 6 mi. west of Gypsum, 6100 ft, 14 May 1954, *W.A. Weber s.n.* [COLO-L-0048121]. **Huerfano:** East of Spanish Peak, south of La Veta, 11500 ft, 17 August 1955, *S. Shushan s.n.* [COLO-L-0048048]. **Larimer:** Estes Park, 9 mi SE of; or 14 mi NW of Lyons; off Denver Highway, 7500ft, 26 July 1949, *W. Kiener 24767* [COLO-L-0047629]; 19 miles north of LaPorte, 1981m, 29 April 1954, *S. Shushan s.n.* [COLO-L-0047793]; 11 mi. east of Trail Ridge Campground, 8500ft, 29 July 1951, *S. Shushan s.n.* [COLO-L-0048050]. **Mesa:** Ca. 7 mi. SW of Whitewater, above East Creek N of Gibbler Gulch, 01 June 1973, *W.A. Weber s.n.* [COLO-L-0047745]. **Montrose:** 4 miles west of Montrose on Colorado highway 90, 1585m, 03 September 1971, *G.K. Arp 1722* [COLO-L-0047885]. **Park** 3 miles west of Florissant, just over Teller-Park county line, 2469m, 12 April 1954, *S. Shushan s.n.* [COLO-L-0047757]. Buffalo Peaks, top of saddle separating Four Mile Creek and Buffalo Meadow drainages, 02 August 1991, 3475m, *R.E. Abbot 275* [COLO-L-0047592].

Figure 3. *Xanthoparmelia coloradoensis* is one of the many salazinic acid-containing species in Colorado. Note its looser adnation to the rock and slightly enhanced foliose appearance compared to *X. lineola* (Figure 8).



Xanthoparmelia conspersa (Ehrh. ex Ach.) Hale, Phytologia 28: 485. 1974. ≡
Lichen conspersus Ehrh. ex Ach., Lichenogr. Suec. Prodr.: 118. 1798. TYPE: Sweden, *collector unknown, s.n.* (lectotype: H-hb. Ach. [H9502091]- image! [designated by Gyelnik in Magyar Bot. Lapok 29: 31. 1930.]).

= *Xanthoparmelia angustiphylla* (Gyel.) Hale, Mycotaxon 33: 401. 1988. ≡ *Parmelia conspersa*
var. angustiphylla Gyeln., Repert. Spec. Nov. Regni. Veg. 29: 153. 1931. TYPE: Hungary,
 Diósjenő, Nógrád County, in decl. of Mt. Csóványos, ca. 600 m.s.m., 1926-1927, *s.c.* (lectotype-
 BP- image! [designated by Hale in Smithsonian Contr. Bot. 74: 166. 1990]).

Morphological and Chemical Description:

Thallus foliose; adnate to loosely adnate; saxicolous. **Lobes** irregular; moderately divided, 1-4 mm wide; separate to moderately imbricate, at times subconvolute; margins browning, apices usually crenate. **Upper surface** yellow-green, smooth, cracking and darkening towards older portions of thallus. **Medulla** white, with continuous algal layer. **Lower surface** black, shiny; rhizines black with black rhizines, occurring frequently **Soredia & isidia** absent in Colorado material. **Apothecia** infrequent to common, sessile; disks light to dark brown; margins subconvex and slightly crenate. **Ascospores** ellipsoid, non-septate, colorless; 6-7x 5µm.

Pycnidia occurring frequently black, sunken below upper cortex. **Figure 4**

Secondary Metabolites- Stictic acid (major), usnic acid (major); norstictic acid (minor).

Spot Tests- Medulla K+ yellow-orange, C-, KC-, P+ orange.

Ecology and Distribution: *Xanthoparmelia conspersa* is very common in the U.S., particularly in the eastern U.S. In Colorado, it can be found mainly in the northern part of the state at elevations ranging from 6,000-10,500 ft. in disturbed cattle ranches to alpine montane regions (see Map 1).

Notes: *Xanthoparmelia conspersa* is the type species for the genus and the namesake of the *Parmelia conspersa* group, which comprises *X. conspersa*, *X. tinctina* (Mah. & Gillet) Hale, *X. piedmontensis* (Hale) Hale, *X. plittii*, *X. dierythra*, *X. mexicana*, and *X. subramigera* (Gyeln.) Hale, which can be characterized by black to light brown lower surface and presence of one of four diagnostic acids: stictic, norstictic, salazinic, and fumarprotocetraric. Of these traits, *X. conspersa* contains stictic acid and has a black lower surface.

Despite its importance as a widespread and abundant species as well as its status as type of the genus, there has been quite a bit of discrepancy as to the delimitation of *Xanthoparmelia conspersa*. Over the last two centuries, that this species is predominately isidiate has been propagated throughout the literature. However, in the protologue written by Jakob Ehrhart (and validated by Acharius), there is clear mention of apothecia present on the specimen he was examining. There is no mention of isidia. In addition (and to make matters more confusing), there are two specimens (located at H-Ach.) on the same sheet that have both been annotated as representing the lectotype. In 1930, Gylenik inadvertently lectotypified the two specimens housed at H-Ach by noting that the top (abundantly isidiate) specimen was representative of *Parmelia isidiata* and the bottom of *X. conspersa* (Hale 1964; Hale 1990). This further confirmed that *X. conspersa* should be considered a fertile species (see Figure 4).

Hale (1964;1990) again lectotypified this species, this time using the other (top) specimen the on the sheet, which is obviously isidiate. However, Hale's attempt to re-lectotypify this species was redundant, and the lower specimen originally annotated as the type by Gyelnik must stand until further investigation is made into this matter.

The synonymy of *X. angustiphylla* and *X. conspersa* is a result of this prior misconception that *X. conspersa* is an asexual species. Due to the evidence in the original descriptions, I chose here to treat *X. conspersa* as a fertile species (see Figure 4), despite the vast majority of literature treating it instead as isidiate (Gyelnik 1930). *Xanthoparmelia conspersa* and *X. angustiphylla* have long been considered as a species pair (Tripp 2016) consisting of isidiate / fertile morphs of each other, as they otherwise have in common all other physical and chemical characteristics. Because I now recognize *X. conspersa* as fertile, these two species must be considered synonymous.

Additional Specimens Examined:

Hinsdale: Cebolla Creek Campground, 9400 ft., 29 July 1964, *W.A. Weber s.n.* [COLO-L-0048000].
Gilpin: Road to Corona, 11 July 1918, *C.C. Plitt s.n.* [COLO-L-0048277]. **Gunnison:** Along East River just below Emerald Lake, 3200m, 13 July 1955, *W.A. Weber s.n.* [COLO-L-0047701]. **Jefferson:** Bancroft property, The Castle, just north of Wellington Lake, 09 July 1976, *W.A. Weber s.n.* [COLO-L-0047803]. **Routt:** Slopes of Hahn's Peak, 3 mi. E of Columbine, 2743m, 22 June 1965, *W.A. Weber s.n.* [COLO-L-0047671].

Figure 4. *Xanthoparmelia conspersa* is here shown with sexual reproductive structures-
apothecia. Its lobe size (1-4 mm wide) and moderate adnation to the substrate is characteristic of
what many people think of when they picture *Xanthoparmelia*.



Xanthoparmelia cumberlandia (Gyel.) Hale, Phytologia 28: 486. 1974. \equiv *Parmelia subconspersa* var. *cumberlandia* Gyel. Repert. Spec. Nov. Regni Veg. 36: 164. 1934. TYPE: U.S.A., Maine, Cumberland, July 1907, *E.B. Chamberlain s.n.* (lectotype: BP- image! [designated by Hale in Smithsonian Contr. Bot. 74: 98. 1990]).

Morphological and Chemical Description:

Thallus foliose; adnate to loosely adnate; saxicolous. **Lobes** irregular; slightly separated, 1-8 mm wide; separate to subimbricate, flat to convolute; margins black at tips, apices mostly crenate. **Upper surface** yellow-green; epruinose, smooth, areolate and darkening towards older portions of thallus. **Medulla** white, with continuous algal layer. **Lower surface** pale brown; rhizines brown to black. **Soredia & isidia** absent in Colorado material. **Apothecia** infrequent to common, sessile; disks light to dark brown; margins subconvex and slightly crenate. **Ascospores** ellipsoid, non-septate, colorless; 6-7 x 4-5 μ m. **Pycnidia** common, black, sunken below upper cortex. **Figure 5**

Secondary Metabolites- Stictic acid (major), usnic acid (major); constipatic acid (trace), norstictic acid (minor).

Spot Tests- Medulla K+ yellow to orange, C-, KC-, P+ orange.

Ecology and Distribution: *Xanthoparmelia cumberlandia* (commonly known as the Cumberland Rock-Shield) is very common across many portions of North America. It however seems to be relatively uncommon in Colorado, where it occurs primarily in the southern Rocky Mountains in coniferous forests and alpine tundra over ca. 7500 ft. (CNALH 2016).

Notes: *Xanthoparmelia cumberlandia* is generally considered the non-isidiate morph of the asexual species *X. plittii* (Figure 14) in that the two share chemistry and other (non-reproductive) morphological features. However in the protologue for *X. cumberlandia*, Gyelnik clearly states that the specimen has a black underside, which is problematic because current usage of the name is for specimens with pale undersides. I am in the process of searching for an alternative, existing name for specimens that otherwise fit the above concept of *X. cumberlandia* but have pale undersides. If a name is not found, a new name for a fertile, stictic acid-containing species with a pale underside that occurs in North America might be needed. I am also in the process of further studying the identity of this species with respect to *X. conspersa* (Figure 4), with which it shares numerous features.

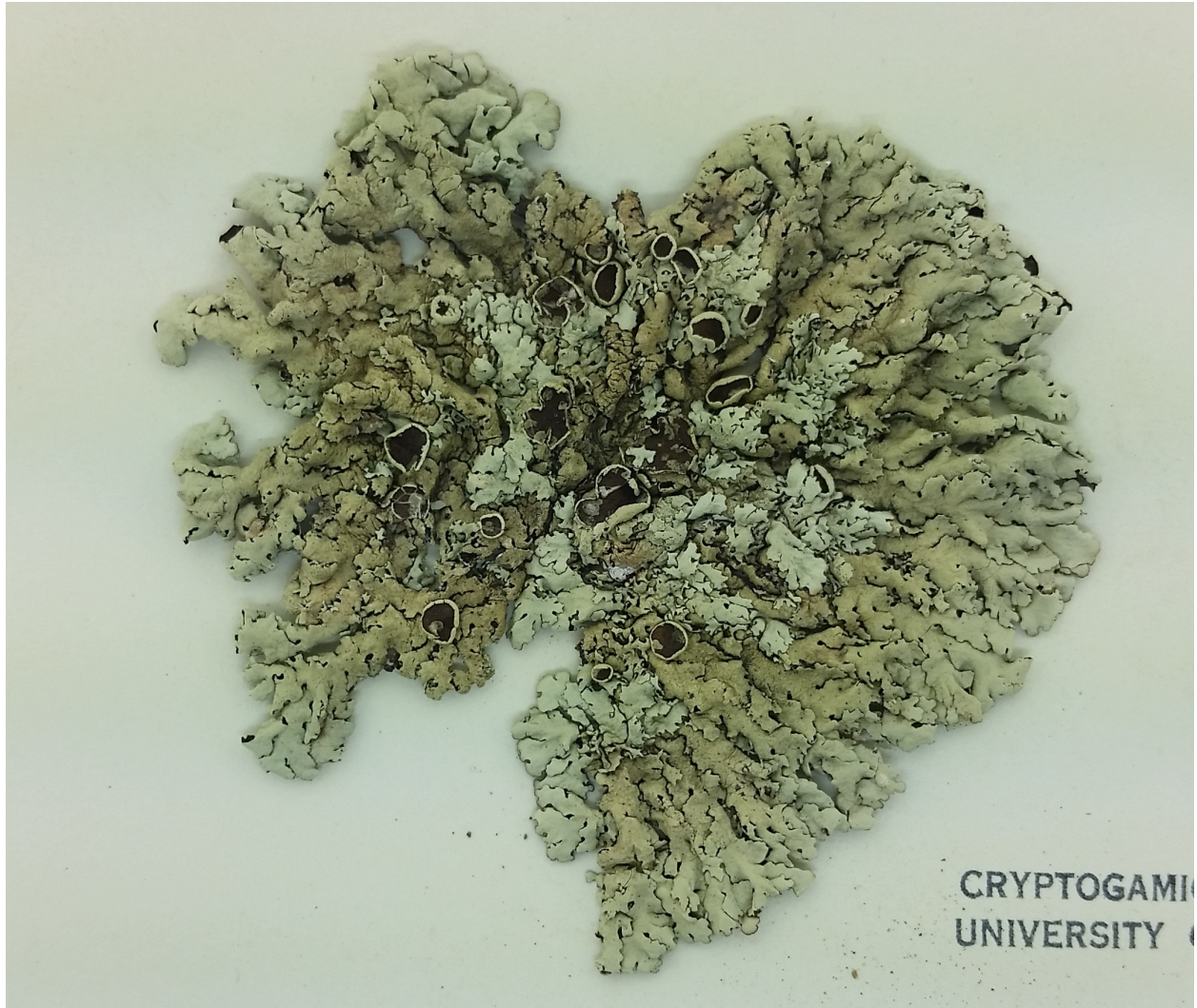
The holotype specimen designated in the protologue was presumably destroyed in Bouly de Lesdain Herbarium in Dunkerque, France during WWII.

Additional Specimens Examined:

Boulder: Just northwest of Boulder, 1829m, 06 April 1962, *W.A. Weber s.n.* [COLO-L-0047517]; Upper Gregory Canyon, ca. 1 mile west of Boulder and 1 mile north of Green Mountain Summit, 1940-1980m, 10 October 1974, *G. Kunkel s.n.* [COLO-L-0047897]; 5 miles northwest of Eldora on trail from 4th of July Canyon, to Arapahoe Glacier, 3048-3353m, 20 August 1957, *S. Shushan s.n.* [COLO-L-0047666]; Boulder Canyon near Tungsten, 12 mi. W. of Boulder, 2438m, 29 April 1959, *S. Shushan s.n.* [COLO-L-0047672]; Rocky Mountain National Park, Longs Peak, 3368m, 17 September 1933, *Walter Kiener 507* [COLO-L-0047683]. **Custer:** South Colony Creek basin, 37.98333 -105.50000, 3566m, 08 July 1941, *W. Kiener 10281* [COLO-L-0047719]. **El Paso:** Golf Links, 2600m, 06 September 1904, *F. E. Clements s.n.* [COLO-L-0047695]. **Garfield:** Trail from Trappers lake to Coffin Lake, ca. 30 miles east of Buford, White River National Forest, 2957m, 13 July 1957, *S. Shushan s.n.* [COLO-L-0047725]. **Grand:** Near base of south slope of Jackstraw Mountain, 1.5 miles west of Timber Lake, 3219-3292m, 04 July 1962, *R.A. Anderson 2330* [COLO-L-0047707]; Tonahutu Creek Trail, 1 mile east of Granite Falls, base of Snowdrift Peak, 3078-3139m, 27 July 1962, *R.A. Anderson 2422* [COLO-L-0047713]. **Gunnison:** Trail along Copper Creek to summit of Conundrum Pass, ca. 10 mi N.E. of Gothic, 10,500ft, 5 August 1955, *W.A. Weber s.n.* [COLO-L-0048074]. **Huerfano:** Apishapa Pass. 10 June 1960, *S. Shushan s.n.* [COLO-L-0047499]. **Jefferson:** Lower slopes of spurs of "The Castle," Bancroft property northwest of Willington Lake, 22 June 1976, *W.A. Weber s.n.* [COLO-L-0048301]. **Rio Blanco:** Lost Creek Campground, White River National Forest, 10 mile northeast of Buford, 2286m, 12 July 1957, *S.*

Shushan s.n. [COLO-L-0047689]; South ridge of Mt. Zirkel, Park Range, east of Slavonia above Gold Creek, 3444m, 28 July 1956, *S. Shushan s.n.* [COLO-L-0047677].

Figure 5. *Xanthoparmelia cumberlandia* is one of the most prominent fertile stictic acid- containing species in Colorado. Note that it is easily separated from its substrate, which is characteristic of this species.



Xanthoparmelia idahoensis Hale, Mycotaxon 34: 547. 1989. TYPE: U.S.A., Idaho, Lemhi County, 4,000 ft. elevation, 04 June 1986, *Roger Rosentreter 3828* (holotype: US [00075673]-image!; isotype: SRP- image!).

Morphological and Chemical Description:

Thallus foliose; irregular; vagrant. **Lobes** sublinear, dichotomously branched, deeply divided 1-4mm; sometimes black at apices; margins subcrenate. **Upper surface** yellow-green; strongly maculate, cracking and darkening towards older portions of thallus. **Medulla** white, with continuous algal layer. **Lower surface** pale yellow to brown, shiny; rhizines infrequent. **Soredia & isidia** absent in Colorado material. **Apothecia & ascospores** absent in Colorado material. **Pycnidia** absent in Colorado specimens. **Figure 6**

Secondary Metabolites- Salazinic acid (major), usnic acid (major); consalazinic acid (trace),

Spot Tests- Medulla K+ red, C-, KC-, P+ orange.

Ecology and Distribution: *Xanthoparmelia idahoensis* is currently only known to occur in very limited portions of Idaho, Canada, and Colorado, and is very rare; the COLO Herbarium only documents it from Grand and Gunnison Counties, at around 7800 ft. elevation (see Map 1).

Xanthoparmelia idahoensis grows in cold, arid areas with low abundance of vascular vegetation (Goffinet 2001). This species is considered by the Idaho Department of Fish and Game to be critically imperiled within the state of Idaho (Moseley 1996). Common names include Idaho *Xanthoparmelia* Lichen, Idaho Range Lichen, and Cherry Plum.

Notes: *Xanthoparmelia idahoensis* greatly resembles *X. chlorochroa* (Figure 2) in chemistry, morphology, and growth habit. One must however examine the upper cortex to find the maculate surface (Figure 6), which distinguishes these two species.

Upon studying the COLO specimens, I came across some slight variation in spot tests (K+ yellow or orange instead of red); I also recovered two unknown compounds via TLC in a few of the specimens. One occurred at an R_F value of approximately 35-40, turning brown with a blue halo under acid and heat. The other compound was at an R_F value of about 60, also turning brown with a blue halo under heat. Because of uncertain taxonomic status of these two specimens, they are excluded from this treatment but are currently under further study.

Additional Specimens Examined:

Grand: T2N, R81W, S26, 40°06'N 106° 25'W. 2300m, *R. Rosentreter* 9339 [COLO-L-0051162]. BLM; Approx. 8.2 air miles N of Kremmling on the east side of HWY 9, 7630 ft, 31 August 2014, *B. Elliot* 16364 [COLO-L-0050864]. **Gunnison:** T2N, R81W, Sec. 26, 40.10000 -106.41000, 2300m, 17 June 1995, *R. Rosentreter* 9339 [COLO-L-0047768]; BLM; Approx. 8.3 air miles N of Kremmling. East of Wolford Mountain Reservoir near CR 25, 40.17763 -106.39828, 2338m, 29 August 2014, *B. Elliot* 16342 [COLO-L-0050876]; BLM; Approx. 7.7 air miles N of Kremmling. East of Wolford Mountain Reservoir near CR 25, 40.16910 -106.39707, 2335m, 29 August 2014, *B. Elliot* 16345 [COLO-L-0050851]; BLM; Approx. 6.2 air miles NE of Kremmling, east of Wolford Mountain Reservoir near CR 25; 40.14727 -106.36011, 2414m, 30 August 2014, *B. Elliot* 16348 [COLO-L-0050853]; BLM; Approx. 2.2 air miles NE of Kremmling. S of Wolford Mountain in the vicinity of Cow Gulch. Near wooden power line, 40.09117 -106.37737, 2344m, *B. Elliot* 16351 [COLO-L-0050856]; BLM; Approx. 8.2 air miles N of Kremmling on the east side of Hwy. 9, 40.17088 -106.43558, 2323m, *B. Elliot* 16363 [COLO-L-0050874]; BLM; Approx. 8.2 air miles N of Kremmling on the east side of Hwy. 9; 40.17524 -106.42466, 2310m, 31 August 2014, *B. Elliot* 16372 [COLO-L-0050869]; BLM; Approx. 8.2 air miles N of Kremmling on the east side of Hwy. 9; 40.17051 -106.42274, 2316m, 31 August 2014, *B. Elliot* 16373 [COLO-L-0050872].

Figure 6. *Xanthoparmelia idahoensis* is characterized by its maculate surface (cracks in the upper cortex and photobiont layer that exposes the white medulla underneath). These maculae can usually be only seen under a dissecting microscope.



Xanthoparmelia lavicola (Gyel.) Hale, Mycotaxon 33: 404. 1988. \equiv *Parmelia lavicola* Gyel., Repert. Spec. Nov. Regni Veg. 36: 157. 1934. TYPE: Mexico, La Estrella, 09 September 1928, *Amable 600* (lectotype: BP-image! [designated by Hale in Smithsonian Contr. Bot. 74: 138. 1990]).

Morphological and Chemical Description:

Thallus foliose; suborbicular; tightly to moderately adnate; saxicolous. **Lobes** subirregular; somewhat divided, 1-3mm wide; subimbricate, flat to subconvolute; margins usually black, apices crenate. **Upper surface** yellow-green; epruinose, smooth, shiny, moderately to densely isidiate. **Medulla** white, with continuous algal layer. **Lower surface** pale; rhizines dark brown, occurring frequently. **Soredia** absent in Colorado material. **Isidia** at first globulose, then becoming cylindrical and branching moderately; at times black or brown on tips. **Apothecia & ascospores** absent in Colorado material. **Pycnidia** absent in Colorado material.

Secondary Metabolites- Psoromic acid (major), usnic acid (major); unknown compound, 2'-*O*-demethylpsoromic acid (trace), norstictic acid (trace). **Figure 7**

Spot Tests- Medulla K+ yellow, C-, KC-, P+ yellow to orange.

Ecology and Distribution: The isidiate *Xanthoparmelia lavicola* occurs primarily in southwestern Arizona and northeastern Mexico. Colorado specimens have been collected from both the eastern and western slopes in prairie and rocky areas at low elevations ranging from 4700-5500 ft. (see Map 1). It should be noted that of the five collections housed at Colorado, three were made at White Rocks Open Space in the City of Boulder.

Notes: *Xanthoparmelia lavicola* morphologically resembles *X. mexicana* (Figure 9) and *X. plittii* (Figure 14), however has a thallus that is more consistently tightly adnate. *Xanthoparmelia lavicola* can ultimately be characterized by the presence of psoromic acid as a major metabolite, which is rare in Colorado species of *Xanthoparmelia* (see Table 2).

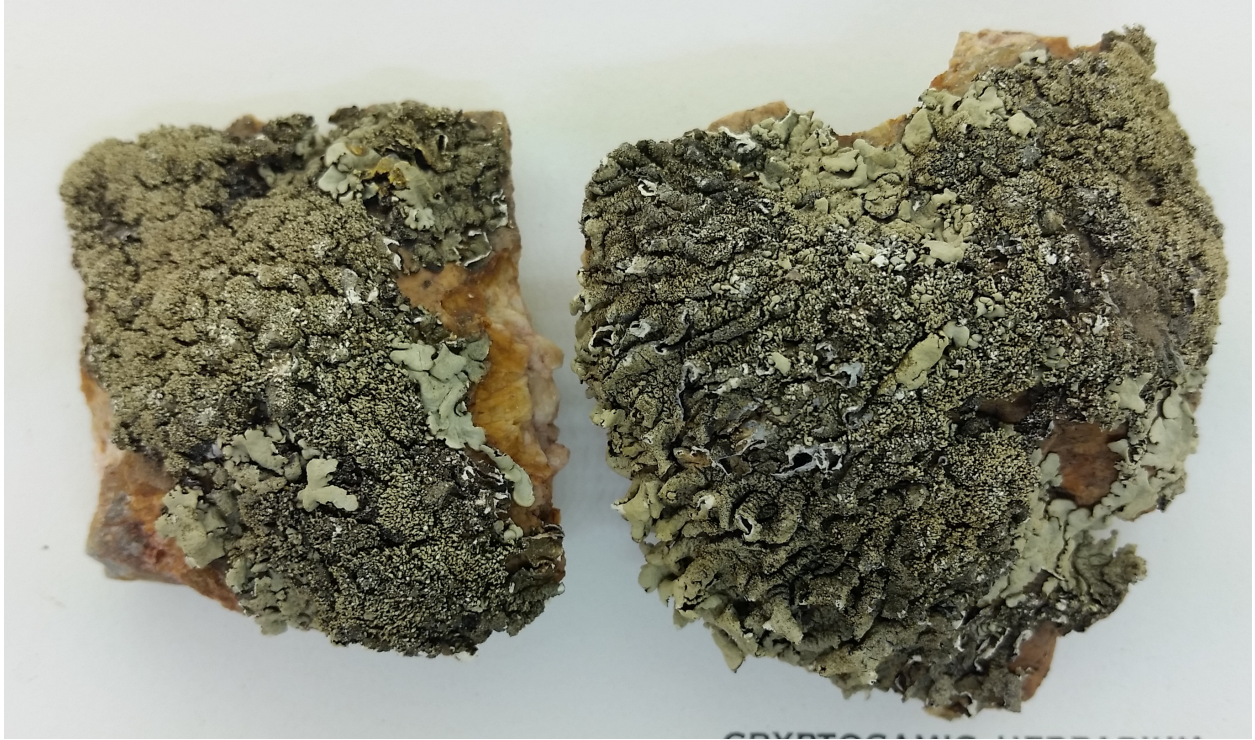
TLC conducted on the BP lectotype by M.E. Hale (annotated on the packet in 1987) indicated the presence of psoromic and norpsoromic acids; TLC conducted at a later date by an unknown researcher indicated the presence of fumarprotocetraric and usnic acids. I suspect that the fumarprotocetraric acid that the unknown researcher found on the BP lectotype is actually 2'-*O*-demethylpsoromic acid, as it has a very similar R_f value, but turns brown instead of grey under acid and heat. I here consider this species to contain psoromic acid (not fumarprotocetraric acid) based on the information above along with my own findings among Colorado material.

The holotype designated in protologue was presumably destroyed in Bouly de Lesdain Herbarium in Dunkerque, France during WWII.

Additional Specimens Examined:

Jefferson: 7 miles S of Boulder, on Rocky Flats Pediment, 26 June 1973, *G. Kunkel C-42* [COLO-L-0047859]; White Rocks Open Space, 5146 ft, 04 October 2014, *E.A. Tripp 4839* [COLO-L-0050573]; White Rocks Open Space, 5146 ft, 04 October 2014, *E.A. Tripp 4874* [COLO-L-0050604] **Las Animas:** West bank of Trinchera Creek, 25 miles east of Trinidad, 1676m, 04 July 1957, *S. Shushan s.n.* [COLO-L-0047831]. **Washington:** Six miles west-northwest of Akron, 1433m, 06 June 1954, *S. Shushan s.n.* [COLO-L-0047848].

Figure 7. *Xanthoparmelia lavicola* is the only isidiate species in Colorado to contain psoromic acid. Chemistry is required to differentiate between *X. laivola* and other asexual *Xanthoparmelia* species in Colorado.



Xanthoparmelia lineola (Berry) Hale, Phytologia 28: 486. 1974. \equiv *Parmelia lineola* E.C. Berry, Ann. Missouri Bot. Gard. 28: 77. 1941. TYPE: U.S.A, Arizona, Apache County, “3 miles northwest of Ft. Defiance” (*fide protologue*), 12 June 1938, *Hubricht B11370* (holotype: location unknown; isotype: NY- image!)

Morphological and Chemical Description:

Thallus foliose; usually orbicular; tightly adnate to substrate; saxicolous. **Lobes** irregular; at times dichotomously branched and divided, 1-3 mm wide; separate (usually at margins) to imbricate; margins blackening. **Upper surface** yellow-green, smooth and shiny, intensely cracking and darkening towards older portions of thallus. **Medulla** white, with continuous algal layer. **Lower surface** dark brown; rhizines dark brown, occurring frequently. **Soredia & isidia** absent in Colorado material. **Apothecia** common, sessile, disks light to dark brown; margins subconvex and slightly crenate. **Ascospores** ellipsoid, non-septate, colorless; 7-8 x 4-5 μ m. **Pycnidia** frequent to occasional, black, sunken below upper cortex. **Figure 8**

Secondary Metabolites- Sictic acid (major), usnic acid (major); norstictic acid (minor).

Spot Tests- Medulla K+ red, C-, KC-, P+ orange.

Ecology and Distribution: *Xanthoparmelia lineola* has been collected extensively in the southwestern United States and tends to grow at higher elevations between 3000-12000 ft. on highly sun-exposed rocks in arid environments (Berry 1941; Nash 1974; CNALH 2016). In Colorado it is found all along the southern Rockies in mountainous regions from elevations ranging between 6000-10000 ft. (see Map 1). It is commonly known as the Tight Rock Shield.

Notes: *Xanthoparmelia lineola* is a member of the salazinic acid containing group that includes *X. chlorochroa* (Figure 2), *X. wyomingica* (Figure 19), and *X. coloradoensis* (Figure 3). It can be distinguished from these other species by being the most tightly adnate member of this group. In 1990, Hale cited the holotype of this specimen to be located at the US herbarium. However, upon contacting the curatorial staff at that institution, it appears this specimen is missing. It was originally located at MO, but their lichen collection was relocated to US; thus, it is possible that the specimen was lost during this transfer. The isotype housed at NY is here confirmed as extant.

Additional Specimens Examined:

Alamosa: Trail to Mosca Pass, Great Sand Dunes National Monument, 10 June 1954, *S. Shushan s.n.* [COLO-L-0047581]. **Boulder:** Boulder Canyon ca. 0.5 miles up from mouth, 1800 m.s.m., 07 July 1976, *W.A. Weber s.n.*, [COLO-L-0048005]; Boulder Canyon near Tungsten, 8,000 ft., 29 April 1959, *S. Shushan s.n.* [COLO-L-0048023]; Steamboat Mountain, 2 mi. N.W. of Lyons, 1829m, 15 October 1972, *W.A. Weber s.n.* [COLO-L-0047740]; Summit of Niwot Ridge, 3505m, 19 July 1951, *M.E Hale s.n.* [COLO-L-0047805]; Between backyard of 6251 Lefthand Canyon and Cocktail Rock (Roosevelt National Forest), 0.3 miles W of Lee Hill Rd. and 0.2 Miles S of Lefthand Canyon Dr., 2195m, 28 March 2014, *E.A. Tripp 4893* [COLO-L-0050912]; Between backyard of 6251 Lefthand Canyon and Cocktail Rock (Roosevelt National Forest), 0.3 miles W of Lee Hill Rd. and 0.2 Miles S of Lefthand Canyon Dr., 2195m, 28 March 2014, *E.A. Tripp 4894* [COLO-L-0050913]. **Custer:** 2 miles north of Ophir campground, San Isabel National Forest, 2560m, 13 June 1951, *S. Shushan s.n.* [COLO-L-0047799]. **Jackson:** Along east edge of Big Creek Lake, east slope of Park Range, 24 miles west of Cowdrey, 2804m, 29 May 1955, *S. Shushan s.n.* [COLO-L-0047781]. **La Plata:** 10-12 miles north of Hesperus, 2743m, 09 June 1958, *S. Shushan s.n.* [COLO-L-0047775]. **Las Animas:** 0.4 miles north of Morley, 2256m, 10 June 1951, *S. Shushan s.n.* [COLO-L-0047787]. **Montrose:** above West Paradox Creek, west end of Paradox Valley, below Buckeye Reservoir, 38.42000 -109.03600, 1768m, 30 May 1960m, *W.A. Weber s.n.* [COLO-L-0047751]. **San Juan:** South Mineral Creek Campground, 2926m, 26 June 1954, *J. Douglass s.n.* [COLO-L-0047739].

Figure 8. *Xanthoparmelia lineola* is one of the most common salazinic acid-containing species within Colorado. Note its very tight adnation to the rock, which what separates it from *X. coloradoensis* and *X. wyomingica*.



Xanthoparmelia mexicana (Gyel.) Hale, Phytologia 28: 486. 1974. \equiv *Parmelia mexicana* Gyel., Repert. Spec. Nov. Regni Veg. 31: 281. 1931. TYPE: Mexico, San Jeronima, 07 October 1926, *Frère Amable 676* (lectotype: BP- image! [designated by Hale in Smithsonian Contr. Bot. 74: 147. 1990]).

Morphological and Chemical Description:

Thallus foliose; moderately to tightly adnate to substrate; saxicolous/terricolous. **Lobes** irregular; somewhat divided, 3-10 mm wide; separate to imbricate; margins usually dark brown entire to crenate. **Upper surface** yellow-green; epruinose, smooth, cracking and becoming rugose towards older portions of thallus. **Medulla** white, with continuous algal layer. **Lower surface** pale brown; rhizines dark brown. **Soredia** absent in Colorado material. **Isidia** at first globulose, then becoming cylindrical and branching frequently; at times black or brown on tips. **Apothecia & ascospores** absent from Colorado material. **Pycnidia** infrequent to occasional, black, sunken below upper cortex. **Figure 9**

Secondary Metabolites- Salazinic acid (major), usnic acid (major); norstictic acid (minor).

Spot Tests- Medulla K+ yellow to red, C-, KC-, P+ orange-red.

Ecology and Distribution: *Xanthoparmelia mexicana* is very common in North America, particularly in the southwestern region of the United States. In Colorado it can be found in the southern Rockies, most commonly on the eastern slope in canyons and slopes at elevations from 5000-9000 ft. (see Map 1). It is commonly known as the Salted Rock-Shield Lichen.

Notes: *Xanthoparmelia mexicana* is considered the isidiate morph of *X. lineola* (Figure 8), and is the most common salazinic-containing asexual species found in the state.

The holotype designated in protologue was presumably destroyed in Bouly de Lesdain Herbarium in Dunkerque, France during WWII.

Additional Specimens Examined:

Boulder: south base of Steamboat Mountain, 1.5 miles north of Lyons, 1676m, 10 March 1959, *S. Shushan s.n.* [COLO-L-0047818]; Upper Gregory Canyon, ca. 1 mile west of Boulder and 1 mile north of Green Mountain Summit, 1940-1980m, 17 May 1975, *G. Kunkel s.n.* [COLO-L-0047824]; Lytle Formation, Dakota Ridge, Rabbit Mountain, 4 miles northeast of Lyons just above the Little Thompson River, 1585-1631m, 15 August 1960, *R.A. Anderson s.n.* [COLO-L-0047830]; Wild Basin, 1.5 miles up Finch Lake Trail, 2743m, 29 June 1962, *R.A. Anderson 2206* [COLO-L-0047836]; Boulder Canyon, ca. 0.5 miles up from mouth, 1800m, 07 July 1976, *W.A. Weber s.n.* [COLO-L-0047842]. **El Paso:** Bear Creek Canyon, west of Colorado Springs, 12 June 1918, *C. C. Plitt s.n.* [COLO-L-0047812]. **Garfield:** 5 mi. N of Rifle, W side of Rifle Creek along south edge of Grand Hogback, 2 mi. SW of Rifle Gap, 1800m, 12 June 1974, *W.A. Weber s.n.* [COLO-L-0047871]; 9.8 miles west of Grand Valley, 04 September 1957, *S. Shushan s.n.* [COLO-L-0047877]. **Jackson:** Big Creek lake, ca. 24 miles northwest of Cowdrey, east slope of Park Range, 2804m, 29 May 1955, *S. Shushan s.n.* [COLO-L-0047829]. **Larimer:** Rocky Mountain National Park: ESE of Endovalley Campground, on extensive north-facing talus, 2658-2707m, 17 June 1966, *R.A. Anderson 5407* [COLO-L-0047811]; Owl Canyon, 9.7 miles north of Teds Place (junction of Highways 287 and 14), 1829m, 06 April 1955, *S. Shushan s.n.* [COLO-L-0047817]; Rocky Mountain National Park, SW slope of Deer Mountain, 2667-2804m, 25 August 1962, *R.A. Anderson 3567* [COLO-L-0047823]; Mummy Range, Mt. Chiquita, 3414-3627m, 14 July 1963, *R.A. Anderson 4019* [COLO-L-0047835]; 4.5 miles SW of Ft. Collins, just above Horsetooth Reservoir; Sec. 32, & T. 6 N., Sec. 5, ca., 1661-1798m, 01 July 1960, *R.A. Anderson s.n.* [COLO-L-0047837]; Near Horseshoe Park and road to Endovalley Campground, 2652-2804m, 23 July 1962, *R.A. Anderson 2801* [COLO-L-0047841]; South Lateral Moraine, 2469-2591m, 17 July 1962, *R.A. Anderson 2642* [COLO-L-0047847]; Estes Park, 9 miles southeast of, or 14 miles northwest of Lyons, off Denver highway, 2286m, 26 July 1949, *W. Kiener 24765* [COLO-L-0047853]. **Mesa:** Ca. 7 miles southwest of Whitewater on benches above East Creek north of Gibbler Gulch, 01 June 1973, *W.A. Weber s.n.* [COLO-L-0047813]; North end of Colorado National Monument, ca. 3 mi. south of Fruita, Dakota-Morrison formation, base of escarpment, 1372m, 12 May 1955, *S. Shushan s.n.* [COLO-L-0047819]; North end of Colorado National Monument, ca. 3 miles south of Fruita; mouth of Fruita Canyon, 1402m, 12 May 1955, *S. Shushan s.n.* [COLO-L-0047825]; Ca. 7 miles southwest of Whitewater on benches above East Creek north of Gibbler Gulch, 01 June 1973, *W.A. Weber s.n.* [COLO-L-0047878]. **Montezuma:** Beaver Creek, 6 miles north of McPhee, 2286m, 12 June 1958, *S. Shushan s.n.* [COLO-L-0047872]. **Montrose:** Escarpment above West Paradox Creek, west end of Paradox Valley, below Buckeye Reservoir, 38.42000 -109.03600, 1768m, 30 May 1960, *W.A. Weber s.n.* [COLO-L-0047866]. **Park:** 11.3 miles east of Jefferson on road to Lost Creek park, 3048m, 03 July 1955, *S. Shushan s.n.* [COLO-L-0047860]. **Summit:** East of Lake Dillon near Keystone, 39.60000 -106.00000, 2700m, 11 September 1981, *W.A. Weber s.n.* [COLO-L-0047854].

Figure 9. *Xanthoparmelia mexicana* is one of the most common asexual *Xanthoparmelia* species in Colorado. Note great resemblance in moderate to tight adnation level, lobe size/ shape, and color to other asexual species (Figures 7, 11, 14).



Xanthoparmelia monticola (J.P. Dey) Hale, Mycotaxon 33: 404. 1988. \equiv *Parmelia monticola* Dey., Castanea 39: 360-361. 1974. TYPE: U.S.A., North Carolina, Buncombe County 1972, *J.P. Dey 1509* (holotype: DUKE- image!; isotype: Herb. Dey- n.v.).

Morphological and Chemical Description:

Thallus foliose; loosely adnate; saxicolous. **Lobes** sublinear; 1-2.5 mm wide; contiguous to imbricate; margins blackening, entire to crenate. **Upper surface** yellow-green; epruinose, smooth. **Medulla** white, with continuous algal layer. **Lower surface** light to dark brown; rhizines light to dark brown, occurring frequently. **Soredia & Isidia** absent in Colorado material. **Apothecia** common, substipitate, light to dark brown, margins smooth. **Ascospores** absent in Colorado material. **Pycnidia** frequent to occasional, black, sunken below upper cortex.

Secondary Metabolites- Fumarprotocetraric acid (major), usnic acid (major); physodalic acid (trace), protocetraric acid (trace). **Figure 10**

Spot Tests- Medulla K-, C-, KC-, P+ orange.

Ecology and Distribution: There has only been one record collected in Colorado of *Xanthoparmelia monticola*, found in Boulder County at an elevation of 6000 ft. (see Map 1). Since the only collection made in Colorado is on the eastern slope, it could be assumed that this species occurs only in that region. However, it could rather be that 1) it is filed elsewhere in other herbaria as its close relative *X. novomexicana* or 2) it is a rare species, an unrepresentative amount of collections have been made. *Xanthoparmelia monticola* is globally ranked by the Nature Conservancy as a G2 species, which means that there are only 6-20 populations known to exist in the world (Perlmutter 2009).

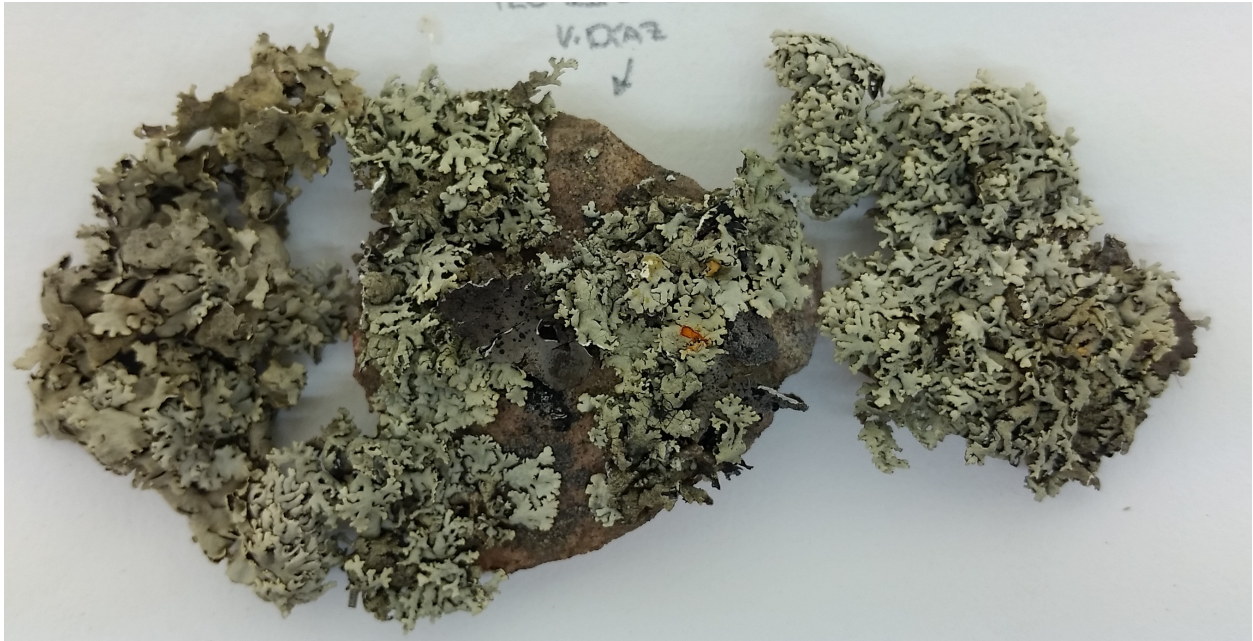
Notes: The presence of physodalic acid is very rare in the genus *Xanthoparmelia*. This in addition to the production of fumarprotocetraric and stictic acids makes this species very chemically highly distinguishable. It might be most commonly confused with *X. novomexicana* (Figure 13), which also contains fumarprotocetraric acid. However, *X. monticola* lacks physodalic acid and is also much more loosely adnate.

While Dey did not describe protocetraric acid in his protologue, there was mention of traces of an unknown element that he stated could possibly be sublimbatic acid. Because protocetraric and sublimbatic acid have very similar R_F values, it is possible that the unknown trace Dey saw on the TLC plate was actually protocetraric acid. In addition, Dey also stated that there were traces of stictic acid in the holotype. It was later concluded that the stictic acid traces were due to an *X. conspersa* contaminant on the DUKE holotype sheet (determined by J. Johnston in 1983).

Additional Specimens Examined:

Boulder: Shanahan Mesa, a colluvial fan spreading out from the base of Bear Peak, south edge of Boulder, 1900m, 02 May 1998, *W.A. Weber s.n.* [COLO-L-0047843].

Figure 10. *Xanthoparmelia monticola* can be differentiated from the chemically identical *X. novomexicana* by its more loose adantion level. Note the lobes lifting of the substrate.



Xanthoparmelia mougeotii (Schaer. in D. Dietr.) Hale, Phytologia 28: 488. 1974. ≡ *Parmelia mougeotii* Schaer. in D. Dietr., Deutschl. Kryptog. Gewächse 4 Abth.: 118. 1846. LECTOTYPE: Tab 288, f 288 [lower half of plate] (the book-image!), designated Elix & Thell, Nordic Lichen Flora 4: 141. 2011. EPITYPE: France, Vosges, Bruyères, “*Ad saxa silacea in summo m. Heledré prope Brujerium* Mougeot.” [fide specimen], Schaerer, Lich. Helv. Exs. No. 548 (UPS-image!), designated by Elix & Thell, Nordic Lichen Flora 4: 141. 2011. Additional syntype: France, Vosges, Bruyères, “*Ad saxa silacea in summo m. Heledré prope Brujerium* Mougeot.” [fide specimen], Schaerer, Lich. Helv. Exs. No. 548 (FH-image!).

Morphological and Chemical Description:

Thallus foliose; tightly adnate; saxicolous. **Lobes** irregular; deeply divided, 3- 10 mm wide; separate to imbricate; margins darkening, entire to crenate at apices. **Upper Surface** dark yellow-green and sometimes partially brown in older sections; shiny, cracking in older portions of thallus. **Medulla** white with continuous algal layer. **Lower Surface** dark brown, shiny; rhizines dark brown. **Soredia** frequent; in orbicular clumps; light yellow-green. **Isidia** absent in Colorado material. **Apothecia & ascospores** absent in Colorado material. **Pycnidia** infrequent, sunken, black. **Figure 11**

Secondary Metabolites- Stictic acid (major), usnic acid (major); constictic acid (trace), norstictic acid (minor).

Spot Tests- Medulla P-, K+ yellow, KC+ yellow, C+ yellow.

Ecology and Distribution: *Xanthoparmelia mougeotii* appears to be very rare in Colorado, with only two confirmed records within the state, both collected in Rocky Mountain National Park at 8800-9100 ft. in a canyon (see Map 1).

Notes: This is the only sorediate *Xanthoparmelia* species found within Colorado that COLO has record of and seems to be an alpine species in the state. In other regions of the U.S.A., it appears to have been collected almost exclusively on the western coast at lower elevations. Until we have more Colorado collections made, ecology and distribution for *X. mougeotii* will be hard to infer. The above description is based on the only two specimens representing this species that are housed at COLO in addition to study of the protologue and the original material cited above.

The secondary metabolites cited above derive from Nash (2002) because the COLO collections are extremely sparse and too scant for destructive sampling.

Hale (1990) attempted to designate the UPS specimen of Schaerer's exsiccate to be a neotype, but this was an error as a lectotype should have been designated. Elix and Thell (2011) correctly typified the name when they designated the illustration as lectotype and the Schaerer exsiccate No. 548 specimen (UPS) as the epitype. Note that Hale (1974; Hale 1990) incorrectly cited Schaerer (1850) as the protologue, rather than the earlier edition of the work in 1846; additionally Elix and Thell (2011) incorrectly cited the starting page number of the protologue as 24 instead of 118, which has been corrected above.

Additional Specimens Examined: **Larimer:** Rocky Mountain National Park, Spruce Canyon, along Spruce Creek, ca. 1 mile from mouth of Forest Canyon, 40.34967°N, 105.67576°W, 2682-2774m, 14 June 1966, R.A. Anderson 5302 [COLO-L-0047896; COLO-L-0047890].

Figure 11. *Xanthoparmelia mougeotii* is distinctive from other asexual species in this treatment in that the only sorediate *Xanthoparmelia* species known to Colorado.



Xanthoparmelia neochlorochroa Hale, Mycotaxon 30: 324. 1987. TYPE: U.S.A., Idaho, Lemhi County, 18 June 1973, Doyle. *E. Anderegg 1480* (holotype: US [00051120]- image!)

Morphological and Chemical Description:

Thallus foliose; vagrant. **Lobes** sublinear; dichotomously- branched and deeply divided, 3-15 mm wide; separate to subimbricate; margins sometimes blackening at tips. **Upper surface** yellow-green; smooth, cracking and darkening towards older portions of thallus. **Medulla** white, with continuous algal layer. **Lower surface** pale to dark brown and shiny; rhizines brown, occurring frequently. **Soredia & isidia** absent in Colorado material. **Apothecia & ascospores** absent in Colorado material. **Pycnidia** infrequent, sunken, black. **Figure 12**

Secondary Metabolites- Usnic acid (major); connorstictic acid (trace), norstictic acid (minor).

Spot Tests- Medulla K+ yellow to red, C-, KC-, P+ orange.

Ecology and Distribution: *Xanthoparmelia neochlorochroa* occurs in northern Colorado on north-facing mountain slopes between elevations of 6000-8000 ft. (see Map 1). It has been found that vagrant lichens thrive in areas with low vascular plant biomass, low-nutrient soil, elevated frequencies of drought, and higher exposure to wind (Rosentreter 1993, MacCracken 1983). Vagrant lichens are also common in grazing lands, which has led to poisoning of livestock.

Notes: This species resembles *X. chlorochroa* (Figure 2) morphologically, however chemically it differs due to its lack of salazinic acid. Researchers should note that the R_F value of salazinic acid is 4, while the R_F value of connorstictic acid is 3. This can pose difficulties in separating *X. chlorochroa* and *X. neochlorochroa* as the latter has connorstictic acid, thus a dependable standard should be used when running TLC on these species.

Additional Specimens Examined:

Grand: BLM; Approx. 2.2 air miles NE of Kremmling. S of Wolford Mountain in the vicinity of Cow Gulch. Near wooden power line, 40.10158 -106.38417, 2387m, 30 August 2014, *B. Elliot 16350* [COLO-L-0050855]. **Moffat:** 13 miles northeast of Craig, 40.66667 -107.46667, 1965m, 26 August 1975, *S. Shushan sl 8909* [COLO-L-0047950]. **Summit:** BLM; Approx. 10.5 air miles S of Kremmling and 2 miles N of Green Mountain Reservoir; east of Hwy. 9 near junction of Hwy. 9 and Road 381; 39.91787 - 106.32752, 2362m, 30 August 2014, *B. Elliot 16358* [COLO-L-0050875].

Figure 12. *Xanthoparmelia neochlorochroa* resembles other vagrant lichens in that it has dichotomous branching and forms rosettes.



Xanthoparmelia novomexicana (Gyel.) Hale, Phytologia 28: 488. 1974. \equiv *Parmelia novomexicana* Gyel., Repert. Spec. Nov. Regni Veg. 36: 161. 1934. TYPE: U.S.A., New Mexico, Las Vegas, 18 February 1930, *Frère Arsène Brouard 20647* (lectotype: BP- image! [designated by Hale in Smithsonian Contr. Bot. 74: 166. 1990]).

= *Xanthoparmelia arseneana* (Gyel.) Hale, Phytologia 28: 486. 1974. \equiv

Parmelia arseneana Gyel., Ann. Mycol. 36: 269. 1938. TYPE: U.S.A., New Mexico, Las Vegas, Gallinas Cañon N., ca. 2300 m.s.m. alt., 1930, *Arsène 21191* (lectotype- BP- image! [designated by Hale in Smithsonian Contr. Bot. 74: 166. 1990]).

Morphological and Chemical Description:

Thallus foliose; tightly to moderately adnate; saxicolous. **Lobes** sublinear; 5-20 mm wide; strongly imbricate towards center of thallus, and non-imbricate at margins; plane to slightly convex margins browning a tips; apices entire to moderately crenulate. **Upper surface** yellow-green; epruinose, smooth at times rugose, areolate, and blackening towards the center. **Medulla** white with continuous algal layer. **Lower surface** pale and darkening towards tips; rhizines dark brown to black, occurring frequently. **Soredia & isidia** absent in Colorado material. **Apothecia** moderate, sessile, disks brown, margins subconvex and slightly crenate. **Ascospores** ellipsoid, non-septate, colorless; 8-9 x 4-5 μ m. **Pycnidia** frequent, sunken, black. **Figure 13**

Secondary Metabolites- Fumarprotocetraric acid (major), protocetraric acid (minor), usnic acid (major).

Spot Tests- Medulla K+ yellow, C-, KC-, P+ orange (dark).

Ecology and Distribution: *Xanthoparmelia novomexicana* is found in montane western regions in North America from Washington and Montana continuing into Oaxaca (CNALH 2016). The ecology of this species is relatively restricted compared to its other *Xanthoparmelia* counterparts, as it is typically only found at elevations ranging from 6800-11000 ft. (Nash 1974).

Notes: *Xanthoparmelia novomexicana* is morphologically very similar to *X. lineola* (Figure 8) but differs chemically in that it contains fumarprotocetraric acid instead of salazinic acid (see Table 2) and has a K- test in the medulla while *X. lineola* has a positive K+ red test. In addition, *X. novomexicana* has a much more limited range than *X. lineola* (Nash 1974).

TLC conducted on BP lectotype by an unknown researcher (annotated on packet in 1987) indicated presence of succinprotocetraric acid. J.A. Elix also conducted TLC on the same specimen (annotated on packet on 23 March 2004) that indicated presence of confumarprotocetraric (trace) and virensic (minor) acids.

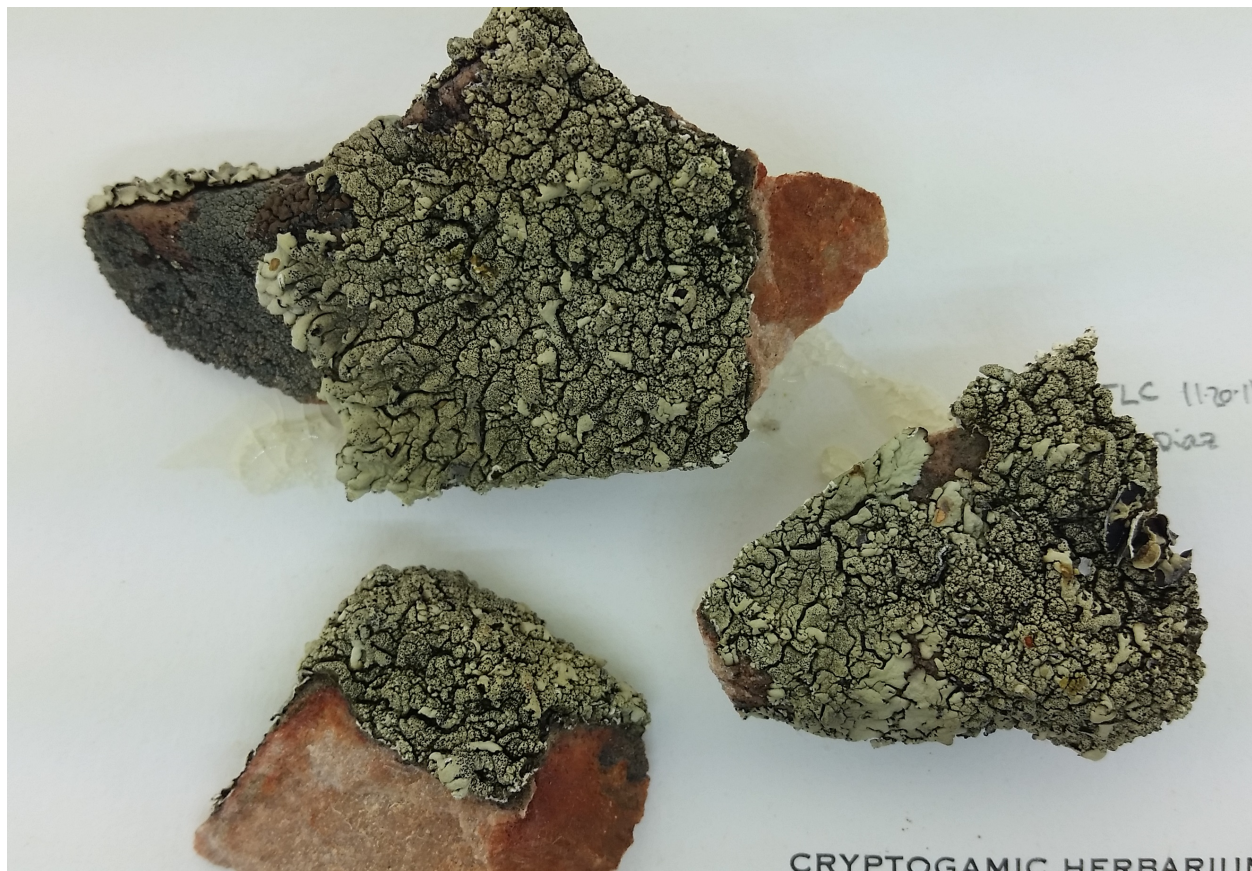
The decision to here propose *Xanthoparmelia arseneana* as a synonym of *X. novomexicana* is based on protologue descriptions and the fact that type specimens were both collected Las Vegas, NM only a few years apart. In the protologue of *X. novomexicana*, Gyelnik stated the underside of the thallus was “blackening”. I choose to interpret this as the underside is otherwise pale, and the darkening may very well be due to age (a common trait among thalli with pale undersides). In addition, upon delving into Vilmos Gyelnik’s (the author on both species) history, it is known that he tended to work fast and at times messily. This resulted in numerous instances of him describing the same species on multiple different occasions (Hale 1990).

The holotype designated in protologue was presumably destroyed in Bouly de Lesdain Herbarium in Dunkerque, France during WWII.

Additional Specimens Examined:

Boulder: Boulder Canyon ca. 0.5 miles up from mouth, 1800 m.s.m., 07 July 1976, *W.A.Weber s.n.* [COLO-L-0048127]; First Flatiron, just above mouth of Gregory Canyon, 1800m, 06 July 1976, W. A. Weber s.n. [COLO-L-0047891]. **Huerfano:** Apishapa Pass, south of La Veta, 10 June 1960, Sam Shushan s.n. [COLO-L-0047499].

Figure 13. *Xanthoparmelia novomexicana* is characteristically very tight to the substrate, similar to *X. lineola* (Figure 8). This tight adnation is also useful in differentiating between *X. monticola* (Figure 10)- its chemically identical counterpart.



Xanthoparmelia plittii (Gyel.) Hale, Phytologia 28: 488. 1974. ≡ *Parmelia plittii* Gyel. Repert. Spec. Nov. Regni Veg. 31: 287. 1931. TYPE: U.S.A., Maryland, Baltimore County, Liberty Road at Gwynna Falls, 31 March 1908, *C.C. Plitt s.n.* (lectotype: BP- image! [designated by Hale in Smithsonian Contr. Bot. 74: 175. 1990]).

Morphological and Chemical Description:

Thallus foliose; moderately to tightly adnate; saxicolous. **Lobes** irregular; moderately to deeply divided, 0.1-3.5 mm wide; non- imbricate to moderately imbricate; margins usually black.

Upper surface yellow-green; shiny and epruinose; smooth, cracking and blackening with age.

Medulla white with continuous algal layer. **Lower surface** pale, shiny; rhizines dark brown.

Soredia absent in Colorado material. **Isidia** frequent to dense, cylindrical, then branching and darkening with age. **Apothecia & ascospores** absent in Colorado material. **Pycnidia** moderate, black sunken. **Figure 14**

Secondary Metabolites- Stictic acid (major) usnic acid (major); constictic acid (trace), cryptostictic acid (trace), unknown compound (trace), norstictic acid (minor).

Ecology and Distribution: *X. plittii* is found very common across both North and South America. In Colorado, it is abundant in the southern Rocky Mountains, on both eastern and western slopes at 4500-6200 ft. elevation (CNALH). In Colorado it is abundant on both eastern and western slopes from prairies to alpine regions at elevations of 4800-9500 ft. (see Map 1).

Notes: This species is considered the isidiate counterpart of the fertile *X. cumberlandia* (Figure 5), as they share ecological, chemical, and morphological features. It also resembles *X. conspersa* (Figure 4), however the latter species has a black lower surface and is primarily fertile.

Additional Specimens Examined:

Gunnison: Lytle Formation, Dakota Group, T1N R71W SEC1, 5800-6400 ft., 01 August 1959, *R.A. Anderson s.n.* [COLO-L-0047617]; Blue Mesa Cutoff road at Hole-in-the-wall, 2438m, 27 July 1955, *W.A. Weber s.n.* [COLO-L-0047928]. **Hinsdale:** Cebolla Creek Campground, between Cathedral and Slumgullion Pass, 2865m, 29 July 1964, *W.A. Weber s.n.* [COLO-L-0047865]. **La Plata:** 3 miles north of Bondad, just east of Animas River, 1829m, 12 June 1955, *S. Shushan s.n.* [COLO-L-0047922]. **Larimer:** Dakota Ridge, 22 miles north of Ft. Collins, two miles SE of Table Mt., 1920-1981m, 23 October 1959, *R.A. Anderson s.n.* [COLO-L-0047916]. **Moffat:** At the northern end of Dinosaur National Monument, the entrance of the Green River into the Canyon of Lodore, about 1 mi. So. of Browns Park, above camp, 29 July 1962, *S. Flowers s.n.* [COLO-L-0047910]. **Montezuma:** ca. 30 miles west of Cortez, vicinity of junction of Yellowjacket and McElmo Creek, 1463m, 10 June 1958, *S. Shushan s.n.* [COLO-L-0047904].

Figure 14. *Xanthoparmelia plittii* is the stictic acid- containing asexual species off *Xanthoparmelia* in Colorado. Note its morphological similarity to *X. mexicana* (Figure 9), which is why TLC is necessary to differentiate the two species.



Xanthoparmelia psoromifera (Kurok. ex Hale) Hale, Phytologia 28: 488. 1974. ≡

Parmelia psoromifera Kurok. ex Hale Bryologist 70: 418. 1967. TYPE: Mexico, Jalisco, 25 km south of Guadalajara, July 1961, *M. Wirth* 22 (holotype: US [00068977]- image!).

Morphological and Chemical Description:

Thallus foliose; moderately to tightly adnate; saxicolous. **Lobes** sublinear; moderately divided 0.1-4 mm wide; non-imbricate; flat to subconvolute; margins starting to brown at tips. **Upper surface** yellow-green; epruinose and shiny, smooth and becoming rugose and blackening towards older portions of the thallus. **Medulla** white with continuous algal layer. **Lower surface**- pale brown; rhizines brown, occurring frequently. **Apothecia** moderate, sessile, disks brown, margins subconvex and slightly crenate. **Soredia & isidia** absent in Colorado material. **Ascospores** ellipsoid, non-septate, colorless; 6-7 x 4-5µm. **Pycnidia** infrequent to frequent, sunken, black. **Figure 15**

Secondary Metabolites- Psoromic acid (major), 2-*O*-demethylpsoromic acid (trace), usnic acid (major).

Spot Tests- Medulla K- or yellow, C-, KC+ yellow, P+ dark yellow.

Ecology and Distribution: The chemically unusual *X. psoromifera* is rarely found in Colorado, as only two collections to date have been made in the state on the eastern slope plains (see additional specimens examined below and Map 1). It is most commonly found in the southwestern U.S.A. (CNALH 2016).

Notes: This is considered to be the non-isidiate morph of *X. lavicola* (Figure 7), as the two resemble one another morphologically. Both are rare in Colorado.

Additional Specimens Examined: **Bent:** Vicinity of Raven's Nest, E on Rd T from HWY 101S and S on Route 16, 06 June 2015, *E.A. Tripp 5656* [in processing]. **Las Animas:** Comanche National Grassland, vicinity of Picketwire Canyon and Withers Campground, above (W) Purgatory River, 05 June 2015, *E.A. Tripp 5630* [in processing].

Figure 15. *Xanthoparmelia psoromifera* is morphologically similar to its asexual counterpart- *X. lavicola* (Figure 7). Its tight adnation level and lobe type, it often resembles *X. lineola* (Figure 7) and *X. novomexicana* (Figure 13).



Xanthoparmelia stenophylla (Ach.) Ahti & D. Hawksw., Lichenologist 37: 363. 2005. ≡

Parmelia conspersa var. [β] *stenophylla* Acharius, Methodus (Acharius) 206. 1803. ≡ *Parmelia*

stenophylla (Ach.) Heugel, Corresp. Naturf. Ver. Riga 8: 109 (1855) TYPE: Sweden?, "Habitat ad montes" [*fide* protologue], *s.d.*, *s.c.* (lectotype: H-hb. Ach. [9502092]-image!; isolectotype: BM-Ach. 607-n.v. [designated by Hale in Smithsonian Contr. Bot. 192. 1990]).

Morphological and Chemical Description:

Thallus foliose; orbicular; adnate to loosely adnate; saxicolous. **Lobes** irregular; 0.5- 1.5 cm

wide; heavily imbricate; at times convolute; blackening at margins, at times crenate. **Upper**

surface yellow-green; smooth, shiny. **Medulla** white with continuous algal layer. **Lower**

surface dark brown; rhizines black. **Soredia and isidia** absent in examined material. **Apothecia**

moderately occurring, sessile, disks light to dark brown, margins somewhat convolute.

Ascospores absent in Colorado material. **Pycnidia** occurring moderately, sunken, black.

Secondary Metabolites- Salazinic acid (major), usnic acid (major). **Figure 16**

Spot Tests- K+ red. C-, KC-, P+ orange.

Ecology and Distribution: *Xanthoparmelia stenophylla*, like its *X. wyomingica* counterpart, is generally found at higher elevations (7000+ ft.). Colorado material has been collected mainly on mountain slopes on the eastern slope (see Map 1).

Notes: This species occurs within very large salazinic acid-containing group that can be hard to identify in the field. While *X. stenophylla* does resemble *X. wyomingica* (Figure 19) in that it has narrow lobes and is loosely adnate to substrates, one can differentiate it by its much less convoluted and slightly broader lobes and overall flat mat-like growth formation. It is also more

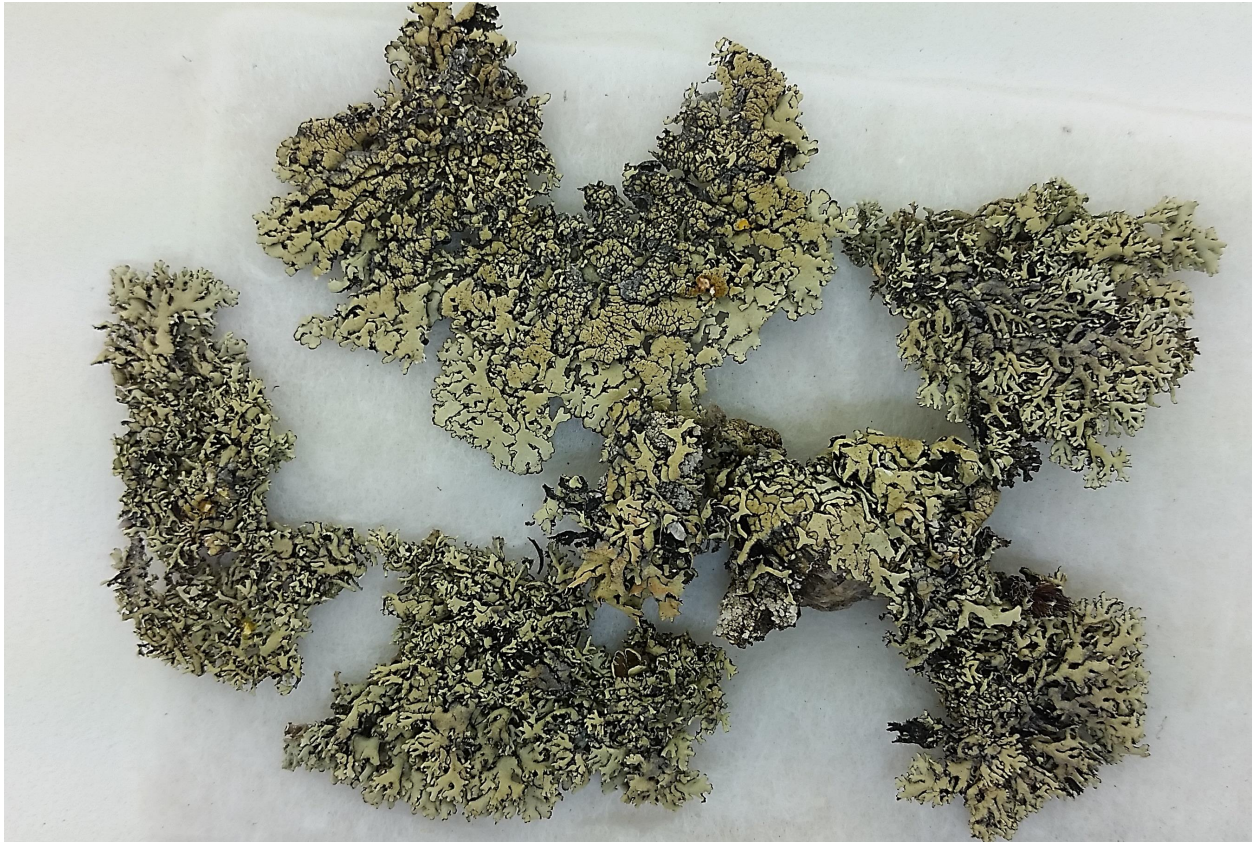
likely to be found growing on rocks (albeit somewhat loosely), while *X. wyomingica* is more likely to be found growing at least partially on pebbles or soil.

There has been some dispute over this name over the past few decades (Hale 1990, Ahti et al. 2005). This has resulted in unclear delimitation of this species and inconsistent herbaria filing practices of *X. stenophylla*. Ahti (2005) resolved the issue and provided the combination into *Xanthoparmelia*, but it should be noted that many herbaria have yet to update their specimens, which are still filed under *X. somloensis*.

Additional Specimens Examined:

Boulder: 0.8 miles south of Eldora. South shore of Lake Eldora, 9000 ft., 26 October 1952, *W.A. Weber s.n.* [COLO-L-0047987]; 1 mi. S.E. of Science Lodge and ca. 8 mi. N. of Nederland; west of Peak to peak Hwy., 9500 ft., 17 May 1958, *S. Shushan s.n.* [COLO-L-004993]. **El Paso:** Northwest slope of Pikes Peak, 13300 ft, 01 August 1955, *S. Shushan s.n.* [COLO-L-0048034]. **Larimer:** Mummy Range, southeast of Lawn Lake, base of Mummy Mountains, 3316-3365m, 19 June 1962, *R.A. Anderson 2074* [COLO-L-0047505]; 8.0 miles w.s.w. of Loveland. Cottonwood Canyon, 7000 ft., 05 April 1952, *M.L. Matton s.n.* [COLO-L-0048018]; Estes Park, 9 miles SE of; or 14 mi. NW of Lyons; off of Denver Highway, 7500 ft., July 26 1949, *W. Kiener 24819* [COLO-L-0048031]; Trail Ridge, N of Toll Memorial, 11800 ft, 27 August 1962, *R.A. Anderson s.n.* [COLO-L-0048012]. **Unknown:** Colorado, *C.L. Hayward s.n.* [COLO-L-0048260].

Figure 16. *Xanthoparmelia stenophylla* forms tight mats, often in rosettes. Its loose adnation level results in a high morphological resemblance to *X. wyomingica* (Figure 19).



Xanthoparmelia subdecipiens (Vain. ex Lyngé) Hale, Phytologia 28: 489. 1974. \equiv *Parmelia subdecipiens* Vain ex Lyngé Rev. Bryol. Lichenol. 10: 89. 1937. TYPE: South Africa, Klapmuts, Cape Province, *P. v. d. Býl s.n.* (holotype: TUR-image!).

Morphological and Chemical Description:

Thallus foliose; adnate to substrate; saxicolous. **Lobes** irregular; moderately to deeply divided, 1.0- 3.0 cm wide; separate to slightly imbricate; occasionally inner lobes subconvolute; margins darkening; apices usually crenate. **Upper surface** yellow-green; darkening and becoming rugose with age. **Medulla** white with continuous algal layer. **Lower surface** pale brown; rhizines pale brown, occurring frequently. **Soredia & isidia** absent in Colorado material. **Apothecia** frequent, sessile, disks light to dark brown, at times subconvex. **Ascospores** ellipsoid, non-septate, colorless; 8-9 x 6-7 μ m. **Pycnidia** frequent, sunken and black. **Figure 17**

Secondary Metabolites- Atranorin (major or trace), usnic acids (major); constipatic (trace), dehydroconstipatic, protoconstipatic (minor), and 3 unknown fatty acids.

Spot Tests- Medulla K-, C-, KC-, P-.

Ecology and Distribution: *Xanthoparmelia subdecipiens* is common in southern California and in the Arizonan / New Mexican Mountains. In Colorado it occurs along the western slope at elevations ranging from 4800-9500 ft. (see Map 1), particularly on the eastern slope on mesa tops and roadsides.

Notes: *Xanthoparmelia subdecipiens* shares morphological similarity with *X. lineola* (Figure 8), however it is generally more loosely adnate and does not contain salazinic acid. Diagnostic characteristics are its negative P test and the presence of atranorin, a compound that rarely occurs

in Colorado *Xanthoparmelia*. Future researchers should note that, for unknown reasons, I had particular difficulty obtaining TLC results from the Colorado collections. I suggest heavy spotting and multiple runs per collection if sufficient material exists.

TLC conducted on holotype by F.A. Brusse (annotated on 08 March 1977) indicated presence of aliphaticum(?), and five unknown compounds. It can be assumed that these unknown compounds included compounds listed among the secondary metabolites above, as they were later found in a more recent TLC run of the holotype by J. Johnston. Among Colorado material at COLO, I did not find aliphaticum in my TLC results; however, because this compound is only found in trace amounts in this species, I am confident of my identifications based on the other compounds found in the material I examined.

Additional Specimens Examined:

Boulder: Shanahan Mesa, a colluvial fan spreading out from the base of Bear Peak, south edge of Boulder, 1900m, 02 May 1998, *W.A. Weber s.n.* [COLO-L-0047986]. **Fremont:** 5 miles southwest of Coaldale, on US Highway 50, 2591m, 07 June 1958, *S. Shushan s.n.* [COLO-L-0047980]. **Jefferson:** 7 mi. S of Boulder, on Rocky Flats Pediment, ridge S of farm buildings, 26 July 1973, *G. Kunkel s.n.* [COLO-L-0047962]; 7 mi. S of Boulder, on Rocky Flats Pediment, 09 July 1973, *G. Kunkel C-32* [COLO-L-0047968]; 7 mi. S of Boulder, on Rocky Flats Pediment, *G. Kunkel C-55* [COLO-L-0047974].

Figure 17. *Xanthoparmelia subdecepiens* resembles a number of *Xanthoparmelia* species, including *X. cumberlandia* (Figure 5) and *X. lineola* (Figure 8). Its unique atranorin-containing chemistry makes this species unique among other *Xanthoparmelia* species in Colorado.



Xanthoparmelia vagans (Nyl.) Hale, Phytologia 28: 490. 1974. ≡ *Endocarpon vagans* Nyl., Expos. Synopt. Pyrenocarp. :13. 1858. TYPE: Ecuador, *s.c.*, *s.n.*, (holotype: H [H9505472]-image!; syntype: H [H9506798]-image!).

Morphological and Chemical Description:

Thallus irregular; vagrant, usually free-growing over but not attached to soil or rocks. **Lobes** sublinear; 0.5- 3.5 mm; somewhat convex; dark brown/ black margins; deeply divided; usually crenate at apices. **Upper Surface** yellow-green; epruinose; smooth. **Medulla** white with continuous algal layer. **Lower Surface** brown; rhizines brown, frequently occurring. **Soredia & isidia** absent in Colorado material. **Apothecia & ascospores** absent in Colorado material. **Pycnidia** frequent, sunken, black. **Figure 18**

Secondary Metabolites- Stictic acid (major), usnic acid (major); constictic acid (trace), cryptostictic acid (trace), unknown compound (trace), norstictic acid (minor).

Spot Tests- Medulla K+ yellow- dark orange, C-, KC+ pink, P+ orange.

Ecology and Distribution: Vagrant lichens are most commonly found in steppes, tundras, deserts, and alpine regions around the world (Pérez 1997). *Xanthoparmelia vagans* is found in Colorado on both eastern and western slopes in canyons, plains, and mountainous areas (see Map 1). It is the only vagrant lichen known within the state to contain stictic acid.

Notes: *Xanthoparmelia vagans* is one of the few vagrant species found in Colorado. It can be difficult to tell the difference between this species and *X. chorochoa* (Figure 2) based only on morphology. The quickest way to start to distinguish the two is to conduct a K spot test, which will indicate the presence of salazinic (red) or stictic acid (yellow) in the medulla.

Additional Specimens Examined:

Boulder: Wild Basin, NE slope of Mt. Copeland 0.5 mile s of Ouzel Lake, 11000 ft, 28 June 1962, *R.A. Anderson 2124* [COLO-L-0048070]; Continental Divide, summit of Rollins Pass, 11800 ft, 22 July 1960, *S. Shushan s.n.* [COLO-L-0048051]; Little Royal Gorge" of Como Creek, tributary to North Boulder Creek; gorge below and west of Peak-to-Peak Highway between Caribou Ranch and CU Mountain Research Station, 40.01969 -105.51417, 2713m, 29 April 2000, *W.A. Weber s.n.* [COLO-L-0048180]; Niwot Ridge, east of Navajo Peak, east slope of Front Range, 3658m, 23 September 1956, *S. Shushan s.n.* [COLO-L-0048241]; 1 mi. SE of Science Lodge and ca. 8 mi. N. of Nederland, 9500 ft, 17 May 1958, *S. Shushan s.n.* [COLO-L-0047993]; Rocky Mountain National Park, Longs Peak, Elynetum, 3200m, 03 September 1935, *W. Kiener 3443* [COLO-L-0047511]. **Gunnison:** Cebolla Canyon, 07 July 1961, *S. Flowers s.n.* [COLO-L-48054]. **Jackson:** Big Creek Lake, ca. 24 mi. n.w. of Cowdrey, east slope of Park Range, 9200 ft, 29 May 1955, *S. Shushan s.n.* [COLO-L-0048052]. **Larimer:** Stonewall Creek Canyon, 6100 ft, 4 miles NNW, 16 November 1975, *F.J. Hermann 26981* [COLO-L-0048024]; Estes Park, 9 miles SE of; or 14 mi. NW of Lyons; off Denver Highway, 7500 ft, 26 July 1949, *W. Kiener 24760* [COLO-L-0048006]. **Saguache:** Rio Grande National Forest, La Garita Mountains, vicinity of Carnero Pass, 38.01667 -106.40000, 3000m, 10 July 1993, *B. Goffinet 3358* [COLO-L-0048197].

Figure 18. *Xanthoparmelia vagans* resembles other vagrant *Xanthoparmelia* species in Colorado in lobe type and growth form. However, its stictic acid chemistry is what separates *X. vagans* from other vagrant species.



Xanthoparmelia wyomingica (Gyel.) Hale, Phytologia 28: 490. 1974. ≡ *Parmelia digitulata* var. *wyomingica* Gyel., Ann. Mycol. 36: 277. 1938. TYPE: U.S.A., Wyoming, Big Horn Mts., 19 August 1898, *Thos. A. Williams 316* (lectotype: BP- image! [designated by Hale in Smithsonian Contr. Bot. 74: 226. 1990.]; isotype: US [00068794]- image!).

Morphological and Chemical Description:

Thallus foliose; often forming rosettes; loosely adnate to almost free-growing;

saxicolous/terricolous. **Lobes** sublinear; subdichotomously branched primarily narrow, 0.5-2.0 cm wide; separate to imbricate; at times tips convolute; margins black and crenate. **Upper**

Surface yellow-green; shiny, smooth. **Medulla** white, with continuous algal layer. **Lower**

Surface light to dark brown; rhizines light to dark brown, occurring frequently. **Soredia & isidia** absent in Colorado material. **Apothecia** infrequent; substipitate; disks light to dark brown.

Ascospores hyaline, simple, 6-7 x 4-5µm. **Pycnidia** frequent to occasional, black, sunken below upper cortex. **Figure 19**

Secondary Metabolites- Salazinic acid (major), usnic acid (major); norstictic acid (minor).

Spot Tests: K+ yellow to red, C-, KC-, P+ orange.

Ecology and Distribution: *Xanthoparmelia wyomingica* is most commonly found in the southern Rocky Mountains at elevations 9000 ft. and higher in arid areas, often with *X. chlorochroa* (see Map 1). Common names for *X. wyomingica* include Shingled Shield Rock Lichen and Variable Rockfrog.

Notes: *Xanthoparmelia wyomingica* is potentially confusable with *X. chlorochroa* (Figure 2) and *X. coloradoënsis* (Figure 3) because the former is very loosely adnate to occasionally free-

growing on soil and the three species share chemical traits. The presence of apothecia in *X. wyomingica* is relatively common, while *X. chlorochroa* (Tuck.) Hale usually lacks sexual structures. *Xanthoparmelia chlorochroa* and *X. coloradoënsis* is also generally found at lower elevations.

The holotype specimen designated in the protologue was presumably destroyed in Bouly de Lesdain Herbarium in Dunkerque, France during WWII.

Additional Specimens Examined:

Boulder: Windy Gap, ca. 7 mi. n.w. of Nederland (ca. 1 mi. n.w. of Caribou), 9600 ft, 05 July 1958, R.A. Pursell 3299 [COLO-L-0048063]; Mt. Audubon; Roosevelt National Forest; 4.5 miles WNW of Ward; 40° 6' 10" N. lat., 105° 35' 15" W. long., 11800 ft, 30 July 1967, R.S. Egan El-709 [COLO-L-0048068]; 5 mi. N.W. of Eldora on trail from 4th of July Canyon to Arapahoe Glacier, 10-11,000 ft, 20 August 1957, S. Shushan s.n. [COLO-L-0047999]; Niwot Ridge, Front Range between Ward, 3505-3658m, 14 July 1994, W.A. Weber s.n. [COLO-L-0048174]; S side of Route 103 / Riverside Drive, just E of Raymond, ~100 m uphill from road, 40.16026 -105.44878, 2365m, 08 November 2014, E.A. Tripp 5131 [COLO-L-0050951]. **Clear Creek:** Summit Lake, Mount Evans, 05 July 1990, 3901m, W.A. Weber s.n. [COLO-L-0047580]. 400 yards east of Summit Lake near Mt. Evans, 12780 ft, 04 September 1951, S. Shushan s.n. [COLO-L-0047976]; Southwest of Georgetown, along road to Argentine Pass, 7.6 km from Guanella Pass Road, 39.66667 -105.75000, 1036m, 30 July 1975, R. A. Anderson s.n. [COLO-L-0048253]. **Custer:** South Colony Creek, 11700 ft, 08 August 1941, W. Kiener 10281 [COLO-L-0047964]; Humbolt Peak, 13000 ft, 28 August 1938, W. Kiener 9427 [COLO-L-0047970]; South Colony Creek basin, 3566m, 08 July 1941, W. Kiener 10282 [COLO-L-0048247]. **El Paso:** summit of Pikes Peak, 14100 ft, 01 August, S. Shushan s.n. [COLO-L-0048028]. **Grand:** Never Summer Mountains, Mt. Richthofen, 3414-3658m, 16 August 1962, R.A. Anderson 3386 [COLO-L-0048265]; 1 mile north of Kremmling, off Highway 40, 40.08000 -106.41000, 2287m, 31 August 2011, R. Rosentreter 17385 [COLO-L-0048271]; Frazer Experimental Forest, above Fool Creek, 3505m, 01 August 1953, W.A. Weber s.n. [COLO-L-0048295]. **Gunnison:** Trail along Copper Creek to summit of Conundrum Pass, Elk Mountains, ca. 10 miles northeast of Gothic, 39.00300 -106.94200, 3871m, 04 August 1955, W.A. Weber s.n. [COLO-L-0048289]. **Jackson:** Summit of Flattop Mountain, headwaters of Gold Creek, Park Range south of Mount Zirkel, 3658m, 29 July 1956, S. Shushan s.n. [COLO-L-0048283]. **Larimer:** Beaver Meadows, 2576m, 16 September 1962, R. A. Anderson 3718 [COLO-L-0048248]; Larimer, Neota Wilderness, southeast of Cameron Pass of Highway 14, near twin knobs on south side of Coral Creek drainage, 7 miles in on Long Draw Road, 3414m, 20 August 1992, J. K. Nelson 1389 [COLO-L-0048254]; Neota Wilderness, southeast of Cameron Pass of Highway 14, summit of Mt. Neota, 3566m, 08 August 1992, J. K. Nelson 1222 [COLO-L-0048307]. **Park:** Hoosier Ridge, east of Hoosier pass, between Alma and Breckenridge, 3505-3810m, 10 July 1959, S. Shushan s.n. [COLO-L-0048242]; East end of Hoosier Ridge, ca. 11 miles north of Fairplay, 3962m, 08 July 1956, S. Shushan s.n. [COLO-L-0048266].

Figure 19. *Xanthoparmelia wyomingica* forming rosettes similar to *X. chlorochroa* (Figure 2). Note that the lobes of *X. wyomingica* are less convolute than *X. chlorochroa*, and is not entirely free-growing.



List of Excluded Names: The following names have been excluded from the list of Colorado Xanthoparmelia species.

Xanthoparmelia hypopsila (Müll. Arg.) Hale, Phytologia 28:488. 1974. \equiv *Parmelia hypopsila* Müll. Arg., Flora (Regensburg) 70: 317. 1887. TYPE: Uruguay, 1886, *J. Arechavaleta y Balpardo 12*, (holotype: G [G00292908]- image!).

Xanthoparmelia taractica (Kremp.) Hale, Phytologia 28: 485. 1974. \equiv *Parmelia taractica* Kremp., Flora 61: 439. 1878. TYPE: Argentina, “Regiones alpinae Andium, ad terram, inter gramina” (*fide protologue*), 1872-1874, *P.G. Lorentz & G. Hieronymus 27* (holotype: M [M0024921]-image!; isotype: G[G00294521]-image!, US[00069064]-image!).

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